Supreme Court Case No. S277893

IN THE SUPREME COURT OF THE STATE OF CALIFORNIA

ANOTHER PLANET ENTERTAINMENT, LLC,

Petitioner,

v.

VIGILANT INSURANCE COMPANY,

Respondent.

Request for Certification to Decide a Matter of California Law Presented in a Matter Pending in the U.S. Court of Appeals, Ninth Circuit
Case No. 21-16093

PETITIONER ANOTHER PLANET ENTERTAINMENT'S APPENDIX OF MATERIALS CITED IN ITS OPENING BRIEF

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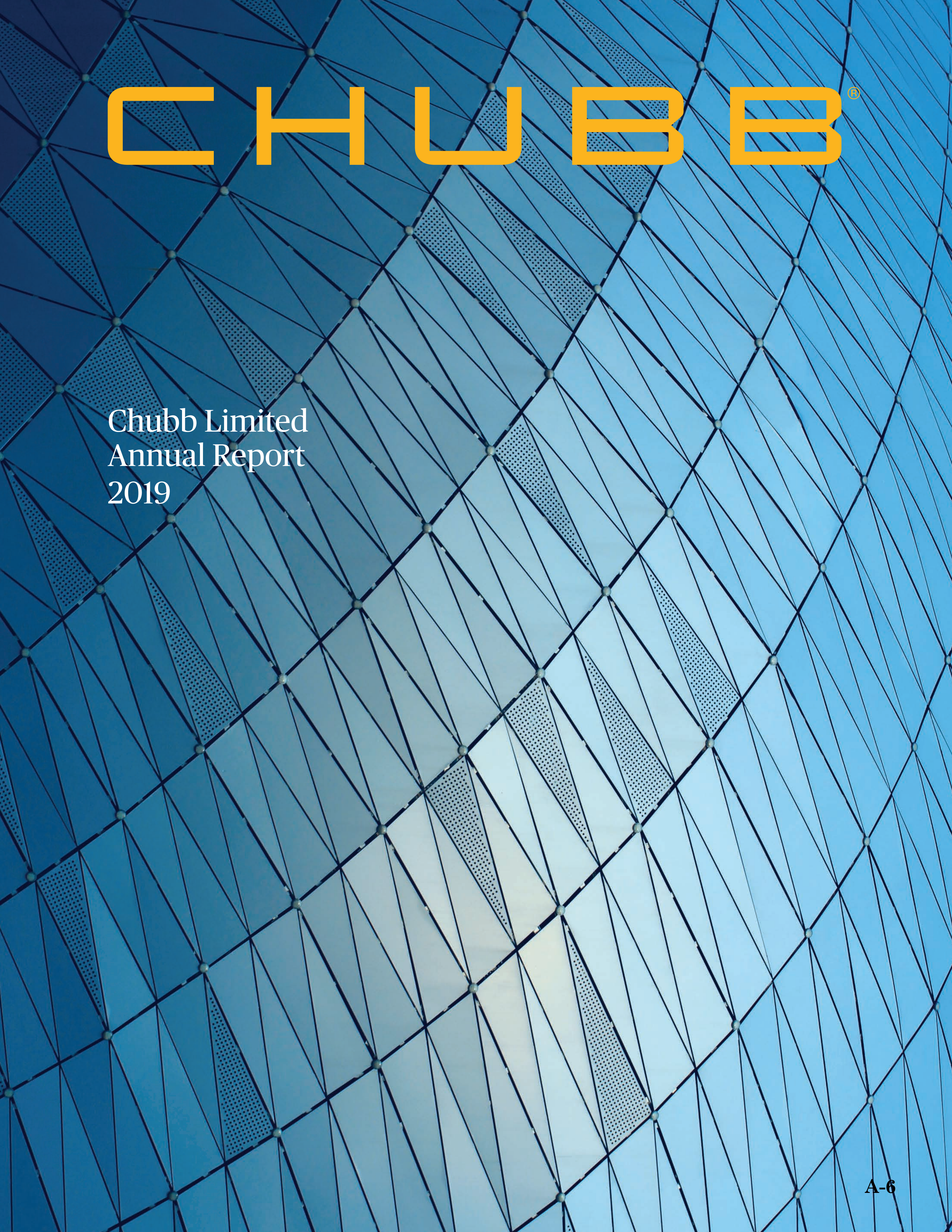
APPENDIX



CHUBB®

Chubb Limited Annual Report 2019

Financial Summary

In millions of U.S. dollars
except per share data and ratios

	Year Ended Dec. 31, 2019	Year Ended Dec. 31, 2018	Percentage Change	Percentage Change Constant Dollars
Gross premiums written	$40,124	$37,968	5.7%	7.0%
Net premiums written	32,275	30,579	5.5%	7.0%
Net premiums earned	31,290	30,064	4.1%	5.5%
P&C combined ratio	90.6%	90.6%	NM	
Current accident year P&C combined ratio excluding catastrophe losses	89.2%	88.0%	NM	
Net income	4,454	3,962	12.4%	
Core operating income	4,641	4,407	5.3%	6.8%
Diluted earnings per share – net income	9.71	8.49	14.4%	
Diluted earnings per share – core operating income	10.11	9.44	7.1%	8.6%
Total investments	109,234	100,968	8.2%	
Total assets	176,943	167,771	5.5%	
Shareholders' equity	55,331	50,312	10.0%	
Book value per share	122.42	109.56	11.7%	
Tangible book value per share	78.14	65.89	18.6%	
Return on equity	8.4%	7.8%	NM	
Core operating return on equity	9.0%	8.7%	NM	
Core operating return on tangible equity	14.6%	14.6%	NM	

This document contains non-GAAP financial measures. Refer to pages 50-52 for reconciliations to the most directly comparable GAAP measures.

NM–not meaningful

Evan G. Greenberg
Chairman and Chief Executive Officer
Chubb Group

To My Fellow Shareholders

As this letter goes to press, the U.S. and many other nations of the world are shutting down much of their social and economic activity in response to the spread and threat of the coronavirus. We simply don't know at this time how fast or far it will spread, or how effective we will be in slowing the spread, treating victims and dealing with the consequences. For Chubb, we are clear about our priorities and resolute in our response: To the extent possible, we will take care of our people and keep them safe; we will remain consistent in how we take care of our customers and business partners, doing everything in our power to serve their needs with minimal disruption; and we will be a responsible citizen in our community, heeding the advice of government and health authorities, and as a solid contributor to recovery.

Chubb had a very good year in 2019. We produced strong financial results, including per share growth in earnings, book value and tangible book value. We capitalized on opportunity, benefiting from improved commercial property and casualty (P&C) pricing and underwriting conditions globally and generating our best organic premium revenue growth in over five years. We achieved another year of excellent underwriting profitability – a direct result of our time-tested discipline in underwriting and managing risk. Driven by growth in our invested assets, we generated record investment income despite low interest rates.

Throughout the year, Chubb professionals distinguished themselves through their actions serving customers and business partners, contributing to our admired brand and reputation for quality service. We made progress in our efforts to advance our many longer-term strategies that will position us for future growth, including our presence in China with an increased ownership stake in Huatai Insurance Group. We demonstrated leadership in environmental sustainability by announcing a progressive policy curtailing our underwriting and investments in coal. We concluded the year in excellent financial, operational and competitive shape and have real momentum going into '20 for future growth and profitability.

In my judgment, all successful companies have a clearly articulated view of who they are and why they exist, so let me begin by describing in a few words our unique and distinctive company. Chubb is the largest publicly traded P&C insurer and the fifth largest insurer in the world as measured by market capitalization. (Fifteen years ago, we were #5 and #26, respectively – we are patient and persistent.) We are a truly global commercial and consumer insurer – one of only a few in the world. With substantial local operations in 54 countries and territories, we compete for local business while serving the needs of multinationals. We have an enviable long-term track record of financial performance including growth in earnings, book and tangible book value and market capitalization, underpinned by distinguished underwriting performance.

In the United States, which represents about 30% of the global insurance market, we are a top-two commercial P&C insurer that serves all sizes of companies – from global to middle market to small businesses – with hundreds of traditional and specialty coverages, including a leading position in the wholesale market for excess and surplus (E&S) or difficult to place risks, and we are the #1 crop insurer. On the consumer side, Chubb is by far the leading personal lines insurer protecting America's affluent individuals and families. Our Combined Insurance affiliate serves middle-income households with a variety of personal accident and supplemental health insurance products.

About 40% of our business originates outside the United States and it's growing faster than our U.S. business. Our extensive local operations throughout Europe and the United Kingdom, which represent about half of our international portfolio, in 2019 had their best growth in a decade. The balance is equally split between the developed and developing markets of Asia and Latin America, both of which are growing at high-single or double-digit rates. Our international insurance businesses are essentially split 50/50 in terms of their commercial and consumer focus. In addition to our retail commercial P&C businesses present in just about every major market around the globe, we also have significant E&S wholesale market operations in London and Bermuda. We serve consumers in international markets through our large global accident and health (A&H) business, which writes personal accident and supplemental health insurance, and our international personal lines business, which underwrites everything from cell phones to autos to homes and their contents.

As the first company to convert a domestic Chinese financial services holding company to a foreign-invested joint venture, we are on a path, subject to regulatory and shareholder approvals, to achieve majority ownership of China's Huatai Insurance Group, the holding company of P&C, life and asset management subsidiaries with over 600 offices. We also have a growing Asia-based life insurance business that is becoming a more important contributor to earnings.

Taken together, Chubb has a thoughtfully constructed and managed global portfolio of simply outstanding businesses. Most are top-performing multibillion-dollar businesses, with substantial scale and scope for growth, and the envy of the industry. We have a well-balanced mix of business – 66% commercial lines, 34% consumer lines – and our product breadth and balance are a real strength. We sell our products globally through an extensive range of distribution channels: over 50,000 brokers and independent agents, more than 85,000 exclusive life and health agents, and hundreds of direct-to-consumer partnerships that give us access to tens of millions of potential customers through digital, phone and face-to-face marketing tools and techniques – another strength. At the same time, in aggregate, we are not overly dependent on any one channel.

For the year, total gross premiums written for the company were $40.1 billion while net premiums written, which are the premiums we retain on our balance sheet, were $32.3 billion, both up 7% before the impact of foreign exchange. Our balance sheet is exceptionally strong, with $70 billion in total capital and over $55 billion in equity at December 31, and our company is rated AA by S&P and A++ by AM Best. With a good balance of underwriting and investment income, last year we produced core operating income of $4.6 billion, or $10.11 per share, up 7.1% on a per share basis from 2018.

The macro environment in 2019

I would have characterized the external operating environment in '19 and as we began to move into '20 as marked by great opportunity, risk and complexity. That is until the coronavirus outbreak, which began in China and subsequently spread to the rest of the world. Now, with the specter of a true pandemic upon us, and the substantial damage to be inflicted on society, economies and commerce alike, markets are severely stressed and signaling global recession. As of this writing, to what degree and how long it will last is simply unknowable – it depends on the rate and severity of infection. We lack visibility. However, the coronavirus has already had a real impact on China economically and politically, as well as the global economy, including the U.S.

Beneath the shadow of the coronavirus, U.S. economic performance has remained the strongest in the world among large economies, while the global economy has slowed from trade-related headwinds, poor government policy in many countries, and geopolitical events. Business thrives in an environment of certainty, and business confidence has suffered, and that has impacted business investment. 2019 concluded on a more encouraging note with the signing of the USMCA trade agreement and a phase one U.S.-China trade pact, both a net positive given where we were, as well as increased political certainty surrounding Brexit. By themselves, these developments may provide moderately improved business confidence and, in turn, increased investment, although we still face considerable uncertainty:

• Tariffs with China remain in place, as do tariffs with others at year-end. Manufacturing globally is in recession. The phase one agreement, while a good start, doesn't address many of the fundamental trade issues with China – in that regard, it kicks the can down the road.

• More broadly, protectionist sentiments persist. The rules-based trading system is under attack from the world's two largest economies with the U.S. unilateral approach using tariffs and a strong-arm approach (and by the way the EU is on deck later this year) and China, with its predatory behavior, gaming the global system to its advantage. We are evolving from a unipolar to a multipolar world – China is emerging and the U.S. is more unilateral and inward-looking, both sources of increased tension.

• U.S.-China relations are headed in the wrong direction, marked by lack of trust and cooperation, and increasing confrontation.

• We have numerous geopolitical hot spots including North Korea and Iran.

Industry conditions last year: improving commercial P&C pricing

The insurance industry is experiencing improved commercial P&C underwriting conditions in the U.S. and a number of major international locations. After years of slower growth and shrinking some of our important businesses as we maintained discipline around inadequate terms, market conditions have improved and are spreading to more classes of risk and more countries, which means a time for growth. We built our company to capitalize on conditions such as these and have patiently waited. Today we are achieving rate above loss cost trend in many lines and territories, particularly in those classes where margins have been under pressure. Given the current environment and our longer-term secular growth strategies, this bodes well for future growth in revenue and earnings. I expect the positive market conditions to continue throughout ’20 and beyond, and Chubb will benefit.

For perspective, prices in a number of important classes continue to remain below what is adequate to earn a reasonable return for the risk taken. Prices in others have achieved sufficiency, and in those cases we are growing. P&C insurance is a cyclical business. Generally speaking, with few exceptions, loss costs rise every year, and when rates don’t keep pace, margins naturally decline, disappear or worse. Companies that in the past pursued market share at inadequate pricing and terms are suffering and will experience margin and potentially reserve pressure. Many in the industry are not earning their cost of capital. On top of that, there is volatility in the loss environment in certain casualty- and property-related classes. It’s no surprise, therefore, that we have seen a pull-back and retrenchment by those insurers that took on too much underpriced and poorly underwritten exposures. That’s what creates cycles.

The industry’s insured natural catastrophe (CAT) losses last year are estimated at $50 billion to $55 billion, down substantially from the previous two years. We continued to observe a rise in weather-related volatility, including increased frequency of large events ($1 billion or greater in losses); more extreme conditions linked to temperature and moisture producing bigger tornadoes, larger floods, wildfires and hurricanes with more moisture; and changing seasonality. This volatility, which is driven by climate change and urbanization resulting in a greater concentration of exposures in coastal and inland locations, we expect to continue. For Chubb, pre-tax net CAT losses were $1.2 billion, down from $1.6 billion in 2018 – an improvement but about $220 million more than we planned for when calculating our “expected” CATs for the year.

Given its concentration of risk exposed to temperature and moisture, crop insurance is a business with CAT-like features. There is a fair degree of volatility and season-to-season variability to growing conditions and commodity prices. Adverse weather in parts of the United States last year impacted growing conditions. After three exceptional years from ’16 to ’18, last year was below-average. Even so, we recorded a calendar year combined ratio of 95.1%. Crop insurance has been a very good business for Chubb. We are the national leader with the most experienced people and deepest knowledge based on decades of data on over 3 million farm fields, which improves risk selection. Notably, both the CAT and crop losses in 2019 were

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comfortably within our risk tolerance. We purposely take these risks and have no regrets as long as our underwriting is good and we are properly paid.

Craftsmanship: the art and science of underwriting

Chubb is an underwriting company – everything starts with underwriting and assuming risk is at the heart of our business. Our company is led by underwriters and our culture is centered on the art and science of taking risk. We practice our craft better than any company of size and we have an enduring track record of outperformance to prove it. Over the past 15 years, Chubb's P&C combined ratio has outperformed our peers by an average of seven percentage points over any time period. Last year we produced $2.7 billion of pre-tax P&C underwriting income, an increase of nearly 7% in constant dollars, and a 2019 calendar year P&C combined ratio of 90.6%, which was flat with prior year. Our underwriting performance for the results of the current in-force business is measured by the current accident year combined ratio excluding catastrophe losses, a preferred industry measure, which was 89.2% compared with 88.0% prior year, and including anticipated or expected CAT losses, which I believe is a better measure, it was 92.6% compared with 91.4%.

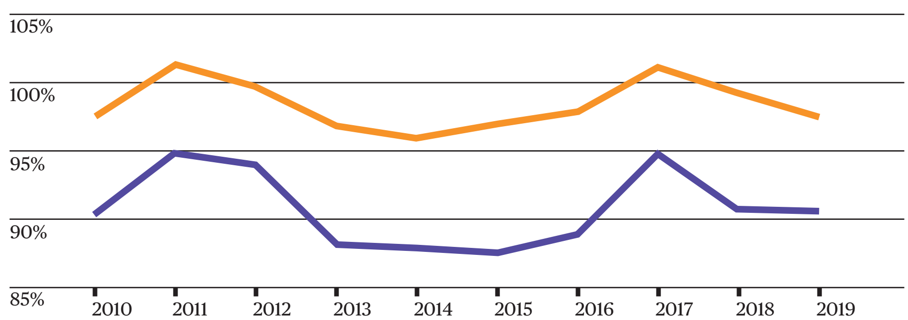
At Chubb, accountability for underwriting discipline starts at the top – management owns it and is deeply engaged at every level and in all parts of the organization around the world. We have operationalized our underwriting culture with a balance between local capability and autonomy and global command and control, which enables us to move nimbly between offense and defense, conditions depending. When we see market opportunity, we strive to quickly seize it. On the other hand, our willingness to trade market share for underwriting profitability, along with relentless expense management and efficiency, contributes to our competitive profile. By the way, expense discipline doesn't mean failing to invest in our people and technology – these are investments.

As I have observed to you previously, generally speaking, loss costs rise every year. For our company, loss costs in aggregate across all P&C lines of business rose 4.5% last year. If pricing doesn't rise at the same rate, all things being equal, loss ratios rise. In our industry, rates have not kept pace with rising loss costs for a number of years now. Separately, the loss trend for certain casualty and property-related lines has worsened due to a changing loss environment, both weather and man-made related. This has stressed insurers' margins and created greater volatility and uncertainty that together have impacted their confidence in taking risk.

In the U.S. and a few international locations, severity and frequency in "first-dollar" layers for casualty classes of business have been relatively steady. However, in the excess layers of certain classes, overall frequency and frequency of severity of large individual claims have been increasing and putting pressure on results for a number of reasons. The most benign reason is casualty attachment points (the level of loss where coverage

P&C Combined Ratio versus Peers

The company's underwriting results have outperformed the average of its peers over the last 10 years.



Averages:	1 year	3 year	5 year	10 year
Peers[1]	97.4%	99.3%	98.5%	98.3%
Chubb	90.6%	92.0%	90.4%	90.7%

[1] Includes AIG, Allianz, AXA, CNA, HIG, QBE, RSA, TRV, XL, Zurich. XL's 2018 and 2019 results are for the AXA-XL division of AXA.

Source: SNL and company disclosures

begins) have not moved for years – a $1 million attachment point for casualty excess 10 years ago is worth a fraction of the amount today.

Contributing to frequency and frequency of severity is so-called social inflation, resulting in increased litigation activity and size of awards primarily driven by (a) increased litigation financing – a new asset class; (b) populist sentiment, including growing distrust of large corporations, expressed in jury attitudes; (c) growing jury insensitivities to large dollar verdicts; (d) erosion of previous tort reform remedies; (e) changing definition or interpretation of corporate responsibility (if something went wrong, someone is strictly liable); and (f) changing social norms in terms of tolerance and definition of gender bias and sexual abuse. This increased litigation is apparent in class actions from securities and anti-trust related cases to science-based: chemical, pharma and physical trauma-related. One-off casualty CAT-type events reflecting society's increasing abhorrence and zero-tolerance with sexual abuse and harassment are leading to legislative actions such as reviver statutes, where it's simply too early to know the ultimate financial impact.

One class of business where costs continue to rise is coverage for directors and officers, or D&O, as the frequency and severity of litigation from securities class actions and M&A objections have worsened. Last year was no exception. Securities class action filings remained at an all-time high – the third consecutive year with more than 400 cases filed and 9% of U.S. publicly traded companies the target of a class action. Meanwhile, severity, as measured by the median settlement value, climbed to the highest recorded level since 2012 and was 25% higher than the median for the previous three years.

Litigation is a necessary process to decide disputes that cannot otherwise be resolved, and the legal profession is a profit-making industry like any other. But our inefficient system benefits lawyers at the expense of shareholders. Excessive litigation is a tax on society and business, enriching the trial bar with little benefit in most cases going to the supposed aggrieved. According to a NERA Economic Consulting study, more than two-thirds of the cases in 2019 resolved in favor of the defendant with no payment made to plaintiffs but plenty to their lawyers. Nearly 90% of M&A objection suits are dismissed. Based on our data, in the last seven years, about half of the money paid in securities claims, including legal expenses and settlements, has gone to the lawyers, both plaintiff and defense, and in the case of M&A objections, it's over 70%. Federal and state legislation will be required to remedy abuses. Reforms should include requiring fees paid to plaintiffs' attorneys be proportional, barring fees for frivolous disclosure suits, and requiring disclosure of all relationships between plaintiffs and their lawyers and third-party funders.

Litigation funding is a new investment asset class in which investors who have suffered no harm pay litigation costs for the sole purpose of sharing in the proceeds of a favorable judgment or settlement. This is a growing problem in the U.S. and a number of other countries, including the U.K. and Australia. It is linked to approximately 75% of all class actions and, in the U.S., more than $7 billion of funding

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is waiting to be invested in lawsuits. Enriching a few, litigation funding is an investment activity that in the main hardly benefits society. Working with the U.S. Chamber of Commerce's Institute for Legal Reform and other organizations, we are educating regulators and members of the judiciary in the U.S. and abroad about the consequences of unrestricted financial speculation in our civil justice system and the need for adequate disclosure and other reasonable regulation. We continue to seek like-minded allies who want to join our coalition.

Growth in invested assets supports growth in investment income

The other source of our earnings is investment income, and in 2019 we generated pre-tax adjusted net investment income of $3.6 billion, up only 1%. During the year, in response to a slowing global economy and trade-related headwinds, the U.S. Federal Reserve reversed course and lowered interest rates again to historically low levels. Our strong operating cash flow of $6.3 billion helped to mitigate the impact and will continue to support investment income as we grow our invested assets, which stood at $109 billion at December 31. Nevertheless, growth in investment income will remain relatively low as long as interest rates remain so. We will continue to maintain a conservative approach to the management of our invested assets by seeking adequate risk-adjusted returns and not reaching for yield. For the year, the portfolio generated an average book yield of 3.5% versus average new money rates of about 3%.

We expect the current low interest rate environment will continue for the foreseeable future, especially

Long-Term Operational & Financial Outperformance (10 Years)

Chubb has delivered on its financial goals and outperformed its peers across most metrics

	Premium & Earnings Growth		Underwriting Profit	Book Value Growth		Average Return on Equity & Return on Tangible Equity		Valuation	Outperformance Since Merger 3 Years Post Merger	
	Net Premiums Written ('09-'19)	Operating Earnings ('09-'19)[1]	P&C Combined Ratio ('10-'19 Avg.)	Book Value per Share (12/09-12/19)[2]	Tangible Book Value per Share (12/09-12/19)[2]	Average Return on Equity ('10-'19)	Average Return on Tangible Equity ('10-'19)	Market Cap Growth (12/09-12/19)[3]	Tangible Book Value per Share (12/16-12/19)	Average Return on Tangible Equity ('17-'19)
Chubb	143%	68%	90.7%	109%	67%	10.6%	14.6%	315%	29%	14.2%
Avg. Peers[4]	1%	40%	98.9%	42%	53%	8.9%	11.3%	77%	6%	11.7%

[1] AIG excluded due to negative earnings in 2009
[2] AIG adjusted for U.S. Treasury Equity Investment in 2009
[3] AIG excluded due to impact from government intervention
[4] Peers include AIG, Allianz, AXA, CNA, Hartford, Travelers, Zurich
Annual metrics through full year 2019 actuals: Net premiums written, Operating earnings, P&C combined ratio, Average return on equity and Average return on tangible equity. Point-in-time metrics (Book value per share, Tangible book value per share and Market Cap) through December 2019 actuals

given the potential consequences of the coronavirus. The combination of generally sluggish global growth and low inflation encourages exceptionally accommodative central bank monetary policies. These have become a poor substitute for better government economic and fiscal policies. Approximately $15 trillion globally is now invested at negative yields and some political leaders think that's acceptable. However, in my judgment, these conditions won't last. Overreliance on monetary policy is misguided – it hurts savers of all kinds, including pension funds and insurers, and encourages overly aggressive investment behavior that inflates asset values while failing to materially stimulate growth. Many investors are chasing absolute yield instead of risk-adjusted returns, and that never ends well. Given inflated balance sheets and exceptionally low interest rates, central banks have limited room to move in the next economic downturn.

Book and tangible book value growth

Chubb is a growth company. We define that as growth in book and tangible book value over time. Our priority is to grow shareholder value by first growing our company, both revenue and earnings, while deploying capital efficiently. As the chart nearby illustrates, we grew our company faster than the average of our peers over the past 10 years. Premiums increased 143% and core operating income grew 68%. Book value growth of 181% followed, with per share book value up 109%. As a result of our performance, our market capitalization is up over 300%. The second-highest of our peers rose 145% during that period, and most were below 100%. The scale we have today is a strategic advantage for future value creation.

For investor clarity, let me share my thoughts regarding two important metrics – return on equity (ROE) and return on tangible equity (ROTE). ROE is an accounting concept and an inexact measure of returns. If all of the capital we used to acquire The Chubb Corporation in 2016 was used instead to repurchase shares, the denominator of the ROE equation would be reduced, resulting in a higher ROE. But would that have increased the franchise value of our company, and would the returns on deployed capital be higher and more sustainable than they are for Chubb today? Hardly – and what would our future value creation look like if we had done so?

Our core operating ROE currently stands at 9%, well in excess of our cost of equity of approximately 7%. The ROE is impacted by goodwill, which we incurred as a result of acquiring several excellent businesses, Chubb in particular. In my judgment, goodwill is an income producer and an appreciating – not depreciating – asset over time. Look at what that goodwill has created: It has helped transform our company into the franchise that we are today – a leading brand with substantial scale, a portfolio of market-leading businesses and earning power and, critically important, optionality for future growth globally. Our ROE will increase over time as we continue to grow the company and further leverage the scale and capabilities we have built. The goodwill has opened a path for us that we could not have pursued without it.

We are in the risk business. We are a balance sheet business. The most important value-creating measures, in my judgment, are growth in tangible book value and core operating return on tangible equity, or ROTE, which was 14.6% last year. Tangible equity is the most constraining measure to value creation. It is the most fundamental measure that governs our ability to take

"We are in the risk business. We are a balance sheet business. The most important value-creating measures, in my judgment, are growth in tangible book value and core operating return on tangible equity, or ROTE, which was 14.6% last year."

risk and to grow the company, and it shows how our underlying business intrinsically performs. Everything we do is measured against it: We can only pay claims from tangible; premium growth is governed by tangible because exposure is leveraged against tangible; and M&A and debt leverage are dependent on tangible equity.

Our average ROTE over the 10-year period is 14.6%, with growth in tangible book value of 124%. Both are quite strong, but ROTE was impacted by the 2016 Chubb acquisition. We paid a price to build this franchise, and that dilution impacted both tangible book value per share and average ROTE. It took us approximately 3.5 years to recover the dilution, which speaks to the franchise earning power. By the way, when measured over the three-year period following the Chubb acquisition, our average ROTE is over 14%, which is top class, and our tangible book value per share growth leads all peers at 29%.

Our stock price increased 21% last year and produced a total return of 23%, a decent performance but not superior to the S&P 500's 32% or our peers, some of which benefited from a steeper rise from lower price-to-book valuations. The Chubb share price remains a bargain in my judgment. Insurance is a long-term business and attractive long-term shareholder returns are simply a derivative of doing our job well. In that regard, our 10-year total return is 288% and compares well to the S&P 500 (257%) and the S&P 500/Financials (218%) and is equal to the S&P 500/P&C Insurance (289%).

Beyond what we need for risk and growth including M&A, we return surplus capital to shareholders. We have a 25+ year track record of annual dividend increases – earning us membership in the rare "dividend aristocrats" club – and a target payout ratio of approximately 30%. In 2019, we returned to shareholders about $1.4 billion in dividends and over $1.5 billion in share repurchases. We repurchased our shares at an average price of $147, which equals a price-to-book of 1.2 – cheap.

Strategic growth priorities: cyclical and secular

We are builders at Chubb, executing on multi-year plans that take advantage of both cyclical and longer-term secular growth trends taking place around the world. Earlier I said capitalizing on the current commercial P&C market conditions is a major strategic priority right now for a growing number of our businesses. About 45% of our portfolio, representing many short- and long-tail classes, is now benefiting from the improved market conditions – and I expect that percentage to increase.

Beyond the cyclical, our company is focused on important long-term secular trends. There is so much opportunity in so many places, not least in the U.S., which remains a major growth market given its vibrant economy and its wellspring of entrepreneurial spirit, risk-taking and innovation. Here are four others:

• The growth of small and mid-sized businesses in many parts of the globe, particularly Asia and Latin America. As nations in these regions develop, economic growth comes predominantly from small and mid-sized business creation. We have an extensive range of commercial insurance offerings and distribution channels to serve them.

• The rising middle class in many of the developing economies of Asia and Latin America. We have significant future growth opportunity serving these consumers, who need the basic savings and protection products our company provides.

• China looms large as a potential long-term growth opportunity, and our presence there is expanding.

• Digitization is sweeping through society globally, including the business of insurance, offering ways to improve or transform so much of what we do.

Let me take a little time and describe these cyclical and secular growth opportunities in the context of our businesses and tell you how they performed last year and how they are positioned for future growth.

Chubb's North America Commercial P&C Insurance operation, excluding agriculture, produced good growth in 2019 with net premiums written overall increasing over 7%. Momentum built steadily as the year progressed with first half growth of 5.6%, second half growth of 8.6%, and fourth quarter accelerating to 9.4%. Our $8 billion Major Accounts division serves the insurance needs of large domestic and multinational corporations, and Chubb is the leader not only in terms of size but capability, presence and know-how. Even though 90% of the Fortune 1000 are clients, there's still billions of dollars of opportunity available by writing more coverage for each customer. For instance, out of a universe of approximately 5,000 of the largest companies in the U.S., there are about 2,000 accounts where we write fewer than three lines of coverage. This business is benefiting from favorable underwriting conditions and a flight to quality, and it grew over 5% last year and is currently growing even faster.

Our North America middle-market and small business commercial P&C franchise, at $6 billion, is next in size. This business addresses an incredibly large segment of the U.S. economy. With an extensive field organization and the broadest array of traditional and specialty products, we provide coverage and service to businesses ranging from multinational publicly traded mid-sized organizations to single-location private companies. Our two dozen industry practices advise and provide coverage to industries ranging from life sciences and healthcare to CleanTech and advanced manufacturing. Our fast-growing small business division offers a highly automated digital experience – nearly 85% of the more than 50,000 submissions we receive each quarter are not touched by human hands after they leave the agent's office. We have 4,500 agencies in the U.S. using our Chubb Marketplace platform to digitally quote and issue policies and service their clients. Our middle-market and small commercial division benefited from more favorable underwriting conditions as the year progressed, growing 5.5% in the first half and 6.6% in the second. We expect the positive growth trend to continue in '20.

Westchester is our E&S wholesale business in the United States and writes about $2.8 billion in gross premiums. E&S insurers specialize in hard-to-place or unusual risks that require tailored coverages standard companies cannot or won't write. We have a broad product line-up – from specialty property and liability offerings to product recall and railroad liability, as examples. After years of shrinking due to soft underwriting conditions, Westchester took advantage of a rapidly improving marketplace in 2019 and grew over 9%. Chubb Bermuda, our original insurance company founded in 1985, is our other E&S business in North America and specializes in high excess, low frequency coverage for casualty, property, financial lines and political risks. This business experienced some of the fastest price and terms improvement as the year progressed, leading to growth of over 30%. For both Westchester and Chubb Bermuda, good growth should continue in '20 as more E&S risks move toward adequate pricing.

Chubb Personal Risk Services serves the personal lines insurance needs of affluent individuals and families in the U.S. and Canada. We lead this sector with an estimated market share of nearly 60%. In 2019, we more tightly focused the portfolio of this $5.5 billion business on clients who value the richness of Chubb's coverage and service and are willing to pay the price for it. We are constantly adding new coverages and services to respond to the risk management needs of these discerning customers. We continue to refine our risk selection and pricing capabilities through improved analytics and our wealth of data. In this business, customer experience is truly the product and we continued to distinguish ourselves with the industry's most admired claims service while enhancing our clients' digital experience with us. Our clients truly love Chubb – we retain 90% of our customers and 97% of the premium annually – and so it's no wonder that this business is a wellhead of our brand in America. As for growth, net premiums written were up about 2.5% for the year, but 4.6% in the fourth quarter on an adjusted basis.

Chubb Overseas General is our $11.3 billion international P&C business. We have operations in 51 countries and territories outside North America including significant presence and

"We are builders at Chubb, executing on multi-year plans that take advantage of both cyclical and longer-term secular growth trends taking place around the world."

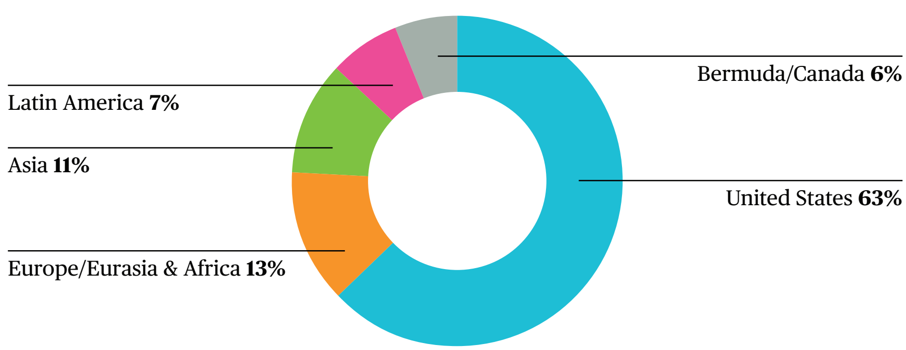
capabilities in Europe, Asia Pacific and Latin America. This division serves large corporates, middle-market and small commercial companies, or SMEs, and individual consumers with a wide range of products and services. We experienced some of our best growth last year, with net premiums up more than 8.5% in constant dollars. Over the years we have built extraordinary local capabilities around the globe to take advantage of local opportunity, including cyclical market conditions wherever they happen. For example, after years of shrinking our Lloyd's London-based wholesale division by almost half when the pricing for risk was inadequate, we experienced four consecutive quarters of serious double-digit growth ranging from 15% to 29%. In Australia, after years of relatively low growth due to overly competitive conditions, our quarterly premium revenue growth hasn't dipped below 16% for the last two years.

A key driver of future growth for Chubb in both the U.S. and internationally is our consumer lines operations, which consists of two large businesses: our global accident and health division and our international personal lines division. Together, this $7 billion operation grew about 5.5% in 2019 in constant dollars and employs multiple distribution methods including telemarketing, agency, broker and digital partners. For example, in North America, Chubb Workplace Benefits, which we built from scratch in our Combined Insurance affiliate, provides voluntary employee benefits for mid-to-large companies in North America. The business leverages our nationwide P&C broker and agent relationships and sales were up 40% last year. In Europe, our cell phone replacement insurance product is offered by 23 mobile network operators in 13 countries. In Mexico, where we now insure almost 2 million consumers, our auto and residential products business grew 22% last year.

Distribution partnerships enable us to reach tens of millions of potential new customers, both individual consumers and businesses. We have more than 150 of these partnerships with banks, retailers, airlines and mobile network operators. In Mexico, for example, after our first year of an exclusive long-term relationship with Citibanamex, we are selling more than 30,000 new policies per month to their 12 million customers through branches, telesales and digital platforms. In Chile, we are selling nearly 50,000 policies each month with Banco de Chile, which generated about $400 million in insurance revenue in 2018 with other insurers before becoming our exclusive distribution partner. On the other side of the world, through our partnership with DBS, the largest and most respected bank in Southeast Asia, we are selling a variety of products – from travel insurance online to

Geographic Sources of Premium

2019 gross premiums written



Premium Growth by Geography

Percentage change in gross premiums written in 2019 versus 2018 in constant dollars

- United States **5.6%**
- Latin America **10.1%**
- Europe/Eurasia & Africa **7.3%**
- Bermuda/Canada **13.5%**
- Asia **9.2%**

home contents coverage to business insurance for SMEs – to more than 11 million of their customers in five countries and revenue is growing briskly.

China: on the path to increased ownership of Huatai Group

Early in 2019, we received support from the Chinese government to increase our ownership in Huatai Insurance Group, which has life, P&C and asset management subsidiaries, and more than 600 branches and 11 million customers. We were granted permission to convert Huatai from a domestic Chinese financial services holding company to a Sino-foreign joint venture – an historic first. The change of status created a path to increased ownership. Later in the year, we announced agreements to make significant additional purchases which, if approved, will take our ownership position to over 50%.

Our investment in Huatai, which we have worked on over the course of 20 years, is another great example of Chubb as a long-term builder. China is currently the world's second-largest economy and is on its way to becoming the largest. Its financial services industry, including insurance, remains underdeveloped. China represents a significant opportunity for Chubb to build an important Chinese insurance and asset management company that will meet the growing savings and protection needs of its consumers and businesses. The country's continued growth and influence will also impact the growth of Asia and enhance other opportunities for Chubb across the region. Over the coming decade or so, I can imagine Huatai becoming a major contributor to Chubb's revenue and earnings, but it's not without risk. Nothing is guaranteed.

Our Asia-focused life insurance business, which has 49,000 captive agents in six countries, now generates $2.4 billion in premium and deposits. International life revenue grew 13% last year in constant dollars and we earned over $150 million of income, up from about $25 million three years ago. These numbers exclude Huatai Life, which we do not consolidate. We expect Huatai Life, which has 35,000 agents, to become over time the centerpiece of our life operation. Life insurance is today a relatively modest business for Chubb, but it has a lot of long-term potential.

Digital begins with the customer experience

Chubb must be vital and compelling in a digital age if we want to remain relevant. This is central to both our short- and long-term strategies, and we are making good progress. Digital begins with the customer experience and cuts across our distribution channels with both our traditional and non-traditional partners. At the same time, we are redefining or modernizing what insurance does and how it does it. Through the use of data and analytics, robotics and machine learning, digital is improving our risk selection and pricing, our underwriting and ability to service and pay claims, our customer experience and our efficiency. It represents a sea change for our business.

Our digital strategy from a customer perspective is focused primarily but not exclusively on consumers and small businesses. The strategy is global in scale, with particular emphasis on the U.S., Asia and Latin America. We

> "Distribution partnerships enable us to reach tens of millions of potential new customers, both individual consumers and businesses. We have more than 150 of these partnerships with banks, retailers, airlines and mobile network operators."

are creating new products, enhancing service response and experience, and forming new distribution partnerships with digitally native platforms and financial institutions. We are now generating revenue that wouldn't have been possible without our growing digital capability.

New technologies are beginning to help us engineer the risk environment in a real way so clients can manage their exposures. Deploying Internet of Things technologies helps us to predict and prevent losses for both commercial and consumer insureds. For example, we are monitoring temperature, water/humidity and vibration in environments that are vulnerable to loss – from helping hospitals keep safe their high-value medical equipment and supplies to ensuring the proper storage of a family wine collection.

Digital offers us significant potential to reduce our cost structure. Straight-through processing, robotics and machine learning are eliminating low-value activities to reduce expense and enhance efficiencies. We're digitizing and improving the effectiveness and efficiency of our traditional agent and broker distribution channels to help our business partners remain relevant in a digital age.

Climate change and sustainability: reality and responsibility

We and our industry have an opportunity and responsibility to do our part to support society in managing a risk environment that is both volatile and changing due to global climate change. Our response is guided by our core business competencies and values, and our perspective begins with the obvious: We are an insurance company and our job as underwriters is to assess and manage risk using analysis that is data-driven and apolitical. Applying this approach to the perils of climate change, we recognize a growing global risk that requires action from government, the private sector and, in fact, society at large to manage and mitigate the growing threat.

As an insurer, our first responsibility is to use our expertise in risk management to provide products and services that protect individuals, businesses and communities against the effects of climate change. We manage risk – that's our business. We employ sophisticated modeling and have considerable data that identify the physical and economic impact of climate-related risk on individuals, businesses and communities, and this is reflected in the prices we charge for insurance protection. We essentially serve as a market signal of the rising costs of climate change – as the risk increases, insurance prices increase, or availability becomes more limited.

Importantly, climate change is a long-dated risk but for insurers, such as Chubb, it's generally a short-dated liability. Our insurance contracts are typically limited to a single year, and we can quickly respond to changes we see in the risk environment by adjusting our pricing or by restricting our exposure (e.g., limiting our property risk exposure in coastal regions). As modeling and data around specific perils, i.e., flood and wildfire, get better, we have the ability to take more risk, particularly for clients that adapt to changing conditions by mitigating their risk. Lastly, as we do with all other risks, we can only assume climate-related risk to the extent of our balance sheet wherewithal.

Chubb is a leading provider of insurance for renewable energy project construction and operation, and clean tech companies that are creating new technology to reduce CO_2 emissions.

Complementing our insurance coverage, Chubb risk engineers work with our commercial and consumer clients to moderate the risks from climate change perils and make them more resilient. We bring deep technical knowledge to this work, from providing guidance on construction standards, wildfire land management and coastal protection to the development of lithium battery storage systems.

On the investment side, we apply the same risk management rigor to our broadly diversified fixed income portfolio. For example, asset concentrations are carefully managed in hurricane- and flood-exposed areas. The impact of climate risk on underlying credits will naturally be an increased factor in our investment decision-making over time given the future impact on certain long-dated asset classes, such as mortgages and municipal bonds. Our portfolio is relatively short-dated with an average duration of less than four years.

We are realistic about what a single company can achieve in limiting the effects of global warming and advancing sustainability goals. At the same time, it is hard to be optimistic about the likelihood of timely and effective government action. Most governments are focused on the short-term, both political and economic. Despite a plethora of multilateral organizations, we live in a nation-state world generally incapable of addressing a global problem due to the nature of nation-state self-interest. Yet, only government can raise the cost of carbon use by putting a price on carbon, through tax, cap and trade or other measures. Measures should recognize the cost to the planet of carbon and provide economic incentives to move to less carbon-intensive fuels as well as carbon-free alternative sources of energy. Last year, Chubb implemented a new policy restricting our underwriting of thermal coal businesses and precluding our investment in companies that generate more than 30% of their revenues from coal-related mining or energy production.

Finally, as part of good corporate citizenship, we have a responsibility to take actions to reduce Chubb's environmental footprint and, through our philanthropy and public advocacy, to support efforts that strengthen the resilience of communities and protect biodiversity against the effects of climate change. Most recently, we made a commitment in 2019 to reduce our GHG emissions on an absolute basis by another 20% in five years – a goal we already achieved by year-end – and 40% by 2035. These science-based goals are aligned with the two-degree Celsius limit outlined in the Paris Climate Agreement.

While we can't push back sea level rise, we are engaged in projects such as with The Nature Conservancy to support a resilience project in Miami to increase flood protection and serve as a model for replication in other threatened coastal cities. And while we can't stop storm surge, we supported the expansion of a reef restoration project on Mexico's Yucatan Peninsula that included transplanting 10,000 new coral colonies as a natural barrier to help protect the critical tourist economy – a great example of the sustainable economy. We have supported for many years the Conservation Fund's efforts to enhance and protect biodiversity through the preservation of more than 8 million acres of threatened land and water habitats, as well as extensive forest restoration projects across the U.S. and Canada.

As our work and philanthropy demonstrate, we are serious about understanding and responding to climate change. We are committed to undertaking responsible actions to do our part to provide insurance protection for people, businesses and society from the impact of global temperature increases, develop effective mitigation strategies and support the collective action necessary to address this existential threat.

The case for America and the democratization of capitalism

In America today, the media and many in the political establishment dwell endlessly on what's wrong with our country. For sure, as a nation, we have many challenges:

• A civil society where behavior is now more tribal, less inclusive and no longer so civil;

• A deeply polarized political system incapable of solving tough problems, particularly at the federal level, including insufficient education and skills training, issues of healthcare access and affordability for many, and aging or obsolete infrastructure;

• Senior political leadership that fails to lead with the values and principles that have defined American exceptionalism;

• Rising populism, born in part from the financial crisis, fueled by inequality of wealth and opportunity;

• Growing distrust in our basic institutions including big business and government, with an increasing number of younger people questioning the efficacy of democracy and capitalism; and

"Our open society and values make America a magnet for talented individuals all over the world. But to secure our future and maintain our leadership position, we must recognize and lead with our advantages and strengths while correcting things that hold us back. We need to run a better race."

• Insecurity and anger from the feeling that our way of life, our communities and our well-being are somehow threatened by "foreigners," particularly those south of the border.

Our failure to address problems makes them begin to appear intractable, and because we focus predominantly on what's wrong, we lose perspective and that causes us to lose confidence in our country and what has made us great.

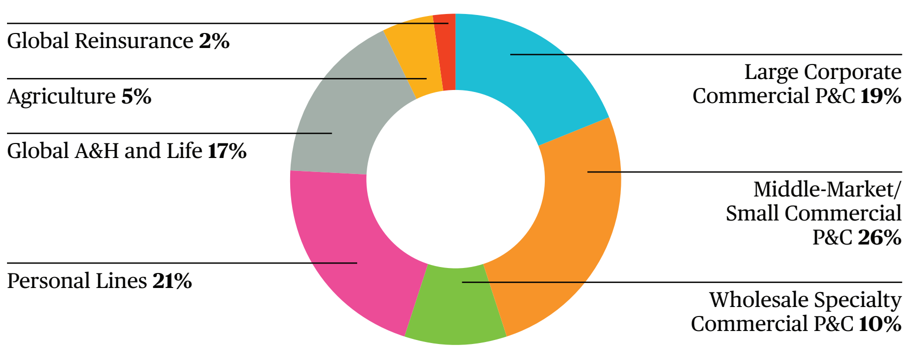
As Americans, we have many reasons to be optimistic. Just look at everything we have: basic natural resource security such as food, energy and water; physical security from two oceans and two neighbors bordering us that are our allies; a society built on values that protect the sanctity of the individual and private property; a democracy supported by an active civil society, the rule of law and independent institutions to safeguard and administer them; an economic and political system with the flexibility and tolerance to embrace creative destruction, a basis for the fostering of innovation and economic dynamism; finally, the English language is the global lingua franca of business, science and diplomacy around the world. Our open society and values make America a magnet for talented individuals all over the world. I have confidence in America. But to secure our future and maintain our leadership position, we must recognize and lead with our advantages and strengths while correcting things that hold us back. We need to run a better race.

Our global system of alliances is a force multiplier. Size matters on the world stage. Just add the number of citizens and economic output of our long-term allies to our own influence and strength and you have over a billion people and tens of trillions in GDP aligned around common value and goals. All alliances require trade-offs and are bound by national self-interest – you give to get. Our brand of America First nationalism, however, fails to account for this trade-off. We should be working together with our allies to defend and improve the rules-based, market-oriented trading system that has contributed enormously to our mutual prosperity. America has been and should remain the model for other nations to follow. After all, the liberal world order that we constructed and have supported for over 70 years was built around this. In this regard, we were the motivating force behind globalization. Through our alliances, we should share the burden of global security. With a clearer sense of our own national security interests and priorities, while recognizing the limits of our own resources, we should strengthen our security alliances, leading efforts in some cases and supporting in others. For example, our government is giving increasing priority to developments in Asia Pacific. After nearly 20 years of war in the Middle East, and supported by our own energy self-sufficiency, we can now concentrate our national focus on other priorities.

We should double down on capitalism. No other system on the planet is more efficient at allocating resources than an open market-oriented system. Governments cannot solve all of our problems and they create distortions. No other system has improved the quality of life for the largest and broadest number of people in history than capitalism. However, it is not perfect. We should do a better job spreading its benefits to all by further democratizing capitalism and creating greater equality of opportunity and access to capital. Our frontier nation was created by bold and driven explorers and entrepreneurs willing

Premium Distribution by Product

2019 net premiums written



to take risks to build something out of nothing. We need to focus on creating the conditions for more builders to flourish in our country while, at the same time, care for the millions who are marginalized or displaced by technological advancements or by globalization. Closing the opportunity gap will require massive investment in people. For this, the private and the public sectors must develop partnerships at scale for skills-based training. We must work together to reform our education system to be able to prepare and accompany individuals from early childhood to career or late career. The business community needs to do a better job of telling leaders of our community colleges and universities what skills we will need and what jobs will be available in the future. Colleges and universities will adapt their educational programs if they receive stronger and clearer market signals from the business world.

We need immigration at scale. In order to remain competitive, we need to increase the size of our population. If we want to grow the size of our economy, and grow much faster, we need many millions more of young people working and paying taxes. For this, we need a pragmatic immigration policy that satisfies America's economic needs while, at the same time, recognizes and preserves the fundamental values of our society and secures our borders. We need to attract the best and brightest by the millions from all over the world. And we welcome those who want to improve their lives and can contribute in productive ways at all levels of our society. In the process they strengthen our culture and values of personal opportunity, responsibility and hard work.

We should borrow to invest in our future. Our public debt exceeds 18 trillion dollars and represents 80% of our GDP. Moreover, nearly 70% of government spending is committed to debt service and entitlements. This level of indebtedness and the health of our public finances put us at risk. The rest of the world will not endlessly lend to us at current low rates. And, we need to reform our entitlement programs, especially Social Security and Medicare. More young migrants will lower the average population age and will translate into a bigger workforce. That will improve worker-retiree ratios and reduce the pressure of entitlements on our government finances. As a nation, we should basically borrow to invest in our future prosperity – to improve our competitiveness – and in our security. Otherwise, we are mortgaging the future of our kids. With more fiscal discipline and more revenue, the government will be able to invest in people, infrastructure, security and R&D. It will also be able to support and nurture key industries that will be crucial to sustain our economic and military preeminence in the 21st century.

In sum, America is the most productive, creative and innovative nation on the planet, and we should be more optimistic but more disciplined about our future. If we run a better race and have more confidence in ourselves, we will have more strategic patience in imagining and guiding the geopolitical future, including our relationship with a rising China.

The U.S.-China relationship

Without a doubt, the U.S.-China relationship is the most important bilateral relationship in the world. However, over the last decade, we have seen it deteriorate. Our relationship is marked by increasing tension and

"We strive to be an inclusive meritocracy, where all employees regardless of gender or background can thrive, and we develop citizens of our culture with our values, work ethic and discipline."

a growing distrust. We have a clash of national interests, values and political systems. We are in strategic drift, failing to define a strategic vision that recognizes each of our priorities and current realities. We need a framework for cooperation in key areas, and rules or understandings for competition and rivalry in others. Today, constituents in both countries see each other as a threat or even as an enemy. Many advocate for disengagement or economic and technological decoupling, and this may form an element of our strategy to defend, but it's hardly the entire answer. In the absence of strategic purpose and sustained diplomatic engagement, we will continue to move in the wrong direction and increase the risk of conflict.

The relationship is broad with many issues of mutual interest and concern. These include, but are not limited to, global warming, terrorism, nuclear proliferation and protection of the commons. We should work together in areas where our interests are aligned and create a framework for dialogue and hopefully clear rules of engagement in the areas where we compete or are at odds. Technology and cybersecurity come to mind.

China is an old civilization with highly talented people, an admirable work ethic and an ambition to be number one in the world. New technologies are seen as their opportunity to reach economic and military primacy. While it is true they have the advantage of size and scale (which is important when it comes to economic and political influence), they are not a juggernaut – and we should not view them as such.

China, too, has many weaknesses and vulnerabilities. First of all, and as opposed to America, they are not resource self-sufficient. They depend on other countries to supply the natural resources they need to survive and grow. They do not have enough food, raw materials or energy, and they are surrounded by distrustful or hostile neighbors, a number of which are nuclear-armed. Their political system is a one-party-controlled techno-authoritarian state that values social stability above all else – a system less conducive to innovation. China's centrally directed economy allocates capital inefficiently, led by Chinese state-owned enterprises (SOEs) whose return on capital is in the low single digits. China substantially lacks the rule of law and the independent institutions to administer it, and this creates uncertainty. Private entrepreneurs are slowing investment as the uncertainty about the future of China's market economy rises. And the Chinese language and a more-closed society are less conducive to attracting outside talent and ideas.

The trade agreement announced at the end of 2019, although modest, created a temporary floor under our trade relationship. The American business community does not support tariffs as a strategy. However, we advocate for fair rules-based competition and a level playing field. We need agreements that address China's predatory policies and practices intended to dominate markets and technologies. We need the same level of access to their markets and opportunities as they find abroad. China is a huge beneficiary of the global trading system, yet their markets remain closed and protected in important ways.

Make no mistake, China is and will be a formidable rival and, in the future, we will share global leadership and influence. We should recognize this fact. If we run our own race well, and have confidence in who we are and our ability, we will sustain our leadership advantages.

Attracting, developing and retaining top talent

Foundational to Chubb's long-term success is our disciplined approach to attracting, developing and retaining the next generation of insurance professionals and leaders. We strive to be an inclusive meritocracy, where all employees regardless of gender or background can thrive, and we develop citizens of our culture with our values, work ethic and discipline. We recognize and reward responsibility, ambition and results with opportunity for individuals to achieve their full potential and advance through our organization. We offer colleagues opportunities to continuously learn, gain valuable new experiences and prove themselves – to grow as individuals. We strive to get to know our people, and we are constantly on the lookout for top performers and those who have the aspiration and commitment to succeed.

We begin by attracting and nurturing early career talent. Hundreds of college grads join us every year on a two-year development journey primarily in the basic core competencies of underwriting and claims, IT and other functional areas. We have been doing this for years now and our success rate has been quite good, with high levels of engagement and rates of promotion. Our talent development efforts are for all employee levels, including mid-career and senior managers. Our Craftsmanship curriculum includes on-the-job and formal training, and opportunities to continuously broaden skills, achieve technical proficiency and hone leadership effectiveness. We give talented employees opportunity to experience a new country and culture, and to bring their skills and knowledge from one market to another, which is so important for a global company. For more seasoned employees, we provide education on new technologies and new areas of insurance. All employees have access to a mix of traditional and virtual classes and team-based projects, which we encourage in their individual development plans.

The development of our leadership and talent pipelines is a focus of senior management, starting with me. We spend several days each year on succession plans including development priorities, talent gaps and ways to further strengthen our bench. In 2019, we promoted from within to fill 100% of all senior executive roles that became open due to retirement or resignations. This resulted in seamless transitions and continuity of service that benefited both Chubb and our customers and business partners. Just as we measure results in other areas of our business, we set clear goals for ourselves concerning our people and we track our progress. Our retention of employees at all levels is at or above external benchmarks and we are achieving improved representation of employees as measured by gender, nationality and experience, including at middle and senior levels of management. We can continue to improve our ability to attract, develop, recognize and retain our employees as we strive to create a company where all who choose to achieve their full potential can do so. As the company grows bigger and we compete for talent, it's mission critical.

A decade of growth and accomplishment

I have many to thank for a gratifying 2019 and a decade of tremendous growth and accomplishment for our company, beginning with my fellow employees and senior management team. I'm surrounded by dedicated, engaged and supportive professionals – amazing people who care so much about our company and their customers. We are a company of builders, and builders want to win. Without their personal and collective sacrifice, our achievements, and the mission we are on to create greatness, simply would not have been possible.

I also want to thank Chubb's active and supportive board of directors, whose commitment and counsel have been essential to our company's success. This year marks the retirement of our lead director, Robert Hernandez. Bob was here at the beginning – he joined the board of ACE when the company was founded in 1985, and for over three and a half decades he actively supported and helped govern the company. As lead director he helped to lead the board in independent governance and deliberation. Bob has been a partner to me for over 15 years. Always supportive yet independent, he exemplifies model governance and represented the interests of shareholders while counseling management – a clear example why rigid term limits are an unnecessary crutch. Bob is a model of wisdom, duty of care and loyalty, and I will miss him. Bob's successor as lead director will be Michael Connors, who has been on our board since 2011. I and my fellow directors look forward to working with Mike and benefiting from his years of experience and counsel in this critical role. Lastly, I want to thank Kimberly Ross, who served as a director from 2014 to 2019, for her contributions and service.

Chubb is a compelling long-term shareholder value creation story. We have a unique, highly competitive global franchise featuring a well-diversified portfolio of market-leading businesses with substantial capabilities, including presence and scale, backed by a world-class service quality reputation and a sterling brand. We have clarity of strategy, purpose and opportunity. Our product and distribution capabilities are well integrated with a disciplined, well-tested execution-oriented culture. Add to that our balance sheet strength and long-term revenue growth and earning power. As we close out one decade and enter an exciting new one with great anticipation, we are confident that our best days are in front of us, and that we will outperform and deliver exceptional value to you, our shareholders, long into the future.

On behalf of the entire organization, thank you for your investment and trust in us.

Sincerely,

Evan Greenberg

Evan G. Greenberg
Chairman and Chief Executive Officer

Consumer and commercial customers have long recognized Chubb for its finely crafted coverage and superior service. We also aspire to create a truly differentiated customer experience. This begins with empathy, is fueled by inspiration and innovation, and brought to life through commitment and resources. We're focused on meeting the insurance needs of customers in ways that provide greater value, ease, speed, convenience and peace of mind. Elevating the customer experience means being there during the moments that matter with relevant capabilities and products that match each customer's lifestyle and life stage.

Using digital technology to enhance the customer experience

In Mexico, where Chubb is the third-largest auto insurer, the company uses technology to get customers back on the road faster after an accident. To expedite the claims process and accelerate car repairs, Chubb insureds use an app to take photos of their damaged auto and digitally select a body shop while a remote adjuster evaluates the claim instantly. When a field adjuster is needed, in-app technology uses a geospatial algorithm to locate the closest adjusters and automatically dispatches one of them for assistance. In most cases – more than 75% of the time in 2019 – a Chubb adjuster arrives at the scene of an accident within 15 minutes of notification, drastically reducing the customer's on-site wait time after an accident.

In the U.S., Chubb Personal Risk Services customers can use Chubb at the Wheel, a new mobile app for family members such as teen drivers and their parents who choose to improve driving safety through monitoring and education. When a teen logs into the app, it records their driving habits, including acceleration and braking, and distracting behaviors, such as texting or calling. The app compiles data to provide a driving score at the end of each ride. New and inexperienced drivers can use app feedback to hone their driving skills. Parents and teens both feel safer knowing that roadside assistance and vehicle location are easily accessible, providing a sense of security in the event of an accident.

Moving from "repair and replace" to "predict and prevent"

For policyholders, the experience that matters most is what happens when they have a claim. But what is the value of an insurer – armed with risk engineering expertise, technology, data and analytics – that can prevent a claim from happening in the first place?

Chubb is helping to answer that question by installing sensors that alert consumer and commercial customers to risks from water, failing equipment and other exposures that can damage property and displace people from their home or workplace for weeks or even months.

For homeowners, sensors installed in wine cellars track temperature and humidity data to diagnose issues before they can cause spoilage of a valuable collection. Chubb-installed sensors can help ensure a stable cellar environment, allowing customers to know their collection is safe.

For commercial customers, Chubb is installing sensors that monitor water, temperature and humidity changes in hospitals and other large, complex properties. Chubb has the expertise to know where large interior water loss damage is likely to occur, and places sensors in the right locations. Avoiding a loss provides real value beyond just the claim payment. It's about avoiding the disruption to the customer that comes with getting damaged assets repaired or replaced.

When the experience is the product

Insurance companies often talk about the coverages they offer as "products." As digital capabilities advance, and opportunities to create tailored and frictionless experiences for customers increase, the experience itself – fast, customized, simple and mobile – can be the product. That vision stands behind a growing number of innovations at Chubb featuring a digital service and experience.

Through its exclusive distribution partnership with Grab, the leading ride-hailing and mobile payments company in Southeast Asia, Chubb offers Singapore-based customers an affordable daily travel product, called Travel Cover. Using the Grab app, customers get an instant quote to purchase travel insurance right up to the time of departure. Available for travel to any destination globally, the per day cost begins at less than $2. Customers can also save their travel profiles on the Grab app, making future purchases easy and convenient.

Beginning in 2019, travel insurance customers in Singapore benefited from a completely automated experience for certain frequent travel-related claims, including overseas medical expense reimbursement, and baggage and travel inconvenience claims. Using their smart phone, computer or tablet, customers complete the claims process in minutes and without the need to download an app or create an account.

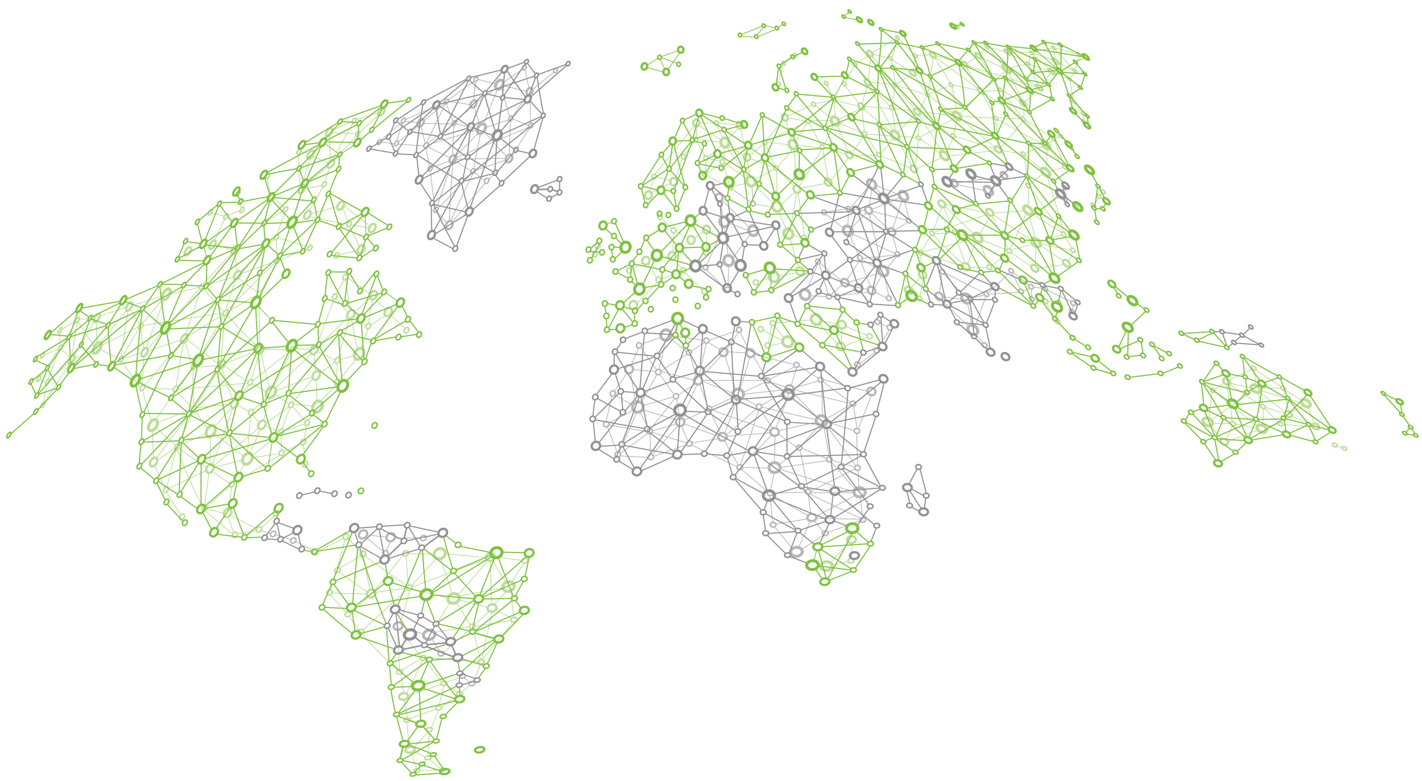
Making it easier to do business with Chubb

A decade ago, Chubb introduced Worldview®, an award-winning web-based application that provides real-time access to Chubb's systems and expertise in one application. Worldview® transformed program management for the complex insurance needs of multinational clients and their brokers, and it remains the most powerful, effective and transparent tool of its kind in the industry. Today, more than 10,000 Chubb clients and brokers utilize the system.

The application has been expanded to include additional product lines and capabilities, including a seamless user experience bolstered by an interactive dashboard. With Worldview®, clients and brokers can also request and upload translations of policies from a local language to English. Adoption and use of Worldview continues to grow, with the number of active users increasing 14% in 2019.

A growing number of small business owners in the U.S. and globally are using the Chubb Commercial Client Center, an intuitive self-service platform that allows insureds to view their billing history and recent statements, pay bills, submit claims, access policy documents and request an endorsement or a certificate of insurance (COI). In addition to bringing greater convenience to customers, Client Center reduces administrative overhead for independent agents. Chubb's investments in the Client Center customer experience are paying off: since its launch, an average of 1,000 new users per month have been added.

A Global Leader in Property and Casualty Insurance



Argentina
Australia
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Belgium
Bermuda
Brazil
Canada
Chile
China
Colombia
Czech Republic
Denmark
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Russia
Saudi Arabia
Singapore
South Africa
Spain
Sweden
Switzerland
Taiwan
Thailand
Tunisia
Turkey
United Arab Emirates
United Kingdom
United States
Vietnam

A local presence in 54 countries and territories around the world

Chubb has operations in the countries and territories listed here and can help clients manage their risks anywhere in the world.

Chubb Senior Operating Leaders

John Lupica

Vice Chairman,
Chubb Group;
President, North America
Major Accounts and
Specialty Insurance

John Keogh

Executive Vice Chairman,
Chubb Group;
Chief Operating Officer

Paul J. Krump

Executive Vice President,
Chubb Group;
President, North America
Commercial and
Personal Insurance

Juan Luis Ortega

Executive Vice President,
Chubb Group;
President, Overseas
General Insurance

Chubb's senior operating leadership includes the company's Chief Operating Officer and the leaders of North America and Overseas General insurance operations.

Key Financial Results

Dollars in millions

Total North America P&C Insurance

2019	
Gross premiums written	$25,480
Net premiums written	$19,972
Combined ratio	87.8%
P&C current accident year combined ratio excluding catastrophe losses	87.1%

North America Commercial P&C Insurance

2019	
Gross premiums written	$17,604
Net premiums written	$13,375
Combined ratio	85.6%
P&C current accident year combined ratio excluding catastrophe losses	87.4%
Segment income	$3,942

North America Personal P&C Insurance

2019	
Gross premiums written	$5,461
Net premiums written	$4,787
Combined ratio	91.1%
P&C current accident year combined ratio excluding catastrophe losses	81.4%
Segment income	$660

North America Agricultural Insurance

2019	
Gross premiums written	$2,415
Net premiums written	$1,810
Combined ratio	95.1%
P&C current accident year combined ratio excluding catastrophe losses	99.1%
Segment income	$90

Chubb's insurance businesses in North America serve clients ranging from the largest multinationals, middle-market companies and small businesses to successful individuals and families, and the agriculture community.

For commercial property and casualty insurers in North America, the major theme of 2019 was the improving operating environment. For Chubb, a market with firming pricing and conditions created an opportunity to bring the company's signature capabilities to more clients in more lines of business at risk-adjusted rates in line with rising loss costs.

"The quality of Chubb stood out in 2019," said John Keogh, Executive Vice Chairman, Chubb Group and Chief Operating Officer. "In a market that was sometimes chaotic, Chubb demonstrated that we are professional, stable, consistent and a reliable partner. As a result, we further burnished the Chubb brand and reinforced our industry leadership."

Three North American businesses – **Major Accounts, Westchester** and **Chubb Bermuda** – were best positioned to benefit as headwinds were replaced by tailwinds. The operating environment for Chubb's **Commercial Insurance** retail P&C business serving middle-market companies began to turn bullish mid-year and accelerated in the second half. Chubb core strengths, along with its investments in people and digital technology, have also positioned the company's other North American businesses for secular growth opportunities, including the Commercial Insurance segment serving small businesses, **Chubb Personal Risk Services** and the company's agricultural insurance business.

Total net premiums written for the company's North America P&C insurance businesses were $20.0 billion, up 6.6% from 2018. Chubb reported a world-class combined ratio of 87.8% for its North American P&C insurance operations. Excluding catastrophe losses, the current accident year combined ratio was 87.1%.

"Our combination of products, claims and risk engineering services, expertise and underwriting excellence is a powerful differentiator for Chubb, particularly in a firming P&C market cycle," said Paul Krump, Executive Vice President, Chubb Group and President, North America Commercial and Personal Insurance. "When others are reducing capacity and appetite, Chubb's consistency and quality make us a go-to source for agents and brokers to serve their customers."

John Lupica, Vice Chairman of Chubb Group and President, North America Major Accounts & Specialty Insurance, pointed to another Chubb strength: the North American field operation with 49 branches across the U.S. and Canada. "The field plays a critical role in managing the flow of business, cross-sell opportunities and the

Chubb's North America Insurance Business Units

Major Accounts	Commercial P&C insurance products for the large corporate market sold by retail brokers
Commercial Insurance	Commercial P&C insurance products for middle market and small businesses sold by independent agents and retail brokers
Personal Risk Services	Personal lines coverage, including home, auto, valuables, umbrella and recreational marine insurance, for successful individuals and families sold by independent agents and brokers
Westchester	Commercial P&C excess and surplus lines sold through wholesale brokers
Chubb Bermuda	Liability, property, political risk coverage and captive programs sold by large international brokers
Agriculture	Crop insurance from Rain and Hail and farm and other P&C coverages sold by agents and brokers

introduction of new products," he said. "The market environment in 2019 really put a spotlight on the strength and value of our field operation. With our local presence, agents know we're there for them and, at the same time, we can educate clients on the need for adequate pricing."

North America Commercial P&C Insurance

Chubb is one of the largest commercial P&C insurers in the U.S., offering a full range of traditional and specialty products for businesses of all sizes. Net premiums written for North America Commercial P&C Insurance increased 7.1% from 2018. The combined ratio for the segment was 85.6%. Underwriting income was $1.9 billion, and segment income was $3.9 billion.

Major Accounts, Chubb's P&C business unit that serves large companies, is recognized for the breadth and depth of its product and service offerings, technical underwriting experience, superior client service, and a global platform built to service complex, bespoke insurance programs in many countries around the world. It's a high-touch business where Chubb, with its strong client- and broker-centric culture, has developed long-term, enduring relationships. Chubb serves more than 90% of the Fortune 1000.

"In a market that was sometimes chaotic, Chubb demonstrated that we are professional, stable, consistent and a reliable partner. As a result, we further burnished the Chubb brand and reinforced our industry leadership."

– John Keogh

"Over the past two decades we've built a franchise that is second to none and very difficult to replicate," said Mr. Lupica. "With our proven reputation as a thoughtful underwriter and a partner known for service excellence, we were able to benefit from the 'flight to quality' in 2019. We knew it was important to lead the market by communicating with clients and brokers, expressing the need for rate adequacy in lines where premiums have not kept up with loss costs. A healthier market, where insurers are able to be paid more appropriately for the risk they assume, is good for Chubb because clients value our consistency, services and the relationships we have built over time."

In 2019, the retention rate for Major Accounts was more than 95%, a record. Cross-selling services to existing customers accounted for more than 81% of new business.

Among Major Accounts' distinguishing capabilities are its industry practices, including transportation, private equity, real estate and construction. Multiline clients also have access to a Global Client Executive, who knows the insured and serves as a single point of contact to navigate the Chubb network across the globe. For claims handling, customers also have access to a Claims Client Executive. Worldview®, Chubb's award-winning proprietary portal, enables client risk managers and brokers to manage and track all aspects of their insurance program in real time. More than 10,000 clients and brokers utilize the system.

For the year, Major Accounts and the excess and surplus (E&S) wholesale businesses generated 7.9% growth in net written premiums.

In the E&S lines market, **Westchester** specializes in hard-to-place casualty, property catastrophe and specialty lines for large corporate, middle-market and small businesses. Wholesale brokers distribute these products, including specialty classes such as financial lines, product recall and cyber. Traditional brokerage accounts for about 60% of Westchester's premiums, with the balance from its binding and programs divisions.

In recent years, Chubb has pointed to Westchester as a proof point for the underwriting discipline that defines the entire company: We will trade market share for profitability. From 2015 to 2018, Westchester's net premiums written shrunk an average of 2.6% per year. Yet over the past 13 years, the business produced an average combined ratio of 92.8%. In the current environment, Westchester demonstrates Chubb's ability to react quickly to market changes, and outperform the broader market, which began to turn in late 2018 and accelerated throughout 2019. For the year, the business grew 9.1%.

Westchester's ability to seize opportunities in a changing market is due to investments made to broaden the product set, retain experienced talent, develop the next generation of underwriters, reward experienced underwriters for remaining disciplined, and deploy technology that enables the business to scale efficiently. Investments in digital capabilities, for example, allowed Westchester to make a record number of API connections with E&S agents in the binding division.

North American Business Unit Leaders

(From left)

Scott Arnold
Vice President, Chubb Group; Division President, Chubb Agriculture; President, Rain and Hail

Judy Gonsalves
Vice President, Chubb Group; Division President, Chubb Bermuda

Christopher A. Maleno
Senior Vice President, Chubb Group; Division President, North America Field Operations

Bruce L. Kessler
Senior Vice President, Chubb Group; Division President, Westchester

Chubb Bermuda provides excess coverage in three product areas: casualty, property and financial lines. It also houses the company's political risk group. Operating with a high severity/low frequency business model and offering broad coverage and sizable capacity to clients and brokers around the world, the business produced strong results across all products in 2019.

"Our property business produced record results for the year. Because brokers have been trading with our property team for years – or even decades – they knew where to find access to quality capacity at the right price," said Mr. Lupica.

Commercial Insurance is Chubb's division that provides P&C coverages to middle-market companies with revenues up to $1 billion and small businesses. In the middle-market segment, Chubb is distinguished by its more than 25 industry practices, each handled by teams of experienced underwriting, claims and risk engineering professionals who understand the particular exposures of that industry. The business's core package product is complemented by the industry's largest offering of standard and specialty coverages, including auto, workers compensation, marine, cyber, environmental, multinational, directors and officers (D&O) and errors and omissions (E&O) coverages.

Chubb's commercial P&C offering for small businesses includes a core package product as well as an expanding range of specialty products. This segment is growing rapidly, drawing strength from the company's middle-market expertise as well as capabilities from Marketplace, Chubb's fully automated digital platform that makes it easy for agents to quote, issue and service all of their small business accounts. In 2019, net premiums written in Chubb's middle market and small business division grew 6.1%.

Together, the addressable market for Commercial Insurance includes businesses from sole proprietorships, "A healthier market, where insurers are able to be paid more appropriately for the risk they assume, is good for Chubb because clients value our consistency, services and the relationships we have built over time."

– John Lupica

family businesses and single-location private companies to publicly traded entities with a multinational footprint. Chubb's commercial P&C business has the expertise and appetite to address about 85% of this important growth sector of the economy.

"In the middle market we were able to capitalize on the market shift and seek more opportunities," said Mr. Krump. "This was a direct result of our continued focus on underwriting discipline, delivering exceptional service to our customers and producers, and writing new business in the industries where we have distinct expertise and appetite."

Chubb's North American middle-market and small commercial businesses are at the nexus of several important company initiatives. They serve as the model for Chubb to export and expand its ability to serve these market segments in other regions of the world. The growing technical capabilities of the Marketplace platform, which originally focused on small businesses, are increasingly relevant to companies at the lower end of the middle market. The branch network is also a key channel to distribute Chubb's specialty insurance products to middle-market customers.

Cross-selling is an important part of the Chubb middle-market story. In 2019, nearly 50% of new business written was sold to existing clients. "For mid-market companies, we are an account solution. Our account retention is high – 92% in 2019 – and our average time on a risk is 15 years," said Mr. Krump. "We grow with clients, and work with them to manage through market cycles."

In 2019, Chubb's middle-market business continued to deepen its product offering, developing and launching 15 enhancements to its package coverage, including expanded flood and earthquake coverage.

Chubb has invested in the success of its agents, including developing online resource centers and providing research and marketing and prospecting resources to help them fuel their own business growth. In 2019, Chubb introduced The Cyber COPE Insurance Certification℠ program, an eight-month program for Chubb brokers and agents to learn best practices in cybersecurity risk management, governance and operations.

Chubb also sponsors the National Center for the Middle Market (NCMM) at The Ohio State University. Along with NCMM, Chubb is publishing the Middle Market Indicator, a quarterly survey of 1,000 C-suite middle market company executives across all industries.

For Chubb's small business segment, which had its beginnings just four years ago, 2019 was a year of strong growth and progress. Net written premiums were up 35%, with new business growth approaching 35%. Transactions on Marketplace were up 55% from 2018. The business unit ended 2019 with an annual run rate of $400 million of gross written premium.

North American Business Unit Leaders

(From left)

Matthew Merna
Senior Vice President,
Chubb Group;
Division President,
North America
Major Accounts

Frances D. O'Brien
Senior Vice President,
Chubb Group;
Division President,
North America
Personal Risk Services

Benjamin Rockwell
Vice President,
Chubb Group;
Division President,
North America
Middle Market

James Williamson
Vice President,
Chubb Group;
Division President,
North America
Small Business

Adoption of Marketplace continued to grow. By year-end 2019, the platform was deployed to more than 40,000 users at more than 4,500 agencies. Each day, an average of 1,000 agents log in to the platform to transact business. Nearly 85% of submissions for the core package product are processed on a "straight-through" basis, where the agent receives a fast answer from the system without having to interact with an underwriter.

In this high-volume, low-touch segment, the ability to offer a digital experience for agents is paramount. Marketplace was built to scale, and Chubb regularly adds new products, industry segments and services to better serve small businesses as they grow and move into the lower middle market. In 2020, Marketplace is on track to begin offering personal accident and supplemental health products from Chubb's North American A&H business.

Chubb is making other investments to make it easier for customers and agents to do business with the company while driving superior risk selection across the portfolio. By harnessing data and analytics, Chubb is on a path to reduce average quote times for less complex risks to less than three minutes, predict risk classification for the majority of submissions and, ultimately, reduce the number of underwriting questions that must be asked to just two.

Digital investments are also strengthening the company's ability to serve affinity group partners. For example, in 2019 Chubb announced a partnership with the National Association of Women Business Owners (NAWBO), an organization representing nearly 12 million women-owned businesses. NAWBO members now have access to an industry-leading resource for small business insurance needs and education along with access to insurance products and services generally reserved for the larger corporations, including Chubb's cyber enterprise risk management policy.

"We're positioned in a way to bring more product to more types of insurance through our agents than anybody else. It's happening now," said Mr. Krump.

"Our combination of products, claims and risk engineering services, expertise and underwriting excellence is a powerful differentiator for Chubb, particularly in a firming P&C market cycle."

– Paul Krump

North America Agricultural Insurance

Chubb's Rain and Hail subsidiary is the leading crop insurance managing general agency in North America. The business serves approximately 125,000 farmers, insuring more than 100 different crops on 80 million acres. With distribution through 5,600 independent agents, Rain and Hail has the largest agency footprint in this sector. In addition, Chubb's North America agriculture segment includes farm, ranch and P&C commercial agriculture coverages.

Crop insurance is a public-private partnership that operates with a proven model. While the results of the business are not typically correlated with the P&C insurance market cycle, crop insurance is a business with CAT-like risks. In 2019, poor growing conditions in agricultural regions in the U.S. led to crop yield shortfalls and elevated prevented planting claims. For the year, the segment produced a combined ratio of 95.1%. Segment income was $90 million on net written premiums of $1.8 billion.

In a challenging year for farmers, Chubb distinguished itself by delivering superior service and getting claims payments into the hands of farmers quickly.

"Chubb is committed to the crop insurance business, and it's in times of stress that Rain and Hail's service and claims-handling capabilities make a real difference," said Mr. Lupica. "We saw it in 2012, a year of record drought. We saw it again in 2019, when the peril was excessive rain. We responded when our customers needed us, paying all prevented planting claims in record time. Rain and Hail shined in 2019, making it a year when we extended the value of the brand."

North America Personal P&C Insurance

Chubb is the leading provider of personal lines insurance for successful individuals and families in the U.S. and Canada. It's been 40 years since Chubb pioneered insurance solutions crafted for this discerning market segment. Over the years, the company has built and maintained its leadership by continuing to raise the bar for the coverage and services it offers customers, including a broad product offering, superior claims and risk consulting services, and access to Chubb's extensive branch network in the U.S. and Canada. Clients of Chubb Personal Risk Services also benefit from the company's global presence, which offers protection for their assets around the world.

Net premiums written for the North America Personal P&C Insurance segment were $4.8 billion. The 2019 combined ratio was 91.1%. The current accident year combined ratio excluding catastrophe losses was 81.4%. Segment income was $660 million.

As the risk environment evolves, Chubb continues to find innovative ways to help protect clients from the everyday risks of owning a home and automobile as well as the unique risks that come with achieving considerable success in their lives and professions.

"Our clients are becoming increasingly aware of the risks they may be facing from severe weather events, distracted drivers texting and using social media, social movements like #MeToo, and the need to protect their data and their privacy," said Mr. Krump. "As a result, customers want to engage with us at a much higher level in order to understand what they can do to mitigate their potential for a loss."

Chubb's investments in digital capabilities are making it easier for customers, agents and brokers to interact with us on their preferred terms, from the web and mobile app to phone and in-person. Two years ago, Chubb Personal Risk Services significantly expanded the capabilities of its web portal. By the end of 2019, more than half of all customers were actively using it. Adoption of the mobile app, with features that include biometric login, voice commands, text and email alerts, has been accelerating: An average of 3,000 clients per month downloaded the app in 2019. Customers are using the web portal and app to quickly access their auto identification information, file a first notice of loss digitally or to find a trusted service provider, such as a fine-art transit service or home alarm company.

Chubb Personal Risk Services has continued to expand and deepen the services available to clients. In 2019, the company introduced a first-of-its-kind solution to protect personally identifiable information when an auto is totaled. Chubb's service, available at no additional cost to auto clients who experience an insured total loss, will wipe all sensitive information stored on the vehicle's electronics system, such as mobile contacts, text messages, GPS data and garage and gate opening codes.

Chubb Property Manager^{SM} provides policyholders with assistance for second homes that suffer damage from hurricane-force winds. Once an area is safely accessible, Chubb will dispatch a representative to inspect the home and provide a detailed report on its condition.

For policyholders in states prone to wildfires, Chubb offers Wildfire Defense Services to monitor and protect homes threatened by this peril. Wildfire Defense Services will take actions such as clearing of hazardous objects and material around the home to create a more defensible space, installing sprinklers, addressing hot spots and, as a last line of defense in home protection, applying fire retardant gel to the home. Tens of thousands of policyholders in 18 states are enrolled in this complimentary service.

Chubb also engages with clients to raise awareness about risks such as flooding and internal water leaks. Water damage from burst pipes, frayed hoses and other plumbing failures remains the number one loss a homeowner is likely to face. Through awareness and education campaigns directed at both customers and agents, Chubb encourages policyholders to install water leak detection devices or to turn off their main water valve when they leave their home for extended periods of time.

In 2019, Chubb Personal Risk Services launched a pilot program for clients with wine collections to install sensors to monitor temperature and humidity. When a change that could lead to damage is detected, the homeowner is alerted via an app to take preventative action before damage or a claim occurs. Chubb's risk consultants also visit customers' homes to identify potential exposures and advise clients on actions that could prevent a loss. Thermographic scans, for example, can detect moisture and hot spots behind walls that could indicate threats from water damage or electrical fires.

Benefiting from decades of experience, a broad dataset and increasingly sophisticated analytics capabilities, Chubb identifies clients that have a higher propensity for a loss, and is working with them and their agents proactively to mitigate or prevent a loss from happening in the first place.

"We're very optimistic about the opportunities for Personal Risk Services," said Mr. Krump. "With clients increasingly aware of the risks they face, they are looking for a company that can provide products and services to help them manage those risks. With our deep history and capabilities across the Chubb organization, we have so much to offer them."

"Chubb is well positioned to serve our customers and distribution partners across all of our North American businesses because of the investments we've made in technology, product and distribution," said Mr. Keogh. "But our most important investments are in our people – training, developing and growing the men and women who are the future of this company."

Key Financial Results

Dollars in millions

Overseas General Insurance

2019	
Gross premiums written	$11,408
Net premiums written	$9,262
Combined ratio	91.6%
P&C current accident year combined ratio excluding catastrophe losses	90.9%
Segment income	$1,273

"Chubb is able to transport best practices from one strategic distribution partnership to another, enabling us to create unique customer experiences that match our partners' digital assets."

– Juan Luis Ortega

Chubb's international general insurance operation is comprised of two main businesses: one with retail operations in five regions of the world and the other an excess and surplus (E&S) lines operation in the London wholesale market and a presence at Lloyd's.

As in North America, the major theme in 2019 for Chubb's international general insurance operations was the operating environment. When the year began, firming conditions were already underway in a few select locations including the London wholesale market and the commercial P&C market in Australia. The trend gained momentum during the year, and extended to the U.K. retail market and Continental Europe.

"The market momentum in 2019 was notable, but it is only part of the story," said Juan Luis Ortega, Executive Vice President, Chubb Group and President, Overseas General Insurance. "Our progress and performance also reflect the investments we have made in recent years to advance our market segmentation strategies for commercial P&C, digital initiatives to enhance the customer experience, and distribution partnerships that give us access to millions of customers for both our consumer and commercial product offerings."

"Chubb's capabilities – our diversity in geography, products and distribution – have taken years to build," said Mr. Keogh. "They are a sustainable competitive advantage that is getting stronger by the day."

Overseas General Insurance generated net premiums written of $9.3 billion in 2019, up 8.4% in constant dollars. The combined ratio for the year was 91.6%. The current accident year combined ratio excluding catastrophe losses was 90.9%, and segment income was $1.3 billion.

Commercial P&C insurance represents about 60% of Chubb's international business. In 2019, Chubb's retail commercial P&C segments – Major Accounts and middle market and small businesses – benefited from a more favorable operating environment as well as initiatives to further build out the company's capabilities. Highlights for Major Accounts included strong growth across Asia Pacific, the U.K. and Ireland, as well as Continental Europe.

In the middle market, Chubb's focus on key markets and on expanding industry practices helped to drive results. Double-digit growth in the small commercial segment was highlighted by strong results in Australia. By the end of 2019, small commercial represented 21% of international commercial P&C premiums.

Alongside P&C insurance, Chubb offers accident and health and personal lines coverage globally. These two businesses meet the protection needs of consumers against accidents, hospitalization, critical illness and protect things that consumers own, such as their home, car and even their phone.

Chubb's ever-expanding digital capabilities, along with product breadth and claims service, have positioned the company as the distribution partner of choice for banks, retailers, airlines and mobile network operators that want to be able to offer best-in-class protection to their customers. Four major partnerships established in the past two years alone – with Citibanamex, Banco de Chile, DBS and Grab – provide access to over 60 million customers. Worldwide, Chubb has more than 150 distribution partnerships.

Chubb's Overseas General Insurance Business Units

International	Commercial P&C, A&H and traditional and specialty personal lines sold by retail brokers, agents and other channels in five regions:
Europe	Operations in the U.K. and 18 other countries comprised of P&C commercial lines and consumer lines, including A&H and specialty personal lines
Asia Pacific	Operations in 14 countries and territories serving commercial customers and consumers with P&C, A&H and personal lines
Latin America	Operations in nine countries serving commercial customers with P&C products and consumers through A&H and personal lines
Far East	Operations in Japan serving commercial customers with P&C products and consumers through A&H and personal lines
Eurasia & Africa	Operations in eight countries serving commercial customers with P&C products and consumers through A&H and personal lines
Chubb Global Markets	Commercial P&C excess and surplus lines and A&H sold by wholesale brokers in the London market and through Lloyd's

"With our consistency in local delivery, Chubb is able to transport best practices from one strategic distribution partnership to another, enabling us to create unique customer experiences that match our partners' digital assets," said Mr. Ortega. "In 2019, we gained real traction on digital distribution of consumer insurance across Asia and Latin America."

In Chubb's core direct marketing business, Korea was a standout, achieving a new milestone of 2 million policyholders. During the year, Chubb closed 20 new direct marketing sponsorships. In Chubb's travel insurance business, a new partnership with Aeromexico announced in early 2020 was one of 25 new relationships secured in the past year. Other highlights in Chubb's international A&H insurance business include Europe and Japan, which both generated the highest growth in several years.

Personal lines generated strong growth in 2019, particularly in the emerging markets of Asia and Latin America. Highlights included the company's motor insurance business in Mexico, which is recognized for its top-tier sales and service capabilities. Another highlight is specialty personal lines, where Chubb has a market-leading position in the distribution of cell phone insurance to customers of mobile network operators across Europe. This business, which had a strong year in 2019, is a showcase for the company's claims handling and service – customers want their phones fixed or replaced quickly – as well as evolving digital capabilities. Today, most cell phone replacement claims are handled with straight-through processing without any human intervention.

Chubb's international general insurance operations benefit from the movement of people within the organization. One of the principal ways the company develops talent is by promoting intra- and inter-regional mobility that exposes employees to different markets and cultures. In the past three years, nearly 300 colleagues have undertaken international assignments. Every year, more than 1,200 colleagues are promoted into a new job or granted expanded responsibilities. These career progression opportunities recognize the performance of colleagues and create an environment for continuous learning.

Chubb's **Asia Pacific** region generated gross premiums written of $2.9 billion, up 9% in constant dollars from prior year, which represents 7% of the company total.

In its partnership with Grab, the leading ride-hailing and mobile payments company in Southeast Asia, Chubb introduced an affordable daily travel product, called Travel Cover, which offers a simple and convenient way for Singapore-based customers to purchase travel insurance on the Grab app right up to the time of departure. Six other new products were launched in 2019 on Grab's passenger and driver apps in Singapore and Malaysia.

Premium growth from Chubb's partnership with DBS, the largest financial services group in Southeast Asia, was driven by A&H products for retail customers in Singapore and by P&C coverages for businesses in Hong Kong. Chubb was also a partner in the 2019 launch of DBS Travel Marketplace, the first one-stop integrated travel marketplace in Singapore. Through this platform, consumers can find airfares and hotel rates for more than 25,000 global destinations, as well as free travel insurance coverage underwritten by Chubb.

Digital capabilities, including API technology, are enabling these and other partnerships, which offer consumers and businesses innovative products and an enhanced customer experience. Chubb's partnership with Grab, for example, has produced the first end-to-end API-integrated insurance product that covers policy issuance, administration and claims investigation in a single app.

The growth of the A&H business in Korea reflects several Chubb strengths in direct marketing, including a sponsor base comprised of every major credit card issuer in the country; a diverse range of products; multiple distribution channels, including outbound telemarketing and home shopping; and advanced data and analytical capabilities.

In retail commercial P&C, Chubb continued to develop its Major Accounts practice serving large corporations in Asia, Australia and New Zealand, including establishing Client Advisory Boards in each sub-region of Asia Pacific. Another major focus in Australia was navigating customers through market disruptions stemming from the operating environment for property and directors and officers insurance.

Chubb's middle-market and small business segments in Australia generated double-digit premium growth. During the year, Chubb launched an online broker platform in this market that is designed to improve efficiency in the quote, bind and policy fulfillment process for the small commercial customer segment. The platform leverages the capabilities of Marketplace, which was introduced in North America in 2017. In Australia, the initial product focus is business package and cyber ERM products.

In **China**, the largest economy in Asia and the second-largest in the world, Chubb focused on building and deepening its presence. The company has a significant and increasing ownership stake in Huatai Insurance Group, a holding company with P&C, life and asset management subsidiaries. When pending transactions and agreements are completed, Chubb is expected to own a majority of Huatai Insurance Group. The group's insurance operations have more than 600 branches and 11 million customers.

Chubb also operates a fully licensed, 100% Chubb-owned subsidiary with branch offices in Shanghai, Beijing, Jiangsu and Guangdong. Chubb China offers one of the largest commercial P&C product portfolios in the Chinese insurance market. It also offers a series of protection products such as personal accident, homeowners, travel and personal devices insurance via the rapidly growing internet channel to Chinese families and individuals across the country.

Chubb's **Latin America** region generated gross premiums written of $2.9 billion, up 11% in constant dollars from 2018, representing 7% of the company total. Continuing execution of its growth strategies contributed to strong premium revenue in the company's personal lines and commercial P&C businesses.

Overseas General Business Unit Leaders

(From left)

Darryl Page
Vice President,
Chubb Group;
Division President,
Personal Insurance

John Thompson
Division President,
International
Accident & Health

Timothy O'Donnell
Vice President,
Chubb Group;
Division President,
Commercial Property
and Casualty

Chubb's business across Latin America is well balanced. In Brazil, the company has the second-largest commercial P&C business, which is distinguished by its track record of superior technical ability and multiple affinity distribution partnerships. In Mexico, the company is a leading provider of personal lines insurance, large corporate P&C, as well as surety. Chubb also has a strong presence in the Andean region – Colombia, Ecuador, Peru, Argentina and Chile – that accounts for about 30% of the total region, and where the company operates in all segments of commercial P&C through brokers and affinity partners. In the Caribbean and Central America, Chubb operates through wholly owned subsidiaries in Puerto Rico and Panama as well as corporate P&C insurance and bancassurance partnerships in other locations.

Like Asia, Latin America has favorable long-term growth characteristics, including GDP, a growing middle class and new small business creation. Through its strategies, investments and local presence, Chubb is positioned to further grow in these developing markets. A decade ago, Asia and Latin America represented about one-third of Chubb's international general insurance premium revenue. Today, those regions account for more than half of premium revenue.

In 2019, Chubb made good progress developing its distribution partnerships with leading banks in Mexico and Chile. With Banco de Chile, a major focus was building out the product offering. During the year, the team launched dedicated campaigns for residential, personal lines and commercial P&C coverages across multiple channels, including branches, ATMs, telemarketing and digital.

With Citibanamex in Mexico, Chubb introduced a dozen new products in 2019 and has plans to introduce a dozen more in 2020. These market-driven products are designed in part based on an analysis of purchasing behavior. By the end of 2019, Chubb was selling more than 30,000 policies per month through digital platforms, branches and telesales.

Other highlights in the region included another year of strong results in Mexico personal lines, driven by the auto insurance business. In A&H lines, Chubb's partnership with LATAM airlines contributed to strong premium growth in travel insurance. Chubb has long-term distribution agreements with many of the top airlines based in the region.

Europe is Chubb's second largest region behind North America, operating in 19 countries, with $3.7 billion of gross premiums written, representing 9% of the company total. In 2019, Chubb achieved its best growth in many years and underwriting profitability in an improving operating environment.

Chubb European Group's first order of business in 2019 was completing the redomicile of its EU business from London to Paris as planned on January 1 related to Brexit. Throughout the year, the business remained focused on delivering clarity, continuity of service and certainty for customers, brokers and other partners to ensure continuous, uninterrupted service as Brexit deadlines approached.

Highlights included growth in Major Accounts across the U.K., Ireland and Continental Europe. In Germany and the Netherlands, the upper middle-market segment also performed well. Chubb's global presence, servicing capability, broad product range, financial strength and underwriting leadership contributed to this success.

Other 2019 initiatives included the launch of a new media industry practice for the U.K. and Ireland. The practice offers a range of bespoke coverages for media liability, cyber, property and casualty as well as personal accident and travel coverages for middle market and multinational advertising, public relations, branding and publishing companies. This industry practice also provides value-added services, including a free legal advice helpline staffed by senior media lawyers.

Beginning in 2019, commercial customers of all sizes across Europe had access to Chubb's Environmental Incident Alert, a free service that helps clients identify qualified incident-response contractors, monitor clean-up costs and mitigate potential liabilities associated with environmental releases. The Environmental Incident Alert service uses customized alerts via email and/or text message and also provides response coordination assistance and incident documentation. It is available 24/7 and is now operational in more than 50 countries.

In Germany, the company launched a new digital partnership, called Quick Cargo Insurance, with Hapag-Lloyd AG, one of the world's largest cargo container carriers. The partnership is facilitated through a bespoke online system that quotes and binds single-shipment coverage for small commercial clients of Hapag-Lloyd when they place business orders for marine cargo online. This capability embodies Chubb's drive to offer a superior customer experience by engaging directly with partners and delivering an offering that benefits the partner, their client and Chubb.

During the year, Chubb also launched Easy Solutions Vin in France, which includes a range of property and casualty insurance coverages for wine producers.

Chubb's international A&H business introduced an extended range of new eLearning modules as part of its Chubb Travel Smart app for business travelers, including pre-travel eLearning, direct access to medical and security assistance and live location-based alerts to help avoid trouble and stay safe. Chubb Travel Smart is the company's duty of care solution designed specifically for employers to help manage and mitigate travel risks of their employees.

In specialty personal lines, Chubb entered into several large relationships with European mobile network operators, strengthening its leadership in this market.

Chubb's **Far East** region, which encompasses Japan, had a record year, with growth in premium revenue significantly outpacing the overall market. The business benefited from both an improving operating environment and continued focus on executing its growth strategies. All product lines and distribution channels contributed to the strong results.

Highlights included double-digit growth in property, casualty, financial lines and surety. In the large commercial segment, Chubb's strong underwriting and risk engineering capabilities were strengths in a firming market. For small and middle-market businesses, the company expanded its industry practices, including entertainment, infotech and life sciences.

A&H remains a significant growth engine in Japan with Chubb further building out its multi-channel distribution with agents, brokers, direct marketing and online. Chubb is focused on adding direct marketing partners through customer-segmented campaigns as well as new online travel partners by seamlessly integrating insurance products into their digital purchase path. Relevant and flexible products, such as personal accident and trip cancellation coverages, helped to differentiate Chubb in the marketplace. Each channel is supported by continuous enhancements to product offerings within personal accident, supplemental medical and travel categories.

Overseas General Regional Leaders

(From left)

David Furby
Senior Vice President, Chubb Group; Regional President, European Group

Paul McNamee
Senior Vice President, Chubb Group; Regional President, Asia Pacific

Marcos Gunn
Senior Vice President, Chubb Group; Regional President, Latin America

In 2020, Chubb celebrates a century of doing business in Japan.

Eurasia and Africa also experienced a changing market environment in 2019, with pricing moving closer to the realities of risk in the region, especially in energy and financial lines. The region generated strong premium revenue growth and posted solid underwriting results, recording a combined ratio of 88%. Investment in new IT infrastructure and refinements of the operating model again contributed to an improved expense ratio and will enable future efficiencies.

Chubb Global Markets

Chubb Global Markets, the company's London market wholesale and international excess and surplus business, provides global access to specialist underwriters in aviation, energy, financial lines, marine, political risk and credit, property, and accident and health.

For several years, pricing for risk in the P&C E&S insurance too often failed to meet the company's targets to maintain an adequate underwriting profit. In response, Chubb shrank the business. The overall London market, however, continued to grow, even as Chubb's share of it fell.

The rate environment began to change in 2018, and accelerated throughout 2019, as many carriers narrowed their risk appetites or withdrew from certain classes. The stress was most evident in property and marine lines, but increasingly moved into casualty and professional lines.

"Because we had kept our powder dry, we had the ability to deploy capacity when pricing became adequate again," said Mr. Ortega. "That time came in 2019, and our patience and discipline were rewarded with four consecutive quarters of double-digit growth."

"Overseas General is a big and important contributor to Chubb's success, and our company has never been better positioned to take advantage of the vast opportunities outside North America," said Mr. Keogh. "It's an expanding and profitable organization with plenty of runway for future growth in the years ahead. We will continue to be on our front foot to meet the evolving needs of our customers and distribution partners while creating opportunities for our employees."

Key Financial Results

Dollars in millions

Life Insurance

2019	
Net premiums written	$2,392
Segment income	$366
International life insurance segment income	$152

"The progress we have made building this business in recent years is gaining momentum. We are well positioned to continue to build the breadth and depth of our life business across Asia."

– Russell Bundschuh

Chubb's Life Insurance segment comprises two businesses. Chubb Life is an international life insurer, primarily focused on Asia, that provides protection and savings-oriented life insurance products to individuals and groups. Combined Insurance provides personal accident and supplemental health insurance coverages to consumers in North America.

For the year, the Life segment generated net premiums written of $2.4 billion, up 5.3%, or 6.4% in constant dollars, from prior year. Segment income was $366 million, up 18.6%.

Chubb Life

Chubb Life serves the needs of consumers through a variety of distribution channels including primarily captive agents, but also through banks, retailers, brokers, independent agents and direct marketing. Chubb Life has operations in seven Asian markets – Hong Kong, Indonesia, Korea, Taiwan, Thailand, Vietnam and, beginning in 2019, Myanmar. In China, the company is also a joint venture partner in Huatai Life, a fast-growing life insurer that serves more than 1.3 million customers with a broad portfolio of savings and protection products. Together, Chubb Life and Huatai Life have nearly 630 offices, 5,000 employees and 85,000 agents.

Life insurance is a long-term business, and Chubb has been pursuing a consistent strategy to build Chubb Life primarily through organic growth. With its growing scale, Chubb's international life business has begun to emerge as a meaningful contributor to the company's growth and profitability. In 2018, international life earnings reached $100 million for the first time.

In 2019, earnings rose 48% to $152 million. International life insurance net premiums written were up 12.6% in constant dollars.

"In 2019, we continued to diversify and expand our captive agency force across several countries, opened new offices and looked for ways to do more for our external distribution partners, including banks and affinity groups," said Russell Bundschuh, Senior Vice President, Chubb Group and President of Chubb Life. "We made good progress advancing our digital initiatives focused on enhancing the customer experience, launching new digitally enabled products and making it easier for agents and distribution partners to interact with us and serve customers."

In an environment of continuing low interest rates, the business kept its sales focus on protection-oriented products. At the same time, Chubb Life increased its emphasis on developing and launching health and wellness products.

One of the business's milestones in 2019 was establishing a 100% owned life insurance subsidiary in Myanmar, a nation of more than 54 million people. Following a competitive review process, Chubb was one of five foreign companies awarded a license for a wholly owned life insurance business by the Myanmar Ministry of Planning and Finance. Chubb is committed to working with the Myanmar government, regulators and local organizations to help build and strengthen the nation's life insurance sector. The headquarters in Yangon is up and running, and the business has already recruited hundreds of agents.

Global A&H, Life Insurance and Reinsurance Business Unit Leaders

(From left)

Joe Vasquez
Senior Vice President,
Chubb Group;
Global Accident & Health;
President,
Combined Insurance

Russell Bundschuh
Senior Vice President,
Chubb Group;
President,
Chubb Life

James E. Wixtead
Senior Vice President,
Chubb Group;
President,
Chubb Tempest Re Group

Cunqiang Li
Chief Operating Officer,
Chubb Life

In 2019, Chubb Life Thailand experienced double-digit growth in total premium. The agency business benefited from its focus on productivity, supported by new health and critical illness riders launched with whole life. In the group business, growth was driven by expanding existing client relationships as well as the addition of two new partners.

Vietnam also delivered double-digit growth with an agency force that has now surpassed 40,000 agents. In early 2019, Chubb Life Vietnam launched an e-submission app that enables agents to prepare and submit insurance applications online via their tablet or laptop. By the end of 2019, 94% of all insurance applications submitted to the company were via the new app. Vietnam plans to eliminate the use of printed insurance application forms in 2020.

In Hong Kong SAR, Chubb Life introduced a new digital platform for agents to engage with and serve their customers. With Chubb Link℠, each agent has a unique URL, enabling them to highlight their own individual experience, product knowledge, and professional awards and achievements. Customers can contact individual agents directly through the hub as well as find news and information about promotions and products. Currently, nearly two-thirds of agents are using the new tool.

While protests in Hong Kong SAR in 2019 made it more challenging for agents to meet with their clients, the broker channel continued to perform well. Across the region, Chubb Life has been developing strategies to expand sales through brokers, an effective channel to market protection-oriented products, as well as banks. In 2019, Chubb Life forged 44 new brokerage partnerships.

In China, Huatai Life had a strong year in 2019, with its rate of growth again outpacing the overall market. Huatai Life now operates in 20 provinces and has approximately 35,000 agents. Chubb has a significant and increasing ownership stake in Huatai Life's parent, Huatai Insurance Group, a financial services holding company that has property and casualty, asset management and other subsidiaries.

In Korea, Chubb Life launched a new initiative offering life products to non-life customers by leveraging the multi-product telemarketing sales channel of the company's international A&H business. This approach generates synergies coupled with a superior product value proposition and enhanced customer purchase experience. Term life and new critical illness products were launched.

Early in 2020, the business launched a new health and well-being initiative in the form of a new mobile app, called Chubb LifeBalance, in Hong Kong SAR and Thailand. Chubb LifeBalance better engages customers by providing support and guidance to live a healthier, more balanced life. It gives personalized AI-powered coaching following a 360-degree approach to a user's health and well-being.

While Chubb Life is focused on Asia, it has operations in other parts of the world. In 2019, Chubb Life expanded its presence in Chile with the acquisition of Banchile Seguros de Vida (Banchile Life), a Santiago-based life insurance company with a long-standing insurance relationship with Banco de Chile, the largest bank based in Chile. Banchile Life, which offers a broad range of life, personal accident and supplemental health insurance products, generated over $200 million of gross premiums written in 2018.

The addition of Banchile Life, along with Chubb's exclusive distribution partnership with Banco de Chile for P&C and A&H products, significantly extends Chubb's distribution and presence in Chile, enabling the company to reach and serve millions of new customers, including in digitally advanced ways.

"The progress we have made building this business in recent years is gaining momentum," said Mr. Bundschuh. "We are well positioned to continue to build the breadth and depth of our life business across Asia."

Combined Insurance

Combined Insurance generated solid results in 2019, driven by double-digit growth in Chubb Workplace Benefits, which serves large and middle-market companies by partnering with benefit brokers, agents and consultants to offer a line of supplemental insurance products, including accident, critical illness, hospital indemnity, life and disability income. Chubb has been investing in this business, which brings together the strengths of Combined Insurance's workplace products, Chubb's extensive branch network and the company's substantial relationships with national and regional insurance brokerage firms.

Combined Insurance is focused on building out its capabilities, sales organization and distribution to be fully aligned with Chubb's North American field organization, and to better serve commercial clients of all sizes – large, middle market and small businesses. As enrollment in voluntary benefits programs has moved online, the company is making investments to enhance customer-facing and back-office systems as the business grows.

"Since it was launched in 2016, Chubb Workplace Benefits has made significant progress, and we're committed to building this business with the people, products, technology and capabilities to keep pace with our growth," said Joe Vasquez, Senior Vice President, Chubb Group, Global Accident & Health and President of Combined Insurance. "The continued expansion of our workplace benefits business shows the breadth of our A&H offerings as well as the power of the Chubb branch network in the U.S."

The Combined Insurance core agency force – which now numbers more than 3,300 agents in the U.S. and Canada – has historically focused on distributing personal accident, life and supplemental health insurance coverages directly to consumers. Now, Combined Insurance is putting more emphasis on tapping the small commercial market. Proprietors and employers of Main Street businesses, as well as the individuals who work for them, fit the customer profile for the company's affordable A&H products. Combined Insurance is supporting this initiative with learning and development programs to help agents adapt to selling in a small business workplace instead of over a kitchen table.

In building its agency force, Combined Insurance continues to focus on Spanish-speaking agents, who bring the company's insurance offering to the underserved Latino market in the U.S., as well as build on its signature success recruiting veterans looking to re-enter the workforce.

In 2019, Combined Insurance again was recognized for its military-friendly hiring practices. For example, VIQTORY named the company the number one Military Friendly® Employer in the over $1 billion revenue category – the eighth consecutive year on the top 10 list and fifth consecutive year in the top five.

"We truly value the service veterans have provided to our country, and in return, we give them the tools they need to help them be successful in their career here," Mr. Vasquez said.

Key Financial Results

Dollars in millions

Global Reinsurance

2019	
Gross premiums written	$719
Net premiums written	$649
Combined ratio	85.0%
P&C current accident year combined ratio excluding catastrophe losses	82.1%
Segment income	$376

"The market took a turn in 2019, making it an interesting year. We quoted a lot more business in 2019 than we had in recent years."

– James Wixtead

Chubb's reinsurance business, which operates under the Chubb Tempest Re brand, offers a broad range of products to a diverse group of primary property and casualty insurers worldwide. Doing business globally with offices in Bermuda, Stamford, London, Montreal and Zurich, the business has deep underwriting, actuarial and claims expertise. Chubb Tempest Re's position as a subsidiary of a leading global P&C insurer sets it apart from many other reinsurance companies: The business can be patient and deploy capital only when there are opportunities to achieve rate adequacy.

Reinsurance is a cyclical business, and the operating environment for reinsurers has been challenging. Chubb Tempest Re has consistently demonstrated underwriting discipline, which has enabled it to perform in the top quartile of reinsurers in terms of profitability as measured by combined ratio. In 2019, Chubb's Global Reinsurance segment posted net written premiums of $649 million, down 3.2% from prior year. The combined ratio was 85.0%, and the current accident year combined ratio excluding catastrophe losses was 82.1%. Segment income was $376 million, up 35.7% from 2018.

In 2019, there were signs that the market was transitioning and the trading environment becoming more attractive. The shift could be seen in reduced limits and increases in pricing in many lines and jurisdictions that accelerated throughout the year.

"The market took a turn in 2019, making it an interesting year. We quoted a lot more business in 2019 than we had in recent years," said James Wixtead, Senior Vice President, Chubb Group and President of Chubb Tempest Re Group. "But while improving, the market needs to move a bit more in order to match our appetite for deploying significantly more capital."

As the market continues to transition, Chubb Tempest Re will be looking for more opportunities, including more emphasis on higher-margin long-tail lines, a part of the overall portfolio that was significantly reduced in recent years.

"Our view of risk is very consistent," said Mr. Wixtead. "Many members of our team have been with us for 20 years or more. They understand how we fit into the Chubb organization, and where we can add value to our client and broker partners. This team, along with our systems, infrastructure and the financial strength of Chubb, position us well as we look to the trading environment for Chubb Tempest Re to improve in 2020."

Corporate and Global Functional Leaders

(From left)

Joseph Wayland
Executive Vice President,
Chubb Group;
General Counsel

Ivy Kusinga
Chief Culture Officer,
Chubb Group

Sean Ringsted
Executive Vice President,
Chubb Group;
Chief Risk Officer and Chief
Digital Officer

Michael W. Smith
Senior Vice President,
Chubb Group;
Global Claims Officer

(From left)

Timothy Boroughs
Executive Vice President,
Chubb Group;
Chief Investment Officer

Philip Bancroft
Executive Vice President,
Chubb Group;
Chief Financial Officer

Paul Medini
Senior Vice President,
Chubb Group;
Chief Accounting Officer

Julie Dillman
Senior Vice President,
Chubb Group;
Global Head of Operations

(From left)

Paul O'Connell
Senior Vice President,
Chubb Group;
Chief Actuary

Rainer Kirchgaessner
Executive Vice President,
Chubb Group;
Global Corporate
Development Officer

Jo Ann Rabitz
Global Human Resources
Officer,
Chubb Group

Our Mission

Protecting the Present and Building a Better Future

Good corporate citizenship lies at our core – how we practice our craft of insurance, how we work together to serve our customers, how we treat each other, and how we work to help make a better world for our communities and our planet. Citizenship is about responsibility – and we express that responsibility in a way that reflects our core values and our mission to protect the present and build a better future.

We accomplish our mission by providing the security from risk that allows people and businesses to grow and prosper. Our mission is realized by sustaining a culture that values and rewards excellence, integrity, inclusion and opportunity; by working to protect our planet and assisting less fortunate individuals and communities in achieving and sustaining productive and healthy lives; and by promoting the rule of law.

From our roots in 18th century Philadelphia, we have built Chubb to be a dynamic, forward-looking global enterprise with a commitment to responsible citizenship. We act on this promise of responsibility through a wide range of activities that include our contributions of time and money.

Philanthropy

Chubb recognizes its responsibility to assist less fortunate individuals and communities in achieving and sustaining productive and healthy lives in geographic areas where the company operates. The company's philanthropy is funded principally through the Chubb Charitable Foundation and the Chubb Rule of Law Fund.

The Chubb Charitable Foundation addresses actionable problems and contributes to helping alleviate poverty, improve the health of at-risk populations, provide access to quality education and protect the environment. In the last 10 years, the company has contributed more than $100 million to the Foundation.

For many years, for example, the Foundation has supported the International Rescue Committee, including its efforts to help refugees get settled and establish productive lives. The Foundation has helped build schools in China and Vietnam, fund micro-finance projects in Mexico and Colombia, and serve as a major partner for Teach for America and Teach for All programs in the United States and around the globe.

Environment

Chubb recognizes the reality of climate change and the substantial impact of human activity on our planet. Our environmental initiatives reflect our desire to take actions that reduce Chubb's environmental footprint and, through our philanthropy, strengthen the resilience of communities and protect biodiversity against the effects of climate change.

The Chubb Charitable Foundation and the company's employees support a range of environmental philanthropies, including The Nature Conservancy and the Conservation Fund, as well as volunteer activities in local communities around the world. Chubb Charitable Foundation grants have helped preserve sensitive lands and habitats, finance green business entrepreneurs, and support educational programs that promote a healthy and sustainable environment in the U.S. and around the world.

In 2019, Chubb adopted a new policy concerning coal-related underwriting and investment and established new science-based greenhouse gas (GHG) emissions reduction goals using 2016 as the baseline. By year-end, the company achieved its first goal to reduce absolute GHG emissions by 20%. These goals are being achieved through a combination of real estate portfolio optimization, energy efficiency projects and the purchase of renewable electricity. In 2019, the company earned a score of B on the CDP's climate change program ranking.

Diversity and Inclusion

At Chubb, we recognize our responsibility to ensure opportunity within our own organization, where we foster a diverse and inclusive meritocracy. We can't succeed unless we give everyone the opportunity to thrive and advance in our company, and we hold our leaders accountable for achieving a diverse mix of talent, regardless of creed or background.

The company's extensive efforts in this area include mentorships, affinity groups, diversity awareness training, management development programs, and mandating diverse slates in recruiting and promotion.

Examples of initiatives include the company's Business Roundtables and Regional Inclusion Councils, which promote dynamic networking across the business and engage hundreds of employees in constructive dialogue. Other initiatives include Chubb Start, a program that supports the continuous professional development of early career women, and Chubb Signatures, a global and regional lecture series for successful senior women, diverse men and inclusion champions to share their unique backgrounds, experiences and hard-earned lessons in business.

Chubb Rule of Law Fund

As a corporate citizen, Chubb recognizes the rule of law as the foundation of a liberal world order that the company embraces as essential to the proper functioning of markets and the protection of personal freedoms. Through the Chubb Rule of Law Fund, a unique corporate initiative, we support projects around the world that promote the preservation and advancement of the rule of law.

Since it was founded in 2008, the Fund has supported 55 projects in countries around the world focused on improving access to justice, strengthening courts, fighting corruption and creating the conditions of security and freedom in which our customers, employees and fellow citizens can thrive.

The Chubb Rule of Law Fund is funded by the Chubb Charitable Foundation and contributions from 15 of Chubb's partner law firms. In 2019, 10 new projects were funded. Among them were initiatives to strengthen the independence of the judiciary in Guatemala; litigation support for juveniles facing life imprisonment without parole in the U.S.; supporting administrative law in Vietnam; and protecting the rights of children in mental health units in England and Wales.

Officers and Executives

Chubb Group Corporate Officers

Evan G. Greenberg*
Chairman and Chief Executive Officer, Chubb Group

John Keogh*
Executive Vice Chairman, Chubb Group;
Chief Operating Officer

John Lupica**
Vice Chairman, Chubb Group;
President, North America Major Accounts and Specialty Insurance

Paul J. Krump**
Executive Vice President, Chubb Group;
President, North America Commercial and Personal Insurance

Juan Luis Ortega**
Executive Vice President, Chubb Group;
President, Overseas General Insurance

Philip Bancroft*
Executive Vice President, Chubb Group;
Chief Financial Officer

Timothy Boroughs**
Executive Vice President, Chubb Group;
Chief Investment Officer

Rainer Kirchgaessner
Executive Vice President, Chubb Group;
Global Corporate Development Officer

Sean Ringsted**
Executive Vice President, Chubb Group;
Chief Risk Officer and Chief Digital Officer

Joseph Wayland*
Executive Vice President, Chubb Group;
General Counsel

Brad Bennett
Senior Vice President, Chubb Group;
Regional President, Far East

Russell Bundschuh
Senior Vice President, Chubb Group;
President, Chubb Life

Julie Dillman
Senior Vice President, Chubb Group;
Global Head of Operations

David Furby
Senior Vice President, Chubb Group;
Regional President, European Group

Marcos Gunn
Senior Vice President, Chubb Group;
Regional President, Latin America

Bruce L. Kessler
Senior Vice President, Chubb Group;
Division President, Westchester

Ken Koreyva
Senior Vice President, Chubb Group;
Finance

Christopher A. Maleno
Senior Vice President, Chubb Group;
Division President, North America Field Operations

Patrick McGovern
Senior Vice President, Chubb Group;
Chief Communications Officer

Paul McNamee
Senior Vice President, Chubb Group;
Regional President, Asia Pacific

Paul Medini
Senior Vice President, Chubb Group;
Chief Accounting Officer

Matthew Merna
Senior Vice President, Chubb Group;
Division President, North America Major Accounts

Scott A. Meyer
Senior Vice President, Chubb Group;
Division President, North America Financial Lines

Frances D. O'Brien
Senior Vice President, Chubb Group;
Division President, North America Personal Risk Services

Paul O'Connell
Senior Vice President, Chubb Group;
Chief Actuary

Michael W. Smith
Senior Vice President, Chubb Group;
Global Claims Officer

Derek Talbott
Senior Vice President, Chubb Group;
Division President, North America Property

Joe Vasquez
Senior Vice President, Chubb Group;
Global Accident & Health;
President, Combined Insurance

*Chubb Limited Executive Management and Executive Officer for SEC reporting purposes
**Executive Officer for SEC reporting purposes

James E. Wixtead
Senior Vice President, Chubb Group;
President, Chubb Tempest Re Group

Scott Arnold
Vice President, Chubb Group;
Division President, Chubb Agriculture;
President, Rain and Hail

Ross Bertossi
Vice President, Chubb Group;
Global Underwriting

Joseph S. Clabby
Vice President, Chubb Group;
Chairman, Chubb Bermuda;
Executive Vice President, North America Field Operations

Sean Corridon
Vice President, Chubb Group;
Deputy Chief Investment Officer

Judy Gonsalves
Vice President, Chubb Group;
Division President, Chubb Bermuda

Stephen M. Haney
Vice President, Chubb Group;
Division President, North America Surety;
Chief Underwriting Officer, Global Surety

Michael Kessler
Vice President, Chubb Group;
Chief Reinsurance Officer

Timothy O'Donnell
Vice President, Chubb Group;
Division President, Commercial Property and Casualty
Overseas General Insurance

Darryl Page
Vice President, Chubb Group;
Division President, Personal Insurance
Overseas General Insurance

Benjamin Rockwell
Vice President, Chubb Group;
Division President, North America Middle Market

James Williamson
Vice President, Chubb Group;
Division President, North America Small Business

Other Executives

Adam Clifford
Division President, Continental Europe

Samantha Froud
Chief Administration Officer, Bermuda Operations

Mark Hammond
Treasurer, Chubb Group

Jason Keen
Division President, Chubb Global Markets

Ivy Kusinga
Chief Culture Officer, Chubb Group

Eric Larson
Chief Compliance Officer, Chubb Group

Cunqiang Li
Chief Operating Officer, Chubb Life

David Lupica
Chief Operating & Distribution Management Officer
Westchester

Timothy Mardon
Division President, Chubb Tempest Re Bermuda

Sara Mitchell
Division President, U.K and Ireland

Michael O'Donnell
Division President, Chubb Tempest Re USA

George Ohsiek
Chief Auditor, Chubb Group

Jo Ann Rabitz
Global Human Resources Officer, Chubb Group

Steve Roberts
Division President, Chubb Tempest Re International

John Thompson
Division President, International Accident & Health
Overseas General Insurance

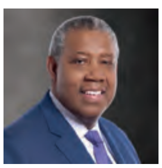
Giles Ward
Regional President, Eurasia & Africa

Chubb Limited Board of Directors

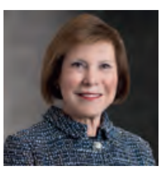
Evan G. Greenberg
Chairman and
Chief Executive Officer
Chubb Limited

Michael G. Atieh
Retired Chief Financial
and Business Officer
Ophthotech Corporation

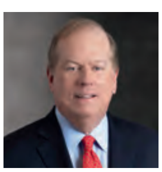
Sheila P. Burke
Faculty Research Fellow
John F. Kennedy School
of Government
Harvard University



James I. Cash
Emeritus Professor of
Business Administration
Harvard University



Mary Cirillo
Retired Executive
Vice President and
Managing Director
Deutsche Bank



Michael P. Connors
Chairman and
Chief Executive Officer
Information Services
Group, Inc.

John A. Edwardson
Retired Chairman and
Chief Executive Officer
CDW Corporation

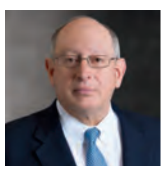
Robert M. Hernandez
Lead Director
Chubb Limited

Retired Vice Chairman
and Chief Financial Officer
USX Corporation

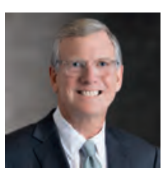
Kimberly A. Ross
Chief Financial Officer
WeWork

Robert W. Scully
Retired Co-President
Morgan Stanley

Eugene B. Shanks, Jr.
Retired President
Bankers Trust Company



Theodore E. Shasta
Retired Partner
Wellington Management
Company



David H. Sidwell
Retired Chief
Financial Officer
Morgan Stanley

Olivier Steimer
Former Chairman
Banque Cantonale
Vaudoise

Board Committees

Audit Committee
Robert W. Scully, Chair
James I. Cash
Kimberly A. Ross
Theodore E. Shasta
David H. Sidwell

Compensation Committee
Michael P. Connors, Chair
Mary Cirillo
John A. Edwardson
Robert M. Hernandez

Nominating & Governance Committee
Mary Cirillo, Chair
Michael P. Connors
John A. Edwardson
Robert M. Hernandez

Risk & Finance Committee
Olivier Steimer, Chair
Michael G. Atieh
Sheila P. Burke
Eugene B. Shanks, Jr.

Executive Committee
Evan G. Greenberg, Chair
Mary Cirillo
Michael P. Connors
Robert M. Hernandez
Robert W. Scully
Olivier Steimer

Shareholder Information

Visit investors.chubb.com, write to the Investor Relations Department at Chubb Limited or e-mail investorrelations@chubb.com for copies of the company's reports to the Securities and Exchange Commission on Form 10-K, Form 10-Q or Form 8-K, all of which are available without charge.

Address Investor Relations Inquiries to:

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Chubb Limited
1133 Avenue of the Americas
11th Floor
New York, NY 10036
Tel: 212 827 4445
E-mail: investorrelations@chubb.com

Transfer Agent & Registrar

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Louisville, KY 40202 USA
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Outside the U.S.: 201 680 6898

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Louisville, KY 40233-5000 USA

By overnight delivery:
Computershare
462 South 4th Street
Louisville, KY 40202 USA
Website:
www-us.computershare.com/Investor

Send Certificates for Transfer and Address Changes to:

Computershare
P.O. Box 505000
Louisville, KY 40233-5000 USA

Independent Auditors

PricewaterhouseCoopers AG
Birchstrasse 160
8050 Zurich
Switzerland
Tel: 41 58 792 44 00

PricewaterhouseCoopers LLP
Two Commerce Square, Suite 1800
Philadelphia, PA 19103 USA
Tel: 267 330 3000

New York Stock Exchange Symbol

CB

Chubb Common Shares CUSIP Number

H1467J 104

Price Range of Common Shares and Dividends

As of February 13, 2020, the company had 451,907,796 Common Shares outstanding with 6,902 registered holders of Common Shares. The accompanying table sets forth the cash dividends and the high/low closing sales prices of the company's Common Shares, as reported on the NYSE Composite Tape for the periods indicated. We have paid dividends each quarter since we became a public company in 1993. The method of payment of our dividend approved at our May 2019 and May 2018 annual general meetings was a distribution from capital contribution reserves (additional paid-in capital).

	2019				2018			
			Dividends				Dividends	
Quarter Ending	**High**	**Low**	**USD**	**CHF**	High	Low	USD	CHF
March 31	**$140.08**	**$124.67**	**$0.73**	**0.72**	$156.15	$134.57	$0.71	0.66
June 30	**$150.94**	**$136.57**	**$0.75**	**0.75**	$138.29	$124.57	$0.73	0.73
September 30	**$161.44**	**$146.74**	**$0.75**	**0.73**	$140.12	$126.81	$0.73	0.72
December 31	**$162.06**	**$147.72**	**$0.75**	**0.74**	$136.59	$120.19	$0.73	0.73

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Non-GAAP Financial Measures
This document contains non-GAAP financial measures. The below non-GAAP financial measures, which may be defined differently by other companies, are important for an understanding of our overall results of operations and financial condition. However, these measures should not be viewed as a substitute for measures determined in accordance with generally accepted accounting principles (GAAP).

We provide certain financial measures on a constant-dollar basis (i.e., excluding the impact of foreign exchange). We believe it is useful to evaluate the trends in our results exclusive of the effect of fluctuations in exchange rates between the U.S. dollar and the currencies in which our international business is transacted, as these exchange rates could fluctuate significantly between periods and distort the analysis of trends. The impact is determined by assuming constant foreign exchange rates between periods by translating prior period results using the same local currency exchange rates as the comparable current period.

Core operating income, net of tax, excludes from net income the after-tax impact of adjusted net realized gains (losses), Chubb integration expenses, and the amortization of fair value adjustment of acquired invested assets and long-term debt related to the Chubb Corp acquisition. We believe this presentation enhances the understanding of our results of operations by highlighting the underlying profitability of our insurance business. We exclude adjusted net realized gains (losses) because the amount of these gains (losses) are heavily influenced by, and fluctuate in part according to, the availability of market opportunities. We exclude the amortization of the fair value adjustments related to purchased invested assets and long-term debt and Chubb integration expenses due to the size and complexity of this acquisition. These integration expenses are distortive to our results and are not indicative of our underlying profitability. We believe that excluding these integration expenses facilitates the comparison of our financial results to our historical operating results. References to core operating income measures mean net of tax, whether or not noted.

The following table presents the reconciliation of Net income to Core operating income:

(in millions of U.S. dollars except share and per share data)	Full Year 2019	Full Year 2018
Net income, as reported	$4,454	$3,962
Amortization of fair value adjustment of acquired invested assets and long-term debt, pre-tax	(140)	(215)
Tax benefit on amortization adjustment	26	40
Chubb integration expenses, pre-tax	(23)	(59)
Tax benefit on Chubb integration expenses	4	12
Adjusted realized gains (losses), pre-tax[1]	(522)	(649)
Net realized gains (losses) related to unconsolidated entities, pre-tax[2]	483	431
Tax (expense) benefit on adjusted net realized gains (losses)	(15)	(5)
Core operating income	$4,641	$4,407
Denominator	458,914,663	466,802,348
Diluted earnings per share		
Net income	$9.71	$8.49
Amortization of fair value adjustment of acquired invested assets and long-term debt, net of tax	(0.25)	(0.37)
Chubb integration expenses, net of tax	(0.04)	(0.10)
Adjusted net realized gains (losses), net of tax	(0.11)	(0.48)
Core operating income	$10.11	$9.44
% Change from prior year	7.1%	

[1] Excludes realized losses on crop derivatives of $8 million and $3 million for 2019 and 2018, respectively.
[2] Realized gains (losses) on partially owned entities, which are investments where we hold more than an insignificant percentage of the investee's shares. The net income or loss is included in other income (expense).

Core operating return on equity (ROE) and Core operating return on tangible equity (ROTE) are annualized non-GAAP financial measures. The numerator includes core operating income, net of tax. The denominator includes the average shareholders' equity for the period adjusted to exclude unrealized gains (losses) on investments, net of tax. For the ROTE calculation, the denominator is also adjusted to exclude goodwill and other intangible assets, net of tax. These measures enhance the understanding of the return on shareholders' equity by highlighting the underlying profitability relative to shareholders' equity and tangible equity excluding the effect of unrealized gains and losses on our investments.

(in millions of U.S. dollars except ratios)	Full Year 2019	Full Year 2018
Net income	$4,454	$3,962
Core operating income	$4,641	$4,407
Equity – beginning of period as reported [1]	$50,300	$51,172
Less: unrealized gains (losses) on investments, net of deferred tax	(545)	1,154
Equity – beginning of period, as adjusted	$50,845	$50,018
Less: goodwill and other intangible assets, net of tax	$20,054	$20,621
Equity – beginning of period, as adjusted, excluding goodwill and other intangible assets	$30,791	$29,397
Equity – end of period, as reported	$55,331	$50,312
Less: unrealized gains (losses) on investments, net of deferred tax	2,543	(545)
Equity – beginning of period, as adjusted	$52,788	$50,857
Less: goodwill and other intangible assets, net of tax	$20,012	$20,054
Equity – end of period, as adjusted, excluding goodwill and other intangible assets	$32,776	$30,803
Weighted average equity, as reported	$52,816	$50,742
Weighted average equity, as adjusted	$51,817	$50,438
Weighted average equity, as adjusted, excluding goodwill and other intangible assets	$31,784	$30,100
ROE	8.4%	7.8%
Core operating ROE	9.0%	8.7%
Core operating ROTE	14.6%	14.6%

[1] January 1, 2019 included a $12 million after-tax reduction to beginning equity related to the adoption of new accounting guidance on premium amortization of purchased callable debt securities.

Combined ratio measures the underwriting profitability of our property and casualty business. **P&C combined ratio** and **Current accident year (CAY) P&C combined ratio excluding catastrophe losses (CATs)** are non-GAAP financial measures. Refer to the Non-GAAP Reconciliation section in the 2019 Form 10-K, on pages 70-73 for the definition of these non-GAAP financial measures and reconciliation to the Combined ratio.

CAY P&C combined ratio with expected level of CATs is a non-GAAP financial measure which excludes CATs above or below managements' view of expected CATs for that period. For this purpose, the normalized level of CATs, **or expected level of CATs**, is not intended to represent a probability weighted expectation for the company but rather to represent management's view of what might be more typical for a given period based on various factors, including historical experience, seasonal patterns, and consideration of both modeled CATs (e.g., windstorm and earthquake) as well as non-modeled CATs (e.g., wildfires, floods and freeze).

	Full Year 2019	Full Year 2018
Combined ratio	90.6%	90.6%
Add: impact of gains and losses on crop derivatives	0.0%	0.0%
P&C combined ratio	90.6%	90.6%
Less: Catastrophe losses	4.1%	5.9%
Less: Prior period development	-2.7%	-3.3%
CAY P&C combined ratio excluding CATs	89.2%	88.0%
Add: Expected level of CATs	3.4%	3.4%
CAY P&C combined ratio with expected level of CATs	92.6%	91.4%

The following table presents the reconciliation of Catastrophe losses, pre-tax, to Catastrophe losses above expected levels, pre-tax:

(in millions of U.S. dollars)	Full Year 2019
Catastrophe losses, pre-tax	$1,187
Less: Expected levels of CATs, pre-tax	969
Catastrophe losses above expected levels, pre-tax	$218

Tangible book value per common share is shareholders' equity less goodwill and other intangible assets, net of tax, divided by the shares outstanding. We believe that goodwill and other intangible assets are not indicative of our underlying insurance results or trends and make book value comparisons to less acquisitive peer companies less meaningful.

(in millions of U.S. dollars, except share and per share data)	December 31 2019	December 31 2018	% Change
Shareholders' equity	$55,331	$50,312	
Less: goodwill and other intangible assets, net of tax	20,012	20,054	
Numerator for tangible book value per share	$35,319	$30,258	
Shares outstanding	451,971,567	459,203,378	
Book value per common share	$122.42	$109.56	11.7%
Tangible book value per common share	$78.14	$65.89	18.6%

P&C underwriting income is a non-GAAP financial measure which excludes the Life Insurance segment. P&C underwriting income is used to monitor results of operations without the impact of certain factors as detailed below. We believe that P&C underwriting income is a useful measure as it enhances the understanding of our results of operations by highlighting the underlying profitability of our P&C insurance business.

The following table presents a reconciliation of Net income to P&C underwriting income:

(In millions of U.S. dollars)		Full Year 2019	Full Year 2018
Net income		$4,454	$3,962
Less:	Income tax (expense) benefit	(795)	(695)
	Chubb integration expenses	(23)	(59)
	Amortization expense of purchased intangibles	(305)	(339)
	Other income (expense)	596	434
	Interest expense	(552)	(641)
	Net investment income	3,426	3,305
	Net realized gains (losses)	(530)	(652)
	Life Insurance underwriting loss [1]	(97)	(5)
Add:	Realized losses on crop derivatives	(8)	(3)
	P&C underwriting income	$2,726	$2,611

[1] Excludes gains (losses) from fair value changes in separate account assets of $44 million in 2019 and $(38) million in 2018 and Life Insurance net investment income of $373 million in 2019 and $341 million in 2018.

International life insurance net premiums written and deposits is a non-GAAP financial measure which includes International life insurance net premiums written and deposits collected on universal life and investment contracts. Deposits collected on universal life and investment contracts (life deposits) are not reflected as revenues in our consolidated statements of operations in accordance with GAAP. However, new life deposits are an important component of production and key to our efforts to grow our business.

(in millions of U.S. dollars)	Full Year 2019
International life insurance net premiums written	$981
International life insurance deposits	1,463
Total international life insurance net premiums written and deposits [1]	$2,444

[1] Excludes Combined North America and Life reinsurance businesses.

Adjusted net investment income is net investment income excluding the amortization of the fair value adjustment on acquired invested assets. We believe this measure is meaningful as it highlights the underlying performance of our invested assets and portfolio management in support of our lines of business.

The following table presents a reconciliation of net investment income to adjusted net investment income:

(in millions of U.S. dollars)		Full Year 2019	Full Year 2018
Net investment income		$3,426	$3,305
Less:	Amortization expense of fair value adjustment on acquired invested assets	(161)	(248)
	Adjusted net investment income	$3,587	$3,553
	% Change from prior year	1.0%	

Net premiums written on an adjusted basis is net premiums written in the company's North America Personal P&C Insurance segment adjusted to exclude the year-over-year net impact for the quarter of additional reinsurance and reinstatement premiums. We believe this measure is meaningful to evaluate trends in the underlying business on a comparable basis.

The following table presents a reconciliation of North America Personal P&C Insurance net premiums written change versus prior year to change versus prior year on an adjusted basis:

	% Change 4Q-19 vs. 4Q-18
Net premiums written	9.2%
Net premiums written adjustments	-4.6%
Net premiums written on an adjusted basis	4.6%

UNITED STATES SECURITIES AND EXCHANGE COMMISSION

Washington, D.C. 20549

FORM 10-K

☑ ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934

For the fiscal year ended December 31, 2019

OR

☐ TRANSITION REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934

For the Transition Period from to

Commission File No. 1-11778

CHUBB LIMITED

(Exact name of registrant as specified in its charter)

Switzerland	**98-0091805**
(State or other jurisdiction of incorporation or organization)	(I.R.S. Employer Identification No.)

Baerengasse 32

Zurich, Switzerland CH-8001

(Address of principal executive offices) (Zip Code)

+41 (0)43 456 76 00

(Registrant's telephone number, including area code)

Securities registered pursuant to Section 12(b) of the Act:

Title of each class	Trading Symbol(s)	Name of each exchange on which registered
Common Shares, par value CHF 24.15 per share	CB	New York Stock Exchange
Guarantee of Chubb INA Holdings Inc. 0.30% Senior Notes due 2024	CB/24A	New York Stock Exchange
Guarantee of Chubb INA Holdings Inc. 0.875% Senior Notes due 2027	CB/27	New York Stock Exchange
Guarantee of Chubb INA Holdings Inc. 1.55% Senior Notes due 2028	CB/28	New York Stock Exchange
Guarantee of Chubb INA Holdings Inc. 0.875% Senior Notes due 2029	CB/29A	New York Stock Exchange
Guarantee of Chubb INA Holdings Inc. 1.40% Senior Notes due 2031	CB/31	New York Stock Exchange
Guarantee of Chubb INA Holdings Inc. 2.50% Senior Notes due 2038	CB/38A	New York Stock Exchange

Securities registered pursuant to Section 12(g) of the Act: None

Indicate by check mark if the registrant is a well-known seasoned issuer, as defined in Rule 405 of the Securities Act. Yes ☑ No ☐

Indicate by check mark if the registrant is not required to file reports pursuant to Section 13 or Section 15(d) of the Act. Yes ☐ No ☑

Indicate by check mark whether the registrant (1) has filed all reports required to be filed by Section 13 or 15 (d) of the Securities Exchange Act of 1934 during the preceding 12 months (or for such shorter period that the registrant was required to file such reports), and (2) has been subject to such filing requirements for the past 90 days. Yes ☑ No ☐

Indicate by check mark whether the registrant has submitted electronically every Interactive Data File required to be submitted pursuant to Rule 405 of Regulation S-T (§232.405 of this chapter) during the preceding 12 months (or for such shorter period that the registrant was required to submit such files). Yes ☑ No ☐

Indicate by check mark whether the registrant is a large accelerated filer, an accelerated filer, a non-accelerated filer, a smaller reporting company, or an emerging growth company. See the definitions of "large accelerated filer," "accelerated filer," "smaller reporting company," and "emerging growth company" in Rule 12b-2 of the Exchange Act.

Large accelerated filer	☑	Accelerated filer	☐
Non-accelerated filer	☐	Smaller reporting company	☐
		Emerging growth company	☐

If an emerging growth company, indicate by check mark if the registrant has elected not to use the extended transition period for complying with any new or revised financial accounting standards provided pursuant to Section 13(a) of the Exchange Act. ☐

Indicate by check mark whether the registrant is a shell company (as defined in Rule 12b-2 of the Act). Yes ☐ No ☑

The aggregate market value of voting stock held by non-affiliates as of June 28, 2019 (the last business day of the registrant's most recently completed second fiscal quarter), was approximately $67 billion. For the purposes of this computation, shares held by directors and officers of the registrant have been excluded. Such exclusion is not intended, nor shall it be deemed, to be an admission that such persons are affiliates of the registrant.

As of February 13, 2020 there were 451,907,796 Common Shares par value CHF 24.15 of the registrant outstanding.

Documents Incorporated by Reference

Certain portions of the registrant's definitive proxy statement relating to its 2020 Annual General Meeting of Shareholders are incorporated by reference into Part III of this report.

ITEM 1. Business

General

Chubb Limited is the Swiss-incorporated holding company of the Chubb Group of Companies. Chubb Limited, which is headquartered in Zurich, Switzerland, and its direct and indirect subsidiaries (collectively, the Chubb Group of Companies, Chubb, we, us, or our) are a global insurance and reinsurance organization, serving the needs of a diverse group of clients worldwide. At December 31, 2019, we had total assets of $177 billion and shareholders' equity of $55 billion. Chubb was incorporated in 1985 at which time it opened its first business office in Bermuda and continues to maintain operations in Bermuda. We have grown our business through increased premium volume, expansion of product offerings and geographic reach, and the acquisition of other companies to become a global property and casualty (P&C) leader.

With operations in 54 countries and territories, Chubb provides commercial and personal property and casualty insurance, personal accident and supplemental health insurance (A&H), reinsurance, and life insurance to a diverse group of clients. We offer commercial insurance products and service offerings such as risk management programs, loss control, and engineering and complex claims management. We provide specialized insurance products ranging from Directors & Officers (D&O) and professional liability to various specialty-casualty and umbrella and excess casualty lines to niche areas such as aviation and energy. We also offer personal lines insurance coverage including homeowners, automobile, valuables, umbrella liability, and recreational marine products. In addition, we supply personal accident, supplemental health, and life insurance to individuals in select countries.

We serve multinational corporations, mid-size and small businesses with property and casualty insurance and risk engineering services; affluent and high net worth individuals with substantial assets to protect; individuals purchasing life, personal accident, supplemental health, homeowners, automobile, and specialty personal insurance coverage; companies and affinity groups providing or offering accident and health insurance programs and life insurance to their employees or members; and insurers managing exposures with reinsurance coverage.

At December 31, 2019, we employed approximately 33,000 people. We believe that employee relations are satisfactory.

We make available free of charge through our website (investors.chubb.com, under Financials) our annual report on Form 10-K, quarterly reports on Form 10-Q, current reports on Form 8-K, and amendments to those reports, if any, filed or furnished pursuant to Section 13(a) or 15(d) of the Exchange Act as soon as reasonably practicable after they have been electronically filed with or furnished to the U.S. Securities and Exchange Commission (SEC). Also available through our website (under Investor Relations / Corporate Governance) are our Corporate Governance Guidelines, Code of Conduct, and Charters for the Committees of the Board of Directors (the Board). Printed documents are available by contacting our Investor Relations Department (Telephone: +1 (212) 827-4445, E-mail: investorrelations@chubb.com).

We also use our website as a means of disclosing material, non-public information and for complying with our disclosure obligations under SEC Regulation FD (Fair Disclosure). Accordingly, investors should monitor the Investor Relations portion of our website, in addition to following our press releases, SEC filings, and public conference calls and webcasts. The information contained on, or that may be accessed through, our website is not incorporated by reference into, and is not a part of, this report. The SEC maintains an Internet site (www.sec.gov) that contains reports, proxy and information statements, and other information regarding issuers that file with the SEC.

Customers

For most commercial and personal lines of business we offer, insureds typically use the services of an insurance broker or agent. An insurance broker acts as an agent for the insureds, offering advice on the types and amount of insurance to purchase, and assists in the negotiation of price and terms and conditions. We obtain business from the local and major international insurance brokers and typically pay a commission to brokers for any business accepted and bound. Loss of all or a substantial portion of the business provided by one or more of these brokers could have a material adverse effect on our business. In our opinion, no material part of our business is dependent upon a single insured or group of insureds. We do not believe that the loss of any one insured would have a material adverse effect on our financial condition or results of operations, and no one insured or group of affiliated insureds account for as much as 10 percent of our total revenues.

Competition

Competition in the insurance and reinsurance marketplace is substantial. We compete on an international and regional basis with major U.S., Bermuda, European, and other international insurers and reinsurers and with underwriting syndicates, some of which have greater financial, technological, marketing, distribution and management resources than we do. In addition, capital market participants have created alternative products that are intended to compete with reinsurance products. We also compete with new companies and existing companies that move into the insurance and reinsurance markets. Competitors include other stock companies, mutual companies, alternative risk sharing groups (such as group captives and catastrophe pools), and other underwriting organizations. Competitors sell through various distribution channels and business models, across a broad array of product lines, and with a high level of variation regarding geographic, marketing, and customer segmentation. We compete for business not only on the basis of price but also on the basis of availability of coverage desired by customers and quality of service.

The insurance industry is changing rapidly. Our ability to compete is dependent on a number of factors, particularly our ability to maintain the appropriate financial strength ratings as assigned by independent rating agencies and effectively utilize new technology in our business. Our broad market capabilities in personal, commercial, specialty, and A&H lines made available by our underwriting expertise, business infrastructure, and global presence, help define our competitive advantage. Our strong balance sheet is attractive to businesses, and our strong capital position and global platform affords us opportunities for growth not available to smaller, less diversified insurance companies. Refer to “Segment Information” for competitive environment by segment.

Trademarks and Trade Names

Various trademarks and trade names we use protect names of certain products and services we offer and are important to the extent they provide goodwill and name recognition in the insurance industry. We use commercially reasonable efforts to protect these proprietary rights, including various trade secret and trademark laws. We intend to retain material trademark rights in perpetuity, so long as it satisfies the use and registration requirements of applicable countries. One or more of the trademarks and trade names could be material to our ability to sell our products and services. We have taken appropriate steps to protect our ownership of key names, and we believe it is unlikely that anyone would be able to prevent us from using names in places or circumstances material to our operations.

Segment Information

Chubb operates through six business segments: North America Commercial P&C Insurance, North America Personal P&C Insurance, North America Agricultural Insurance, Overseas General Insurance, Global Reinsurance, and Life Insurance.

In 2019, consolidated net premiums earned was $31,290 million. Additional financial information about our segments, including net premiums earned by geographic region, is included in Note 15 to the Consolidated Financial Statements.

North America Commercial P&C Insurance (41 percent of 2019 Consolidated NPE)

Overview

The North America Commercial P&C Insurance segment comprises operations that provide P&C insurance and services to large, middle market, and small commercial businesses in the U.S., Canada, and Bermuda. This segment includes:

- Major Accounts, the retail division focused on large institutional organizations and corporate companies
- Commercial Insurance, which includes the retail division focused on middle market customers and small businesses
- Westchester and Chubb Bermuda, our wholesale and specialty divisions

Products and Distribution

Major Accounts provides a broad array of traditional and specialty P&C, A&H, and risk management products and services to large U.S. and Canadian-based institutional organizations and corporate companies. Major Accounts distributes its insurance products primarily through a limited number of retail brokers. In addition to using brokers, certain products are also distributed through general agents, independent agents, managing general agents (MGA), managing general underwriters, alliances, affinity groups, and direct marketing operations. Products and services offered include property, professional liability, cyber risk, excess casualty, workers’ compensation, general liability, automobile liability, commercial marine, surety, environmental, construction, medical risk, inland marine, A&H coverages, as well as claims and risk management products and services.

The Major Accounts operations, which represented approximately 40 percent of North America Commercial P&C Insurance's net premiums earned in 2019, are organized into the following distinct business units, each offering specialized products and services targeted at specific markets:

- Chubb Global Casualty offers a range of customized risk management primary casualty products designed to help large insureds, including national accounts, address the significant costs of financing and managing risk for workers' compensation, general liability and automobile liability coverages as well as offering casualty insurance solutions for commercial real estate. Chubb Global Casualty also provides products which insure specific global operating risks of U.S.-based multinational companies and include deductible programs, captive programs, and paid or incurred loss retrospective plans. Within Chubb Global Casualty, Chubb Alternative Risk Solutions Group underwrites contractual indemnification policies which provides prospective coverage for loss events within the insured's policy retention levels and underwrites assumed loss portfolio transfer (LPT) contracts in which insured loss events have occurred prior to the inception of the contract.
- Property provides products and services including primary, quota share and excess all-risk insurance, risk management programs and services, commercial, inland marine, and aerospace products.
- Casualty Risk provides coverages including umbrella and excess liability, environmental risk, casualty programs for commercial construction related projects for companies and institutions, and medical risk specialty liability products for the healthcare industry.
- Surety offers a wide variety of surety products and specializes in underwriting both commercial and contract bonds and has the capacity for bond issuance on an international basis.
- Accident & Health (A&H) products include employee benefit plans, occupational accident, student accident, and worldwide travel accident and global medical programs. With respect to products that include supplemental medical and hospital indemnity coverages, we typically pay fixed amounts for claims and are therefore insulated from rising healthcare costs. A&H also provides specialty personal lines products, including credit card enhancement programs (identity theft, rental car collision damage waiver, trip travel, and purchase protection benefits) distributed through affinity groups.
- Financial Lines provides management liability and professional liability (D&O and E&O), transactional risk and cyber risk products to public companies as well as to private and not for profit organizations.
- ESIS Inc. (ESIS) is an in-house third-party claims administrator that performs claims management and risk control services for domestic and international organizations as well as for the North America Commercial P&C Insurance segment. ESIS services include comprehensive medical managed care; integrated disability services; pre-loss control and risk management; health, safety and environmental consulting; salvage and subrogation; and healthcare recovery services. The net results for ESIS are included in North America Commercial P&C Insurance's administrative expenses.

The Commercial Insurance operations, which include Small Commercial, represented approximately 40 percent of North America Commercial P&C Insurance's net premiums earned in 2019. Commercial Insurance provides a broad range of P&C, financial lines, and A&H products targeted to U.S and Canadian-based middle market customers in a variety of industries, while the Small Commercial operations provide a broad range of property and casualty, workers' compensation, small commercial management and professional liability for small businesses based in the U.S.

- Commercial Insurance products and services offered include traditional property and casualty lines of business, including Package, which combines property and general liability, workers' compensation, automobile, umbrella; financial lines of business, including professional liability, management liability and cyber risk coverage; and other lines including environmental, A&H, and international coverages. Commercial Insurance distributes its insurance products through a North American network of independent retail agents, and regional, multinational and digital brokers. Generally, our customers purchase insurance through a single retail agent or broker, do not employ a risk management department, and do not retain significant risk through self-insured retentions. The majority of our customers purchase a Package product or a portfolio of products, which is a collection of insurance offerings designed to cover various needs.
- Small Commercial Insurance products and services offered include property and casualty lines of business, including a business owner policy which contains property and general liability; financial lines, including professional liability, management liability, cyber risk; and other lines including workers' compensation, automobile liability, and international coverages. Products are generally offered through a North American network of independent agents and brokers, as well as eTraditional, which are digital platforms where we electronically quote, bind, and issue for agents and brokers. An example of this is the Chubb Marketplace.

Wholesale and Specialty, which represented approximately 20 percent of North America Commercial P&C Insurance's net premiums earned in 2019, comprises Westchester and Chubb Bermuda.

- Westchester serves the market for business risks that tend to be hard to place or not easily covered by traditional policies due to unique or complex exposures and provides specialty products for property, casualty, environmental, professional liability, inland marine, product recall, small business, binding and program coverages in the U.S., Canada, and Bermuda. Products are offered through the wholesale distribution channel.
- Chubb Bermuda provides commercial insurance products on an excess basis including excess liability, D&O, professional liability, property, and political risk, the latter being written by Sovereign Risk Insurance Ltd., a wholly-owned managing agent. Chubb Bermuda focuses on Fortune 1000 companies and targets risks that are generally low in frequency and high in severity. Products are offered primarily through the Bermuda offices of major, internationally recognized insurance brokers.

Competitive Environment

Major Accounts competes against a number of large, global carriers as well as regional competitors and other entities offering risk alternatives such as self-insured retentions and captive programs. The markets in which we compete are subject to significant cycles of fluctuating capacity and wide disparities in price adequacy. We pursue a specialist strategy and focus on market opportunities where we can compete effectively based on service levels and product design, while still achieving an adequate level of profitability. We also achieve a competitive advantage through Major Accounts' innovative product offerings and our ability to provide multiple products to a single client due to our nationwide local presence. In addition, all our domestic commercial units are able to deliver global products and coverage to customers in concert with our Overseas General Insurance segment.

The Commercial Insurance operations compete against numerous insurance companies ranging from large national carriers to small and mid-size insurers who provide specialty coverages and standard P&C products. Recent competitive developments include the growth of new digital-based distribution models.

Westchester competes against a number of large, national carriers as well as regional competitors and other entities offering risk alternatives such as self-insured retentions and captive programs. Chubb Bermuda competes against international commercial carriers writing business on an excess of loss basis.

North America Personal P&C Insurance (15 percent of 2019 Consolidated NPE)

Overview

The North America Personal P&C Insurance segment includes the business written by Chubb Personal Risk Services division, which includes high net worth personal lines business, with operations in the U.S. and Canada. This segment provides affluent and high net worth individuals and families with homeowners, automobile and collector cars, valuable articles (including fine arts), personal and excess liability, travel insurance, and recreational marine insurance and services. Our homeowners business, including valuable articles, represented 68 percent of North America Personal P&C Insurance's net premiums earned in 2019.

Products and Distribution

Chubb Personal Risk Services offers comprehensive personal insurance products and services to meet the evolving needs of high net worth families and individuals. Our seamless customer experience and superior coverage protect not only our clients' most valuable possessions, but also their standard of living. Our target customers consist of high net worth consumers with insurance needs that typically extend beyond what mass market carriers can offer. These coverages are offered solely through independent regional agents and brokers.

Competitive Environment

Chubb Personal Risk Services competes against insurance companies of varying sizes that sell personal lines products through various distribution channels, including retail agents as well as online distribution channels. We achieve a competitive advantage through our ability to address the specific needs of high net worth families and individuals, to provide superior service to our customers, and to develop and deploy digital production and processes.

North America Agricultural Insurance (6 percent of 2019 Consolidated NPE)

Overview
The North America Agricultural Insurance segment comprises our U.S. and Canadian-based businesses that provide a variety of coverages including crop insurance, primarily Multiple Peril Crop Insurance (MPCI) and crop-hail insurance through Rain and Hail Insurance Service, Inc. (Rain and Hail) as well as farm and ranch and specialty P&C commercial insurance products and services through our Chubb Agribusiness unit.

Products and Distribution
Rain and Hail provides comprehensive MPCI and crop-hail insurance coverages.

- MPCI is federally subsidized crop protection from numerous causes of loss, including drought, excessive moisture, freeze, disease and more. The MPCI program is offered in conjunction with the U.S. Department of Agriculture. MPCI products include revenue protection (defined as providing both commodity price and yield coverages), yield protection, margin protection, prevented planting coverage and replant coverage. For additional information on our MPCI program, refer to "Crop Insurance" under Item 7.
- Crop-Hail coverage provides crop protection from damage caused by hail and/or fire, with options in some markets for other perils such as wind or theft. Coverage is provided on an acre-by-acre basis and is available in the U.S. and in some parts of Canada. Crop-Hail can be used in conjunction with MPCI or other comprehensive coverages to offset the deductible and provide protection up to the actual cash value of the crop.

Chubb Agribusiness comprises Commercial Agribusiness and Farm and Ranch Agribusiness.

- Commercial Agribusiness offers specialty P&C coverages for commercial companies that manufacture, process and distribute agricultural products. Commercial products and services include property, general liability for premises/operations and product liability, commercial automobile, workers' compensation, employment practices liability coverage, built-in coverage for premises pollution, cyber and information security, and product withdrawal.
- Farm and Ranch Agribusiness offers an extensive line of coverages for farming operations from Hobby/Gentleman farms to complex corporate farms and equine services including personal use, boarding, and training. Coverages include farm and ranch structures, machinery and other equipment, automobile and other vehicle coverages, and livestock.

Competitive Environment
Rain and Hail primarily operates in a federally regulated program where all approved providers offer the same product forms and rates through independent and/or captive agents. We seek a competitive advantage through our ability to provide superior service to our customers, including the development of digital solutions. Chubb Agribusiness competes against both national and regional competitors offering specialty P&C insurance coverages to companies that manufacture, process, and distribute agricultural products.

Overseas General Insurance (28 percent of 2019 Consolidated NPE)

Overview
The Overseas General Insurance segment comprises Chubb International and Chubb Global Markets (CGM). CGM, our London-based international specialty and excess and surplus lines business, includes Lloyd's of London (Lloyd's) Syndicate 2488, a wholly-owned Chubb syndicate supported by funds at Lloyd's provided by Chubb Corporate Members. Syndicate 2488 has an underwriting capacity of £480 million for the Lloyd's 2020 account year. The syndicate is managed by Chubb's Lloyd's managing agency, Chubb Underwriting Agencies Limited.

Products and Distribution
Chubb International maintains a presence in every major insurance market in the world and is organized geographically along product lines as follows: Europe, Asia Pacific and Far East, Eurasia and Africa, and Latin America. Products offered include P&C, A&H, specialty coverages, and personal lines insurance products and services. Chubb International's P&C business is generally written, on both a direct and assumed basis, through major international, regional, and local brokers and agents. Certain European branded products are also offered via an eTraditional digital-commerce platform, Chubb Online, that allows brokers to quote, bind, and issue specialty policies online. Asia Pacific also utilizes similar eTraditional platforms to quote, bind,

and issue policies. Property insurance products include traditional commercial fire coverage as well as energy industry-related, marine, construction, and other technical coverages. Principal casualty products are commercial primary and excess casualty, environmental, and general liability. A&H and other consumer lines products are distributed through brokers, agents, direct marketing programs, including thousands of telemarketers, and sponsor relationships. The A&H operations primarily offer personal accident and supplemental medical coverages including accidental death, business/holiday travel, specified disease, disability, medical and hospital indemnity, and income protection. We are not in the primary healthcare business. With respect to our supplemental medical and hospital indemnity products, we typically pay fixed amounts for claims and are therefore largely insulated from the direct impact of rising healthcare costs. Chubb International specialty coverages include D&O, professional indemnity, energy, aviation, political risk, and specialty personal lines products. Chubb International's personal lines operations provide specialty products and services designed to meet the needs of specific target markets and include property damage, automobile, homeowners, and personal liability.

Chubb International’s presence in China also includes its 30.9 percent ownership interest in Huatai Insurance Group Company Limited (Huatai Group). Huatai Group wholly owns Huatai Property & Casualty Insurance Co., Ltd. (Huatai P&C). Therefore, Chubb owns an approximately 30.9 percent indirect ownership interest in Huatai P&C, which provides a range of commercial and personal P&C products in China, including property, professional liability, product liability, employer liability, business interruption, marine cargo, personal accident and specialty risk. These products are marketed through a variety of distribution channels including over 200 licensed sales locations in 28 Chinese provinces. Chubb is in the process of increasing its ownership interest in Huatai Group.

CGM offers products through its parallel distribution network via two legal entities, Chubb European Group SE (CEG) and Chubb Underwriting Agencies Limited, managing agent of Syndicate 2488. CGM uses the Syndicate to underwrite P&C business on a global basis through Lloyd's worldwide licenses. CGM uses CEG to underwrite similar classes of business through its network of U.K. and European licenses, and in the U.S. where it is eligible to write excess and surplus lines business. Factors influencing the decision to place business with the Syndicate or CEG include licensing eligibilities, capitalization requirements, and client/ broker preference. All business underwritten by CGM is accessed through registered brokers. The main lines of business include aviation, property, energy, professional lines, marine, financial lines, political risk, and A&H.

Competitive Environment
Chubb International's primary competitors include U.S.-based companies with global operations, as well as non-U.S. global carriers and indigenous companies in regional and local markets. For the A&H lines of business, locally based competitors also include financial institutions and bank owned insurance subsidiaries. Our international operations have the distinct advantage of being part of one of the few international insurance groups with a global network of licensed companies able to write policies on a locally admitted basis. The principal competitive factors that affect the international operations are underwriting expertise and pricing, relative operating efficiency, product differentiation, producer relations, and the quality of policyholder services. A competitive strength of our international operations is our global network and breadth of insurance programs, which assist individuals and business organizations to meet their risk management objectives, while also having a significant presence in all of the countries in which we operate, giving us the advantage of accessing local technical expertise and regulatory environments, understanding local markets and culture, accomplishing a spread of risk, and offering a global network to service multinational accounts.

CGM is one of the preeminent international specialty insurers in London and is an established lead underwriter on a significant portion of the risks it underwrites for all lines of business. All lines of business face competition, depending on the business class, from Lloyd's syndicates, the London market, and other major international insurers and reinsurers. Competition for international risks is also seen from domestic insurers in the country of origin of the insured. CGM differentiates itself from competitors through long standing experience in its product lines, its multiple insurance entities (Syndicate 2488 and CEG), and the quality of its underwriting and claims service.

Global Reinsurance (2 percent of 2019 Consolidated NPE)

Overview
The Global Reinsurance segment represents Chubb's reinsurance operations comprising Chubb Tempest Re Bermuda, Chubb Tempest Re USA, Chubb Tempest Re International, and Chubb Tempest Re Canada. Global Reinsurance markets reinsurance products worldwide under the Chubb Tempest Re brand name and provides solutions for small to mid-sized clients and multinational ceding companies. Global Re offers a broad array of traditional and non-traditional (e.g., loss portfolio transfer) property and casualty products.

Products and Distribution
Global Reinsurance services clients globally through its major units. Major international brokers submit business to one or more of these units' underwriting teams who have built strong relationships with both key brokers and clients by providing a responsive, client-focused approach to risk assessment and pricing.

Chubb Tempest Re Bermuda principally provides property catastrophe reinsurance globally to insurers of commercial and personal property. Property catastrophe reinsurance is on an occurrence or aggregate basis and protects a ceding company against an accumulation of losses covered by its issued insurance policies, arising from a common event or occurrence. Chubb Tempest Re Bermuda underwrites reinsurance principally on an excess of loss basis, meaning that its exposure only arises after the ceding company's accumulated losses have exceeded the attachment point of the reinsurance policy. Chubb Tempest Re Bermuda also writes other types of reinsurance on a limited basis for selected clients. Chubb Tempest Re Bermuda's business is produced through reinsurance intermediaries.

Chubb Tempest Re USA writes all lines of traditional and specialty P&C reinsurance for the North American market, principally on a treaty basis, with a focus on writing property per risk and casualty reinsurance. Chubb Tempest Re USA underwrites reinsurance on both a proportional and excess of loss basis. This unit's diversified portfolio is produced through reinsurance intermediaries.

Chubb Tempest Re International provides traditional and specialty P&C reinsurance to insurance companies worldwide, with emphasis on non-U.S. and Canadian risks. Chubb Tempest Re International writes all lines of traditional and specialty reinsurance including property risk, property catastrophe, casualty, marine, aviation, and specialty through our London- and Zurich-based offices. The London-based office of Chubb Tempest Re International focuses on the development of business sourced through London market brokers. The Zurich-based office focuses on providing reinsurance to continental European insurers via continental European brokers while also serving Asian and Latin American markets. The London- and Zurich-based offices write a diverse book of international business using Syndicate 2488, CEG, and Chubb Insurance (Switzerland) Limited. Chubb Tempest Re International underwrites reinsurance on both a proportional and excess of loss basis.

Chubb Tempest Re Canada offers a full array of traditional and specialty P&C, and reinsurance to the Canadian market, including casualty, property risk, property catastrophe, surety, and crop hail. Chubb Tempest Re Canada provides coverage through its Canadian company platform and also offers clients access to Syndicate 2488. Chubb Tempest Re Canada underwrites reinsurance on both a proportional and excess of loss basis.

Competitive Environment
The Global Reinsurance segment competes worldwide with major U.S. and non-U.S. reinsurers as well as reinsurance departments of numerous multi-line insurance organizations. In addition, capital markets participants have developed alternative capital sources intended to compete with traditional reinsurance. Additionally, government sponsored or backed catastrophe funds can affect demand for reinsurance. Global Reinsurance is considered a lead reinsurer and is typically involved in the negotiation and quotation of the terms and conditions of the majority of the contracts in which it participates. Global Reinsurance competes effectively in P&C markets worldwide because of its strong capital position, analytical capabilities and quality customer service. The key competitors in our markets vary by geographic region and product line. An advantage of our international platform is that we can change our mix of business in response to changes in competitive conditions in the territories in which we operate. Our geographic reach is also sought by multinational ceding companies since our offices, except for Bermuda, provide local reinsurance license capabilities which benefit our clients in dealing with country regulators.

Life Insurance (8 percent of 2019 Consolidated NPE)

Overview
The Life Insurance segment comprises Chubb's international life operations (Chubb Life), Chubb Tempest Life Re (Chubb Life Re), and the North American supplemental A&H and life business of Combined Insurance.

Products and Distribution
Chubb Life provides individual life and group benefit insurance primarily in Asia, including Hong Kong, Indonesia, South Korea, Taiwan, Thailand, and Vietnam; throughout Latin America; selectively in Europe; Egypt; and in China through a non-consolidated joint venture insurance company. Chubb Life offers a broad portfolio of protection and savings products including whole life, endowment plans, individual term life, group term life, medical and health, personal accident, credit life, universal life, Group Employee benefits, unit linked contracts, and credit protection insurance for automobile, motorcycle and home loans.

The policies written by Chubb Life generally provide funds to beneficiaries of insureds after death and/or protection and/or savings benefits while the contract owner is living. Chubb Life sells to consumers through a variety of distribution channels including captive and independent agencies, bancassurance, worksite marketing, retailers, brokers, telemarketing, mobilassurance, and direct to consumer marketing. We continue to expand Chubb Life with a focus on opportunities in developing markets that we believe will result in strong and sustainable operating profits as well as a favorable return on capital commitments over time. Our dedicated captive agency distribution channel, whereby agents sell Chubb Life products exclusively, enables us to maintain direct contact with the individual consumer, promote quality sales practices, and exercise greater control over the future of the business. We have developed a substantial sales force of agents principally located in our Asia-Pacific countries. As of December 31, 2019, Chubb had a 45 percent direct and indirect ownership interest in Huatai Life Insurance Co., Ltd. (Huatai Life), comprising a 20 percent direct ownership interest as well as a 25 percent indirect ownership interest through Huatai Group, the parent company of Huatai Life. Huatai Life commenced operations in 2005 and has since grown to become one of the larger life insurance foreign joint ventures in China. Huatai Life offers a broad portfolio of insurance products including whole life, universal life, medical and health, personal accident and disability. These products are marketed through a variety of distribution channels including approximately 454 licensed sales locations in 20 Chinese provinces. Chubb is in the process of increasing its ownership interest in Huatai Group.

Chubb Life Re's core business is a Bermuda-based operation which provides reinsurance to primary life insurers, focusing on guarantees included in certain variable annuity products and also on more traditional mortality reinsurance protection. Chubb Life Re's U.S.-based traditional life reinsurance operation was discontinued for new business in January 2010. Since 2007, Chubb Life Re has not quoted on new opportunities in the variable annuity reinsurance marketplace and our focus has been on managing the current portfolio of risk, both in the aggregate and on a contract basis. This business is managed with a long-term perspective and short-term earnings volatility is expected.

Combined Insurance distributes specialty supplemental A&H and life insurance products targeted to middle income consumers and businesses in the U.S. and Canada. Combined Insurance's substantial North American sales force distributes a wide range of supplemental accident and sickness insurance products, including personal accident, short-term disability, critical illness, Medicare supplement products, and hospital confinement/recovery. Most of these products are primarily fixed-indemnity benefit obligations and are not directly subject to escalating medical cost inflation.

Competitive Environment

Chubb Life's competition differs by location but generally includes multinational insurers, and in some locations, local insurers, joint ventures, or state-owned insurers. Chubb's financial strength and reputation as an entrepreneurial organization with a global presence gives Chubb Life a strong base from which to compete. While Chubb Life Re is not currently quoting on new opportunities in the variable annuity reinsurance marketplace, we continue to monitor developments in this market. Combined Insurance competes for A&H business in the U.S. against numerous A&H and life insurance companies across various industry segments.

Corporate

Corporate results primarily include results of all run-off asbestos and environmental (A&E) exposures, the results of our run-off Brandywine business, the results of Westchester specialty operations for 1996 and prior years, certain other run-off exposures, and income and expenses not attributable to reportable segments and the results of our non-insurance companies. The run-off operations do not actively sell insurance products, but are responsible for the management of existing policies and settlement of related claims.

Our exposure to A&E claims principally arises out of liabilities acquired when we purchased Westchester Specialty in 1998, CIGNA's P&C business in 1999, and The Chubb Corporation in 2016. The A&E liabilities principally relate to claims arising from bodily-injury claims related to asbestos products and remediation costs associated with hazardous waste sites.

Underwriting

Chubb is an underwriting company and we strive to emphasize quality of underwriting rather than volume of business or market share. Our underwriting strategy is to manage risk by employing consistent, disciplined pricing and risk selection. This, coupled with writing a number of less cyclical product lines, has helped us develop flexibility and stability of our business, and has allowed us to maintain a profitable book of business throughout market cycles. Clearly defined underwriting authorities, standards, and guidelines coupled with a strong underwriting audit function are in place in each of our local operations and global profit centers. Global product boards ensure consistency of approach and the establishment of best practices throughout the world. Our priority is to help ensure adherence to criteria for risk selection by maintaining high levels of experience and expertise in our underwriting staff. In addition, we employ a business review structure that helps ensure control of risk quality and appropriate use of policy limits and terms and conditions. Underwriting discipline is at the heart of our operating philosophy.

Actuaries in each region work closely with the underwriting teams to provide additional expertise in the underwriting process. We use internal and external data together with sophisticated analytical, catastrophe loss and risk modeling techniques to ensure an appropriate understanding of risk, including diversification and correlation effects, across different product lines and territories. We recognize that climate changes and weather patterns are integral to our underwriting process and we continually adjust our process to address these changes. This is intended to help ensure that losses are contained within our risk tolerance and appetite for individual product lines, businesses, and Chubb as a whole. Our use of such tools and data also reflects an understanding of their inherent limitations and uncertainties.

We also purchase protection from third parties, including, but not limited to, reinsurance as a tool to diversify risk and limit the net loss potential of catastrophes and large or unusually hazardous risks. For additional information refer to "Risk Factors" under Item 1A, “Reinsurance Protection”, below, “Catastrophe Management” and “Natural Catastrophe Property Reinsurance Program”, under Item 7, and Note 5 to the Consolidated Financial Statements, under Item 8.

Reinsurance Protection

As part of our risk management strategy, we purchase reinsurance protection to mitigate our exposure to losses, including certain catastrophes, to a level consistent with our risk appetite. Although reinsurance agreements contractually obligate our reinsurers to reimburse us for an agreed-upon portion of our gross paid losses, reinsurance does not discharge our primary liability to our insureds and, thus, we ultimately remain liable for the gross direct losses. In certain countries, reinsurer selection is limited by local laws or regulations. In most countries there is more freedom of choice, and the counterparty is selected based upon its financial strength, claims settlement record, management, line of business expertise, and its price for assuming the risk transferred. In support of this process, we maintain a Chubb authorized reinsurer list that stratifies these authorized reinsurers by classes of business and acceptable limits. This list is maintained by our Reinsurance Security Committee (RSC), a committee comprising senior management personnel and a dedicated reinsurer security team. Changes to the list are authorized by the RSC and recommended to the Chair of the Risk and Underwriting Committee. The reinsurers on the authorized list and potential new markets are regularly reviewed and the list may be modified following these reviews. In addition to the authorized list, there is a formal exception process that allows authorized reinsurance buyers to use reinsurers already on the authorized list for higher limits or different lines of business, for example, or other reinsurers not on the authorized list if their use is supported by compelling business reasons for a particular reinsurance program.

A separate policy and process exists for captive reinsurance companies. Generally, these reinsurance companies are established by our clients or our clients have an interest in them. It is generally our policy to obtain collateral equal to the expected losses that may be ceded to the captive. Where appropriate, exceptions to the collateral requirement are granted but only after senior management review. Specific collateral guidelines and an exception process are in place for the North America Commercial P&C Insurance, North America Personal P&C Insurance, and Overseas General Insurance segments, all of which have credit management units evaluating the captive's credit quality and that of their parent company. The credit management units, working with actuaries, determine reasonable exposure estimates (collateral calculations), ensure receipt of collateral in an acceptable form, and coordinate collateral adjustments as and when needed. Financial reviews and expected loss evaluations are performed annually for active captive accounts and as needed for run-off exposures. In addition to collateral, parental guarantees are often used to enhance the credit quality of the captive.

In general, we seek to place our reinsurance with highly rated companies with which we have a strong trading relationship. For additional information refer to “Catastrophe Management” and “Natural Catastrophe Property Reinsurance Program” under Item 7, and Note 5 to the Consolidated Financial Statements, under Item 8.

Unpaid Losses and Loss Expenses

We establish reserves for unpaid losses and loss expenses, which are estimates of future payments on reported and unreported claims for losses and related expenses, with respect to insured events that have occurred. These reserves are recorded in Unpaid losses and loss expenses in the Consolidated balance sheets. The process of establishing loss and loss expense reserves for P&C claims can be complex and is subject to considerable uncertainty as it requires the use of informed estimates and judgments based on circumstances known at the date of accrual. These estimates and judgments are based on numerous factors, and may be revised as additional experience and other data become available and are reviewed, as new or improved methodologies are developed, or as laws change. Internal actuaries regularly analyze the levels of loss and loss expense reserves, taking into consideration factors that may impact the ultimate settlement value of the unpaid losses and loss expenses. These analyses could result in future changes in the estimates of loss and loss expense reserves or reinsurance recoverables and any such changes would be reflected in our results of operations in the period in which the estimates are changed. Losses and loss expenses are charged to income as incurred. The reserve for unpaid losses and loss expenses represents the estimated ultimate losses and loss expenses less paid losses and loss expenses, and comprises case reserves and incurred but not reported (IBNR) reserves. With the exception of certain structured settlements, for which the timing and amount of future claim payments are reliably determinable, and certain reserves for unsettled claims, our loss reserves are not discounted for the time value of money. In connection with such structured settlements and certain reserves for unsettled claims, we carried net discounted reserves of $74 million at December 31, 2019.

For each product line, management, after consultation with internal actuaries, develops a “best estimate” of the ultimate settlement value of the unpaid losses and loss expenses that it believes provides a reasonable estimate of the required reserve. We evaluate our estimates of reserves quarterly in light of developing information. While we are unable at this time to determine whether additional reserves may be necessary in the future, we believe that our reserves for unpaid losses and loss expenses are adequate at December 31, 2019. Future additions to reserves, if needed, could have a material adverse effect on our financial condition, results of operations, and cash flows. For additional information refer to “Critical Accounting Estimates – Unpaid losses and loss expenses”, under Item 7, and Note 7 to the Consolidated Financial Statements, under Item 8.

Investments

Our objective is to maximize investment income and total return while ensuring an appropriate level of liquidity, investment quality, and diversification. As such, Chubb's investment portfolio is invested primarily in investment-grade fixed-income securities as measured by the major rating agencies. We do not allow leverage in our investment portfolio.

The critical aspects of the investment process are controlled by Chubb Asset Management, an indirect wholly-owned subsidiary of Chubb. These aspects include asset allocation, portfolio and guideline design, risk management, and oversight of external asset managers. In this regard, Chubb Asset Management:

- conducts formal asset allocation modeling for each of the Chubb subsidiaries, providing formal recommendations for the portfolio's structure;
- establishes recommended investment guidelines that are appropriate to the prescribed asset allocation targets;
- provides the analysis, evaluation, and selection of our external investment advisors;
- establishes and develops investment-related analytics to enhance portfolio engineering and risk control;
- monitors and aggregates the correlated risk of the overall investment portfolio; and
- provides governance over the investment process for each of our operating companies to ensure consistency of approach and adherence to investment guidelines.

Under our guidance and direction, external asset managers conduct security and sector selection and transaction execution. Use of multiple managers benefits Chubb in several ways – it provides us with operational and cost efficiencies, diversity of styles and approaches, innovations in investment research and credit and risk management, all of which enhance the risk adjusted returns of our portfolios.

Chubb Asset Management determines the investment portfolio's allowable, targeted asset allocation and ranges for each of the segments. These asset allocation targets are derived from sophisticated asset and liability modeling that measures correlated histories of returns and volatility of returns. Allowable investment classes are further refined through analysis of our operating environment including expected volatility of cash flows, potential impact on our capital position, and regulatory and rating agency considerations.

The Board has established a Risk & Finance Committee which helps execute the Board's supervisory responsibilities pertaining to enterprise risk management including investment risk. Under the overall supervision of the Risk & Finance Committee, Chubb's governance over investment management is rigorous and ongoing. Among its responsibilities, the Risk & Finance Committee of the Board:

- reviews and approves asset allocation targets and investment policy to ensure that it is consistent with our overall goals, strategies, and objectives;
- reviews and approves investment guidelines to ensure that appropriate levels of portfolio liquidity, credit quality, diversification, and volatility are maintained; and
- systematically reviews the portfolio's exposures including any potential violations of investment guidelines.

We have long-standing global credit limits for our entire portfolio across the organization and for individual obligors. Exposures are aggregated, monitored, and actively managed by our Global Credit Committee, comprising senior executives, including our Chief Financial Officer, our Chief Risk Officer, our Chief Investment Officer, and our Treasurer.

Within the guidelines and asset allocation parameters established by the Risk & Finance Committee, individual investment committees of the segments determine tactical asset allocation. Additionally, these committees review all investment-related activity that affects their operating company, including the selection of outside investment advisors, proposed asset allocation changes, and the systematic review of investment guidelines.

For additional information regarding the investment portfolio, including breakdowns of the sector and maturity distributions, refer to Note 3 to the Consolidated Financial Statements under Item 8.

Regulation

Our insurance and reinsurance subsidiaries conduct business globally, including in all 50 states of the United States and the District of Columbia. Our business is subject to varying degrees of regulation and supervision in each of the jurisdictions in which our insurance and reinsurance subsidiaries are domiciled and on a group basis. The laws and regulations of the jurisdictions in which our insurance and reinsurance subsidiaries are domiciled require among other things that these subsidiaries maintain minimum levels of statutory capital, surplus, and liquidity, meet solvency standards, and submit to periodic examinations of their financial condition. The complex regulatory environments in which Chubb operates are subject to change and are regularly monitored.

Group Supervision

In 2012, the Pennsylvania Insurance Department (Department), in consultation with other insurance regulatory bodies that oversee Chubb's insurance activities, convened the first Chubb Supervisory College (College). Regulators from approximately ten jurisdictions attended the College in Philadelphia, Pennsylvania, during which the supervisors reviewed information on Chubb. The Department, in cooperation with the other supervisory college regulators, published a notice of its determination that it is the appropriate group-wide supervisor for Chubb.

Since 2012, the College has convened bi-annually in-person; and, in July 2017, the College convened its first interim College teleconference, with the most recent teleconference held in September 2019. During these meetings, the College reviewed extensive information about Chubb, without material adverse comment. The next in-person College is scheduled for September 2020 in Philadelphia, Pennsylvania.

The following is an overview of regulations for our operations in Switzerland, the U.S., Bermuda, and other international locations.

Swiss Operations

The Swiss Financial Market Supervisory Authority (FINMA) has the discretion to supervise Chubb on a group-wide basis. However, FINMA acknowledges the Department's assumption of group supervision over us.

In 2008, we formed Chubb Insurance (Switzerland) Limited which offers property and casualty insurance to Swiss companies, A&H insurance for individuals of Swiss Corporations as well as reinsurance predominantly in Continental Europe. We have also formed a reinsurance subsidiary named Chubb Reinsurance (Switzerland) Limited, which we operate as primarily a provider of reinsurance to Chubb entities. Both companies are licensed and governed by FINMA.

U.S. Operations

Our U.S. insurance subsidiaries are subject to extensive regulation and supervision by the states in which they do business. The laws of the various states establish departments of insurance with broad authority to regulate, among other things: the standards of solvency that must be met and maintained, the licensing of insurers and their producers, approval of policy forms and rates, the nature of and limitations on investments, restrictions on the size of the risks which may be insured under a single policy, deposits of securities for the benefit of policyholders, requirements for the acceptability of reinsurers, periodic examinations of the affairs of insurance companies, the form and content of reports of financial condition required to be filed, and the adequacy of reserves for unearned premiums, losses, and other exposures.

Our U.S. insurance subsidiaries are required to file detailed annual and quarterly reports with state insurance regulators. In addition, our U.S. insurance subsidiaries' operations and financial records are subject to examination at regular intervals by state regulators.

All states have enacted legislation that regulates insurance holding companies. This legislation provides that each insurance company in the insurance holding company system (system) is required to register with the insurance department of its state of domicile and furnish information concerning the operations of companies within the system that may materially affect the operations, management, or financial condition of the insurers within the system. We are required to file an annual enterprise risk report with the Department, identifying the material risks within our system that could pose enterprise risk to the insurance subsidiaries in the system. All transactions within a system must be fair and equitable. Notice to the insurance departments is required prior to the consummation of transactions affecting the ownership or control of an insurer and of certain material transactions between an insurer and an entity in its system. In addition, certain transactions may not be consummated without the department's prior approval.

We are also required to file an annual report with the Department, reflecting our internal assessment of material risks associated with our current business plan and the sufficiency of our capital resources to support those risks.

Statutory surplus is an important measure used by the regulators and rating agencies to assess our U.S. insurance subsidiaries' ability to support business operations and provide dividend capacity. Our U.S. insurance subsidiaries are subject to various state statutory and regulatory restrictions that limit the amount of dividends that may be paid without prior approval from regulatory authorities. These restrictions differ by state, but are generally based on calculations incorporating statutory surplus, statutory net income, and/or investment income.

The National Association of Insurance Commissioners (NAIC) has a risk-based capital requirement for P&C insurance companies. This risk-based capital formula is used by many state regulatory authorities to identify insurance companies that may be undercapitalized and which merit further regulatory attention. These requirements are designed to monitor capital adequacy using a formula that prescribes a series of risk measurements to determine a minimum capital amount for an insurance company, based on the profile of the individual company. The ratio of a company's actual policyholder surplus to its minimum capital requirement will determine whether any state regulatory action is required. There are progressive risk-based capital failure levels that trigger more stringent regulatory action. If an insurer's policyholders' surplus falls below the Mandatory Control Level (70 percent of the Authorized Control Level, as defined by the NAIC), the relevant insurance commissioner is required to place the insurer under regulatory control.

However, an insurance regulator may allow a P&C company operating below the Mandatory Control Level that is writing no business and is running off its existing business to continue its run-off. Brandywine is running off its liabilities consistent with the terms of an order issued by the Insurance Commissioner of Pennsylvania. This includes periodic reporting obligations to the Department.

Government intervention continued in the insurance and reinsurance markets in relation to terrorism coverage in the U.S. (and through industry initiatives in other countries). The U.S. Terrorism Risk Insurance Act (TRIA), which was enacted in 2002 to ensure the availability of insurance coverage for certain types of terrorist acts in the U.S., was extended in December 2019 through December 31, 2027, and applies to certain of our operations.

From time to time, Chubb and its subsidiaries and affiliates receive inquiries from state agencies and attorneys general, with which we generally comply, seeking information concerning business practices, such as underwriting and non-traditional or loss mitigation insurance products. Moreover, many recent factors, such as consequences of and reactions to industry and economic conditions and focus on domestic issues, have contributed to the potential for change in the legal and regulatory framework applicable to Chubb's U.S. operations and businesses. We cannot assure that changes in laws or investigative or enforcement activities in the various states in the U.S. will not have a material adverse impact on our financial condition, results of operations, or business practices.

We are subject to numerous U.S. federal and state laws governing the protection of personal and confidential information of our clients or employees. These laws and regulations are increasing in complexity, and the requirements are extensive and detailed. Numerous states require us to certify our compliance with their data protection laws.

We are subject to the New York Department of Financial Services' Cybersecurity Regulation (the NYDFS Cybersecurity Regulation) which mandates detailed cybersecurity standards for all institutions, including insurance entities, authorized by the NYDFS to operate in New York. Among the requirements are the maintenance of a cybersecurity program with governance controls, risk-based minimum data security standards for technology systems, cyber breach preparedness and response requirements, including reporting obligations, vendor oversight, training, and program record keeping and certification obligations. Because our North America systems are integrated, our companies domiciled in other states may also be impacted by this requirement.

Additionally, the NAIC adopted an Insurance Data Security Model Law, which require licensed insurance entities to comply with detailed information security requirements. The NAIC model law is similar in many respects to the NYDFS Cybersecurity Regulation.

Bermuda Operations

The Insurance Act 1978 of Bermuda and related regulations, as amended (the Insurance Act), regulates the insurance business of our Bermuda domiciled (re)insurance subsidiaries (Bermuda domiciled subsidiaries) and provides that no person may carry on any insurance business in or from within Bermuda unless registered as an insurer by the Bermuda Monetary Authority (BMA). The Insurance Act imposes solvency and liquidity standards and auditing and reporting requirements on Bermuda insurance companies and grants the BMA powers to supervise, investigate, and intervene in the affairs of insurance companies.

Bermuda domiciled subsidiaries must prepare and file with the BMA, audited annual statutory financial statements and audited annual financial statements prepared in accordance with accounting principles generally accepted in the U.S. (GAAP), International Financial Reporting Standards (IFRS), or any such other generally accepted accounting principles as the BMA may recognize. These audited financial statements are made public by the BMA. The Insurance Act prescribes rules for the preparation and content of the statutory financial statements that require Bermuda domiciled subsidiaries to give detailed information and analyses regarding premiums, claims, reinsurance, and investments. In addition, the Bermuda domiciled subsidiaries are required to prepare and publish a Financial Condition Report (FCR). The FCR provides details of measures governing the business operations, corporate governance framework, solvency and financial performance. The FCR must be filed with the BMA and requires Bermuda insurance companies to make the FCR publicly available.

Bermuda's regulatory regime provides a risk-based capital model, termed the Bermuda Solvency Capital Requirement (BSCR), as a tool to assist the BMA both in measuring risk and in determining appropriate levels of capitalization. The BSCR employs a standard mathematical model that correlates the risk underwritten by Bermuda insurers to their capital. The BSCR framework applies a standard measurement format to the risk associated with an insurer's assets, liabilities, and premiums, including a formula to take into account catastrophe risk exposure.

The BMA established risk-based regulatory capital adequacy and solvency margin requirements for Bermuda insurers that mandate that a Bermuda domiciled subsidiary's Enhanced Capital Requirement (ECR) be calculated by either (a) BSCR, or (b) an internal capital model which the BMA has approved for use for this purpose. The Bermuda domiciled subsidiaries use the BSCR in calculating their solvency requirements. Bermuda statutory reporting rules include an Economic Balance Sheet (EBS) framework. The EBS framework is embedded as part of the BSCR and forms the basis of our ECR.

In order to minimize the risk of a shortfall in capital arising from an unexpected adverse deviation and in moving towards the implementation of a risk based capital approach, the BMA has established a threshold capital level, (termed the Target Capital Level (TCL)), set at 120 percent of ECR, that serves as an early warning tool for the BMA. Failure to maintain statutory capital at least equal to the TCL would likely result in increased BMA regulatory oversight.

Under the Insurance Act, Chubb's Bermuda domiciled subsidiaries are prohibited from declaring or paying any dividends of more than 25 percent of total statutory capital and surplus, as shown in its previous financial year unconsolidated statutory balance sheet, unless at least seven days before payment of the dividends, it files with the BMA an affidavit that it will continue to meet its required solvency margins. Furthermore, Bermuda domiciled subsidiaries may only declare and pay a dividend from retained earnings and a dividend or distribution from contributed surplus if it has no reasonable grounds for believing that it is, or would after the payment be, unable to pay its liabilities as they become due, or if the realizable value of its assets would be less than the aggregate of its liabilities and its issued share capital and share premium accounts.

In addition, Chubb's Bermuda domiciled subsidiaries must obtain the BMA's prior approval before reducing total statutory capital, as shown in its previous financial year statutory balance sheet, by 15 percent or more.

Other International Operations

The extent of insurance regulation varies significantly among the countries in which non-U.S. Chubb operations conduct business. While each country imposes licensing, solvency, auditing, and financial reporting requirements, the type and extent of the requirements differ substantially. For example:

- in some countries, insurers are required to prepare and file monthly and/or quarterly financial reports, and in others, only annual reports;
- some regulators require intermediaries to be involved in the sale of insurance products, whereas other regulators permit direct sales contact between the insurer and the customer;
- the extent of restrictions imposed upon an insurer's use of local and offshore reinsurance vary;
- policy form filing and rate regulation vary by country;
- the frequency of contact and periodic on-site examinations by insurance authorities differ by country; and
- regulatory requirements relating to insurer dividend policies vary by country.

Significant variations can also be found in the size, structure, and resources of the local regulatory departments that oversee insurance activities. Certain regulators prefer close relationships with all subject insurers and others operate a risk-based approach.

Chubb operates in some countries through subsidiaries and in some countries through branches of subsidiaries. Local capital requirements applicable to a subsidiary generally include its branches. Certain Chubb companies are jointly owned with local companies to comply with legal requirements for local ownership. Other legal requirements include discretionary licensing procedures, compulsory cessions of reinsurance, local retention of funds and records, data privacy and protection program requirements, and foreign exchange controls. Chubb's international companies are also subject to multinational application of certain U.S. laws.

There are various regulatory bodies and initiatives that impact Chubb in multiple international jurisdictions and the potential for significant impact on Chubb could be heightened as a result of recent industry and economic developments.

In 2016, the United Kingdom (UK) voted in a national referendum to withdraw from the EU. In anticipation of the UK leaving the EU, effective January 1, 2019, we redomiciled the headquarters of our European carriers to Paris, France, which is also the principal office for our Continental European operations. Chubb continues to have a substantial presence in London in addition to its offices and operations across the UK and EU.

In 2018, the EU's General Data Protection Regulation (GDPR) came into effect. The GDPR is a privacy regulation with protection for the personal data of EU residents on a global basis.

Enterprise Risk Management

As an insurer, Chubb is in the business of profitably managing risk for its customers. Since risk management must permeate an organization conducting a global insurance business, we have an established Enterprise Risk Management (ERM) framework that is integrated into management of our businesses and is led by Chubb's senior management. As a result, ERM is a part of the day-to-day management of Chubb and its operations.

Our global ERM framework is broadly multi-disciplinary and its strategic objectives include:

- **External Risks**: identify, analyze, quantify, and where possible, mitigate significant external risks that could materially hamper the financial condition of Chubb and/or the achievement of corporate business objectives over the next 36 months;

- **Exposure Accumulations**: identify and quantify the accumulation of exposure to individual counterparties, products or industry sectors, particularly those that materially extend across or correlate between business units or divisions and/or the balance sheet;
- **Risk Modeling**: develop and use various data-sets, analytical tools, metrics and processes (including economic capital models and advanced analytics, including catastrophe models to quantify natural catastrophe risk for product pricing, risk management, capital allocation and to simulate and estimate hurricane losses) that help business and corporate leaders make informed underwriting, portfolio management and risk management decisions within a consistent risk/reward framework;
- **Governance**:
  - establish and coordinate risk guidelines that reflect the corporate appetite for risk;
  - monitor exposure accumulations relative to established guidelines; and
  - ensure effective internal risk management communication up to management and the Board, (including our Risk & Finance Committee and our Nominating & Governance Committee), down to the various business units and legal entities, and across the firm; and
- **Disclosure**: develop protocols and processes for risk-related disclosure internally as well as externally to rating agencies, regulators, shareholders and analysts.

Chubb Group's Risk and Underwriting Committee (RUC) reports to and assists the Chief Executive Officer in the oversight and review of the ERM framework which covers the processes and guidelines used to manage insurance risk, financial risk, strategic risk, and operational risk. The RUC is chaired by Chubb Group's Chief Risk Officer. The RUC meets at least monthly, and is comprised of Chubb Group's most senior executives, in addition to the Chair, including the Chief Executive Officer, Chief Operating Officer, Chief Financial Officer, Chief Investment Officer, Chief Actuary, Chief Claims Officer, General Counsel, President – North America Commercial and Personal Insurance, President – North America Major Accounts and Specialty Insurance, President – Overseas General Insurance, and Chief Underwriting Officer.

The RUC is assisted in its activities by Chubb's Enterprise Risk Unit (ERU) and Product Boards. The ERU is responsible for the collation and analysis of risk insight in two key areas. First, external information that provides insight to the RUC on existing or emerging risks that might significantly impact Chubb's key objectives and second, internal risk aggregations arising from Chubb's business writings and other activities such as investments and operations. The ERU is independent of the operating units and reports to our Chief Risk Officer. The Product Boards exist to provide oversight for products that we offer globally. A Product Board currently exists for each of Chubb's major product areas. Each Product Board is responsible for ensuring consistency in underwriting and pricing standards, identification of emerging issues, and guidelines for relevant accumulations.

Chubb's Chief Risk Officer also reports to the Board's Risk & Finance Committee, which helps execute the Board's supervisory responsibilities pertaining to ERM. The role of the Risk & Finance Committee includes evaluation of the integrity and effectiveness of our ERM procedures, systems, and information; governance on major policy decisions pertaining to risk aggregation and minimization; and assessment of our major decisions and preparedness levels pertaining to perceived material risks. The Audit Committee meets annually and on an as-needed basis with the Risk & Finance Committee in order to exercise its duties under New York Stock Exchange Rules.

Others within the ERM structure contribute toward accomplishing Chubb's ERM objectives, including regional management, Corporate Underwriting, Internal Audit, Compliance, external consultants, and managers of our internal control processes and procedures.

Tax Matters

Refer to "Risk Factors", under Item 1A and Note 1 o) and Note 8 to the Consolidated Financial Statements, under Item 8.

Information about our Executive Officers

Name	Age	Position
Evan G. Greenberg	65	Chairman, President, Chief Executive Officer, and Director
John W. Keogh	55	Executive Vice Chairman and Chief Operating Officer
Philip V. Bancroft	60	Executive Vice President and Chief Financial Officer
John J. Lupica	54	Vice Chairman; President, North America Major Accounts & Specialty Insurance
Joseph F. Wayland	62	Executive Vice President and General Counsel
Sean Ringsted	57	Executive Vice President, Chief Digital Officer, and Chief Risk Officer
Timothy A. Boroughs	70	Executive Vice President and Chief Investment Officer
Paul J. Krump	60	Executive Vice President; President, North America Commercial and Personal Insurance
Juan Luis Ortega	45	Executive Vice President; President, Overseas General Insurance

Evan G. Greenberg has been a director of Chubb Limited since August 2002. Mr. Greenberg was elected Chairman of the Board of Directors in May 2007. Mr. Greenberg was a director of The Coca-Cola Company from February 2011 until his resignation in October 2016. Mr. Greenberg was appointed to the position of President and Chief Executive Officer of Chubb Limited in May 2004, and in June 2003, was appointed President and Chief Operating Officer of Chubb Limited. Mr. Greenberg was appointed to the position of Chief Executive Officer of Chubb Overseas General in April 2002. He joined Chubb as Vice Chairman, Chubb Limited, and Chief Executive Officer of Chubb Tempest Re in November 2001. Prior to joining Chubb, Mr. Greenberg was most recently President and Chief Operating Officer of American International Group (AIG), a position he held from 1997 until 2000.

John W. Keogh was appointed Executive Vice Chairman of Chubb Limited in November 2015. Mr. Keogh has served as Chief Operating Officer of Chubb Limited since July 2011 and Vice Chairman of Chubb Limited and Chubb Group Holdings since August 2010. Mr. Keogh joined Chubb as Chief Executive Officer of Overseas General Insurance in April 2006 and became Chairman of Overseas General Insurance in August 2010. Prior to joining Chubb, Mr. Keogh served as Senior Vice President, Domestic General Insurance of AIG, and President and Chief Executive Officer of National Union Fire Insurance Company, AIG's member company that specializes in D&O and fiduciary liability coverages. Mr. Keogh joined AIG in 1986. He served in a number of other senior positions there including as Executive Vice President of AIG's Domestic Brokerage Group and as President and Chief Operating Officer of AIG's Lexington Insurance Company unit.

Philip V. Bancroft was appointed Chief Financial Officer of Chubb Limited in January 2002. For nearly 20 years, Mr. Bancroft worked for PricewaterhouseCoopers LLP. Prior to joining Chubb, he served as partner-in-charge of the New York Regional Insurance Practice. Mr. Bancroft had been a partner with PricewaterhouseCoopers LLP for ten years.

John J. Lupica was appointed President, North America Major Accounts & Specialty Insurance in January 2016, Vice Chairman of Chubb Limited and Chubb Group Holdings in November 2013 and Chairman, Insurance - North America, in July 2011. Mr. Lupica had been Chief Operating Officer, Insurance - North America, since 2010 and President of ACE USA since 2006. He also previously served as Division President of U.S. Professional Risk business and U.S. Regional Operations. Mr. Lupica joined Chubb as Executive Vice President of Professional Risk in 2000. Prior to joining Chubb, he served as Senior Vice President for Munich-American Risk Partners, Inc. He also held various management positions at AIG.

Joseph F. Wayland was appointed Executive Vice President of Chubb Limited in January 2016, General Counsel and Secretary of Chubb Limited in July 2013. Mr. Wayland joined Chubb from the law firm of Simpson Thacher & Bartlett LLP, where he was a partner since 1994. From 2010 to 2012, he served in the United States Department of Justice, first as Deputy Assistant Attorney General of the Antitrust Division, and was later appointed as the Acting Assistant Attorney General in charge of that division.

Sean Ringsted was appointed Executive Vice President and Chief Digital Officer in February 2017 and Chief Risk Officer in November 2008. Mr. Ringsted previously served as Chief Actuary of Chubb Limited from November 2008 to January 2017. Mr. Ringsted's previous roles at Chubb also include Chief Actuary for Chubb Group from 2004 to 2008, Executive Vice President and Chief Risk Officer for Chubb Tempest Re from 2002 to 2004, and Senior Vice President and Chief Actuary for Chubb Tempest Re from 1998 to 2002. Prior to joining Chubb, Mr. Ringsted was a consultant at Tillinghast-Towers Perrin.

Timothy A. Boroughs was appointed Executive Vice President and Chief Investment Officer of Chubb Group in June 2000. Prior to joining Chubb, Mr. Boroughs was Director of Fixed Income at Tudor Investment Corporation from 1997 to 2000, and Managing Partner and Director of Global Leveraged Investment Activity at Fischer Francis Trees & Watts from 1976 to 1997.

Paul J. Krump was appointed Executive Vice President, Chubb Group and President North America Commercial and Personal Insurance in January 2016. Prior to Chubb Limited's January 2016 acquisition of The Chubb Corporation, Mr. Krump was Chief Operating Officer of The Chubb Corporation, responsible for the company's Commercial, Specialty, Personal and Accident & Health insurance lines; Claims; Global Field Operations; Information Technology; Human Resources; Communications; and External Affairs. Mr. Krump joined The Chubb Corporation in 1982 as a commercial underwriting trainee in the Minneapolis office. He held numerous headquarters and field positions in the United States and Europe, including President of Personal Lines and Claims and President of Commercial and Specialty Lines.

Juan Luis Ortega was appointed Executive Vice President, Chubb Group and President, Overseas General Insurance in August 2019. Mr. Ortega previously served as Senior Vice President, Chubb Group and Regional President of Latin America since 2016 and Regional President of Asia Pacific from 2013 to 2016. Mr. Ortega's previous roles at Chubb also include Senior Vice President, Accident & Health, for the Asia Pacific region from 2011 to 2013 and Senior Vice President and Regional Head of Accident & Health for the Latin America region from 2008 to 2010. Mr. Ortega joined Chubb in 1999 and advanced through a series of accident and health and credit insurance management positions in Miami, Puerto Rico and Mexico, before being named Country President of Chile in 2005.

ITEM 1A. Risk Factors

Factors that could have a material impact on our results of operations or financial condition are outlined below. Additional risks not presently known to us or that we currently deem insignificant may also impair our business or results of operations as they become known or as facts and circumstances change. Any of the risks described below could result in a material adverse effect on our results of operations or financial condition.

Insurance

Our results of operations or financial condition could be adversely affected by the occurrence of natural and man-made disasters.

We have substantial exposure to losses resulting from natural disasters, man-made catastrophes such as terrorism or cyber-attack, and other catastrophic events, including pandemics. This could impact a variety of our businesses, including our commercial and personal lines, and life and accident and health (A&H) products. Catastrophes can be caused by various events, including hurricanes, typhoons, earthquakes, hailstorms, droughts, explosions, severe winter weather, fires, war, acts of terrorism, nuclear accidents, political instability, and other natural or man-made disasters, including a global or other wide-impact pandemic or a significant cyber-attack. The incidence and severity of catastrophes are inherently unpredictable and our losses from catastrophes could be substantial. In addition, climate change and resulting changes in global temperatures, weather patterns, and sea levels may both increase the frequency and severity of natural catastrophes and the resulting losses in the future and impact our risk modeling assumptions. We cannot predict the impact that changing climate conditions, if any, may have on our results of operations or our financial condition. Additionally, we cannot predict how legal, regulatory and/or social responses to concerns around global climate change may impact our business. The occurrence of claims from catastrophic events could result in substantial volatility in our results of operations or financial condition for any fiscal quarter or year. Although we attempt to manage our exposure to such events through the use of underwriting controls, risk models, and the purchase of third-party reinsurance, catastrophic events are inherently unpredictable and the actual nature of such events when they occur could be more frequent or severe than contemplated in our pricing and risk management expectations. As a result, the occurrence of one or more catastrophic events could have an adverse effect on our results of operations and financial condition.

If actual claims exceed our loss reserves, our financial results could be adversely affected.

Our results of operations and financial condition depend upon our ability to accurately assess the potential losses associated with the risks that we insure and reinsure. We establish reserves for unpaid losses and loss expenses, which are estimates of future payments of reported and unreported claims for losses and related expenses, with respect to insured events that have occurred at or prior to the balance sheet date. The process of establishing reserves can be highly complex and is subject to considerable variability as it requires the use of informed estimates and judgments.

Actuarial staff in each of our segments regularly evaluates the levels of loss reserves. Any such evaluation could result in future changes in estimates of losses or reinsurance recoverables and would be reflected in our results of operations in the period in which the estimates are changed. Losses and loss expenses are charged to income as incurred. During the loss settlement period, which can be many years in duration for some of our lines of business, additional facts regarding individual claims and trends often will become known which may result in a change in overall reserves. In addition, application of statistical and actuarial methods may require the adjustment of overall reserves upward or downward from time to time.

Included in our loss reserves are liabilities for latent claims such as asbestos and environmental (A&E), which are principally related to claims arising from remediation costs associated with hazardous waste sites and bodily-injury claims related to exposure to asbestos products and environmental hazards. At December 31, 2019, gross A&E liabilities represented approximately 3.2 percent of our gross loss reserves. The estimation of these liabilities is subject to many complex variables including: the current legal environment; specific settlements that may be used as precedents to settle future claims; assumptions regarding trends with respect to claim severity and the frequency of higher severity claims; assumptions regarding the ability to allocate liability among defendants (including bankruptcy trusts) and other insurers; the ability of a claimant to bring a claim in a state in which it has no residency or exposure; the ability of a policyholder to claim the right to non-products coverage; whether high-level excess policies have the potential to be accessed given the policyholder's claim trends and liability situation; payments to unimpaired claimants; and the potential liability of peripheral defendants. Accordingly, the ultimate settlement of losses, arising from either latent or non-latent causes, may be significantly greater or less than the loss and loss expense reserves held at the balance sheet date. In addition, the amount and timing of the settlement of our P&C liabilities are uncertain and our actual payments could be higher than contemplated in our loss reserves owing to the impact of insurance, judicial decisions, and/or social inflation. If our loss reserves are determined to be inadequate, we may be required to increase loss reserves at the time of the determination and our net income and capital may be reduced.

The effects of emerging claim and coverage issues on our business are uncertain.
As industry practices and legislative, regulatory, judicial, social, financial, technological and other environmental conditions change, unexpected and unintended issues related to claims and coverage may emerge. These issues may adversely affect our business by either extending coverage beyond our underwriting intent or by increasing the frequency and severity of claims. In some instances, these changes may not become apparent until after we have issued insurance or reinsurance contracts that are affected by the changes. For example, recently enacted "reviver" legislation in certain states does allow civil claims relating to molestation and abuse to be asserted against policyholders that would otherwise be barred by statutes of limitations. As a result, the full extent of liability under our insurance or reinsurance contracts may not be known for many years after issuance.

The failure of any of the loss limitation methods we use could have an adverse effect on our results of operations and financial condition.
We seek to manage our loss exposure by maintaining a disciplined underwriting process throughout our insurance operations. We also look to limit our loss exposure by writing a number of our insurance and reinsurance contracts on an excess of loss basis. Excess of loss insurance and reinsurance indemnifies the insured against losses in excess of a specified amount. In addition, we limit program size for each client and purchase third-party reinsurance for our own account. In the case of our assumed proportional reinsurance treaties, we seek per occurrence limitations or loss and loss expense ratio caps to limit the impact of losses ceded by the client. In proportional reinsurance, the reinsurer shares a proportional part of the premiums and losses of the reinsured. We also seek to limit our loss exposure by geographic diversification. Geographic zone limitations involve significant underwriting judgments, including the determination of the area of the zones and the inclusion of a particular policy within a particular zone's limits.

However, there are inherent limitations in all of these tactics and no assurance can be given against the possibility of an event or series of events that could result in loss levels that could have an adverse effect on our financial condition or results of operations. It is also possible that losses could manifest themselves in ways that we do not anticipate and that our risk mitigation strategies are not designed to address. Additionally, various provisions of our policies, such as limitations or exclusions from coverage or choice of forum negotiated to limit our risks, may not be enforceable in the manner we intend. As a result, one or more natural catastrophes and/or terrorism or other events could result in claims that substantially exceed our expectations, which could have an adverse effect on our results of operations and financial condition.

We may be unable to purchase reinsurance, and/or if we successfully purchase reinsurance, we are subject to the possibility of non-payment.
We purchase protection from third parties including, but not limited to, reinsurance to protect against catastrophes and other sources of volatility, to increase the amount of protection we can provide our clients, and as part of our overall risk management strategy. Our reinsurance business also purchases retrocessional protection which allows a reinsurer to cede to another company all or part of the reinsurance originally assumed by the reinsurer. A reinsurer's or retrocessionaire's insolvency or inability or unwillingness to make timely payments under the terms of its reinsurance agreement with us could have an adverse effect on us because we remain liable to the insured. From time to time, market conditions have limited, and in some cases have prevented, insurers and reinsurers from obtaining the types and amounts of reinsurance or retrocessional reinsurance that they consider adequate for their business needs.

There is no guarantee our desired amounts of reinsurance or retrocessional reinsurance will be available in the marketplace in the future. In addition to capacity risk, the remaining capacity may not be on terms we deem appropriate or acceptable or with companies with whom we want to do business. Finally, we face some degree of counterparty risk whenever we purchase reinsurance or retrocessional reinsurance. Consequently, the insolvency of these counterparties, or the inability, or unwillingness of any of our present or future reinsurers to make timely payments to us under the terms of our reinsurance or retrocessional agreements could have an adverse effect on us. At December 31, 2019, we had $15.4 billion of reinsurance recoverables, net of reserves for uncollectible recoverables.

Certain active Chubb companies are primarily liable for A&E and other exposures they have reinsured to our inactive run-off company Century Indemnity Company (Century). At December 31, 2019, the aggregate reinsurance balances ceded by our active subsidiaries to Century were approximately $1.5 billion. Should Century's loss reserves experience adverse development in the future and should Century be placed into rehabilitation or liquidation, the reinsurance recoverables due from Century to its affiliates would be payable only after the payment in full of third-party expenses and liabilities, including administrative expenses and direct policy liabilities. Thus, the intercompany reinsurance recoverables would be at risk to the extent of the shortage of assets remaining to pay these recoverables. While we believe the intercompany reinsurance recoverables from Century are not impaired at this time, we cannot assure that adverse development with respect to Century's loss reserves, if manifested, will not result in Century's insolvency, which could result in our recognizing a loss to the extent of any uncollectible reinsurance from Century. This could have an adverse effect on our results of operations and financial condition.

Our net income may be volatile because certain products sold by our Life Insurance business expose us to reserve and fair value liability changes that are directly affected by market and other factors and assumptions.
Our pricing, establishment of reserves for future policy benefits and valuation of life insurance and annuity products, including reinsurance programs, are based upon various assumptions, including but not limited to equity market changes, interest rates, mortality rates, morbidity rates, and policyholder behavior. The process of establishing reserves for future policy benefits relies on our ability to accurately estimate insured events that have not yet occurred but that are expected to occur in future periods. Significant deviations in actual experience from assumptions used for pricing and for reserves for future policy benefits could have an adverse effect on the profitability of our products and our business.

Under reinsurance programs covering variable annuity guarantees, we assumed the risk of guaranteed minimum death benefits (GMDB) and guaranteed living benefits (GLB), principally guaranteed minimum income benefits (GMIB), associated with variable annuity contracts. We ceased writing this business in 2007. Our net income is directly impacted by changes in the reserves calculated in connection with the reinsurance of GMDB and GLB liabilities. In addition, our net income is directly impacted by the change in the fair value of the GLB liability. Reported liabilities for both GMDB and GLB reinsurance are determined using internal valuation models which require considerable judgment and are subject to significant uncertainty. Refer to the "Critical Accounting Estimates – Guaranteed living benefits (GLB) derivatives" under Item 7 and "Quantitative and Qualitative Disclosures about Market Risk – Reinsurance of GMDB and GLB guarantees" under Item 7A for additional information on the assumptions used in this program. We view our variable annuity reinsurance business as having a similar risk profile to that of catastrophe reinsurance, with the probability of long-term economic loss relatively small at the time of pricing. Adverse changes in market factors and policyholder behavior will have an impact on both Life Insurance underwriting income and consolidated net income.

Payment of obligations under surety bonds could have an adverse effect on our results of operations.
The surety business tends to be characterized by infrequent but potentially high severity losses. The majority of our surety obligations are intended to be performance-based guarantees. When losses occur, they may be mitigated, at times, by recovery rights to the customer's assets, contract payments, and collateral and bankruptcy recoveries. We have substantial commercial and construction surety exposure for current and prior customers. In that regard, we have exposures related to surety bonds issued on behalf of companies that have experienced or may experience deterioration in creditworthiness. If the financial condition of these companies were adversely affected by the economy or otherwise, we may experience an increase in filed claims and may incur high severity losses, which could have an adverse effect on our results of operations.

Our exposure to various commercial and contractual counterparties, our reliance on brokers, and certain of our policies may subject us to credit risk.
We have exposure to counterparties through a variety of commercial transactions and arrangements, including reinsurance transactions; agreements with banks, hedge funds and other investment vehicles; and derivative transactions, that expose us to credit risk in the event our counterparty fails to perform its obligations. This includes exposure to financial institutions in the form of secured and unsecured debt instruments and equity securities. Moreover, we paid deposits in connection with our pending acquisition of additional shares of Huatai Insurance Group Company Limited (Huatai Group), which exposes us to risk if the transactions are not completed.

In accordance with industry practice, we generally pay amounts owed on claims to brokers who, in turn, remit these amounts to the insured or ceding insurer. Although the law is unsettled and depends upon the facts and circumstances of the particular case, in some jurisdictions, if a broker fails to make such a payment, we might remain liable to the insured or ceding insurer for the deficiency. Conversely, in certain jurisdictions, if a broker does not remit premiums paid for these policies over to us, these premiums might be considered to have been paid and the insured or ceding insurer will no longer be liable to us for those amounts, whether or not we have actually received the premiums from the broker. Consequently, we assume a degree of credit risk associated with a broker with whom we transact business. However, due to the unsettled and fact-specific nature of the law, we are unable to quantify our exposure to this risk. To date, we have not experienced any material losses related to this credit risk.

Under the terms of certain high-deductible policies which we offer, such as workers' compensation and general liability, our customers are responsible to reimburse us for an agreed-upon dollar amount per claim. In nearly all cases we are required under such policies to pay covered claims first, and then seek reimbursement for amounts within the applicable deductible from our customers. This obligation subjects us to credit risk from these customers. While we generally seek to mitigate this risk through collateral agreements and maintain a provision for uncollectible accounts associated with this credit exposure, an increased inability of customers to reimburse us in this context could have an adverse effect on our financial condition and results of operations. In addition, a lack of credit available to our customers could impact our ability to collateralize this risk to our satisfaction, which in turn, could reduce the amount of high-deductible policies we could offer.

Since we depend on a few distribution and bancassurance partners for a large portion of our revenues, loss of business provided by any one of them could adversely affect us.
We market our insurance and reinsurance worldwide primarily through independent insurance agents, insurance and reinsurance brokers, and bancassurance relationships. Accordingly, our business is dependent on the willingness of these agents and brokers to recommend our products to their customers, who may also promote and distribute the products of our competitors. Deterioration in relationships with our agent and broker distribution network or their increased promotion and distribution of our competitors' products could adversely affect our ability to sell our products. Loss of all or a substantial portion of the business provided by one or more of these agents and brokers could have an adverse effect on our business.

Financial

Our investment performance may affect our financial results and our ability to conduct business.
Our investment assets are invested by professional investment management firms under the direction of our management team in accordance with investment guidelines approved by the Risk & Finance Committee of the Board of Directors. Although our investment guidelines stress diversification of risks and conservation of principal and liquidity, our investments are subject to market risks and risks inherent in individual securities. Interest rates are highly sensitive to many factors, including inflation, monetary and fiscal policies, and domestic and international political conditions. Given the risk that London Interbank Offered Rate (LIBOR) will no longer be available, we are monitoring industry efforts via our external investment managers to transition away from LIBOR by the end of 2021. The volatility of our losses may force us to liquidate securities, which may cause us to incur capital losses. Realized and unrealized losses in our investment portfolio would reduce our book value, and if significant, can affect our ability to conduct business.

Volatility in interest rates could impact the performance of our investment portfolio which could have an adverse effect on our investment income and operating results. Although we take measures to manage the risks of investing in a changing interest rate environment, we may not be able to effectively mitigate interest rate sensitivity. Our mitigation efforts include maintaining a high quality portfolio of primarily fixed income investments with a relatively short duration to reduce the effect of interest rate changes on book value. A significant increase in interest rates would generally have an adverse effect on our book value. Our life insurance investments typically focus on longer duration bonds to better match the obligations of this business. For the life insurance business, policyholder behavior may be influenced by changing interest rate conditions and require a re-balancing of duration to effectively manage our asset/liability position.

As stated, our fixed income portfolio is primarily invested in high quality, investment-grade securities. However, a smaller portion of the portfolio, approximately 16 percent at December 31, 2019, is invested in below investment-grade securities. These securities, which pay a higher rate of interest, also have a higher degree of credit or default risk and may also be less liquid in times of economic weakness or market disruptions. While we have put in place procedures to monitor the credit risk and liquidity of our invested assets, it is possible that, in periods of economic weakness (such as recession), we may experience credit or default losses in our portfolio, which could adversely affect our results of operations and financial condition.

As a part of our ongoing analysis of our investment portfolio, we are required to assess whether the fixed maturities we hold for which we have recorded an unrealized loss have been “other-than-temporarily impaired” under GAAP, which implies an inability to recover the full economic benefits of these securities. Refer to Note 2 to the Consolidated Financial Statements for additional information. This analysis requires a high degree of judgment and requires us to make certain assessments about the potential for recovery of the assets we hold. Declines in relevant stock and other financial markets, and other factors impacting the value of our investments, could result in impairments and could adversely affect our net income and other financial results.

We may require additional capital or financing sources in the future, which may not be available or may be available only on unfavorable terms.
Our future capital and financing requirements depend on many factors, including our ability to write new business successfully and to establish premium rates and reserves at levels sufficient to cover losses, as well as our investment performance and capital expenditure obligations, including with respect to acquisitions. We may need to raise additional funds through financings

or access funds through existing or new credit facilities or through short-term repurchase agreements. We also from time to time seek to refinance debt or credit as amounts become due or commitments expire. Any equity or debt financing or refinancing, if available at all, may be on terms that are not favorable to us. In the case of equity financings, dilution to our shareholders could result, and in any case, such securities may have rights, preferences, and privileges that are senior to those of our Common Shares. Our access to funds under existing credit facilities is dependent on the ability of the banks that are parties to the facilities to meet their funding commitments. Under Swiss law we would be prohibited from selling shares in an equity financing at a purchase price below our then-current par value. If we cannot obtain adequate capital or sources of credit on favorable terms, or at all, we could be forced to use assets otherwise available for our business operations, and our business, results of operations, and financial condition could be adversely affected.

We may be required to post additional collateral because of changes in our reinsurance liabilities to regulated insurance companies, or because of regulatory changes that affect our companies.
If our reinsurance liabilities increase, including in our property & casualty and variable annuity reinsurance businesses, we may be required to post additional collateral for insurance company clients. In addition, regulatory changes sometimes affect our obligations to post collateral. The need to post this additional collateral, if significant enough, may require us to sell investments at a loss in order to provide securities of suitable credit quality or otherwise secure adequate capital at an unattractive cost. This could adversely impact our net income and liquidity and capital resources.

U.S. and global economic and financial industry events and their consequences could harm our business, our liquidity and financial condition, and our stock price.
The consequences of adverse global or regional market and economic conditions may affect (among other aspects of our business) the demand for and claims made under our products, the ability of customers, counterparties, and others to establish or maintain their relationships with us, our ability to access and efficiently use internal and external capital resources, the availability of reinsurance protection, the risks we assume under reinsurance programs covering variable annuity guarantees, and our investment performance. The increasing impact of climate change could affect our cost of claims, loss ratios, and financial results. Volatility in the U.S. and other securities markets may adversely affect our stock price.

A decline in our financial strength ratings could affect our standing among distribution partners and customers and cause our premiums and earnings to decrease. A decline in our debt ratings could increase our borrowing costs and impact our ability to access capital markets.
Ratings are an important factor in establishing the competitive position of insurance and reinsurance companies. The objective of these rating systems is to provide an opinion of an insurer's financial strength and ability to meet ongoing obligations to its policyholders. A ratings downgrade could result in a substantial loss of business as insureds, ceding companies, and brokers move to other insurers and reinsurers with higher ratings. If one or more of our debt ratings were downgraded, we could also incur higher borrowing costs, and our ability to access the capital markets could be impacted. Additionally, we could be required to post collateral or be faced with the cancellation of policies and resulting premium in certain circumstances. We cannot give any assurance regarding whether or to what extent any of the rating agencies might downgrade our ratings in the future.

Our ability to pay dividends and/or to make payments on indebtedness may be constrained by our holding company structure.
Chubb Limited is a holding company that owns shares of its operating insurance and reinsurance subsidiaries along with several loans receivable from affiliates. Beyond this it does not itself have any significant operations or liquid assets. Repayment of loans receivable, guarantee fees and dividends and other permitted distributions from our insurance subsidiaries are its primary sources of funds to meet ongoing cash requirements, including any future debt service payments, other expenses, repurchases of its shares, and to pay dividends to our shareholders. Some of our insurance subsidiaries are subject to significant regulatory restrictions limiting their ability to declare and pay dividends. The inability of our insurance subsidiaries to pay dividends (or other intercompany amounts due, such as intercompany debt obligations) in an amount sufficient to enable us to meet our cash requirements at the holding company level could have an adverse effect on our operations and our ability to repurchase shares and pay dividends to our shareholders.

Swiss law imposes certain restrictions on our ability to repurchase our shares.
Swiss law imposes certain withholding tax and other restrictions on a Swiss company’s ability to return earnings or capital to its shareholders, including through the repurchase of its own shares. We may only repurchase shares to the extent that sufficient freely distributable reserves are available. In addition, Swiss law requires that the total par value of Chubb's acquisition of treasury shares must not be in excess of 10 percent of its total share capital. As a result, in order to maintain our share repurchase program, our shareholders must periodically authorize, through ballot item approval at our annual general meeting,

a reduction in our share capital through the cancellation of designated blocks of repurchased shares held in treasury. If our shareholders do not approve the cancellation of previously repurchased shares, we may be unable to return capital to shareholders through share repurchases in the future. Furthermore, our current repurchase program relies on a Swiss tax ruling. Any future revocation or loss of our Swiss tax ruling or the inability to conduct repurchases in accordance with the ruling could also jeopardize our ability to continue repurchasing our shares.

Our operating results and shareholders' equity may be adversely affected by currency fluctuations.
Our reporting currency is the U.S. dollar. In general, we match assets and liabilities in local currencies. Where possible, capital levels in local currencies are limited to satisfy minimum regulatory requirements and to support local insurance operations. The principal currencies creating foreign exchange risk are the British pound sterling, the euro, the Mexican peso, the Brazilian real, the Korean won, the Canadian dollar, the Japanese yen, the Thai baht, the Australian dollar, and the Hong Kong dollar. At December 31, 2019, approximately 16.6 percent of our net assets were denominated in foreign currencies. We may experience losses resulting from fluctuations in the values of non-U.S. currencies, which could adversely impact our results of operations and financial condition.

Operational

The regulatory and political regimes under which we operate, and their volatility, could have an adverse effect on our business.
We may from time to time face challenges resulting from changes in applicable law and regulations in particular jurisdictions, or changes in approach to oversight of our business from insurance or other regulators.

Our insurance and reinsurance subsidiaries conduct business globally. Our businesses in each jurisdiction are subject to varying degrees of regulation and supervision. The laws and regulations of the jurisdictions in which our insurance and reinsurance subsidiaries are domiciled require, among other things, maintenance of minimum levels of statutory capital, surplus, and liquidity; various solvency standards; and periodic examinations of subsidiaries' financial condition. In some jurisdictions, laws and regulations also restrict payments of dividends and reductions of capital. Applicable statutes, regulations, and policies may also restrict the ability of these subsidiaries to write insurance and reinsurance policies, to make certain investments, and to distribute funds. The purpose of insurance laws and regulations generally is to protect policyholders and ceding insurance companies, not our shareholders. For example, some jurisdictions have enacted various consumer protection laws that make it more burdensome for insurance companies to sell policies and interact with customers in personal lines businesses. Failure to comply with such regulations can lead to significant penalties and reputational injury.

The foreign and U.S. federal and state laws and regulations that are applicable to our operations are complex and may increase the costs of regulatory compliance or subject our business to the possibility of regulatory actions or proceedings. Laws and regulations not specifically related to the insurance industry include trade sanctions that relate to certain countries, anti-money laundering laws, and anti-corruption laws. The insurance industry is also affected by political, judicial, and legal developments that may create new and expanded regulations and theories of liability. The current economic and financial climates present additional uncertainties and risks relating to increased regulation and the potential for increased involvement of the U.S. and other governments in the financial services industry.

Regulators in countries where we have operations are working with the International Association of Insurance Supervisors (IAIS) to consider changes to insurance company supervision, including with respect to group supervision and solvency requirements. The IAIS has developed a Common Framework for the Supervision of Internationally Active Insurance Groups (ComFrame) which is focused on the effective group-wide supervision of international active insurance groups (IAIGs), such as Chubb. As part of ComFrame, the IAIS has announced plans to develop an international capital standard for insurance groups. The details of ComFrame including this global capital standard and its applicability to Chubb are uncertain at this time. In addition, Chubb businesses across the EU are subject to Solvency II, a capital and risk management regime and our Bermuda businesses are subject to an equivalent of the EU's Solvency II regime. Also applicable to Chubb businesses are the requirements of the Swiss Financial Market Supervisory Authority (FINMA) whose regulations include Swiss Solvency Tests. There are also Risk Based Capital (RBC) requirements in the U.S. which are also subject to revision in response to global developments. While it is not certain how or if these actions will impact Chubb, we do not currently expect that our capital management strategies, results of operations and financial condition will be materially affected by these regulatory changes.

Evolving privacy and data security regulations could adversely affect our business.
We are subject to numerous U.S. federal and state laws and non-U.S. regulations governing the protection of personal and confidential information of our clients and employees, including in relation to medical records, credit card data and financial

information. These laws and regulations are increasing in complexity and number, change frequently, sometimes conflict, and could expose Chubb to significant monetary damages, regulatory enforcement actions, fines and/or criminal prosecution in one or more jurisdictions.

We are subject to the New York Department of Financial Services' Cybersecurity Regulation (the NYDFS Cybersecurity Regulation) which mandates detailed cybersecurity standards for all institutions, including insurance entities, authorized by the NYDFS to operate in New York. The NYDFS Cybersecurity Regulation has increased our compliance costs and could increase the risk of noncompliance and subject us to regulatory enforcement actions and penalties, as well as reputation risk.

Additionally, in 2017, the National Association of Insurance Commissioners (NAIC) adopted an Insurance Data Security Model Law, which requires licensed insurance entities to comply with detailed information security requirements. It is not yet known whether or not, and to what extent, states legislatures or insurance regulators where we operate will enact the Insurance Data Security Model Law in whole or in part, or in a modified form. Such enactments, especially if inconsistent between states or with existing laws and regulations could raise compliance costs or increase the risk of noncompliance, with the attendant risk of being subject to regulatory enforcement actions and penalties, as well as reputational harm.

The EU General Data Protection Regulation (the "GDPR"), which became effective in 2018, is a comprehensive regulation applying across all EU member states. All our business units (regardless of whether they are located in the EU) may be subject to the GDPR when personal data is processed in relation to the offer of goods and services to individuals within the EU. Our failure to comply with GDPR and other countries' privacy or data security-related laws, rules or regulations could result in significant penalties imposed by regulators, which could have an adverse effect on our business, financial condition and results of operations.

Significant other comprehensive privacy laws have been enacted by other jurisdictions, most notably the California Consumer Privacy Act (CCPA) and Brazil's Lei Geral de Protecao de Dados, which may affect our use of data and could affect our operations and subject us to fines and actions for noncompliance. In the U.S., several other states are considering similar legislation, and there are ongoing discussions regarding a National Privacy Law. New laws similar to the GDPR and the CCPA are expected to be enacted in coming years in various countries and jurisdictions in which we operate.

Political uncertainty in the United Kingdom and the European Union may lead to volatility and/or have an adverse effect on our business, our liquidity and financial condition, and our stock price.
On June 23, 2016, the United Kingdom (U.K.) voted in a national referendum to withdraw from the European Union (EU). On March 29, 2017, the U.K. government gave notice to the EU, under Article 50(2) of the Treaty on EU, of the U.K.'s intention to withdraw from the EU. The U.K. ratified the withdrawal agreement and ceased to be a Member State of the EU (Brexit) on January 31, 2020.

We have significant operations in the U.K. and other EU member states that, operationally, have been affected by Brexit. In anticipation of Brexit, we redomiciled the headquarters of our European carriers to France effective January 1, 2019. Paris is the principal office for our Continental European operations. We have a significant investment there in both financial and human resources, as well as a large portfolio of commercial and consumer insurance business throughout France. Following Brexit, Chubb will continue to have a substantial presence in London, in addition to its offices and operations across the U.K. and the EU.

Prior to Brexit, the rules governing the EU Single Market (which is made up of the 27 other EU member states and to some extent, Iceland, Liechtenstein, and Norway (together, the European Economic Area or EEA)) permitted U.K. insurers (as well as EEA insurers operating as passported branches in the U.K., such as our French companies Chubb European Group SE and ACE Europe Life SE), to underwrite risks from the U.K. into EEA member states via a "passport" prior to Brexit.

The withdrawal agreement between the U.K. and the EU includes, following Brexit, a transition or implementation period to avoid a "cliff edge" Brexit, meaning that the U.K. remains subject to, and has the benefit of, all EU legislation, including passporting rights, until December 31, 2020. This period is intended to enable the EU and the U.K. to negotiate a trade agreement for the post-Brexit relationship between the U.K. and the EU and can, pursuant to the withdrawal agreement, be extended beyond the end of 2020 with the consent of both the U.K. and the EU. However, the U.K. government included a section in the European Union (United Kingdom Withdrawal Agreement) Act 2020 that has made it illegal for the U.K. Parliament to seek an extension of the transition or implementation period from the EU. To the extent, therefore, that it proves impossible to negotiate a trade agreement between the U.K. and the EU by December 31, 2020, there remains a risk that a "cliff edge" Brexit may nevertheless arise, including the benefits of passporting rights.

Even if a free trade agreement is concluded between the U.K. and the EU prior to the end of the transition or implementation period, such free trade agreement may not maintain the passporting rights of U.K. insurers, nor deem relevant U.K. regulations to be equivalent to those of the EU. In the event that, following the end of the transition or implementation period, U.K. insurers are unable to access the EU Single Market via a passporting arrangement, a regulatory equivalence regime or other similar arrangement, such insurers may not be able to underwrite risks into EEA member states except through local branches incorporated in the EEA. Such branches might require local authorization, regulatory and prudential supervision, and capital to be deposited.

Our worldwide operations, particularly in developing nations, expose us to global geopolitical developments that could have an adverse effect on our business, liquidity, results of operations, and financial condition.

With operations in 54 countries and territories, we provide insurance and reinsurance products and services to a diverse group of clients worldwide, including operations in various developing nations. Both current and future foreign operations could be adversely affected by unfavorable geopolitical developments including law changes; tax changes; changes in trade policies; changes to visa or immigration policies; regulatory restrictions; government leadership changes; political events and upheaval; sociopolitical instability; social, political or economic instability resulting from climate change; and nationalization of our operations without compensation. Adverse activity in any one country could negatively impact operations, increase our loss exposure under certain of our insurance products, and could, otherwise, have an adverse effect on our business, liquidity, results of operations, and financial condition depending on the magnitude of the events and our net financial exposure at that time in that country.

A failure in our operational systems or infrastructure or those of third parties, including due to security breaches or cyber-attacks, could disrupt business, damage our reputation, and cause losses.

Our operations rely on the secure processing, storage, and transmission of confidential and other information and assets, including in our computer systems and networks and those of third-party service providers. Our business depends on effective information security and systems and the integrity and timeliness of the data our information systems use to run our business. Our ability to adequately price products and services, to establish reserves, to provide effective, efficient and secure service to our customers, to value our investments and to timely and accurately report our financial results also depends significantly on the integrity and availability of the data we maintain, including that within our information systems, as well as data in and assets held through third-party service providers and systems. Although we have implemented administrative and technical controls and have taken protective actions to reduce the risk of cyber incidents and to protect our information technology and assets, and although we additionally endeavor to modify such procedures as circumstances warrant and negotiate agreements with third-party providers to protect our assets, such measures may be insufficient to prevent unauthorized access, computer viruses, malware or other malicious code or cyber-attack, business compromise attacks, catastrophic events, system failures and disruptions, employee errors or malfeasance, third party (including outsourced service providers) errors or malfeasance, loss of assets and other events that could have security consequences (each, a Security Event). As the breadth and complexity of our security infrastructure continues to grow, the potential risk of a Security Event increases. Such an event or events may jeopardize Chubb's or its clients' or counterparties' confidential and other information processed and stored within Chubb, and transmitted through its computer systems and networks, or otherwise cause interruptions, delays, or malfunctions in Chubb's, its clients', its counterparties', or third parties' operations, or result in data loss or loss of assets which could result in significant losses, reputational damage or an adverse effect on our operations and critical business functions. Chubb may be required to expend significant additional resources to modify our protective measures or to investigate and remediate vulnerabilities or other exposures and to pursue recovery of lost data or assets and we may be subject to litigation and financial losses that are either not insured against or not fully covered by insurance maintained.

Despite the contingency plans and facilities we have in place and our efforts to observe the regulatory requirements surrounding information security, our ability to conduct business may be adversely affected by a disruption of the infrastructure that supports our business in the communities in which we are located, or of outsourced services or functions. This may include a disruption involving electrical, communications, transportation, or other services used by Chubb. If a disruption occurs in one location and Chubb employees in that location are unable to occupy our offices and conduct business or communicate with or travel to other locations, our ability to service and interact with clients may suffer and we may not be able to successfully implement contingency plans that depend on communication or travel.

We use analytical models to assist our decision making in key areas such as underwriting, claims, reserving, and catastrophe risks but actual results could differ materially from the model outputs and related analyses.

We use various modeling techniques (e.g., scenarios, predictive, stochastic and/or forecasting) and data analytics to analyze and estimate exposures, loss trends and other risks associated with our assets and liabilities. We use the modeled outputs and related analyses to assist us in decision-making (e.g., underwriting, pricing, claims, reserving, reinsurance, and catastrophe risk) and to maintain competitive advantage. The modeled outputs and related analyses are subject to various assumptions, uncertainties, model errors and the inherent limitations of any statistical analysis, including the use of historical internal and industry data. In addition, the modeled outputs and related analyses may from time to time contain inaccuracies, perhaps in material respects, including as a result of inaccurate inputs or applications thereof. Climate change may make modeled outcomes less certain or produce new, non-modeled risks. Consequently, actual results may differ materially from our modeled results. If, based upon these models or other factors, we misprice our products or underestimate the frequency and/or severity of loss events, or overestimate the risks we are exposed to, new business growth and retention of our existing business may be adversely affected which could have an adverse effect on our results of operations and financial condition.

We could be adversely affected by the loss of one or more key executives or by an inability to attract and retain qualified personnel.
Our success depends on our ability to retain the services of our existing key executives and to attract and retain additional qualified personnel in the future. The loss of the services of any of our key executives or the inability to hire and retain other highly qualified personnel in the future could adversely affect our ability to conduct or grow our business. This risk may be particularly acute for us relative to some of our competitors because some of our senior executives work in countries where they are not citizens and work permit and immigration issues could adversely affect the ability to retain or hire key persons. We do not maintain key person life insurance policies with respect to our employees.

Employee error and misconduct may be difficult to detect and prevent and could adversely affect our business, results of operations, and financial condition.
Losses may result from, among other things, fraud, errors, failure to document transactions properly, failure to obtain proper internal authorization, failure to comply with underwriting or other internal guidelines, or failure to comply with regulatory requirements. It is not always possible to deter or prevent employee misconduct and the precautions that we take to prevent and detect this activity may not be effective in all cases. Resultant losses could adversely affect our business, results of operations, and financial condition.

Strategic

The continually changing landscape, including competition, technology and products, and existing and new market entrants could reduce our margins and adversely impact our business and results of operations.
Insurance and reinsurance markets are highly competitive. We compete on an international and regional basis with major U.S., Bermuda, European, and other international insurers and reinsurers and with underwriting syndicates, some of which have greater financial, technological, marketing, distribution and/or management resources than we do. In addition, capital market participants have created alternative products that are intended to compete with reinsurance products. We also compete with new companies and existing companies that move into the insurance and reinsurance markets. If competition, or technological or other changes to the insurance markets in which we operate, limits our ability to retain existing business or write new business at adequate rates or on appropriate terms, our business and results of operations could be materially and adversely affected. Increased competition could also result in fewer submissions, lower premium rates, and less favorable policy terms and conditions, which could reduce our profit margins and adversely impact our net income and shareholders' equity.

Recent technological advancements in the insurance industry and information technology industry present new and fast-evolving competitive risks as participants seek to increase transaction speeds, lower costs and create new opportunities. Advancements in technology are occurring in underwriting, claims, distribution and operations at a pace that may quicken, including as companies increase use of data analytics and technology as part of their business strategy. We will be at a competitive disadvantage if, over time, our competitors are more effective than us in their utilization of technology and evolving data analytics. If we do not anticipate or keep pace with these technological and other changes impacting the insurance industry, it could also limit our ability to compete in desired markets.

Insurance and reinsurance markets are historically cyclical, and we expect to experience periods with excess underwriting capacity and unfavorable premium rates.
The insurance and reinsurance markets have historically been cyclical, characterized by periods of intense price competition due to excessive underwriting capacity as well as periods when shortages of capacity permitted favorable premium levels. An increase in premium levels is often offset by an increasing supply of insurance and reinsurance capacity, either by capital provided by new entrants or by the commitment of additional capital by existing insurers or reinsurers, which may cause prices to decrease. Any of these factors could lead to a significant reduction in premium rates, less favorable policy terms, and fewer submissions for our underwriting services. In addition to these considerations, changes in the frequency and severity of losses

suffered by insureds and insurers may affect the cycles of the insurance and reinsurance markets significantly, as could periods of economic weakness (such as recession).

The integration of acquired companies may not be as successful as we anticipate.
Acquisitions involve numerous operational, strategic, financial, accounting, legal, tax, and other risks; potential liabilities associated with the acquired businesses; and uncertainties related to design, operation and integration of acquired businesses' internal controls over financial reporting. Difficulties in integrating an acquired company, along with its personnel, may result in the acquired company performing differently than we expected, in operational challenges or in our failure to realize anticipated expense-related efficiencies. This may also apply to companies in which we acquire majority ownership. Our existing businesses could also be negatively impacted by acquisitions. In addition, goodwill and intangible assets recorded in connection with insurance company acquisitions may be impaired if premium growth, underwriting profitability, agency retention and policy persistency, among other factors, differ from expectations.

There is also the potential that proposed acquisitions that have been publicly announced will not be consummated, even if a definitive agreement has been signed by the parties. If an agreement is terminated before closing, the result would be that our proposed acquisition would not occur, which could, among other things, expose us to damages or liability and adversely impact our stock price and future operations.

We may be subject to U.S. tax and Bermuda tax which may have an adverse effect on our results of operations and shareholder investment.
Chubb Limited and our non-U.S. subsidiaries operate in a manner so that none of these companies should be subject to U.S. tax (other than U.S. excise tax on insurance and reinsurance premium income attributable to insuring or reinsuring U.S. risks and U.S. withholding tax on some types of U.S. source investment income), because none of these companies should be treated as engaged in a trade or business within the U.S. However, because there is considerable uncertainty as to the activities that constitute being engaged in a trade or business within the U.S., we cannot be certain that the Internal Revenue Service (IRS) will not contend successfully that Chubb Limited or its non-U.S. subsidiaries are engaged in a trade or business in the U.S. If Chubb Limited or any of its non-U.S. subsidiaries were considered to be engaged in a trade or business in the U.S., such entity could be subject to U.S. corporate income and branch profits taxes on the portion of its earnings effectively connected to such U.S. business, in which case our results of operations and our shareholders' investments could be adversely affected.

The Bermuda Minister of Finance, under the Exempted Undertakings Tax Protection Act 1966 of Bermuda, as amended, has given Chubb Limited and its Bermuda insurance subsidiaries a written assurance that if any legislation is enacted in Bermuda that would impose tax computed on profits or income, or computed on any capital asset, gain, or appreciation, or any tax in the nature of estate duty or inheritance tax, then the imposition of any such tax would not be applicable to those companies or any of their respective operations, shares, debentures, or other obligations until March 31, 2035, except insofar as such tax would apply to persons ordinarily resident in Bermuda or is payable by us in respect of real property owned or leased by us in Bermuda. We cannot be certain that we will not be subject to any Bermuda tax after March 31, 2035.

We could be adversely affected by certain features of the 2017 U.S. tax reform legislation.
New tax legislation known as the Tax Cuts and Jobs Act (2017 Tax Act) was enacted in the U.S. on December 22, 2017. In addition to reducing the U.S. corporate income tax rate from 35 percent to 21 percent, it fundamentally changed many elements of the pre-2017 Tax Act U.S. tax law and introduced several new concepts to tax multinational corporations such as us. Among the most notable new rules are the Base Erosion and Anti-Abuse Tax (commonly called BEAT), which may apply as a result of payments by U.S. taxpayers to non-U.S. affiliates, and the Global Intangible Low Taxed Income (GILTI) addition to Subpart F income, which for insurance groups potentially expands U.S. taxation on the earnings of foreign subsidiaries. The 2017 Tax Act also included a one-time reduced-rate transition tax in 2017 on previously untaxed post-1986 earnings of foreign subsidiaries of U.S. corporations. The 2017 Tax Act, which was generally effective in 2018, is a complex law with many significant new provisions. During 2018 and 2019, the IRS and U.S. Treasury Department issued notices, proposed, and final regulations to assist taxpayers in understanding and implementing the new provisions. There may be changes between this guidance and final regulations to be issued in 2020. Thus, there are many uncertainties relating to its ultimate application and effects on our company.

The Organization for Economic Cooperation and Development (OECD) and the European Union (EU) are considering measures that might change long standing tax principles that could increase our taxes.
The OECD has published a framework for taxation that in many respects is different than long standing international tax principles. This framework is a proposal that we expect to develop further in 2020 as it is designed by the OECD Secretariat. This framework is an alternative to digital services taxes that several countries have enacted or are considering. These changes could redefine what income is taxed in which country and institute a global minimum tax. These proposals may be completed

by the end of 2020 which could be adopted by OECD countries in 2021 or later years. As countries unilaterally amend their tax laws to adopt certain parts of the OECD framework, this may increase the company's income taxes and cause uncertainties related to our income taxes.

The OECD has also published an action plan to address base erosion and profit shifting (BEPS) impacting its member countries and other jurisdictions. It is possible that jurisdictions in which we do business could continue to react to the BEPS initiative or their own concerns by enacting tax legislation that could adversely affect us or our shareholders.

Several multilateral organizations, including the EU and the OECD have, in recent years, expressed concern about some countries not participating in adequate tax information exchange arrangements and have threatened those that do not agree to cooperate with punitive sanctions by member countries. It is still unclear what all these sanctions might be, which countries might adopt them, and when or if they might be imposed. We cannot assure, however, that the Tax Information Exchange Agreements (TIEAs) that have been entered into by Switzerland and Bermuda will be sufficient to preclude all of the sanctions described above, which, if ultimately adopted, could adversely affect us or our shareholders.

Shareholders

There are provisions in our charter documents that may reduce the voting rights and diminish the value of our Common Shares.
Our Articles of Association generally provide that shareholders have one vote for each Common Share held by them and are entitled to vote at all meetings of shareholders. However, the voting rights exercisable by a shareholder may be limited so that certain persons or groups are not deemed to hold 10 percent or more of the voting power conferred by our Common Shares. Moreover, these provisions could have the effect of reducing the voting power of some shareholders who would not otherwise be subject to the limitation by virtue of their direct share ownership. The Board of Directors may refuse to register holders of shares as shareholders with voting rights based on certain grounds, including if the holder would, directly or indirectly, formally, constructively or beneficially own (as described in Articles 8 and 14 of our Articles of Association) or otherwise control voting rights with respect to 10 percent or more of the registered share capital recorded in the commercial register. In addition, the Board of Directors shall reject entry of holders of registered shares as shareholders with voting rights in the share register or shall decide on their deregistration when the acquirer or shareholder upon request does not expressly state that she/he has acquired or holds the shares in her/his own name and for her/his account.

Applicable laws may make it difficult to effect a change of control of our company.
Before a person can acquire control of a U.S. insurance company, prior written approval must be obtained from the insurance commissioner of the state where the domestic insurer is domiciled. Prior to granting approval of an application to acquire control of a domestic insurer, the state insurance commissioner will consider such factors as the financial strength of the applicant, the integrity and management of the applicant's Board of Directors and executive officers, the acquirer's plans for the future operations of the domestic insurer, and any anti-competitive results that may arise from the consummation of the acquisition of control. Generally, state statutes provide that control over a domestic insurer is presumed to exist if any person, directly or indirectly, owns, controls, holds with the power to vote, or holds proxies representing 10 percent or more of the voting securities of the domestic insurer. Because a person acquiring 10 percent or more of our Common Shares would indirectly control the same percentage of the stock of our U.S. insurance subsidiaries, the insurance change of control laws of various U.S. jurisdictions would likely apply to such a transaction. Laws of other jurisdictions in which one or more of our existing subsidiaries are, or a future subsidiary may be, organized or domiciled may contain similar restrictions on the acquisition of control of Chubb.

While our Articles of Association limit the voting power of any shareholder to less than 10 percent, we cannot assure that the applicable regulatory body would agree that a shareholder who owned 10 percent or more of our Common Shares did not, because of the limitation on the voting power of such shares, control the applicable insurance subsidiary.

These laws may discourage potential acquisition proposals and may delay, deter, or prevent a change of control of Chubb, including transactions that some or all of our shareholders might consider to be desirable.

Shareholder voting requirements under Swiss law may limit our flexibility with respect to certain aspects of capital management.
Swiss law allows our shareholders to authorize share capital which can be issued by the Board of Directors without shareholder approval but this authorization must be renewed by the shareholders every two years. Swiss law also does not provide as much flexibility in the various terms that can attach to different classes of stock as permitted in other jurisdictions. Swiss law also reserves for approval by shareholders many corporate actions over which the Board of Directors had authority prior to our re-

domestication to Switzerland. For example, dividends must be approved by shareholders. While we do not believe that Swiss law requirements relating to our capital management will have an adverse effect on Chubb, we cannot assure that situations will not arise where such flexibility would have provided substantial benefits to our shareholders.

Chubb Limited is a Swiss company; it may be difficult to enforce judgments against it or its directors and executive officers.
Chubb Limited is incorporated pursuant to the laws of Switzerland. In addition, certain of our directors and officers reside outside the U.S. and all or a substantial portion of our assets and the assets of such persons are located in jurisdictions outside the U.S. As such, it may be difficult or impossible to effect service of process within the U.S. upon those persons or to recover against us or them on judgments of U.S. courts, including judgments predicated upon civil liability provisions of the U.S. federal securities laws.

Chubb has been advised by its Swiss counsel that there is doubt as to whether the courts in Switzerland would enforce:
- judgments of U.S. courts based upon the civil liability provisions of the U.S. federal securities laws obtained in actions against it or its directors and officers, who reside outside the U.S.; or
- original actions brought in Switzerland against these persons or Chubb predicated solely upon U.S. federal securities laws.

Chubb has also been advised by its Swiss counsel that there is no treaty in effect between the U.S. and Switzerland providing for this enforcement and there are grounds upon which Swiss courts may not enforce judgments of U.S. courts. Some remedies available under the laws of U.S. jurisdictions, including some remedies available under the U.S. federal securities laws, would not be allowed in Swiss courts as contrary to that nation's public policy.

Shareholders may be subject to Swiss withholding taxes on the payment of dividends.
Our dividends are generally subject to a Swiss withholding tax at a rate of 35 percent; however, payment of a dividend in the form of a par value reduction or qualifying capital contribution reserve reduction is not subject to Swiss withholding tax. We have previously obtained shareholder approval for dividends to be paid in such form. We currently intend to recommend to shareholders that they annually approve the payment of dividends in such form but we cannot assure that our shareholders will continue to approve a reduction in such form each year or that we will be able to meet the other legal requirements for a reduction in par value, or that Swiss withholding tax rules will not be changed in the future. We estimate we would be able to pay dividends in such form, and thus exempt from Swiss withholding tax until 2028–2033. This range may vary depending upon changes in annual dividends, special dividends, certain share repurchases, fluctuations in U.S. dollar/Swiss franc exchange rate, changes in par value or qualifying capital contribution reserves or changes or new interpretations to Swiss corporate or tax law or regulations.

Under certain circumstances, U.S. shareholders may be subject to adverse U.S. federal income tax consequences.
Under certain circumstances, a U.S. person who owns or is deemed to own 10 percent or more of the voting power or value of a foreign corporation that is a “controlled foreign corporation” (CFC) (a foreign corporation in which 10 percent U.S. shareholders own or are deemed to own more than 50 percent of the voting power or value of the stock of a foreign corporation or more than 25 percent of certain foreign insurance corporations) for any period during a taxable year must include in gross income for U.S. federal income tax purposes a pro rata share of the CFC's "subpart F income". We believe that because of the dispersion of our share ownership it is unlikely that any U.S. person who acquires shares of Chubb Limited directly or indirectly through one or more foreign entities should be required to include any subpart F income in income under the CFC rules of U.S. tax law.

Separately, any U.S. persons who hold shares may be subject to U.S. federal income taxation at ordinary income tax rates on their proportionate share of our Related Person Insurance Income (RPII). If the RPII of any of our non-U.S. insurance subsidiaries (each a "Non-U.S. Insurance Subsidiary") were to equal or exceed 20 percent of that company's gross insurance income in any taxable year and direct or indirect insureds (and persons related to those insureds) own directly or indirectly through foreign entities 20 percent or more of the voting power or value of Chubb Limited, then a U.S. person who owns any shares of Chubb Limited (directly or indirectly through foreign entities) on the last day of the taxable year would be required to include in his or her income for U.S. federal income tax purposes such person's pro rata share of such company's RPII for the taxable year. In addition, any RPII that is includible in the income of a U.S. tax-exempt organization may be treated as unrelated business taxable income. We believe that the gross RPII of each Non-U.S. Insurance Subsidiary did not in prior years of operation and is not expected in the foreseeable future to equal or exceed 20 percent of each such company's gross insurance income. Likewise, we do not expect the direct or indirect insureds of each Non-U.S. Insurance Subsidiary (and persons related to such insureds) to directly or indirectly own 20 percent or more of either the voting power or value of our shares. However, we cannot be certain that this will be the case because some of the factors which determine the extent of RPII may be beyond our control. If these thresholds are met or exceeded, any U.S. person’s investment in Chubb Limited could be adversely affected.

A U.S. tax-exempt organization may recognize unrelated business taxable income if a portion of our insurance income is allocated to the organization. This generally would be the case if either (i) Chubb Limited is considered a CFC and the tax-exempt shareholder is a 10 percent U.S. shareholder or (ii) there is RPII, certain exceptions do not apply, and the tax-exempt organization, directly (or indirectly through foreign entities) owns any shares of Chubb Limited. Although we do not believe that any U.S. tax-exempt organization should be allocated such insurance income, we cannot be certain that this will be the case. Potential U.S. tax-exempt investors are advised to consult their tax advisors.

U.S. persons who hold shares will be subject to adverse tax consequences if we are considered to be a Passive Foreign Investment Company (PFIC) for U.S. federal income tax purposes.

If Chubb Limited is considered a PFIC for U.S. federal income tax purposes, a U.S. person who holds Chubb Limited shares will be subject to adverse U.S. federal income tax consequences in which case their investment could be adversely affected. In addition, if Chubb Limited were considered a PFIC, upon the death of any U.S. individual owning shares, such individual's heirs or estate would not be entitled to a "step-up" in the basis of the shares which might otherwise be available under U.S. federal income tax laws. We believe that we are not, have not been, and currently do not expect to become, a PFIC for U.S. federal income tax purposes. We cannot assure, however, that we will not be deemed a PFIC by the IRS. Recently enacted U.S. federal tax law and recently proposed regulations issued by the IRS and U.S. Treasury Department contain new rules that may affect the application of the PFIC provisions to an insurance company. Final regulations or pronouncements interpreting or clarifying these rules may be forthcoming. We cannot predict what impact, if any, such guidance would have on an investor that is subject to U.S. federal income taxation. Any shareholder electing to apply the newly proposed PFIC regulations could be adversely affected by an investment in us. Shareholders are advised to consult their tax advisors.

ITEM 1B. Unresolved Staff Comments

There are currently no unresolved SEC staff comments regarding our periodic or current reports.

ITEM 2. Properties

We maintain office facilities around the world including in North America, Europe (including our principal executive offices in Switzerland), Bermuda, Latin America, Asia Pacific, and the Far East. Most of our office facilities are leased, although we own major facilities in Hamilton, Bermuda, and in the U.S., including in Philadelphia, Pennsylvania; Wilmington, Delaware; Whitehouse Station, New Jersey; and Simsbury, Connecticut. Management considers its office facilities suitable and adequate for the current level of operations.

ITEM 3. Legal Proceedings

The information required with respect to Item 3 is included in Note 10 h) to the Consolidated Financial Statements, which is hereby incorporated herein by reference.

ITEM 4. Mine Safety Disclosures

Item not applicable.

ITEM 5. Market for Registrant's Common Equity, Related Stockholder Matters and Issuer Purchases of Equity Securities

Our Common Shares have been listed on the New York Stock Exchange since March 25, 1993, with a current par value of CHF 24.15 per share. The trading symbol for our Common Shares is "CB."

We have paid dividends each quarter since we became a public company in 1993. In 2019 and 2018, our annual dividends were paid by way of a distribution from capital contribution reserves (Additional paid-in capital) through the transfer of dividends from Additional paid-in capital to Retained earnings (free reserves) as approved by our shareholders.

Chubb Limited is a holding company whose principal sources of income are dividends and investment income from its operating subsidiaries. The ability of the operating subsidiaries to pay dividends to us and our ability to pay dividends to our shareholders are each subject to legal and regulatory restrictions. The recommendation and payment of future dividends will be based on the determination of the Board of Directors (Board) and will be dependent upon shareholder approval, profits and financial requirements of Chubb and other factors, including legal restrictions on the payment of dividends and other such factors as the Board deems relevant. Refer to Part I, Item 1A and Part II, Item 7 for additional information.

The number of record holders of Common Shares as of February 13, 2020 was 6,902. This is not the actual number of beneficial owners of Chubb's Common Shares since most of our shareholders hold their shares through a stockbroker, bank or other nominee rather than directly in their own names.

Refer to Part III, Item 12 for information relating to compensation plans under which equity securities are authorized for issuance.

Issuer's Repurchases of Equity Securities for the Three Months Ended December 31, 2019

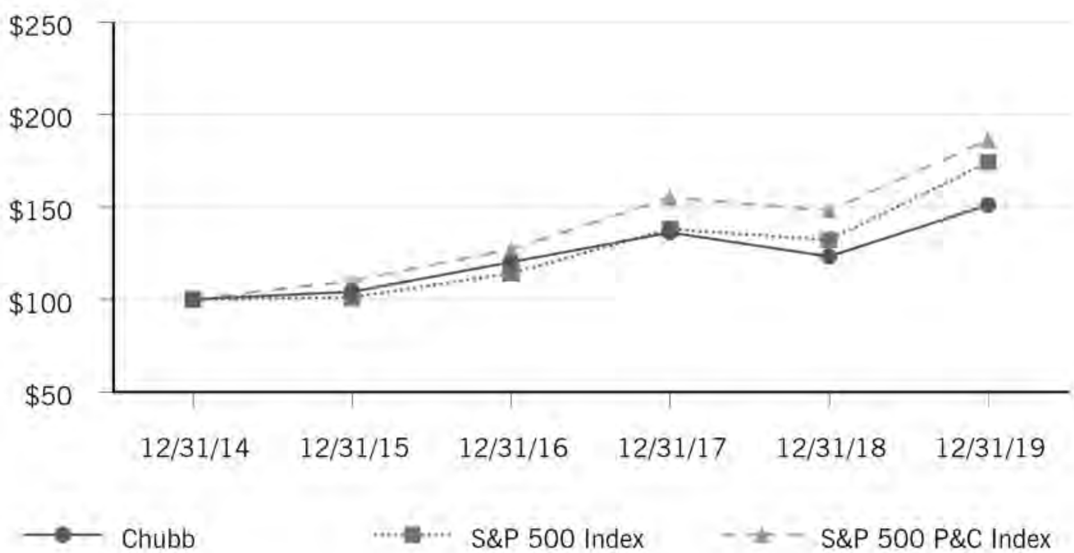
Period	Total Number of Shares Purchased (1)	Average Price Paid per Share	Total Number of Shares Purchased as Part of Publicly Announced Plans (2)	Approximate Dollar Value of Shares that May Yet be Purchased Under Publicly Announced Plans (3)
October 1 through October 31	703,138	$ 153.65	700,900	$ 151 million
November 1 through November 30	677,640	$ 151.41	670,000	$ 1.55 billion
December 1 through December 31	654,352	$ 153.84	653,500	$ 1.45 billion
Total	2,035,130	$ 152.97	2,024,400	

(1) This represents open market share repurchases and the surrender to Chubb of Common Shares to satisfy tax withholding obligations in connection with the vesting of restricted stock issued to employees and the exercise of options by employees.

(2) The aggregate value of shares purchased in the three months ended December 31, 2019 as part of the publicly announced plans was $310 million.

(3) Refer to Note 11 to the Consolidated Financial Statements for more information on the Chubb Limited securities repurchase authorizations. In November 2019, the Board authorized the repurchase of up to $1.5 billion of Chubb's Common Shares from November 21, 2019 through December 31, 2020. The $1.5 billion December 2018 Board authorization remained effective through December 31, 2019, and was used in advance of the $1.5 billion share repurchase authorized in November 2019. For the period January 1, 2020 through February 26, 2020, we repurchased 947,400 Common Shares for a total of $151 million in a series of open market transactions. As of February 26, 2020, $1.30 billion in share repurchase authorization remained through December 31, 2020.

Performance Graph
Set forth below is a line graph comparing the dollar change in the cumulative total shareholder return on Chubb's Common Shares from December 31, 2014, through December 31, 2019, as compared to the cumulative total return of the Standard & Poor's 500 Stock Index and the cumulative total return of the Standard & Poor's Property-Casualty Insurance Index. The cumulative total shareholder return is a concept used to compare the performance of a company's stock over time and is the ratio of the stock price change plus the cumulative amount of dividends over the specified time period (assuming dividend reinvestment), to the stock price at the beginning of the time period. The chart depicts the value on December 31, 2015, 2016, 2017, 2018, and 2019, of a $100 investment made on December 31, 2014, with all dividends reinvested.



	12/31/2014	12/31/2015	12/31/2016	12/31/2017	12/31/2018	12/31/2019
Chubb Limited	$100	$104	$120	$136	$123	$151
S&P 500 Index	$100	$101	$114	$138	$132	$174
S&P 500 P&C Index	$100	$110	$127	$155	$148	$186

ITEM 6. Selected Financial Data

On January 14, 2016, we completed the acquisition of The Chubb Corporation (Chubb Corp). The results of operations of Chubb Corp are included in our results from the acquisition date forward (i.e., after January 14, 2016 and only in the 2016, 2017, 2018 and 2019 columns) within the table below.

(in millions of U.S. dollars, except per share data and ratios)	2019	2018	2017	2016	2015
Operations data:					
Net premiums earned – excluding Life Insurance segment	**$ 28,947**	$ 27,846	$ 26,933	$ 26,694	$ 15,266
Net premiums earned – Life Insurance segment	**2,343**	2,218	2,101	2,055	1,947
Total net premiums earned	**31,290**	30,064	29,034	28,749	17,213
Net investment income	**3,426**	3,305	3,125	2,865	2,194
Losses and loss expenses	**18,730**	18,067	18,454	16,052	9,484
Policy benefits	**740**	590	676	588	543
Policy acquisition costs and administrative expenses	**9,183**	8,798	8,614	8,985	5,211
Net income	**4,454**	3,962	3,861	4,135	2,834
Weighted-average shares outstanding – diluted	**459**	467	471	466	329
Diluted earnings per share	**$ 9.71**	$ 8.49	$ 8.19	$ 8.87	$ 8.62
Balance sheet data (at end of period):					
Total investments	**$ 109,234**	$ 100,968	$ 102,444	$ 99,094	$ 66,251
Total assets	**176,943**	167,771	167,022	159,786	102,306
Net unpaid losses and loss expenses	**48,509**	48,271	49,165	47,832	26,562
Net future policy benefits	**5,617**	5,304	5,137	4,854	4,620
Long-term debt	**13,559**	12,087	11,556	12,610	9,389
Trust preferred securities	**308**	308	308	308	307
Total liabilities	**121,612**	117,459	115,850	111,511	73,171
Shareholders' equity	**55,331**	50,312	51,172	48,275	29,135
Book value per share	**$ 122.42**	$ 109.56	$ 110.32	$ 103.60	$ 89.77
Selected data:					
Loss and loss expense ratio (1)	**62.1%**	62.1%	65.8%	57.7%	58.1%
Underwriting and administrative expense ratio (2)	**28.5%**	28.5%	28.9%	30.6%	29.2%
Combined ratio (3)	**90.6%**	90.6%	94.7%	88.3%	87.3%
Cash dividends per share	**$ 2.98**	$ 2.90	$ 2.82	$ 2.74	$ 2.66

(1) The Loss and loss expense ratio is calculated by dividing losses and loss expenses, excluding the Life Insurance segment, by Net premiums earned – excluding Life Insurance segment. Losses and loss expenses for the Life Insurance segment were $757 million, $766 million, $739 million, $663 million, and $601 million for the years ended December 31, 2019, 2018, 2017, 2016, and 2015, respectively.

(2) The Underwriting and administrative expense ratio is calculated by dividing the policy acquisition costs and administrative expenses, excluding the Life Insurance segment, by Net premiums earned – excluding Life Insurance segment. Policy acquisition costs and administrative expenses for the Life Insurance segment were $943 million, $867 million, $833 million, $816 million, and $767 million for the years ended December 31, 2019, 2018, 2017, 2016, and 2015, respectively.

(3) The combined ratio is the sum of Loss and loss expense ratio and the Underwriting and administrative expense ratio.

ITEM 7. Management's Discussion and Analysis of Financial Condition and Results of Operations

The following is a discussion of our results of operations, financial condition, and liquidity and capital resources as of and for the year ended December 31, 2019. This discussion should be read in conjunction with the consolidated financial statements and related Notes, under Item 8 of this Form 10-K.

All comparisons in this discussion are to the corresponding prior year unless otherwise indicated. All dollar amounts are rounded. However, percent changes and ratios are calculated using whole dollars. Accordingly, calculations using rounded dollars may differ.

Forward-Looking Statements

The Private Securities Litigation Reform Act of 1995 provides a “safe harbor” for forward-looking statements. Any written or oral statements made by us or on our behalf may include forward-looking statements that reflect our current views with respect to future events and financial performance. These forward-looking statements are subject to certain risks, uncertainties, and other factors that could, should potential events occur, cause actual results to differ materially from such statements. These risks, uncertainties, and other factors, which are described in more detail under Part I, Item 1A, under Risk Factors, starting on page 19 and elsewhere herein and in other documents we file with the U.S. Securities and Exchange Commission (SEC), include but are not limited to:

- losses arising out of natural or man-made catastrophes such as hurricanes, typhoons, earthquakes, floods, climate change (including effects on weather patterns; greenhouse gases; sea, land and air temperatures; sea levels; and rain and snow), nuclear accidents, or terrorism which could be affected by:
  - the number of insureds and ceding companies affected;
  - the amount and timing of losses actually incurred and reported by insureds;
  - the impact of these losses on our reinsurers and the amount and timing of reinsurance recoverable actually received;
  - the cost of building materials and labor to reconstruct properties or to perform environmental remediation following a catastrophic event; and
  - complex coverage and regulatory issues such as whether losses occurred from storm surge or flooding and related lawsuits;
- actions that rating agencies may take from time to time, such as financial strength or credit ratings downgrades or placing these ratings on credit watch negative or the equivalent;
- the ability to collect reinsurance recoverable, credit developments of reinsurers, and any delays with respect thereto and changes in the cost, quality, or availability of reinsurance;
- actual loss experience from insured or reinsured events and the timing of claim payments;
- the uncertainties of the loss-reserving and claims-settlement processes, including the difficulties associated with assessing environmental damage and asbestos-related latent injuries, the impact of aggregate-policy-coverage limits, the impact of bankruptcy protection sought by various asbestos producers and other related businesses, and the timing of loss payments;
- changes to our assessment as to whether it is more likely than not that we will be required to sell, or have the intent to sell, available for sale fixed maturity investments before their anticipated recovery;
- infection rates and severity of pandemics and their effects on our business operations and claims activity;
- developments in global financial markets, including changes in interest rates, stock markets, and other financial markets, increased government involvement or intervention in the financial services industry, the cost and availability of financing, and foreign currency exchange rate fluctuations (which we refer to in this report as foreign exchange and foreign currency exchange), which could affect our statement of operations, investment portfolio, financial condition, and financing plans;
- general economic and business conditions resulting from volatility in the stock and credit markets and the depth and duration of potential recession;
- global political conditions, the occurrence of any terrorist attacks, including any nuclear, radiological, biological, or chemical events, or the outbreak and effects of war, and possible business disruption or economic contraction that may result from such events;
- the potential impact of the United Kingdom’s vote to withdraw from the European Union, including political, regulatory, social, and economic uncertainty and market and exchange rate volatility;
- judicial decisions and rulings, new theories of liability, legal tactics, and settlement terms;

- the effects of public company bankruptcies and/or accounting restatements, as well as disclosures by and investigations of public companies relating to possible accounting irregularities, and other corporate governance issues, including the effects of such events on:
  - the capital markets;
  - the markets for directors and officers (D&O) and errors and omissions (E&O) insurance; and
  - claims and litigation arising out of such disclosures or practices by other companies;
- uncertainties relating to governmental, legislative and regulatory policies, developments, actions, investigations, and treaties, which, among other things, could subject us to insurance regulation or taxation in additional jurisdictions or affect our current operations;
- the effects of data privacy or cyber laws or regulation on our current or future business;
- the actual amount of new and renewal business, market acceptance of our products, and risks associated with the introduction of new products and services and entering new markets, including regulatory constraints on exit strategies;
- the competitive environment in which we operate, including trends in pricing or in policy terms and conditions, which may differ from our projections and changes in market conditions that could render our business strategies ineffective or obsolete;
- acquisitions made by us performing differently than expected, our failure to realize anticipated expense-related efficiencies or growth from acquisitions, the impact of acquisitions on our pre-existing organization, or announced acquisitions not closing;
- risks and uncertainties relating to our planned purchases of additional interests in Huatai Insurance Group Company Limited (Huatai Group), including our ability to receive Chinese insurance regulatory approval and complete the purchases;
- risks associated with being a Swiss corporation, including reduced flexibility with respect to certain aspects of capital management and the potential for additional regulatory burdens;
- the potential impact from government-mandated insurance coverage for acts of terrorism;
- the availability of borrowings and letters of credit under our credit facilities;
- the adequacy of collateral supporting funded high deductible programs;
- changes in the distribution or placement of risks due to increased consolidation of insurance and reinsurance brokers;
- material differences between actual and expected assessments for guaranty funds and mandatory pooling arrangements;
- the effects of investigations into market practices in the property and casualty (P&C) industry;
- changing rates of inflation and other economic conditions, for example, recession;
- the amount of dividends received from subsidiaries;
- loss of the services of any of our executive officers without suitable replacements being recruited in a reasonable time frame;
- the ability of our technology resources, including information systems and security, to perform as anticipated such as with respect to preventing material information technology failures or third-party infiltrations or hacking resulting in consequences adverse to Chubb or its customers or partners;
- the ability of our company to increase use of data analytics and technology as part of our business strategy and adapt to new technologies; and
- management's response to these factors and actual events (including, but not limited to, those described above).

The words "believe," "anticipate," "estimate," "project," "should," "plan," "expect," "intend," "hope," "feel," "foresee," "will likely result," or "will continue," and variations thereof and similar expressions, identify forward-looking statements. You are cautioned not to place undue reliance on these forward-looking statements, which speak only as of their dates. We undertake no obligation to publicly update or review any forward-looking statements, whether as a result of new information, future events or otherwise.

Overview

We operate through six business segments: North America Commercial P&C Insurance, North America Personal P&C Insurance, North America Agricultural Insurance, Overseas General Insurance, Global Reinsurance, and Life Insurance. For more information on our segments refer to "Segment Information" under Item 1.

We have grown our business through increased premium volume, expansion of product offerings and geographic reach, and acquisitions of other companies.

Our product and geographic diversification differentiates us from the vast majority of our competitors and has been a source of stability during periods of industry volatility. Our long-term business strategy focuses on sustained growth in book value achieved through a combination of underwriting and investment income. By doing so, we provide value to our clients and shareholders through use of our substantial capital base in the insurance and reinsurance markets.

We are organized along a profit center structure by line of business and territory that does not necessarily correspond to corporate legal entities. Profit centers can access various legal entities subject to licensing and other regulatory rules. Profit centers are expected to generate underwriting income and appropriate risk-adjusted returns. Our corporate structure has facilitated the development of management talent by giving each profit center's senior management team the necessary autonomy within underwriting authorities to make operating decisions and create products and coverages needed by its target customer base. We are focused on delivering underwriting profit by only writing policies which we believe adequately compensate us for the risk we accept.

Our insurance and reinsurance operations generate gross revenues from two principal sources: premiums and investment income. Cash flow is generated from premiums collected and investment income received less paid losses and loss expenses, policy acquisition costs, and administrative expenses. Invested assets are substantially held in liquid, investment grade fixed income securities of relatively short duration. Claims payments in any short-term period are highly unpredictable due to the random nature of loss events and the timing of claims awards or settlements. The value of investments held to pay future claims is subject to market forces such as the level of interest rates, stock market volatility, and credit events such as corporate defaults. The actual cost of claims is also volatile based on loss trends, inflation rates, court awards, and catastrophes. We believe that our cash balance, our highly liquid investments, credit facilities, and reinsurance protection provide sufficient liquidity to meet unforeseen claim demands that might occur in the year ahead. Refer to "Liquidity" and "Capital Resources" for additional information.

Financial Highlights for the Year Ended December 31, 2019

- Net income was $4,454 million compared with $3,962 million in 2018.
- Net premiums written were $32.3 billion, up 5.5 percent, or 7.0 percent on a constant-dollar basis.
- The North America Agricultural Insurance segment combined ratio was 95.1 percent compared with 75.5 percent in 2018, or a decline of $296 million in underwriting income, principally due to the downward revision in the 2019 crop year margin estimate reflecting preventive planting claims due to the impact of wet weather conditions and crop yield shortfalls resulting from poor growing conditions.
- P&C combined ratio was 90.6 percent in both 2019 and 2018. P&C current accident year combined ratio excluding catastrophe losses was 89.2 percent compared with 88.0 percent in 2018, reflecting the increase in the North America Agricultural Insurance segment combined ratio noted above.
- Total pre-tax and after-tax catastrophe losses, including reinstatement premiums, were $1,187 million (4.1 percentage points of the combined ratio) and $966 million, respectively, compared with $1,626 million (5.9 percentage points of the combined ratio) and $1,354 million, respectively, in 2018. Refer to the Consolidated Operating Results section for additional information on our catastrophe losses.
- Total pre-tax and after-tax favorable prior period development were $792 million (2.7 percentage points of the combined ratio) and $624 million, respectively, compared with $896 million (3.3 percentage points of the combined ratio) and $706 million, respectively, in 2018. Pre-tax favorable prior period development in 2018 included favorable reinsurance settlements of $205 million related to legacy run-off exposures.

- Operating cash flow was $6,342 million compared with $5,480 million in 2018, an increase of $862 million primarily due to higher underwriting cash flow. Refer to the Liquidity section for additional information on our cash flows.
- Net investment income was $3,426 million compared with $3,305 million in 2018.
- Share repurchases totaled $1,531 million, or approximately 10.4 million shares for the year, at an average purchase price of $146.61 per share.

Outlook

We completed 2019 with net premiums written growth of 5.5 percent, or 7.0 percent on a constant-dollar basis. Premium growth accelerated globally with the current pricing and underwriting environment, which has continued to improve in more lines of business and more territories. We plan to use our global presence to capitalize on these market conditions in the year ahead, while continuing to focus on our long-term strategic growth initiatives.

Our net investment income increased 3.6 percent in 2019, reflecting strong operating cash flow and a higher invested asset base. There are several factors that impact the variability in investment income, including interest rates and private equity distributions. Nevertheless, we expect our quarterly pre-tax net investment income in 2020 to be in the range of $852 million to $862 million, including the expected amortization of the fair value adjustment on acquired invested assets, at current exchange rates, of approximately $33 million per quarter. Excluding the amortization of the fair value adjustment on acquired invested assets, we expect quarterly pre-tax adjusted net investment income in 2020 to be in the range of $885 million to $895 million. The estimate of amortization expense of the fair value adjustment on acquired invested assets could vary materially based on current market conditions, bond calls, overall duration of the acquired investment portfolio, and foreign exchange.

During 2019, Chubb increased its ownership interest in Huatai Group and is committed to acquire additional interests with the goal of majority and beyond ownership. To that end, Chubb entered into agreements to purchase an additional 22.4 percent ownership in Huatai Group through separate purchases of 15.3 percent and 7.1 percent, respectively, each contingent upon regulatory approvals and other important conditions. At the completion of the 7.1 percent purchase, which is expected by the end of 2021, Chubb is expected to apply consolidation accounting.

Critical Accounting Estimates

Our consolidated financial statements include amounts that, either by their nature or due to requirements of generally accepted accounting principles in the U.S. (GAAP), are determined using best estimates and assumptions. While we believe that the amounts included in our consolidated financial statements reflect our best judgment, actual amounts could ultimately materially differ from those currently presented. We believe the items that require the most subjective and complex estimates are:

- unpaid loss and loss expense reserves, including long-tail asbestos and environmental (A&E) reserves and non-A&E casualty exposures;
- future policy benefits reserves;
- the valuation of value of business acquired (VOBA) and amortization of deferred policy acquisition costs and VOBA;
- the assessment of risk transfer for certain structured insurance and reinsurance contracts;
- reinsurance recoverable, including a provision for uncollectible reinsurance;
- the valuation of our investment portfolio and assessment of other-than-temporary impairments (OTTI);
- the valuation of deferred income taxes;
- the valuation of derivative instruments related to guaranteed living benefits (GLB); and
- the assessment of goodwill for impairment.

We believe our accounting policies for these items are of critical importance to our consolidated financial statements. The following discussion provides more information regarding the estimates and assumptions required to arrive at these amounts and should be read in conjunction with the sections entitled: Prior Period Development, Asbestos and Environmental (A&E), Reinsurance Recoverable on Ceded Reinsurance, Investments, Net Realized and Unrealized Gains (Losses), and Other Income and Expense Items.

Unpaid losses and loss expenses

As an insurance and reinsurance company, we are required by applicable laws and regulations and GAAP to establish loss and loss expense reserves for the estimated unpaid portion of the ultimate liability for losses and loss expenses under the terms of our policies and agreements with our insured and reinsured customers. At December 31, 2019, our gross unpaid loss and loss expense reserves were $62.7 billion and our net unpaid loss and loss expense reserves were $48.5 billion. With the exception of certain structured settlements, for which the timing and amount of future claim payments are reliably determinable, and certain reserves for unsettled claims, our loss reserves are not discounted for the time value of money. In connection with such structured settlements and certain reserves for unsettled claims, we carried net discounted reserves of $74 million and $73 million at December 31, 2019 and 2018, respectively.

The following table presents a roll-forward of our unpaid losses and loss expenses:

	December 31, 2019			December 31, 2018		
(in millions of U.S. dollars)	**Gross Losses**	**Reinsurance Recoverable[1]**	**Net Losses**	Gross Losses	Reinsurance Recoverable[1]	Net Losses
Balance, beginning of year	**$ 62,960**	**$ 14,689**	**$ 48,271**	$ 63,179	$ 14,014	$ 49,165
Losses and loss expenses incurred	**23,657**	**4,927**	**18,730**	23,645	5,578	18,067
Losses and loss expenses paid	**(23,911)**	**(5,438)**	**(18,473)**	(23,079)	(4,739)	(18,340)
Other (including foreign exchange translation)	**(16)**	**3**	**(19)**	(785)	(164)	(621)
Balance, end of year	**$ 62,690**	**$ 14,181**	**$ 48,509**	$ 62,960	$ 14,689	$ 48,271

(1) Net of provision for uncollectible reinsurance.

The estimate of the liabilities includes provisions for claims that have been reported but are unpaid at the balance sheet date (case reserves) and for obligations on claims that have been incurred but not reported (IBNR) at the balance sheet date. IBNR may also include provisions to account for the possibility that reported claims may settle for amounts that differ from the established case reserves. Loss reserves also include an estimate of expenses associated with processing and settling unpaid claims (loss expenses). Our loss reserves comprise approximately 80 percent casualty-related business, which typically encompasses long-tail risks, and other risks where a high degree of judgment is required.

The process of establishing loss reserves for property and casualty claims can be complex and is subject to considerable uncertainty as it requires the use of informed estimates and judgments based on circumstances underlying the insured losses known at the date of accrual. For example, the reserves established for high excess casualty claims, asbestos and environmental claims, claims from major catastrophic events, or for our various product lines each require different assumptions and judgments to be made. Necessary judgments are based on numerous factors and may be revised as additional experience and other data become available and are reviewed, as new or improved methods are developed, or as laws change. Hence, ultimate loss payments may differ from the estimate of the ultimate liabilities made at the balance sheet date. Changes to our previous estimates of prior period loss reserves impact the reported calendar year underwriting results adversely if our estimates increase or favorably if our estimates decrease. The potential for variation in loss reserve estimates is impacted by numerous factors. Reserve estimates for casualty lines are particularly uncertain given the lengthy reporting patterns and corresponding need for IBNR.

Case reserves for those claims reported by insureds or ceding companies to us prior to the balance sheet date and where we have sufficient information are determined by our claims personnel as appropriate based on the circumstances of the claim(s), standard claim handling practices, and professional judgment. Furthermore, for our Brandywine run-off operations and our assumed reinsurance operation, Global Reinsurance, we may adjust the case reserves as notified by the ceding company if the judgment of our respective claims department differs from that of the cedant.

With respect to IBNR reserves and those claims that have been incurred but not reported prior to the balance sheet date, there is, by definition, limited actual information to form the case reserve estimate and reliance is placed upon historical loss experience and actuarial methods to estimate the ultimate loss obligations and the corresponding amount of IBNR. IBNR reserve estimates are generally calculated by first projecting the ultimate amount of losses for a product line and subtracting paid losses and case reserves for reported claims. The judgments involved in projecting the ultimate losses may pertain to the use and interpretation of various standard actuarial reserving methods that place reliance on the extrapolation of actual historical data, loss development patterns, industry data, and other benchmarks as appropriate. The estimate of the required IBNR reserve also requires judgment by actuaries and management to reflect the impact of more contemporary and subjective factors, both qualitative and quantitative. Among some of these factors that might be considered are changes in business mix or volume, changes in ceded reinsurance structures, changes in claims handling practices, reported and projected loss trends, inflation, the legal environment, and the terms and conditions of the contracts sold to our insured parties.

Determining management's best estimate
Our recorded reserves represent management's best estimate of the provision for unpaid claims as of the balance sheet date, and establishing them involves a process that includes collaboration with various relevant parties in the company. For information on our reserving process, refer to Note 7 to the Consolidated Financial Statements.

Sensitivity to underlying assumptions
While we believe that our reserve for unpaid losses and loss expenses at December 31, 2019, is adequate, new information or emerging trends that differ from our assumptions may lead to future development of losses and loss expenses that is significantly greater or less than the recorded reserve, which could have a material effect on future operating results. As noted previously, our best estimate of required loss reserves for most portfolios is judgmentally selected for each origin year after considering the results from a number of reserving methods and is not a purely mechanical process. Therefore, it is difficult to convey, in a simple and quantitative manner, the impact that a change to a single assumption will have on our best estimate. In the examples below, we attempt to give an indication of the potential impact by isolating a single change for a specific reserving method that would be pertinent in establishing the best estimate for the product line described. We consider each of the following sensitivity analyses to represent a reasonably likely deviation in the underlying assumption.

North America Commercial P&C Insurance
Given the long reporting and paid development patterns for workers' compensation business, the development factors used to project actual current losses to ultimate losses for our current exposure require considerable judgment that could be material to consolidated loss and loss expense reserves. Specifically, adjusting ground up ultimate losses by a one percent change in the tail factor (i.e., 1.04 changed to either 1.05 or 1.03) would cause a change of approximately $823 million, either positive or negative, for the projected net loss and loss expense reserves. This represents an impact of about 8.8 percent relative to recorded net loss and loss expense reserves of approximately $9.4 billion.

The reserve portfolio for our Chubb Bermuda operations contains exposure to predominantly high excess liability coverage on an occurrence-first-reported basis (typically with attachment points in excess of $325 million and gross limits of up to $150 million) and D&O and other professional liability coverage on a claims-made basis (typically with attachment points in excess of $125 million and gross limits of up to $75 million). Due to the layer of exposure covered, the expected frequency for this book is very low. As a result of the low frequency/high severity nature of the book, a small difference in the actual vs. expected claim frequency, either positive or negative, could result in a material change to the projected ultimate loss if such change in claim frequency was related to a policy where close to maximum limits were deployed.

North America Personal P&C Insurance
Due to the relatively short-tailed nature of many of the coverages involved (e.g., homeowners property damage), most of the incurred losses in Personal Lines are resolved within a few years of occurrence. As shown in our loss triangle disclosure, the vast majority (over 95 percent) of Personal Lines net ultimate losses and allocated loss adjustment expenses are typically paid within five years of the accident date and over 80 percent within two years. Even though there are significant reserves associated with some liability exposures such as personal excess/umbrella liability, our incurred loss triangle also shows a roughly consistent pattern of only relatively minor movements in incurred estimates over time by accident year especially after twenty-four months of maturity. While the liability exposures are subject to additional uncertainties from more protracted resolution times, the main drivers of volatility in the Personal Lines business are relatively short-term in nature and relate to things like natural catastrophes, non-catastrophe weather events, man-made risks, and individual large loss volatility from other fortuitous claim events.

North America Agricultural Insurance
Approximately 66 percent of the reserves for this segment are from the crop related lines, which all have short payout patterns, with the majority of the liabilities expected to be resolved in the ensuing twelve months. Claim reserves for our Multiple Peril Crop Insurance (MPCI) product are set on a case-by-case basis and our aggregate exposure is subject to state level risk sharing formulae as well as third-party reinsurance. The majority of the development risk arises out of the accuracy of case reserve estimates and the time needed for final crop conditions to be assessed. We do not view our Agriculture reserves as substantially influenced by the general assumptions and risks underlying more typical P&C reserve estimates.

Overseas General Insurance
Certain long-tail lines, such as casualty and professional lines, are particularly susceptible to changes in loss trend and claim inflation. Heightened perceptions of tort and settlement awards around the world can increase the demand for these products as well as contributing to the uncertainty in the reserving estimates. Our reserving methods rely on loss development patterns estimated from historical data and while we attempt to adjust such factors for known changes in the current tort environment, it is possible that such factors may not entirely reflect all recent trends in tort environments. For example, when applying the reported loss development method, the lengthening of our selected loss development patterns by six months would increase reserve estimates on long-tail casualty and professional lines for accident years 2017 and prior by approximately $525 million. This represents an impact of 14.4 percent relative to recorded net loss and loss expense reserves of approximately $3.6 billion.

Global Reinsurance
Typically, there is inherent uncertainty around the length of paid and reported development patterns, especially for certain casualty lines such as excess workers' compensation or general liability, which may take decades to fully develop. This uncertainty is accentuated by the need to supplement client development patterns with industry development patterns due to the sometimes low statistical credibility of the data. The underlying source and selection of the final development patterns can thus have a significant impact on the selected ultimate net losses and loss expenses. For example, a 20 percent shortening or lengthening of the development patterns used for U.S. long-tail lines would cause the loss reserve estimate derived by the reported Bornhuetter-Ferguson method for these lines to change by approximately $285 million. This represents an impact of 43 percent relative to recorded net loss and loss expense reserves of approximately $670 million.

Assumed reinsurance
At December 31, 2019, net unpaid losses and loss expenses for the Global Reinsurance segment aggregated to $1.4 billion, consisting of $769 million of case reserves and $664 million of IBNR. In comparison, at December 31, 2018, net unpaid losses and loss expenses for the Global Reinsurance segment aggregated to $1.6 billion, consisting of $807 million of case reserves and $807 million of IBNR.

For our catastrophe business, we principally estimate unpaid losses and loss expenses on an event basis by considering various sources of information, including specific loss estimates reported by our cedants, ceding company and overall industry loss estimates reported by our brokers, and our internal data regarding reinsured exposures related to the geographical location of the event. Our internal data analysis enables us to establish catastrophe reserves for known events with more certainty at an earlier date than would be the case if we solely relied on reports from third parties to determine carried reserves.

For our casualty reinsurance business, we generally rely on ceding companies to report claims and then use that data as a key input to estimate unpaid losses and loss expenses. Due to the reliance on claims information reported by ceding companies, as well as other factors, the estimation of unpaid losses and loss expenses for assumed reinsurance includes certain risks and uncertainties that are unique relative to our direct insurance business. These include, but are not necessarily limited to, the following:

- The reported claims information could be inaccurate;
- Typically, a lag exists between the reporting of a loss event to a ceding company and its reporting to us as a reinsurance claim. The use of a broker to transmit financial information from a ceding company to us increases the reporting lag. Because most of our reinsurance business is produced by brokers, ceding companies generally first submit claim and other financial information to brokers, who then report the proportionate share of such information to each reinsurer of a particular treaty. The reporting lag generally results in a longer period of time between the date a claim is incurred and the date a claim is reported compared with direct insurance operations. Therefore, the risk of delayed recognition of loss reserve development is higher for assumed reinsurance than for direct insurance lines; and
- The historical claims data for a particular reinsurance contract can be limited relative to our insurance business in that there may be less historical information available. Further, for certain coverages or products, such as excess of loss contracts, there may be relatively few expected claims in a particular year so the actual number of claims may be susceptible to significant variability. In such cases, the actuary often relies on industry data from several recognized sources.

We mitigate the above risks in several ways. In addition to routine analytical reviews of ceding company reports to ensure reported claims information appears reasonable, we perform regular underwriting and claims audits of certain ceding companies to ensure reported claims information is accurate, complete, and timely. As appropriate, audit findings are used to adjust claims in the reserving process. We also use our knowledge of the historical development of losses from individual ceding companies to adjust the level of adequacy we believe exists in the reported ceded losses.

On occasion, there will be differences between our carried loss reserves and unearned premium reserves and the amount of loss reserves and unearned premium reserves reported by the ceding companies. This is due to the fact that we receive consistent and timely information from ceding companies only with respect to case reserves. For IBNR, we use historical experience and other statistical information, depending on the type of business, to estimate the ultimate loss. We estimate our unearned premium reserve by applying estimated earning patterns to net premiums written for each treaty based upon that treaty's coverage basis (i.e., risks attaching or losses occurring). At December 31, 2019, the case reserves reported to us by our ceding companies were $758 million, compared with the $769 million we recorded. Our policy is to post additional case reserves in addition to the amounts reported by our cedants when our evaluation of the ultimate value of a reported claim is different than the evaluation of that claim by our cedant.

Within Corporate, we also have exposure to certain liability reinsurance lines that have been in run-off since 1994. Unpaid losses and loss expenses relating to this run-off reinsurance business resides within the Brandywine Division reported within Corporate. Most of the remaining unpaid loss and loss expense reserves for the run-off reinsurance business relate to A&E claims. Refer to the “Asbestos and Environmental (A&E)” section for additional information.

Asbestos and environmental reserves
Included in our liabilities for losses and loss expenses are amounts for A&E (A&E liabilities). The A&E liabilities principally relate to claims arising from bodily-injury claims related to asbestos products and remediation costs associated with hazardous waste sites. The estimation of our A&E liabilities is particularly sensitive to future changes in the legal, social, and economic environment. We have not assumed any such future changes in setting the value of our A&E liabilities, which include provisions for both reported and IBNR claims.

There are many complex variables that we consider when estimating the reserves for our inventory of asbestos accounts and these variables may directly impact the predicted outcome. We believe the most significant variables relating to our A&E liabilities include the current legal environment; specific settlements that may be used as precedents to settle future claims; assumptions regarding trends with respect to claim severity and the frequency of higher severity claims; assumptions regarding the ability to allocate liability among defendants (including bankruptcy trusts) and other insurers; the ability of a claimant to bring a claim in a state in which they have no residency or exposure; the ability of a policyholder to claim the right to unaggregated coverage; whether high-level excess policies have the potential to be accessed given the policyholder's claim trends and liability situation; payments to unimpaired claimants; and, the potential liability of peripheral defendants. Based on the policies, the facts, the law, and a careful analysis of the impact that these factors will likely have on any given account, we estimate the potential liability for indemnity, policyholder defense costs, and coverage litigation expense.

The results in asbestos cases announced by other carriers or defendants may well have little or no relevance to us because coverage exposures are highly dependent upon the specific facts of individual coverage and resolution status of disputes among carriers, policyholders, and claimants.

For additional information refer to the “Asbestos and Environmental (A&E)” section and to Note 7 to the Consolidated Financial Statements.

Future policy benefits reserves
We issue contracts in our Overseas General Insurance and Life Insurance segments that are classified as long-duration. These contracts generally include accident and supplemental health products, term and whole life products, endowment products, and annuities. In accordance with GAAP, we establish reserves for contracts determined to be long-duration based on approved actuarial methods that include assumptions related to expenses, mortality, morbidity, persistency, and investment yields with a factor for adverse deviation. These assumptions are “locked in” at the inception of the contract, meaning we use our original assumptions throughout the life of the policy and do not subsequently modify them unless we deem the reserves to be inadequate. The future policy benefits reserves balance is regularly evaluated for a premium deficiency. If experience is less favorable than assumptions, additional liabilities may be required, resulting in a charge to policyholder benefits and claims.

Valuation of value of business acquired (VOBA), and amortization of deferred policy acquisition costs and VOBA
As part of the acquisition of businesses that sell long-duration contracts, such as life products, we established an intangible asset related to VOBA, which represented the fair value of the future profits of the in-force contracts. The valuation of VOBA at the time of acquisition is derived from similar assumptions to those used to establish the associated future policy benefits

reserves. The most significant input in this calculation is the discount rate used to arrive at the present value of the net cash flows. We amortize deferred policy acquisition costs associated with long-duration contracts and VOBA (collectively policy acquisition costs) over the estimated life of the contracts, generally in proportion to premium revenue recognized based upon the same assumptions used in estimating the liability for future policy benefits. For non-traditional long-duration contracts, we amortize policy acquisition costs over the expected life of the contracts in proportion to estimates of expected gross profits. The estimated life is established at the inception of the contracts or upon acquisition and is based on current persistency assumptions. Policy acquisition costs, which consist of commissions, premium taxes, and certain underwriting costs related directly to the successful acquisition of a new or renewal insurance contract, are reviewed to determine if they are recoverable from future income, including investment income. Unrecoverable costs are expensed in the period identified.

Risk transfer

In the ordinary course of business, we both purchase (or cede) and sell (or assume) reinsurance protection. We discontinued the purchase of all finite risk reinsurance contracts, as a matter of policy, in 2002. For both ceded and assumed reinsurance, risk transfer requirements must be met in order to use reinsurance accounting, principally resulting in the recognition of cash flows under the contract as premiums and losses. If risk transfer requirements are not met, a contract is to be accounted for as a deposit, typically resulting in the recognition of cash flows under the contract through a deposit asset or liability and not as revenue or expense. To meet risk transfer requirements, a reinsurance contract must include both insurance risk, consisting of underwriting and timing risk, and a reasonable possibility of a significant loss for the assuming entity. We also apply similar risk transfer requirements to determine whether certain commercial insurance contracts should be accounted for as insurance or a deposit. Contracts that include fixed premium (i.e., premium not subject to adjustment based on loss experience under the contract) for fixed coverage generally transfer risk and do not require judgment.

Reinsurance and insurance contracts that include both significant risk sharing provisions, such as adjustments to premiums or loss coverage based on loss experience, and relatively low policy limits, as evidenced by a high proportion of maximum premium assessments to loss limits, can require considerable judgment to determine whether or not risk transfer requirements are met. For such contracts, often referred to as finite or structured products, we require that risk transfer be specifically assessed for each contract by developing expected cash flow analyses at contract inception. To support risk transfer, the cash flow analyses must demonstrate that a significant loss is reasonably possible, such as a scenario in which the ratio of the net present value of losses divided by the net present value of premiums equals or exceeds 110 percent. For purposes of cash flow analyses, we generally use a risk-free rate of return consistent with the expected average duration of loss payments. In addition, to support insurance risk, we must prove the reinsurer's risk of loss varies with that of the reinsured and/or support various scenarios under which the assuming entity can recognize a significant loss.

To ensure risk transfer requirements are routinely assessed, qualitative and quantitative risk transfer analyses and memoranda supporting risk transfer are developed by underwriters for all structured products. We have established protocols for structured products that include criteria triggering an accounting review of the contract prior to quoting. If any criterion is triggered, a contract must be reviewed by a committee established by each of our segments with reporting oversight, including peer review, from our global Structured Transaction Review Committee.

With respect to ceded reinsurance, we entered into a few multi-year excess of loss retrospectively-rated contracts, principally in 2002. These contracts primarily provided severity protection for specific product divisions. Because traditional one-year reinsurance coverage had become relatively costly, these contracts were generally entered into in order to secure a more cost-effective reinsurance program. All of these contracts transferred risk and were accounted for as reinsurance. In addition, we maintain a few aggregate excess of loss reinsurance contracts that were principally entered into prior to 2003, such as the National Indemnity Company (NICO) contracts referred to in the section entitled, "Asbestos and Environmental (A&E)". We have not purchased any other retroactive ceded reinsurance contracts since 1999.

With respect to assumed reinsurance and insurance contracts, products giving rise to judgments regarding risk transfer were primarily sold by our financial solutions business. Although we have significantly curtailed writing financial solutions business, several contracts remain in-force and principally include multi-year retrospectively-rated contracts and loss portfolio transfers. Because transfer of insurance risk is generally a primary client motivation for purchasing these products, relatively few insurance and reinsurance contracts have historically been written for which we concluded that risk transfer criteria had not been met. For certain insurance contracts that have been reported as deposits, the insured desired to self-insure a risk but was required, legally or otherwise, to purchase insurance so that claimants would be protected by a licensed insurance company in the event of non-payment from the insured.

Reinsurance recoverable

Reinsurance recoverable includes balances due to us from reinsurance companies for paid and unpaid losses and loss expenses and is presented net of a provision for uncollectible reinsurance. The provision for uncollectible reinsurance is determined based upon a review of the financial condition of the reinsurers and other factors. Ceded reinsurance contracts do not relieve our primary obligation to our policyholders. Consequently, an exposure exists with respect to reinsurance recoverable to the extent that any reinsurer is unable or unwilling to meet its obligations or disputes the liabilities assumed under the reinsurance contracts. We determine the reinsurance recoverable on unpaid losses and loss expenses using actuarial estimates as well as a determination of our ability to cede unpaid losses and loss expenses under existing reinsurance contracts.

The recognition of a reinsurance recoverable asset requires two key judgments. The first judgment involves our estimation based on the amount of gross reserves and the percentage of that amount which may be ceded to reinsurers. Ceded IBNR, which is a major component of the reinsurance recoverable on unpaid losses and loss expenses, is generally developed as part of our loss reserving process and, consequently, its estimation is subject to similar risks and uncertainties as the estimation of gross IBNR (refer to "Critical Accounting Estimates – Unpaid losses and loss expenses"). The second judgment involves our estimate of the amount of the reinsurance recoverable balance that we may ultimately be unable to recover from reinsurers due to insolvency, contractual dispute, or for other reasons. Estimated uncollectible amounts are reflected in a provision that reduces the reinsurance recoverable asset and, in turn, shareholders' equity. Changes in the provision for uncollectible reinsurance are reflected in net income.

Although the obligation of individual reinsurers to pay their reinsurance obligations is based on specific contract provisions, the collectability of such amounts requires estimation by management. The majority of the recoverable balance will not be due for collection until sometime in the future, and the duration of our recoverables may be longer than the duration of our direct exposures. Over this period of time, economic conditions and operational performance of a particular reinsurer may impact their ability to meet these obligations and while they may continue to acknowledge their contractual obligation to do so, they may not have the financial resources or willingness to fully meet their obligation to us.

To estimate the provision for uncollectible reinsurance, the reinsurance recoverable must first be determined for each reinsurer. This determination is based on a process rather than an estimate, although an element of judgment must be applied. As part of the process, ceded IBNR is allocated to reinsurance contracts because ceded IBNR is not generally calculated on a contract by contract basis. The allocations are generally based on premiums ceded under reinsurance contracts, adjusted for actual loss experience and historical relationships between gross and ceded losses. If actual premium and loss experience vary materially from historical experience, the allocation of reinsurance recoverable by reinsurer will be reviewed and may change. While such change is unlikely to result in a large percentage change in the provision for uncollectible reinsurance, it could, nevertheless, have a material effect on our net income in the period recorded.

Generally, we use a default analysis to estimate uncollectible reinsurance. The primary components of the default analysis are reinsurance recoverable balances by reinsurer, net of collateral, and default factors used to estimate the probability that the reinsurer may be unable to meet its future obligations in full. The definition of collateral for this purpose requires some judgment and is generally limited to assets held in a Chubb-only beneficiary trust, letters of credit, and liabilities held by us with the same legal entity for which we believe there is a right of offset. We do not currently include multi-beneficiary trusts. However, we have several reinsurers that have established multi-beneficiary trusts for which certain of our companies are beneficiaries. The determination of the default factor is principally based on the financial strength rating of the reinsurer and a corresponding default factor applicable to the financial strength rating. Default factors require considerable judgment and are determined using the current financial strength rating, or rating equivalent, of each reinsurer as well as other key considerations and assumptions. Significant considerations and assumptions include, but are not necessarily limited to, the following:

- For reinsurers that maintain a financial strength rating from a major rating agency, and for which recoverable balances are considered representative of the larger population (i.e., default probabilities are consistent with similarly rated reinsurers and payment durations conform to averages), the judgment exercised by management to determine the provision for uncollectible reinsurance of each reinsurer is typically limited because the financial rating is based on a published source and the default factor we apply is based on a historical default factor of a major rating agency applicable to the particular rating class. Default factors applied for financial ratings of AAA, AA, A, BBB, BB, B, and CCC, are 0.8 percent, 1.2 percent, 1.7 percent, 4.9 percent, 19.6 percent, 34.0 percent, and 62.2 percent, respectively. Because our model is predicated on the historical default factors of a major rating agency, we do not generally consider alternative factors. However, when a recoverable is expected to be paid in a brief period of time by a highly-rated reinsurer, such as certain property catastrophe claims, a default factor may not be applied;

- For balances recoverable from reinsurers that are both unrated by a major rating agency and for which management is unable to determine a credible rating equivalent based on a parent or affiliated company, we may determine a rating equivalent based on our analysis of the reinsurer that considers an assessment of the creditworthiness of the particular entity, industry benchmarks, or other factors as considered appropriate. We then apply the applicable default factor for that rating class. For balances recoverable from unrated reinsurers for which our ceded reserve is below a certain threshold, we generally apply a default factor of 34.0 percent;
- For balances recoverable from reinsurers that are either insolvent or under regulatory supervision, we establish a default factor and resulting provision for uncollectible reinsurance based on specific facts and circumstances surrounding each company. Upon initial notification of an insolvency, we generally recognize expense for a substantial portion of all balances outstanding, net of collateral, through a combination of write-offs of recoverable balances and increases to the provision for uncollectible reinsurance. When regulatory action is taken on a reinsurer, we generally recognize a default factor by estimating an expected recovery on all balances outstanding, net of collateral. When sufficient credible information becomes available, we adjust the provision for uncollectible reinsurance by establishing a default factor pursuant to information received; and
- For captives and other recoverables, management determines the provision for uncollectible reinsurance based on the specific facts and circumstances.

The following table summarizes reinsurance recoverables and the provision for uncollectible reinsurance for each type of recoverable balance at December 31, 2019:

(in millions of U.S. dollars)	Gross Reinsurance Recoverables on Losses and Loss Expenses	Recoverables (net of Usable Collateral)	Provision for Uncollectible Reinsurance [1]
Type			
Reinsurers with credit ratings	$ 11,460	$ 10,043	$ 156
Reinsurers not rated	321	190	66
Reinsurers under supervision and insolvent reinsurers	81	79	37
Captives	2,647	378	20
Other - structured settlements and pools	988	978	37
Total	$ 15,497	$ 11,668	$ 316

(1) The provision for uncollectible reinsurance is based on a default analysis applied to gross reinsurance recoverables, net of approximately $3.8 billion of collateral at December 31, 2019.

At December 31, 2019, the use of different assumptions within our approach could have a material effect on the provision for uncollectible reinsurance. To the extent the creditworthiness of our reinsurers were to deteriorate due to an adverse event affecting the reinsurance industry, such as a large number of major catastrophes, actual uncollectible amounts could be significantly greater than our provision for uncollectible reinsurance. Such an event could have a material adverse effect on our financial condition, results of operations, and our liquidity. Given the various considerations used to estimate our uncollectible provision, we cannot precisely quantify the effect a specific industry event may have on the provision for uncollectible reinsurance. However, based on the composition (particularly the average credit quality) of the reinsurance recoverable balance at December 31, 2019, we estimate that a ratings downgrade of one notch for all rated reinsurers (e.g., from A to A- or A- to BBB+) could increase our provision for uncollectible reinsurance by approximately $66 million or approximately 0.4 percent of the gross reinsurance recoverable balance, assuming no other changes relevant to the calculation. While a ratings downgrade would result in an increase in our provision for uncollectible reinsurance and a charge to earnings in that period, a downgrade in and of itself does not imply that we will be unable to collect all of the ceded reinsurance recoverable from the reinsurers in question. Refer to Note 5 to the Consolidated Financial Statements for additional information.

Fair value measurements

Accounting guidance defines fair value as the price to sell an asset or transfer a liability (an exit price) in an orderly transaction between market participants and establishes a three-level valuation hierarchy based on the reliability of the inputs. The fair value hierarchy gives the highest priority to quoted prices in active markets (Level 1 inputs) and the lowest priority to unobservable data (Level 3 inputs). Level 2 includes inputs, other than quoted prices within Level 1, that are observable for assets or liabilities either directly or indirectly. Refer to Note 4 and Note 13 to the Consolidated Financial Statements for information on our fair value measurements.

Other-than-temporary impairments (OTTI)

Each quarter, we review securities in an unrealized loss position (impaired securities), including fixed maturities and securities lending collateral to identify impaired securities to be specifically evaluated for a potential OTTI. Because our investment portfolio is the largest component of consolidated assets, OTTI could be material to our financial condition and results of operations. Refer to Note 3 c) to the Consolidated Financial Statements for a description of the OTTI process.

Deferred income taxes

At December 31, 2019, our net deferred tax liability was $804 million. Our deferred tax assets and liabilities primarily result from temporary differences between the amounts recorded in our consolidated financial statements and the tax basis of our assets and liabilities. We determine deferred tax assets and liabilities separately for each tax-paying component (an individual entity or group of entities that is consolidated for tax purposes) in each tax jurisdiction. The realization of deferred tax assets depends upon the existence of sufficient taxable income within the carryback or carryforward periods under the tax law in the applicable tax jurisdiction. There may be changes in tax laws in a number of countries where we transact business that impact our deferred tax assets and liabilities.

At each balance sheet date, management assesses the need to establish a valuation allowance that reduces deferred tax assets when it is more likely than not that all, or some portion, of the deferred tax assets will not be realized. The determination of the need for a valuation allowance is based on all available information including projections of future taxable income, principally derived from business plans and where appropriate available tax planning strategies. Projections of future taxable income incorporate assumptions of future business and operations that are apt to differ from actual experience. If our assumptions and estimates that resulted in our forecast of future taxable income prove to be incorrect, an additional valuation allowance could become necessary, which could have a material adverse effect on our financial condition, results of operations, and liquidity. At December 31, 2019, the valuation allowance of $114 million reflects management's assessment that it is more likely than not that a portion of the deferred tax assets will not be realized due to the inability of certain foreign subsidiaries to generate sufficient taxable income.

Assumed reinsurance programs involving minimum benefit guarantees under variable annuity contracts

Chubb reinsures various death and living benefit guarantees associated with variable annuities issued primarily in the United States. We ceased writing this business in 2007. Guarantees which are payable on death are referred to as guaranteed minimum death benefits (GMDB). Guarantees on living benefits (GLB) consist mainly of guaranteed minimum income benefits (GMIB). For further description of this product and related accounting treatment, refer to Note 1 j) to the Consolidated Financial Statements.

Guaranteed living benefits (GLB) derivatives

Our GLB reinsurance is classified as a derivative for accounting purposes and therefore carried at fair value. We believe that the most meaningful presentation of these GLB derivatives is as follows:

- Estimates of the average modeled value of future cash outflows is recorded as incurred losses (i.e., benefit reserves). Cash inflows or revenue are reported as net premiums earned and changes in the benefit reserves are reflected as Policy benefits expense in the Consolidated statements of operations, which is included in underwriting income.
- The incremental difference between the fair value of GLB reinsurance contracts and benefit reserves is reflected in Accounts payable, accrued expenses, and other liabilities in the Consolidated balance sheets and related changes in fair value are reflected in Net realized gains (losses) in the Consolidated statements of operations.

Determination of GLB fair value

The fair value of GLB reinsurance is estimated using an internal valuation model, which includes current market information and estimates of policyholder behavior from the perspective of a theoretical market participant that would assume these liabilities. All of our treaties contain claim limits, which are factored into the valuation model. The fair value depends on a number of factors, including interest rates, equity markets, credit risk, current account value, market volatility, expected annuitization rates and other policyholder behavior, and changes in policyholder mortality. The model and related assumptions are regularly re-evaluated by management and enhanced, as appropriate, based upon additional experience obtained related to policyholder behavior and availability of more timely market information. Due to the inherent uncertainties of the assumptions used in the valuation models to determine the fair value of these derivative products, actual experience may differ materially from the estimates reflected in our Consolidated Financial Statements.

We intend to hold these derivative contracts to maturity (i.e., the expiration of the underlying liabilities through lapse, annuitization, death, or expiration of the reinsurance contract). To partially offset the risk of changes in the fair value of GLB reinsurance contracts, we invest in derivative hedge instruments. At maturity, the cumulative realized gains and losses (excluding cumulative hedge gains or losses) from fair value changes of GLB reinsurance contracts will net to zero because, over time, the insurance liability will be increased or decreased to equal our obligation.

Determination of GLB and GMDB benefit reserves

Management established benefit reserves based on a long-term benefit ratio (or loss ratio) calculated using assumptions reflecting management's best estimate of the future short-term and long-term performance of the variable annuity line of business. Despite the long-term nature of the risk, the benefit ratio calculation is impacted by short-term market movements that may be judged by management to be transient. Management regularly examines both qualitative and quantitative analysis, including a review of the differential between the benefit ratio used at the most recent valuation date and the benefit ratio calculated on subsequent dates. Management regularly evaluates its estimates and uses judgment to determine the extent to which assumptions underlying the benefit ratio calculation should be adjusted. For the year ended December 31, 2019, management determined that no change to the benefit ratio was warranted.

For further information on the estimates and assumptions used in determining the fair value of GLB reinsurance, refer to Note 4 to the Consolidated Financial Statements. For a sensitivity discussion of the effect of changes in interest rates, equity indices, and other assumptions on the fair value of GLBs, and the estimated resulting impact on our net income, refer to Item 7A.

Risk Management

We employ a strategy to manage the financial market and policyholder behavior risks embedded in the reinsurance of variable annuity (VA) guarantees. Risk management begins with underwriting a prospective client and guarantee design, with particular focus on protecting our position from policyholder options that, because of anti-selective behavior, could adversely impact our obligation.

A second layer of risk management is the structure of the reinsurance contracts. All VA guarantee reinsurance contracts include some form of annual or aggregate claim limit(s) primarily designed to reduce our exposure to severe equity market and/or interest rate declines (which would cause an increase in expected claims).

A third layer of risk management is the hedging strategy which looks to mitigate both long-term economic loss over time as well as dampen income statement volatility. We owned financial market instruments as part of the hedging strategy with a fair value asset (liability) of $(13) million and $23 million at December 31, 2019 and 2018, respectively. The instruments are substantially collateralized on a daily basis.

We also limit the aggregate amount of variable annuity reinsurance guarantee risk we are willing to assume. The last substantive transactions were quoted in late 2007. The aggregate number of policyholders is currently decreasing through policyholder withdrawals, annuitizations, and deaths at a rate of 5 percent to 15 percent per annum.

Note that GLB claims cannot occur for any reinsured policy until it has reached the end of its "waiting period". As shown in the table below, 92 percent of the policies we reinsure reached the end of their "waiting periods" in 2019 and prior.

Year of first payment eligibility	Percent of living benefit account values
2019 and prior	92%
2020	1%
2021	2%
2022	—%
2023	1%
2024 and after	4%
Total	100%

The following table presents the historical cash flows under these policies for the periods indicated. The amounts represent accrued past premium received and claims paid, split by benefit type.

(in millions of U.S. dollars)			2019			2018			2017
	GMDB	GLB	Total	GMDB	GLB	Total	GMDB	GLB	Total
Premium received	$ 40	$ 91	$ 131	$ 47	$ 96	$ 143	$ 49	$ 110	$ 159
Less paid claims	34	91	125	32	49	81	31	54	85
Net cash received	$ 6	$ —	$ 6	$ 15	$ 47	$ 62	$ 18	$ 56	$ 74

Collateral

Chubb holds collateral on behalf of most of its clients in the form of qualified assets in trust or letters of credit, typically in an amount sufficient for the client to obtain statutory reserve credit for the reinsurance. The timing of the calculation and amount of the collateral varies by client according to the particulars of the reinsurance treaty and the statutory reserve guidelines of the client's domicile.

Goodwill impairment assessment

Goodwill, which represents the excess of acquisition cost over the estimated fair value of net assets acquired, was $15.3 billion at both December 31, 2019 and 2018. Goodwill is assigned to applicable reporting units of acquired entities at the time of acquisition. Our reporting units are the same as our reportable segments. For goodwill balances by reporting units, refer to Note 6 to the Consolidated Financial Statements.

Goodwill is not amortized but is subject to a periodic evaluation for impairment at least annually, or earlier if there are any indications of possible impairment. Impairment is tested at the reporting unit level. The impairment evaluation first uses a qualitative assessment to determine whether it is more likely than not (i.e., more than a 50 percent probability) that the fair value of a reporting unit is greater than its carrying amount. If a reporting unit fails this qualitative assessment, a single quantitative analysis is used to measure and record the amount of the impairment.

In assessing the fair value of a reporting unit, we make assumptions and estimates about the profitability attributable to our reporting units, including:

- short-term and long-term growth rates; and
- estimated cost of equity and changes in long-term risk-free interest rates.

If our assumptions and estimates made in assessing the fair value of acquired entities change, we could be required to write-down the carrying value of goodwill which could be material to our results of operations in the period the charge is taken. Based on our impairment testing for 2019, we determined no impairment was required and none of our reporting units was at risk for impairment.

Consolidated Operating Results – Years Ended December 31, 2019, 2018, and 2017

(in millions of U.S. dollars, except for percentages)	2019	2018	2017	% Change 2019 vs. 2018	% Change 2018 vs. 2017
Net premiums written	**$ 32,275**	$ 30,579	$ 29,244	5.5 %	4.6 %
Net premiums earned	**31,290**	30,064	29,034	4.1 %	3.5 %
Net investment income	**3,426**	3,305	3,125	3.6 %	5.8 %
Net realized gains (losses)	**(530)**	(652)	84	(18.8)%	NM
Total revenues	**34,186**	32,717	32,243	4.5 %	1.5 %
Losses and loss expenses	**18,730**	18,067	18,454	3.7 %	(2.1)%
Policy benefits	**740**	590	676	25.5 %	(12.7)%
Policy acquisition costs	**6,153**	5,912	5,781	4.1 %	2.3 %
Administrative expenses	**3,030**	2,886	2,833	5.0 %	1.9 %
Interest expense	**552**	641	607	(13.9)%	5.6 %
Other (income) expense	**(596)**	(434)	(400)	37.2 %	8.5 %
Amortization of purchased intangibles	**305**	339	260	(10.2)%	30.4 %
Chubb integration expenses	**23**	59	310	(61.7)%	(81.0)%
Total expenses	**28,937**	28,060	28,521	3.1 %	(1.6)%
Income before income tax	**5,249**	4,657	3,722	12.7 %	25.1 %
Income tax expense (benefit)	**795**	695	(139)	14.3 %	NM
Net income	**$ 4,454**	$ 3,962	$ 3,861	12.4 %	2.6 %
Net premiums written - constant dollars [1]				7.0 %	4.1 %
Net premiums earned - constant dollars [1]				5.5 %	3.1 %

NM – not meaningful

[1] On a constant-dollar basis. Amounts are calculated by translating prior period results using the same local currency rates as the comparable current period.

Net Premiums Written

2019 vs. 2018

Net premiums written reflect the premiums we retain after purchasing reinsurance protection. Consolidated net premiums written increased $1.7 billion in 2019, or $2.1 billion on a constant-dollar basis, reflecting growth across most segments.

- Net premiums written in our North America Commercial P&C Insurance segment increased $890 million (7.1 percent) in 2019, reflecting positive rate increases, new business written and strong retention across most retail lines, including property, financial lines, excess casualty, risk management, and commercial package, as well as in our wholesale and high excess Bermuda lines, and in our small commercial businesses.
- Net premiums written in our North America Personal P&C Insurance segment increased $113 million (2.4 percent) in 2019, primarily due to strong retention and rate and exposure increases across most lines, partially offset by a $44 million benefit in 2018 related to the harmonization of our legacy premium registration systems, which unfavorably impacted growth by approximately 0.9 percentage points.
- Net premiums written in our North America Agricultural Insurance segment increased $233 million (14.8 percent) in 2019, primarily due to growth in our MPCI business and growth in our Chubb Agribusiness. Growth in our MPCI premium was driven primarily by higher retention as a result of the premium sharing formulas under the U.S. government, as well as the non-renewal of a quota-share treaty effective with the current crop year and an increase in current year production. Under the MPCI premium sharing formula under the U.S. government, we cede additional premiums to the government during profitable years. In 2018, the program was more profitable which resulted in higher cessions compared to 2019.
- Net premiums written in our Overseas General Insurance segment increased $360 million (4.0 percent) in 2019, or $722 million (8.4 percent) on a constant-dollar basis, reflecting growth across all regions and most lines of business. P&C lines growth was across all regions and was principally due to positive rate increases and new business in property, casualty, and financial lines. Personal lines growth was driven by new business principally in Latin America and Europe. Accident and health (A&H) lines growth was principally in Asia and Latin America driven by new business.

- Net premiums written in our Global Reinsurance segment decreased $22 million (3.2 percent) in 2019, or $12 million (1.7 percent) on a constant-dollar basis, as an increase in new business written in property and marine lines was more than offset by an increase in ceded retrocessions, reductions in the international motor line, and higher reinstatement premiums collected in the prior year.
- Net premiums written in our Life Insurance segment increased $122 million (5.3 percent) in 2019, or $143 million (6.4 percent) on a constant-dollar basis, primarily reflecting growth in our Asian and Latin American international life operations and North American Combined Insurance supplemental A&H program, partially offset by our life reinsurance business, which continues to decline as no new life reinsurance business is being written.

2018 vs. 2017

Consolidated net premiums written increased $1.3 billion in 2018, or $1.2 billion (4.1 percent) on a constant-dollar basis, reflecting growth across most segments.

- Net premiums written in our North America Commercial P&C Insurance segment increased $466 million (3.9 percent) in 2018 reflecting positive rate increases, new business written, and strong renewals across a number of lines. Retail casualty and risk management, A&H, retail property, and continued growth in our small commercial business represented $339 million of the $466 million increase. In addition, the year-over-year increase in large structured transactions was $195 million. This growth was partially offset by merger-related underwriting actions of $123 million and premium reductions from planned portfolio management in our retail and wholesale brokerage financial lines ($62 million).
- Net premiums written in our North America Personal P&C Insurance segment increased $141 million (3.1 percent) for 2018, primarily due to strong retention and new business growth in homeowners and complementary products such as automobiles and valuables. In addition, the non-renewal of a quota share treaty in the second quarter of 2017 covering the acquired Fireman's Fund homeowners and automobile businesses added $47 million of additional net premiums written in 2018. These increases were partially offset by the addition of California to the homeowners quota share reinsurance treaty, effective October 1, 2018 ($47 million), which included a non-recurring unearned premium reserves (UPR) transfer of $32 million.
- Net premiums written in our North America Agricultural Insurance segment increased $61 million (4.0 percent) in 2018, primarily due to growth in our MPCI business and growth in our Chubb Agribusiness. The growth in MPCI premium was driven by policy count growth and the year-over-year impact of the premium sharing formulas under the U.S. government. In 2017, the program was more profitable which resulted in higher cessions compared to 2018. The increase was partially offset by lower volatility factors, which are a component of the policy pricing that measures the likelihood the commodity price will fluctuate over the crop year and reduces the premium we charge.
- Net premiums written in our Overseas General Insurance segment increased $552 million (6.6 percent) in 2018, or $448 million (5.3 percent) on a constant-dollar basis, reflecting growth across most regions and lines of business. P&C lines growth was across all regions, principally in small commercial property and general casualty lines reflecting new business, and in middle market driven by new business and rate increases. Personal lines growth was principally in our automobile line in Mexico driven by new business, as well as in our specialty lines in Asia. A&H lines growth was principally in Asia driven by new business.
- Net premiums written in our Global Reinsurance segment decreased $14 million (2.1 percent) in 2018, or $22 million (3.3 percent) on a constant-dollar basis, primarily due to higher reinstatement premiums collected in the prior year principally relating to the 2017 natural catastrophes ($15 million year-over-year decrease) and lower renewals, which is reflective of competitive market conditions primarily in catastrophe and catastrophe exposed lines of business, partially offset by new business written in the casualty line of business.
- Net premiums written in our Life Insurance segment increased $129 million (6.1 percent) in 2018, or $123 million (5.7 percent) on a constant-dollar basis, primarily due to growth in our North American Combined Insurance supplemental A&H program business, and Asian and Latin American international life operations, partially offset by our life reinsurance business, which continues to decline as no new life reinsurance business is being written.

Net Premiums Written By Line of Business

(in millions of U.S. dollars, except for percentages)	2019	2018	2017	C$ [1] 2018	% Change C$ [1] 2019 vs. 2018
Commercial casualty	**$ 5,654**	$ 5,204	$ 4,721	$ 5,154	9.7 %
Workers' compensation	**2,098**	2,094	2,067	2,094	0.1 %
Professional liability	**3,697**	3,527	3,547	3,479	6.3 %
Surety	**639**	635	627	622	2.7 %
Commercial multiple peril [2]	**983**	910	879	910	8.0 %
Property and other short-tail lines	**4,468**	4,016	3,819	3,930	13.7 %
Total Commercial P&C [3]	**17,539**	16,386	15,660	16,189	8.3 %
Agriculture	**1,810**	1,577	1,516	1,577	14.8 %
Personal automobile	**1,786**	1,695	1,563	1,685	6.0 %
Personal homeowners	**3,513**	3,391	3,302	3,383	3.9 %
Personal other	**1,514**	1,508	1,441	1,454	4.0 %
Total Personal lines	**6,813**	6,594	6,306	6,522	4.4 %
Total Property and Casualty lines	**26,162**	24,557	23,482	24,288	7.7 %
Global A&H lines [4]	**4,315**	4,277	4,056	4,157	3.8 %
Reinsurance lines	**649**	671	685	661	(1.7)%
Life	**1,149**	1,074	1,021	1,059	8.5 %
Total consolidated	**$ 32,275**	$ 30,579	$ 29,244	$ 30,165	7.0 %

(1) On a constant-dollar basis. Amounts are calculated by translating prior period results using the same local currency rates as the comparable current period.

(2) Commercial multiple peril represents retail package business (property and general liability).

(3) 2018 included a reclassification of $56 million from Workers' compensation and $1 million from Commercial multiple peril to Commercial casualty ($48 million) and Property and other short-tail lines ($9 million) to better align the reporting with current year. There is no impact to total Commercial P&C.

(4) For purposes of this schedule only, A&H results from our Combined North America and International businesses, normally included in the Life Insurance and Overseas General Insurance segments, respectively, as well as the A&H results of our North America Commercial P&C segment, are included in Global A&H lines above.

The increase in net premiums written in 2019 reflects growth across most lines of business.

- The growth in commercial casualty was due to new business and rate improvement in North America. In addition, commercial casualty grew internationally due to positive rate increases and new business across Europe, as well as growth in Australia.
- Growth in workers' compensation was adversely impacted by competitive market conditions in North America.
- The increase in professional liability was due to growth in North America and new business in Australia and Europe. Professional liability also had positive rate increases and retention in Australia.
- Surety increased due to new business in North America.
- Commercial multiple peril increased due to new business and higher renewal business in North America.
- Property and other short-tail lines increased due to growth in North America. In addition, property and other short-tail lines increased internationally, primarily due to new business in Australia and across Europe, as well as positive rate increases internationally.
- Our personal lines increased due to strong retention and rate and exposure increases in North America. Personal lines also increased due to growth in Latin America and Europe.
- Global A&H lines increased due to growth in our North American Combined Insurance supplemental A&H program, along with new business in Asia and Latin America.
- The increase in Life was primarily driven by growth in our Asian and Latin American international life operations.

For additional information on net premiums written, refer to the segment results discussions.

Net Premiums Earned

2019 vs. 2018

Net premiums earned for short-duration contracts, typically P&C contracts, generally reflect the portion of net premiums written that were recorded as revenues for the period as the exposure periods expire. Net premiums earned for long-duration contracts, typically traditional life contracts, generally are recognized as earned when due from policyholders. Net premiums earned increased $1.2 billion, or $1.6 billion on a constant-dollar basis in 2019, reflecting the growth in net premiums written described above, including the impact of premiums that were fully earned when written (e.g., large structured transactions and audit and retrospective premium adjustments).

2018 vs. 2017

Net premiums earned increased $1.0 billion, or $912 million on a constant-dollar basis in 2018, primarily due to the same factors driving the increase in net premiums written as described above. Net premiums earned were favorably impacted by the year-over-year increase in large structured transactions ($163 million), a number of which were earned immediately when written. These retroactive transactions did not impact premiums earned in 2019 as they were fully earned in 2018.

P&C Combined Ratio

In evaluating our segments excluding Life Insurance financial performance, we use the P&C combined ratio, the loss and loss expense ratio, the policy acquisition cost ratio, and the administrative expense ratio. We calculate these ratios by dividing the respective expense amounts by net premiums earned. We do not calculate these ratios for the Life Insurance segment as we do not use these measures to monitor or manage that segment. The P&C combined ratio is determined by adding the loss and loss expense ratio, the policy acquisition cost ratio, and the administrative expense ratio. A P&C combined ratio under 100 percent indicates underwriting income, and a combined ratio exceeding 100 percent indicates underwriting loss.

	2019	2018	2017
Loss and loss expense ratio	**62.1%**	62.1%	65.8%
Policy acquisition cost ratio	**19.1%**	19.2%	19.5%
Administrative expense ratio	**9.4%**	9.3%	9.4%
P&C Combined ratio	**90.6%**	90.6%	94.7%

The loss and loss expense ratio decreased 3.7 percentage points in 2018 principally due to the following:

- Lower catastrophe losses;
- Integration-related claims handling expense savings;
- Partially offset by increased frequency and severity of homeowners losses in our North America Personal P&C Insurance segment, primarily non-catastrophe water related events and large fire losses which are trending above our expectations, and higher non-catastrophe large losses in our North America Commercial P&C Insurance segment.

Policy acquisition costs consist of commissions, premium taxes, and certain underwriting costs directly related to the successful acquisition of a new or renewal insurance contract. Our policy acquisition cost ratio decreased 0.3 percentage points in 2018 principally due to increased cessions under certain reinsurance agreements that resulted in higher ceded acquisition costs benefits than in the prior year.

Catastrophe Losses and Prior Period Development

Catastrophe losses exclude reinstatement premiums which are additional premiums paid on certain reinsurance agreements in order to reinstate coverage that had been exhausted by loss occurrences. The reinstatement premium amount is typically a pro rata portion of the original ceded premium paid based on how much of the reinsurance limit had been exhausted. Prior period development is net of related adjustments which typically relate to either profit commission reserves or policyholder dividend reserves based on actual claim experience that develops after the policy period ends. The expense adjustments correlate to the prior period loss development on these same policies. Refer to the Non-GAAP Reconciliation section for further information on reinstatement premiums on catastrophe losses and adjustments to prior period development.

(in millions of U.S dollars)	2019	2018	2017
Catastrophe losses (excludes reinstatement premiums)	$ 1,175	$ 1,622	$ 2,753
Favorable prior period development	$ 792	$ 896	$ 829

We generally define catastrophe loss events consistent with the definition of the Property Claims Service (PCS) for events in the U.S. and Canada. PCS defines a catastrophe as an event that causes damage of $25 million or more in insured property losses and affects a significant number of insureds. For events outside of the U.S. and Canada, we generally use a similar definition. The tables below represent catastrophe loss estimates for events that occurred in the related calendar year only. Changes in catastrophe loss estimates in the current calendar year that relate to loss events that occurred in previous calendar years are considered prior period development and are excluded from the tables below.

The following table presents catastrophe losses and reinstatement premiums (RIPs) collected (expensed) in 2019:

	Catastrophe Loss Charge by Event							
(in millions of U.S. dollars)	North America Commercial P&C Insurance	North America Personal P&C Insurance	North America Agricultural Insurance	Overseas General Insurance	Global Reinsurance	Total excluding RIPs	RIPs collected (expensed)	Total including RIPs
Net losses								
U.S. flooding, hail, tornadoes, and wind events	$ 220	$ 202	$ 7	$ —	$ 9	$ 438	$ —	$ 438
Tornado in Dallas, Texas	55	145	—	—	2	202	(11)	213
Winter-related storms	74	110	1	6	2	193	—	193
Hurricane Dorian	26	30	—	10	8	74	1	73
California wildfires	11	45	—	—	—	56	—	56
Typhoon Hagibis	—	—	—	20	17	37	1	36
Civil unrest in Hong Kong and Chile	—	—	—	33	—	33	(4)	37
International weather-related events	1	2	—	30	—	33	—	33
Tropical Storm Imelda	26	4	—	—	1	31	—	31
Australia storms	—	—	—	27	1	28	—	28
Typhoon Faxai	—	—	—	15	10	25	1	24
Hurricane Barry	3	4	—	—	—	7	—	7
Australia wildfires	—	—	—	5	—	5	—	5
Other	5	1	—	6	1	13	—	13
Total	$ 421	$ 543	$ 8	$ 152	$ 51	$ 1,175		
RIPs collected (expensed)	—	(11)	—	(4)	3		(12)	
Total before income tax	$ 421	$ 554	$ 8	$ 156	$ 48			$ 1,187
Income tax benefit								221
Total after income tax								$ 966

The following table presents catastrophe losses and reinstatement premiums (RIPs) collected (expensed) in 2018:

	Catastrophe Loss Charge by Event							
(in millions of U.S. dollars)	North America Commercial P&C Insurance	North America Personal P&C Insurance	North America Agricultural Insurance	Overseas General Insurance	Global Reinsurance	Total excluding RIPs	RIPs collected (expensed)	Total including RIPs
Net losses								
Hurricane Michael	$ 187	$ 16	$ 6	$ 6	$ 85	$ 300	$ 15	$ 285
U.S. flooding, hail, tornadoes, and wind events [1]	162	157	7	—	6	332	—	332
Northeast winter storms	43	117	—	—	5	165	—	165
California wildfires	51	61	1	1	58	172	(23)	195
Hurricane Florence	109	29	7	15	14	174	1	173
California mudslides	4	120	—	1	—	125	—	125
Colorado rain and hail storm	7	65	—	1	—	73	—	73
International weather-related events	—	—	—	182	31	213	2	211
Other	16	46	—	—	6	68	1	67
Total	$ 579	$ 611	$ 21	$ 206	$ 205	$ 1,622		
RIPs collected (expensed)	—	(26)	—	—	22		(4)	
Total before income tax	$ 579	$ 637	$ 21	$ 206	$ 183			$ 1,626
Income tax benefit								272
Total after income tax								$ 1,354

(1) This grouping comprised of 34 separate events, principally impacting the southern and northeastern regions of the U.S.

The following table presents catastrophe losses and reinstatement premiums (RIPs) collected (expensed) in 2017:

	Catastrophe Loss Charge by Event							
(in millions of U.S. dollars)	North America Commercial P&C Insurance	North America Personal P&C Insurance	North America Agricultural Insurance	Overseas General Insurance	Global Reinsurance	Total excluding RIPs	RIPs collected (expensed)	Total including RIPs
Net losses								
N. California wildfires	$ 61	$ 151	$ —	$ 2	$ 42	$ 256	$ (21)	$ 277
S. California wildfires	23	134	—	—	—	157	—	157
Hurricane Harvey	391	175	1	40	48	655	5	650
Hurricane Irma	464	206	2	79	159	910	30	880
Hurricane Maria	50	—	—	89	55	194	(7)	201
Mexico Earthquakes	—	—	—	25	—	25	—	25
Other	231	205	15	96	9	556	—	556
Total	$ 1,220	$ 871	$ 18	$ 331	$ 313	$ 2,753		
RIPs collected (expensed)	(4)	(22)	—	(4)	37		7	
Total before income tax	$ 1,224	$ 893	$ 18	$ 335	$ 276			$ 2,746
Income tax benefit								575
Total after income tax								$ 2,171

Prior period development (PPD) arises from changes to loss estimates recognized in the current year that relate to loss events that occurred in previous calendar years and excludes the effect of losses from the development of earned premium from previous accident years.

Pre-tax net favorable prior period development for the year ended 2019 was $792 million, which included favorable development of $80 million in our crop insurance business and adverse development of $116 million related to legacy run-off exposures, principally asbestos and environmental liabilities. The remaining favorable development of $828 million comprised 92 percent long-tail lines, principally from accident years 2015 and prior, and 8 percent short-tail lines.

Net favorable prior period development for the year ended 2018 was $896 million, which included favorable reinsurance settlements of $205 million related to legacy run-off exposures, $197 million favorable development related to the 2017 catastrophe events, and favorable development of $110 million in our crop insurance business. There were $216 million of adverse development related to legacy run-off exposures, principally asbestos and environmental liabilities. The remaining favorable development of $600 million comprised 82 percent long-tail lines, principally for the 2014 and prior accident years, and 18 percent short-tail lines.

Refer to the Prior Period Development section in Note 7 to the Consolidated Financial Statements for additional information.

Current Accident Year (CAY) Loss Ratio excluding Catastrophe Losses (CATs)

The following table presents the impact of catastrophe losses and prior period development on our loss and loss expense ratio. Refer to the Non-GAAP Reconciliation section for additional information.

	2019	2018	2017
Loss and loss expense ratio	**62.1 %**	62.1 %	65.8 %
Catastrophe losses	**(4.1)%**	(5.8)%	(10.2)%
Favorable prior period development	**2.8 %**	3.3 %	3.2 %
CAY loss ratio excluding catastrophe losses	**60.8 %**	59.6 %	58.8 %

2019 vs. 2018

The CAY loss ratio excluding catastrophe losses increased 1.2 percentage points in 2019 principally due to the following:

- Downward revision in the 2019 crop year margin estimate reflecting preventive planting claims due to the impact of wet weather conditions and crop yield shortfalls resulting from poor growing conditions;
- Change in mix of business and earned price changes modestly below loss trends in certain classes of our business;
- Partially offset by the adverse impact of elevated homeowners losses in the prior year.

2018 vs. 2017

The CAY loss ratio excluding catastrophe losses increased 0.8 percentage points in 2018 principally due to the following:

- Increased frequency and severity of homeowners losses in our North America Personal P&C Insurance segment, primarily non-catastrophe water related events and large fire losses;
- Higher non-catastrophe large losses in our North America Commercial P&C Insurance segment;
- Partially offset by integration-related claims handling expense savings realized.

CAY P&C Combined Ratio excluding CATs

	2019	2018	2017
CAY Loss and loss expense ratio ex CATs	**60.8%**	59.6%	58.8%
CAY Policy acquisition cost ratio ex CATs	**19.1%**	19.2%	19.4%
CAY Administrative expense ratio ex CATs	**9.3%**	9.2%	9.4%
CAY P&C combined ratio ex CATs	**89.2%**	88.0%	87.6%

Policy benefits
Policy benefits represent losses on contracts classified as long-duration and generally include accident and supplemental health products, term and whole life products, endowment products, and annuities. Refer to the Life Insurance segment operating results section for further discussion.

Policy benefits were $740 million, $590 million and $676 million in 2019, 2018 and 2017, respectively, which included separate account liabilities (gains) losses of $44 million, $(38) million and $97 million, respectively. The offsetting movements of these liabilities are recorded in Other (income) expense on the Consolidated statements of operations. Excluding the separate account gains and losses, Policy benefits were $696 million in 2019, compared with $628 million and $579 million in 2018 and 2017, respectively.

Refer to the respective sections that follow for a discussion of Net investment income, Interest expense, Other (income) expense, Net realized gains and losses, Amortization of purchased intangibles, and Income tax expense.

Segment Operating Results – Years Ended December 31, 2019, 2018, and 2017

We operate through six business segments: North America Commercial P&C Insurance, North America Personal P&C Insurance, North America Agricultural Insurance, Overseas General Insurance, Global Reinsurance, and Life Insurance. In addition, the results of our run-off Brandywine business, including all run-off asbestos and environmental (A&E) exposures, and the results of Westchester specialty operations for 1996 and prior years are presented within Corporate.

North America Commercial P&C Insurance

The North America Commercial P&C Insurance segment comprises operations that provide property and casualty (P&C) insurance and services to large, middle market, and small commercial businesses in the U.S., Canada, and Bermuda. This segment includes our North America Major Accounts and Specialty Insurance division (large corporate accounts and wholesale business), and the North America Commercial Insurance division (principally middle market and small commercial accounts).

				% Change	
(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017	2019 vs. 2018	2018 vs. 2017
Net premiums written	**$ 13,375**	$ 12,485	$ 12,019	7.1 %	3.9 %
Net premiums earned	**12,922**	12,402	12,191	4.2 %	1.7 %
Losses and loss expenses	**8,206**	8,000	8,287	2.6 %	(3.5)%
Policy acquisition costs	**1,831**	1,829	1,873	0.2 %	(2.3)%
Administrative expenses	**1,028**	966	981	6.4 %	(1.5)%
Underwriting income	**1,857**	1,607	1,050	15.5 %	53.0 %
Net investment income	**2,082**	2,033	1,961	2.4 %	3.7 %
Other (income) expense	**(3)**	(25)	1	(86.5)%	NM
Segment income	**$ 3,942**	$ 3,665	$ 3,010	7.5 %	21.8 %
Loss and loss expense ratio	**63.5%**	64.5%	68.0%	(1.0) pt	(3.5) pts
Policy acquisition cost ratio	**14.2%**	14.7%	15.4%	(0.5) pts	(0.7) pts
Administrative expense ratio	**7.9%**	7.8%	8.0%	0.1 pts	(0.2) pts
Combined ratio	**85.6%**	87.0%	91.4%	(1.4) pts	(4.4) pts

NM – not meaningful

Premiums
The table below shows the impact of large structured transactions as well as other transactions that are fully earned when written (e.g., audit and retrospective premium adjustments).

(in millions of U.S. dollars)	**2019**	2018	2017
Net premiums fully earned when written	**$ 391**	$ 342	$ 160

2019 vs. 2018
Net premiums written increased $890 million, or 7.1 percent in 2019, reflecting positive rate increases, new business written and strong retention across most retail lines, including property, financial lines, excess casualty, risk management, and commercial package, as well as in our wholesale and high excess Bermuda lines, and in our small commercial businesses.

Net premiums earned increased $520 million, or 4.2 percent in 2019, due to the growth in net premiums written described above.

2018 vs. 2017
Net premiums written increased $466 million, or 3.9 percent in 2018 reflecting positive rate increases, new business written, and strong renewals across a number of lines. Retail casualty and risk management, A&H, retail property, and continued growth in our small commercial business represented $339 million of the $466 million increase. In addition, the year-over-year increase in large structured transactions was $195 million. This growth was partially offset by merger-related underwriting actions of $123 million and premium reductions from planned portfolio management in our retail and wholesale brokerage financial lines ($62 million).

Net premiums earned increased $211 million, or 1.7 percent in 2018 principally reflecting the net premiums written increases described above and the year-over-year increase in large structured transactions ($163 million), a number of which were earned immediately when written as they were retroactive covers.

Combined Ratio
2019 vs. 2018
The loss and loss expense ratio decreased 1.0 percentage point in 2019, primarily due to lower catastrophe losses, partially offset by a change in mix of business and earned price changes modestly below loss trends in certain classes of our business.

The policy acquisition cost ratio decreased 0.5 percentage points in 2019, due to a change in mix of business towards lower acquisition cost ratio lines and increased cessions under certain reinsurance agreements that resulted in higher ceded acquisition cost benefits than in the prior year.

2018 vs. 2017
The loss and loss expense ratio decreased 3.5 percentage points in 2018, primarily due to lower catastrophe losses and integration-related claims handling expense savings realized, partially offset by lower favorable prior period development, higher non-catastrophe losses (0.4 percentage points), and a less favorable adjustment to our claims handling reserve in the current year relative to 2017.

The policy acquisition cost ratio decreased 0.7 percentage points in 2018, due to increased cessions under certain reinsurance agreements that resulted in higher ceded acquisition costs benefits than in the prior year.

The administrative expense ratio decreased 0.2 percentage points in 2018, primarily due to integration-related expense savings realized, higher net profit from our third-party claims administration business, ESIS, and the net favorable impact of one-time expense accrual releases.

Catastrophe Losses and Prior Period Development

(in millions of U.S. dollars)	**2019**	2018	2017
Catastrophe losses (excludes reinstatement premiums)	**$ 421**	$ 579	$ 1,220
Favorable prior period development	**$ 649**	$ 610	$ 746

Catastrophe losses were primarily from the following events (refer to the table on page 54):
- 2019: Winter-related storms and other severe weather-related events in the U.S., including tornadoes in Texas, Hurricane Dorian, and Tropical Storm Imelda
- 2018: Hurricanes Florence and Michael, and severe weather-related events in the U.S., including California wildfires
- 2017: Hurricanes Harvey, Irma and Maria and severe weather-related events in the U.S., including California wildfires

CAY Loss Ratio excluding Catastrophe Losses

	2019	2018	2017
Loss and loss expense ratio	**63.5 %**	64.5 %	68.0 %
Catastrophe losses	**(3.3)%**	(4.7)%	(10.0)%
Favorable prior period development	**5.1 %**	5.1 %	6.3 %
CAY loss ratio excluding catastrophe losses	**65.3 %**	64.9 %	64.3 %

2019 vs. 2018
The CAY loss ratio excluding catastrophe losses increased 0.4 percentage points for 2019 due to a change in mix of business and earned price changes modestly below loss trends in certain classes of our business.

2018 vs. 2017
The CAY loss ratio excluding catastrophe losses increased 0.6 percentage points for 2018, due to higher year-over-year large loss activity and a less favorable adjustment to our claims handling reserve in the current year relative to 2017, partially offset by integration-related claims handling expense savings realized.

North America Personal P&C Insurance

The North America Personal P&C Insurance segment comprises operations that provide high net worth personal lines products, including homeowners and complementary products such as valuable articles, excess liability, automobile, and recreational marine insurance and services in the U.S. and Canada.

				% Change	
(in millions of U.S. dollars, except for percentages)	2019	2018	2017	2019 vs. 2018	2018 vs. 2017
Net premiums written	**$ 4,787**	$ 4,674	$ 4,533	2.4 %	3.1 %
Net premiums earned	**4,694**	4,593	4,399	2.2 %	4.4 %
Losses and loss expenses	**3,043**	3,229	3,265	(5.8)%	(1.1)%
Policy acquisition costs	**948**	939	899	1.0 %	4.4 %
Administrative expenses	**286**	269	264	6.0 %	1.9 %
Underwriting income (loss)	**417**	156	(29)	167.2 %	NM
Net investment income	**258**	236	226	9.2 %	4.4 %
Other (income) expense	**3**	1	4	117.1 %	(75.0)%
Amortization of purchased intangibles	**12**	13	16	(11.1)%	(18.8)%
Segment income	**$ 660**	$ 378	$ 177	74.7 %	113.6 %
Loss and loss expense ratio	**64.8%**	70.3%	74.2%	(5.5) pts	(3.9) pts
Policy acquisition cost ratio	**20.2%**	20.4%	20.4%	(0.2) pts	—
Administrative expense ratio	**6.1%**	5.9%	6.1%	0.2 pts	(0.2) pts
Combined ratio	**91.1%**	96.6%	100.7%	(5.5) pts	(4.1) pts

NM – not meaningful

Premiums
2019 vs. 2018
Net premiums written increased $113 million, or 2.4 percent for 2019, primarily due to strong retention and rate and exposure increases across most lines, partially offset by a $44 million benefit in 2018 related to the harmonization of our legacy premium registration systems, which unfavorably impacted growth by approximately 0.9 percentage points.

Net premiums earned increased $101 million, or 2.2 percent for 2019, reflecting the growth in net premiums written described above.

2018 vs. 2017

Net premiums written increased $141 million, or 3.1 percent for 2018, primarily due to strong retention and new business growth in homeowners and complementary products such as automobiles and valuables. In addition, the non-renewal of a quota share treaty in the second quarter of 2017 covering the acquired Fireman's Fund homeowners and automobile businesses added $47 million of additional net premiums written in 2018. These increases were partially offset by the addition of California to the homeowners quota share reinsurance treaty, effective October 1, 2018 ($47 million), which included a non-recurring unearned premium reserves (UPR) transfer of $32 million.

Net premiums earned increased $194 million, or 4.4 percent for 2018, primarily due to the factors described above.

Combined Ratio

2019 vs. 2018

The loss and loss expense ratio decreased 5.5 percentage points in 2019, primarily due to lower catastrophe losses and favorable prior period development in the current year compared to unfavorable prior period development in the prior year. Additionally, the prior year underlying loss ratio was elevated principally due to increased frequency and severity, primarily non-catastrophe water and fire losses in our homeowners business.

The policy acquisition cost ratio decreased 0.2 percentage points in 2019, primarily due to higher ceded commission benefits.

2018 vs. 2017

The loss and loss expense ratio decreased 3.9 percentage points in 2018, primarily due to lower catastrophe losses (6.5 percentage points), lower unfavorable prior period development (0.6 percentage points), and integration-related claims handling expense savings realized. These decreases were offset by increased frequency and severity of homeowners losses primarily non-catastrophe water related events and large fire losses which are trending above our expectations (3.3 percentage points).

The policy acquisition cost ratio remained flat in 2018. The administrative expense ratio decreased 0.2 percentage points in 2018, primarily due to integration-related expense savings realized that exceeded normal merit and inflation.

Catastrophe Losses and Prior Period Development

(in millions of U.S. dollars)	**2019**	2018	2017
Catastrophe losses (excludes reinstatement premiums)	**$ 543**	$ 611	$ 871
Favorable (unfavorable) prior period development	**$ 95**	$ (41)	$ (69)

Catastrophe losses were primarily from the following events (refer to the table on page 54):

- 2019: Winter-related storms and other severe weather-related events in the U.S., including tornadoes in Texas, California wildfires and Hurricane Dorian
- 2018: Colorado rain and hailstorms, Hurricanes Florence and Michael, California mudslides, and other severe weather-related events in the U.S., including California wildfires
- 2017: Hurricanes Harvey and Irma and severe weather-related events in the U.S., including California wildfires

CAY Loss Ratio excluding Catastrophe Losses

	2019	2018	2017
Loss and loss expense ratio	**64.8 %**	70.3 %	74.2 %
Catastrophe losses	**(11.6)%**	(13.6)%	(20.1)%
Favorable (unfavorable) prior period development	**1.9 %**	(0.9)%	(1.5)%
CAY loss ratio excluding catastrophe losses	**55.1 %**	55.8 %	52.6 %

2019 vs. 2018

The CAY loss ratio excluding catastrophe losses decreased 0.7 percentage points in 2019. The prior year underlying loss ratio was elevated, principally due to increased frequency and severity, primarily non-catastrophe water and fire losses in our homeowners business.

2018 vs. 2017
The CAY loss ratio excluding catastrophe losses increased 3.2 percentage points in 2018, due to increased frequency and severity of homeowners losses primarily non-catastrophe water related events and large fire losses.

North America Agricultural Insurance

The North America Agricultural Insurance segment comprises our North American based businesses that provide a variety of coverages in the U.S. and Canada including crop insurance, primarily Multiple Peril Crop Insurance (MPCI) and crop-hail through Rain and Hail Insurance Service, Inc. (Rain and Hail) as well as farm and ranch and specialty P&C commercial insurance products and services through our Chubb Agribusiness unit.

(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017	% Change 2019 vs. 2018	% Change 2018 vs. 2017
Net premiums written	**$ 1,810**	$ 1,577	$ 1,516	14.8 %	4.0 %
Net premiums earned	**1,795**	1,569	1,508	14.4 %	4.1 %
Adjusted losses and loss expenses	**1,616**	1,114	1,043	45.1 %	6.8 %
Policy acquisition costs	**84**	79	81	6.8 %	(2.5)%
Administrative expenses	**6**	(9)	(8)	NM	12.5 %
Underwriting income	**89**	385	392	(77.0)%	(1.8)%
Net investment income	**30**	28	25	5.0 %	12.0 %
Other (income) expense	**1**	2	2	(33.6)%	—
Amortization of purchased intangibles	**28**	28	29	(2.0)%	(3.4)%
Segment income	**$ 90**	$ 383	$ 386	(76.6)%	(0.8)%
Loss and loss expense ratio	**90.1%**	71.0 %	69.2 %	19.1 pts	1.8 pts
Policy acquisition cost ratio	**4.7%**	5.0 %	5.4 %	(0.3) pts	(0.4) pts
Administrative expense ratio	**0.3%**	(0.5)%	(0.6)%	0.8 pts	0.1 pts
Combined ratio	**95.1%**	75.5 %	74.0 %	19.6 pts	1.5 pts

NM – not meaningful

Premiums
2019 vs. 2018
Net premiums written increased $233 million, or 14.8 percent in 2019, primarily due to growth in our MPCI business and growth in our Chubb Agribusiness. Growth in our MPCI premium was driven primarily by higher retention as a result of the premium sharing formulas under the U.S. government, as well as the non-renewal of a quota-share treaty effective with the current crop year and an increase in current year production. Under the MPCI premium sharing formula under the U.S. government, we cede additional premiums to the government during profitable years. In 2018, the program was more profitable which resulted in higher cessions compared to 2019.

Net premiums earned increased $226 million, or 14.4 percent in 2019, reflecting the growth in net premiums written described above.

2018 vs. 2017
Net premiums written increased $61 million, or 4.0 percent in 2018, primarily due to growth in our MPCI business and growth in our Chubb Agribusiness. The growth in MPCI premium was driven by policy count growth and the year-over-year impact of the premium sharing formulas under the U.S. government. In 2017, the program was more profitable which resulted in higher cessions compared to 2018. The increase was partially offset by lower volatility factors, which are a component of the policy pricing that measures the likelihood the commodity price will fluctuate over the crop year and reduces the premium we charge.

Net premiums earned increased $61 million, or 4.1 percent in 2018, due to the factors described above.

Combined Ratio

2019 vs. 2018

The loss and loss expense ratio increased 19.1 percentage points in 2019, principally due to lower favorable prior period development and the downward revision in the 2019 crop year margin estimate reflecting preventive planting claims due to the impact of wet weather conditions and crop yield shortfalls resulting from poor growing conditions. The increase in the loss ratio was partially offset by lower catastrophe losses.

The policy acquisition cost ratio decreased 0.3 percentage points in 2019, primarily due to lower agent profit sharing commission.

The administrative expense ratio increased 0.8 percentage points in 2019, primarily due to a reduction in the current year Administrative and Operating (A&O) reimbursements on the MPCI business we received under the government program and normal operating expense and inflationary increases.

2018 vs. 2017

The loss and loss expense ratio increased 1.8 percentage points in 2018 due to higher catastrophe losses and lower favorable prior period development.

The policy acquisition cost ratio decreased 0.4 percentage points in 2018 due to lower MPCI reinsurance cessions in the current year.

Catastrophe Losses and Prior Period Development

(in millions of U.S. dollars)	**2019**	2018	2017
Catastrophe losses (excludes reinstatement premiums)	**$ 8**	$ 21	$ 18
Favorable prior period development	**$ 80**	$ 110	$ 119

Catastrophe losses in 2019, 2018, and 2017 were primarily from severe weather-related events in the U.S. in our farm, ranch and specialty P&C businesses. Refer to the table on page 54.

Net favorable prior period development was $80 million, $110 million, and $119 million in 2019, 2018, and 2017, respectively. For 2019, the prior period development amount included $103 million of favorable incurred losses and $13 million of lower acquisition costs due to lower than expected MPCI losses for the 2018 crop year, partially offset by a $36 million decrease in net premiums earned related to the MPCI profit and loss calculation formula. For 2018, the prior period development amount included $140 million of favorable incurred losses and $10 million of lower acquisition costs due to lower than expected MPCI losses for the 2017 crop year, partially offset by a $40 million decrease in net premiums earned related to the MPCI profit and loss calculation formula.

CAY Loss Ratio excluding Catastrophe Losses

	2019	2018	2017
Loss and loss expense ratio	**90.1 %**	71.0 %	69.2 %
Catastrophe losses	**(0.5)%**	(1.3)%	(1.2)%
Favorable prior period development	**3.9 %**	7.0 %	8.2 %
CAY loss ratio excluding catastrophe losses	**93.5 %**	76.7 %	76.2 %

2019 vs. 2018

The CAY loss ratio excluding catastrophe losses increased 16.8 percentage points in 2019, principally due to the downward revision in the 2019 crop year margin estimate reflecting preventive planting claims due to the impact of wet weather conditions and crop yield shortfalls resulting from poor growing conditions.

2018 vs. 2017

The CAY loss ratio excluding catastrophe losses increased 0.5 percentage points in 2018, primarily due to a less favorable crop margin in the current year versus 2017, partially offset by lower underlying losses in our Chubb Agribusiness unit.

Overseas General Insurance

Overseas General Insurance segment comprises Chubb International and Chubb Global Markets (CGM). Chubb International comprises our international commercial P&C traditional and specialty lines serving large corporations, middle market and small customers; A&H and traditional and specialty personal lines business serving local territories outside the U.S., Bermuda, and Canada. CGM, our London-based international commercial P&C excess and surplus lines business, includes Lloyd's of London (Lloyd's) Syndicate 2488. Chubb provides funds at Lloyd's to support underwriting by Syndicate 2488 which is managed by Chubb Underwriting Agencies Limited.

				% Change	
(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017	2019 vs. 2018	2018 vs. 2017
Net premiums written	**$ 9,262**	$ 8,902	$ 8,350	4.0 %	6.6 %
Net premiums earned	**8,882**	8,612	8,131	3.1 %	5.9 %
Losses and loss expenses	**4,606**	4,429	4,281	4.0 %	3.5 %
Policy acquisition costs	**2,501**	2,346	2,221	6.6 %	5.6 %
Administrative expenses	**1,033**	1,014	982	1.9 %	3.3 %
Underwriting income	**742**	823	647	(9.8)%	27.2 %
Net investment income	**588**	619	610	(5.1)%	1.5 %
Other (income) expense	**12**	—	(4)	NM	NM
Amortization of purchased intangibles	**45**	41	45	8.3 %	(8.9)%
Segment income	**$ 1,273**	$ 1,401	$ 1,216	(9.2)%	15.2 %
Net premiums written - constant dollars [(1)]				8.4 %	5.3 %
Net premiums earned - constant dollars [(1)]				7.6 %	4.7 %
Underwriting income - constant dollars [(1)]				(3.7)%	24.1 %
Loss and loss expense ratio	**51.9%**	51.4%	52.6%	0.5 pts	(1.2) pts
Policy acquisition cost ratio	**28.1%**	27.2%	27.3%	0.9 pts	(0.1) pts
Administrative expense ratio	**11.6%**	11.8%	12.1%	(0.2) pts	(0.3) pts
Combined ratio	**91.6%**	90.4%	92.0%	1.2 pts	(1.6) pts

NM – not meaningful

Net Premiums Written by Region

					% Change		
(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017	C$ [(1)] 2018	2019 vs. 2018	C$ [(1)] 2019 vs. 2018	2018 vs. 2017
Region							
Europe	**$ 3,631**	$ 3,508	$ 3,281	$ 3,357	3.5%	8.2%	6.9 %
Latin America	**2,277**	2,181	2,108	2,059	4.4%	10.6%	3.5 %
Asia	**3,021**	2,884	2,596	2,806	4.7%	7.6%	11.1 %
Other [(2)]	**333**	329	365	318	1.1%	4.8%	(9.9)%
Net premiums written	**$ 9,262**	$ 8,902	$ 8,350	$ 8,540	4.0%	8.4%	6.6 %

	2019 % of Total	2018 % of Total	2017 % of Total
Region			
Europe	**38%**	39%	40%
Latin America	**25%**	25%	25%
Asia	**33%**	32%	31%
Other [(2)]	**4%**	4%	4%
Net premiums written	**100%**	100%	100%

(1) On a constant-dollar basis. Amounts are calculated by translating prior period results using the same local currency rates as the comparable current period.

(2) Comprises Combined International, Eurasia and Africa region, and other international.

Premiums

2019 vs. 2018

Net premiums written increased $360 million in 2019, or $722 million on a constant-dollar basis, reflecting growth across all regions and most lines of business. P&C lines growth was across all regions and was principally due to positive rate increases and new business in property, casualty, and financial lines. Personal lines growth was driven by new business principally in Latin America and Europe. Accident and health (A&H) lines growth was principally in Asia and Latin America driven by new business.

Net premiums earned increased $270 million in 2019, or $629 million on a constant-dollar basis, reflecting the increase in net premiums written.

2018 vs. 2017

Net premiums written increased $552 million in 2018, or $448 million on a constant-dollar basis, reflecting growth across most regions and lines of business. P&C lines growth was across all regions, principally in small commercial property and general casualty lines reflecting new business, and in middle market driven by new business and rate increases. Personal lines growth was principally in our automobile line in Mexico driven by new business, as well as in our specialty lines in Asia. A&H lines growth was principally in Asia driven by new business.

Net premiums earned increased $481 million in 2018, or $384 million on a constant-dollar basis, due to the factors described above.

Combined Ratio

2019 vs. 2018

The loss and loss expense ratio increased 0.5 percentage points in 2019 due to lower favorable prior period development, partially offset by lower catastrophe losses, earned price changes modestly above loss trends, favorable loss experience in certain personal lines, and a change in mix of business towards products and regions that have a lower loss and loss expense ratio and a higher policy acquisition cost ratio.

The policy acquisition cost ratio increased 0.9 percentage points in 2019 due to a change in mix of business towards products and regions that have a higher policy acquisition cost ratio and lower loss and loss expense ratio as noted above, higher underwriting costs resulting from the successful acquisition of business, and higher commissions paid on certain personal lines due to favorable loss experience.

2018 vs. 2017

The loss and loss expense ratio decreased 1.2 percentage points in 2018, reflecting lower catastrophe losses (1.6 percentage points) and a change in the mix of business towards consumer and property and casualty lines in countries that have a lower loss ratio and a higher acquisition cost ratio (0.3 percentage points), partially offset by lower favorable prior period development in 2018 (0.6 percentage points).

The policy acquisition cost ratio was relatively flat in 2018.

The administrative expense ratio decreased 0.3 percentage points in 2018, primarily driven by integration-expense savings realized (0.3 percentage points).

Catastrophe Losses and Prior Period Development

(in millions of U.S. dollars)		**2019**		2018		2017
Catastrophe losses (excludes reinstatement premiums)	**$**	**152**	$	206	$	331
Favorable prior period development	**$**	**92**	$	212	$	252

Catastrophe losses were primarily from the following events (refer to the table on page 54):

- 2019: Typhoons Faxai and Hagibis; Hurricane Dorian; storms in Australia; civil unrest in Hong Kong and Chile; and other international weather-related events
- 2018: Typhoons Jebi, Mangkhut and Trami; Hurricane Florence and storms in Australia
- 2017: Hurricanes Harvey, Irma and Maria; Earthquakes in Mexico, Cyclone Debbie in Australia, and flooding in Latin America

CAY Loss Ratio excluding Catastrophe Losses

	2019	2018	2017
Loss and loss expense ratio	**51.9 %**	51.4 %	52.6 %
Catastrophe losses	**(1.8)%**	(2.4)%	(4.0)%
Favorable prior period development	**1.1 %**	2.5 %	3.1 %
CAY loss ratio excluding catastrophe losses	**51.2 %**	51.5 %	51.7 %

2019 vs. 2018

The CAY loss ratio excluding catastrophe losses decreased 0.3 percentage points in 2019 primarily due to earned price changes modestly above loss trends, favorable loss experience in certain personal lines, and a change in mix of business towards products and regions that have a lower loss and loss expense ratio and a higher policy acquisition cost ratio.

2018 vs. 2017

The CAY loss ratio excluding catastrophe losses decreased 0.2 percentage points in 2018 primarily due to a change in the mix of business towards consumer and property and casualty lines in countries that have a lower loss ratio and a higher acquisition cost ratio.

Global Reinsurance

The Global Reinsurance segment represents our reinsurance operations comprising Chubb Tempest Re Bermuda, Chubb Tempest Re USA, Chubb Tempest Re International, and Chubb Tempest Re Canada. Global Reinsurance markets its reinsurance products worldwide primarily through reinsurance brokers under the Chubb Tempest Re brand name and provides a broad range of traditional and non-traditional reinsurance coverage to a diverse array of primary P&C companies.

				% Change	
(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017	2019 vs. 2018	2018 vs. 2017
Net premiums written	**$ 649**	$ 671	$ 685	(3.2)%	(2.1)%
Net premiums earned	**654**	670	704	(2.3)%	(4.9)%
Losses and loss expenses	**352**	479	561	(26.5)%	(14.7)%
Policy acquisition costs	**169**	162	177	4.2 %	(8.4)%
Administrative expenses	**35**	41	44	(12.7)%	(8.4)%
Underwriting income (loss)	**98**	(12)	(78)	NM	84.8 %
Net investment income	**220**	257	273	(14.4)%	(6.1)%
Other (income) expense	**(58)**	(32)	(1)	80.6 %	NM
Segment income	**$ 376**	$ 277	$ 196	35.7 %	41.3 %
Net premiums written - constant dollars [(1)]				(1.7)%	(3.3)%
Net premiums earned - constant dollars [(1)]				(0.8)%	(6.0)%
Underwriting income - constant dollars [(1)]				NM	84.0 %
Loss and loss expense ratio	**53.9%**	71.6%	79.8%	(17.7) pts	(8.2) pts
Policy acquisition cost ratio	**25.7%**	24.2%	25.1%	1.5 pts	(0.9) pts
Administrative expense ratio	**5.4%**	6.0%	6.3%	(0.6) pts	(0.3) pts
Combined ratio	**85.0%**	101.8%	111.2%	(16.8) pts	(9.4) pts

NM – not meaningful

(1) On a constant-dollar basis. Amounts are calculated by translating prior period results using the same local currency rates as the comparable current period.

Premiums

2019 vs. 2018

Net premiums written decreased $22 million in 2019, or $12 million on a constant-dollar basis, as an increase in new business written in property and marine lines was more than offset by an increase in ceded retrocessions, reductions in the international motor line, and higher reinstatement premiums collected in the prior year.

Net premiums earned decreased $16 million in 2019, or $5 million on a constant-dollar basis, reflecting the decrease in net premiums written described above.

2018 vs. 2017

Net premiums written decreased $14 million in 2018, or $22 million on a constant-dollar basis, primarily due to higher reinstatement premiums collected in the prior year principally relating to the 2017 natural catastrophes ($15 million year-over-year decrease) and lower renewals, which is reflective of competitive market conditions primarily in catastrophe and catastrophe exposed lines of business, partially offset by new business written in the casualty line of business.

Net premiums earned decreased $34 million in 2018, or $42 million on a constant-dollar basis, reflecting the decrease in net premiums written. The decrease was also due to $14 million of short-term treaties (less than one year in duration) earned in the prior year that were written in 2016 and 2017.

Combined Ratio

2019 vs. 2018

The loss and loss expense ratio decreased 17.7 percentage points in 2019 primarily due to lower catastrophe losses, partially offset by lower favorable prior period development.

The policy acquisition cost ratio increased 1.5 percentage points in 2019 primarily due to higher commissions paid on property and motor lines treaties with adjustable commission features, and higher reinstatement premiums collected in the prior year which have a lower acquisition cost.

The administrative expense ratio decreased 0.6 percentage points in 2019 primarily driven by lower variable costs.

2018 vs. 2017

The loss and loss expense ratio decreased 8.2 percentage points in 2018 principally due to lower catastrophe losses partially offset by lower favorable prior period development and a shift in the mix of business from property catastrophe business towards casualty business, which generally has a higher loss ratio.

The policy acquisition cost ratio decreased 0.9 percentage points in 2018 primarily due to lower acquisition expenses from proportional business sold.

The administrative expense ratio decreased 0.3 percentage points in 2018 primarily due to continued expense management.

Catastrophe Losses and Prior Period Development

(in millions of U.S dollars)	**2019**	2018	2017
Catastrophe losses (excludes reinstatement premiums)	**$ 51**	$ 205	$ 313
Favorable prior period development	**$ 29**	$ 50	$ 59

Catastrophe losses were primarily from the following events (refer to the table on page 54):

- 2019: Typhoons Hagibis and Faxai; Hurricane Dorian, and other severe weather-related events primarily in the U.S.
- 2018: Hurricanes Florence and Michael; Typhoons Jebi and Trami; Windstorm Friederike, California Wildfires, and severe weather-related events in the U.S., Canada and Japan
- 2017: Hurricanes Harvey, Irma and Maria; Northern California Wildfires, and severe weather-related events in the U.S.

CAY Loss Ratio excluding Catastrophe Losses

	2019	2018	2017
Loss and loss expense ratio	**53.9 %**	71.6 %	79.8 %
Catastrophe losses	**(7.6)%**	(29.2)%	(42.4)%
Favorable prior period development	**4.3 %**	8.1 %	8.6 %
CAY loss ratio excluding catastrophe losses	**50.6 %**	50.5 %	46.0 %

The CAY loss ratio excluding catastrophe losses remained relatively flat in 2019. The CAY loss ratio excluding catastrophe losses increased 4.5 percentage points in 2018 primarily due to a shift in the mix of business from property catastrophe business towards casualty business which generally has a higher loss ratio and higher losses in our U.S. property lines.

Life Insurance

The Life Insurance segment comprises Chubb's international life operations, Chubb Tempest Life Re (Chubb Life Re), and the North American supplemental A&H and life business of Combined Insurance.

				% Change	
(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017	2019 vs. 2018	2018 vs. 2017
Net premiums written	**$ 2,392**	$ 2,270	$ 2,141	5.3 %	6.1%
Net premiums earned	**2,343**	2,218	2,101	5.6 %	5.6%
Losses and loss expenses	**757**	766	739	(1.1)%	3.7%
Adjusted policy benefits	**696**	628	579	10.8 %	8.5%
Policy acquisition costs	**620**	557	530	11.2 %	5.1%
Administrative expenses	**323**	310	303	4.5 %	2.3%
Net investment income	**373**	341	313	9.2 %	8.9%
Life Insurance underwriting income	**320**	298	263	6.9 %	13.3%
Other (income) expense	**(48)**	(12)	13	NM	NM
Amortization of purchased intangibles	**2**	2	2	—	—
Segment income	**$ 366**	$ 308	$ 248	18.6 %	24.2%
Net premiums written - constant dollars [(1)]				6.4 %	5.7%
Net premiums earned - constant dollars [(1)]				6.6 %	5.3%
Life Insurance underwriting income - constant dollars [(1)]				8.1 %	13.9%

NM – not meaningful

(1) On a constant-dollar basis. Amounts are calculated by translating prior period results using the same local currency rates as the comparable current period.

Premiums

2019 vs. 2018

Net premiums written increased $122 million in 2019, or $143 million on a constant-dollar basis, primarily reflecting growth in our Asian and Latin American international life operations and North American Combined Insurance supplemental A&H program, partially offset by our life reinsurance business, which continues to decline as no new life reinsurance business is being written.

2018 vs. 2017

Net premiums written increased $129 million in 2018, or $123 million on a constant-dollar basis, primarily due to growth in our North American Combined Insurance supplemental A&H program business, and Asian and Latin American international life operations, partially offset by our life reinsurance business, which continues to decline as no new life reinsurance business is being written.

Deposits

The following table presents deposits collected on universal life and investment contracts:

(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017	% Change 2019 vs. 2018	% Change C$ [1] 2019 vs. 2018	% Change 2018 vs. 2017
Deposits collected on universal life and investment contracts	**$ 1,463**	$ 1,538	$ 1,436	(4.9)%	(2.3)%	7.1%

(1) On a constant-dollar basis. Amounts are calculated by translating prior period results using the same local currency rates as the comparable current period.

Deposits collected on universal life and investment contracts (life deposits) are not reflected as revenues in our Consolidated statements of operations in accordance with GAAP. New life deposits are an important component of production, and although they do not significantly affect current period income from operations they are key to our efforts to grow our business. Life deposits collected decreased in 2019 due to declines in Taiwan, driven by competitive market conditions, and Hong Kong, due to the civil unrest negatively impacting growth in the second half of the year, partially offset by growth in Vietnam. Foreign exchange unfavorably impacted growth by $40 million in 2019.

Life deposits collected increased in 2018 due to growth in Korea, Taiwan, and Vietnam. Foreign exchange favorably impacted growth by $14 million in 2018.

Life Insurance underwriting income and Segment income

2019 vs. 2018

Life Insurance underwriting income increased $22 million in 2019 compared to 2018, principally reflecting an increase in net investment income, partially offset by a favorable reserve development in the prior year. Additionally, segment income benefited from other income of $48 million in 2019 compared to $12 million in 2018, principally due to our share of net income from Huatai Life, our partially-owned life insurance entity in China.

2018 vs. 2017

Life Insurance underwriting income increased $35 million in 2018 compared to 2017 primarily due to an increase in net investment income as well as growth as described above.

Corporate

Corporate results primarily include the results of our non-insurance companies, income and expenses not attributable to reportable segments and loss and loss expenses of asbestos and environmental (A&E) liabilities and certain other non-A&E run-off exposures.

Our exposure to A&E claims principally arises out of liabilities acquired when we purchased Westchester Specialty in 1998, CIGNA's P&C business in 1999, and legacy Chubb Corp A&E claims in 2016. Corporate staff expenses and net investment income of Chubb Limited, including the amortization of the fair value adjustment on acquired invested assets and debt, interest expense, amortization of purchased intangibles related to the Chubb Corp acquisition, and Chubb integration expenses are reported within Corporate.

				% Change	
(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017	2019 vs. 2018	2018 vs. 2017
Losses and loss expenses	**$ 158**	$ 53	$ 285	203.0 %	(81.4)%
Administrative expenses	**319**	295	267	8.1 %	10.5 %
Underwriting loss	**477**	348	552	36.6 %	(37.0)%
Net investment income (loss)	**(125)**	(209)	(283)	(40.5)%	(26.1)%
Interest expense	**552**	641	607	(13.9)%	5.6 %
Adjusted net realized gains (losses)	**(522)**	(649)	91	(19.7)%	NM
Other (income) expense	**(459)**	(406)	(318)	12.6 %	27.7 %
Amortization of purchased intangibles	**218**	255	168	(14.3)%	51.8 %
Chubb integration expenses	**23**	59	310	(61.7)%	(81.0)%
Income tax expense (benefit)	**795**	695	(139)	14.4 %	NM
Net loss	**$ (2,253)**	$ (2,450)	$ (1,372)	(8.1)%	78.6 %

NM – not meaningful

Losses and loss expenses in 2019, 2018, and 2017 were primarily from adverse development relating to our Brandywine asbestos and environmental exposures, non-A&E run-off casualty exposure, including workers' compensation, and unallocated loss adjustment expenses of the A&E claims operations. In addition, 2018 included favorable reinsurance settlements of $205 million. Refer to Note 7 of the Consolidated Financial Statements for further information.

Administrative expenses increased $24 million and $28 million in 2019 and 2018, respectively, primarily due to higher global advertising expenses.

Chubb integration expenses are one-time in nature and are not related to the on-going business activities of the segments. The Chief Executive Officer does not manage segment results or allocate resources to segments when considering these costs and they are therefore excluded from our definition of segment income. Chubb integration expenses in 2019 principally consisted of small residual items related to the Chubb acquisition. Chubb integration expenses for 2018 were $59 million and principally consisted of personnel-related expenses ($18 million) and rebranding ($14 million).

Refer to the respective sections that follow for a discussion of Net investment income, Interest expense, Other (income) expense, Net realized gains and losses, Amortization of purchased intangibles, and Income tax expense.

Effective income tax rate
Our effective income tax rate reflects a mix of income or losses in jurisdictions with a wide range of tax rates, permanent differences between US GAAP and local tax laws, and the timing of recording discrete items. A change in the geographic mix of earnings could impact our effective tax rate.

In 2019, 2018, and 2017, our effective income tax rate was 15.1 percent, 14.9 percent, and (3.7) percent, respectively. The effective income tax rate in 2018 was favorably impacted by an increase to the provisional benefit recorded related to the impact of the 2017 Tax Act. The effective income tax rate in 2017 included the favorable income tax benefit of $450 million, which represented our best estimate of the impact of the 2017 Tax Act. In addition, the income tax benefit in 2017 reflected the significant catastrophe losses in the year.

The 2017 Tax Act included provisions for Global Intangible Low-Taxed Income (GILTI) under which taxes may be imposed on income of foreign subsidiaries and for a Base Erosion and Anti-Abuse Tax (BEAT) under which taxes may be imposed on certain payments to affiliated foreign companies. There remain substantial uncertainties in the interpretation of GILTI and BEAT and portions of the formal guidance issued to date are still in part in proposed form. Finalization of the proposed guidance, and changes to the interpretations and assumptions related to these provisions may impact amounts recorded with respect to the international provisions of the 2017 Tax Act, which may be material in the period the adjustment is recorded. Refer to Note 8 to the Consolidated Financial Statements for additional information on the 2017 Tax Act.

Our effective income tax rate reflects the lower corporate tax rates that prevailed outside the United States on income attributed to certain foreign operations, including 7.83 percent in Switzerland and 0.0 percent in Bermuda. During 2019, approximately 42 percent of our total pre-tax income was tax effected based on these lower rates compared with 49 percent and 62 percent in 2018 and 2017, respectively.

Non-GAAP Reconciliation

In presenting our results, we included and discussed certain non-GAAP measures. These non-GAAP measures, which may be defined differently by other companies, are important for an understanding of our overall results of operations and financial condition. However, they should not be viewed as a substitute for measures determined in accordance with generally accepted accounting principles (GAAP).

Adjusted interest expense and adjusted net investment income are non-GAAP financial measures which exclude amortization of the fair value adjustment on assumed long-term debt and acquired invested assets, respectively, related to the Chubb Corp acquisition due to the size and complexity of this acquisition. Refer to the Interest Expense section for a reconciliation of interest expense to adjusted interest expense.

We provide financial measures, including net premiums written, net premiums earned, and underwriting income on a constant-dollar basis. We believe it is useful to evaluate the trends in our results exclusive of the effect of fluctuations in exchange rates between the U.S. dollar and the currencies in which our international business is transacted, as these exchange rates could fluctuate significantly between periods and distort the analysis of trends. The impact is determined by assuming constant foreign exchange rates between periods by translating prior period results using the same local currency exchange rates as the comparable current period.

Adjusted policy benefits include gains and losses from fair value changes in separate account assets, as well as the offsetting movement in separate account liabilities, for purposes of reporting Life Insurance underwriting income. The gains and losses from fair value changes in separate account assets that do not qualify for separate account reporting under GAAP have been reclassified from Other (income) expense. We view gains and losses from fair value changes in both separate account assets and liabilities as part of the results of our underwriting operations, and therefore these gains and losses are reclassified to adjusted policy benefits.

The following table presents a reconciliation of Policy benefits to Adjusted policy benefits:

	Year Ended December 31		
(in millions of U.S. dollars)	**2019**	2018	2017
Policy benefits	**$ 740**	$ 590	$ 676
Add: (Gains) losses from fair value changes in separate account assets	**(44)**	38	(97)
Adjusted policy benefits	**$ 696**	$ 628	$ 579

P&C performance metrics comprise consolidated operating results (including Corporate) and exclude the operating results of the Life Insurance segment. We believe that these measures are useful and meaningful to investors as they are used by management to assess the company's P&C operations which are the most economically similar. We exclude the Life Insurance segment because the results of this business do not always correlate with the results of our P&C operations.

P&C combined ratio is the sum of the loss and loss expense ratio, acquisition cost ratio and the administrative expense ratio excluding the life business and including the realized gains and losses on the crop derivatives. These derivatives were purchased to provide economic benefit, in a manner similar to reinsurance protection, in the event that a significant decline in commodity pricing impacts underwriting results. We view gains and losses on these derivatives as part of the results of our underwriting operations.

CAY P&C combined ratio excluding catastrophe losses (CATs) excludes CATs and prior period development (PPD) from the P&C combined ratio. We exclude CATs as they are not predictable as to timing and amount and PPD as these unexpected loss developments on historical reserves are not indicative of our current underwriting performance. The combined ratio numerator is adjusted to exclude CATs, net premiums earned adjustments on PPD, prior period expense adjustments and reinstatement premiums on PPD, and the denominator is adjusted to exclude net premiums earned adjustments on PPD and reinstatement premiums on CATs and PPD. In periods where there are adjustments on loss sensitive policies, these adjustments are excluded from PPD and net premiums earned when calculating the ratios. We believe this measure provides a better evaluation of our underwriting performance and enhances the understanding of the trends in our P&C business that may be obscured by these items. This measure is commonly reported among our peer companies and allows for a better comparison.

Reinstatement premiums are additional premiums paid on certain reinsurance agreements in order to reinstate coverage that had been exhausted by loss occurrences. The reinstatement premium amount is typically a pro rata portion of the original ceded premium paid based on how much of the reinsurance limit had been exhausted.

Net premiums earned adjustments within PPD are adjustments to the initial premium earned on retrospectively rated policies based on actual claim experience that develops after the policy period ends. The premium adjustments correlate to the prior period loss development on these same policies and are fully earned in the period the adjustments are recorded.

Prior period expense adjustments typically relate to adjustable commission reserves or policyholder dividend reserves based on actual claim experience that develops after the policy period ends. The expense adjustments correlate to the prior period loss development on these same policies.

For this disclosure purpose, the normalized level of CATs, or expected level of CATs, is not intended to represent a probability weighted expectation for the company but rather to represent management's view of what might be more typical for a given period based on various factors, including historical experience, seasonal patterns, and consideration of both modeled CATs (e.g., windstorm and earthquake) as well as non-modeled CATs (e.g., wildfires, floods and freeze).

The following table presents CATs above (below) expected level and the impact on the combined ratio:

	Year Ended December 31		
(in millions of U.S. dollars, except for percentage points)	**2019**	2018	2017
Actual level of CATs - pre-tax	**$ 1,187**	$ 1,626	$ 2,746
Less: Expected level of CATs - pre-tax	**969**	937	908
CATs above expected level - pre-tax	**$ 218**	$ 689	$ 1,838
Adverse impact of CATs above an expected level on combined ratio	**0.7%**	2.5%	6.8%

The following tables present the calculation of combined ratio, as reported for each segment to P&C combined ratio, adjusted for catastrophe losses (CATs) and PPD:

For the Year Ended December 31, 2019 (in millions of U.S. dollars except for ratios)		North America Commercial P&C Insurance	North America Personal P&C Insurance	North America Agricultural Insurance	Overseas General Insurance	Global Reinsurance	Corporate	Total P&C
Numerator								
Losses and loss expenses								
Losses and loss expenses		$ 8,206	$ 3,043	$ 1,608	$ 4,606	$ 352	$ 158	$ 17,973
Realized (gains) losses on crop derivatives		—	—	8	—	—	—	8
Adjusted losses and loss expenses	A	$ 8,206	$ 3,043	$ 1,616	$ 4,606	$ 352	$ 158	$ 17,981
Catastrophe losses and related adjustments								
Catastrophe losses, net of related adjustments		(421)	(554)	(8)	(156)	(48)	—	(1,187)
Reinstatement premiums collected (expensed) on catastrophe losses		—	(11)	—	(4)	3	—	(12)
Catastrophe losses, gross of related adjustments		(421)	(543)	(8)	(152)	(51)	—	(1,175)
PPD and related adjustments								
PPD, net of related adjustments - favorable (unfavorable)		649	95	80	92	29	(153)	792
Net premiums earned adjustments on PPD - unfavorable (favorable)		38	—	36	—	1	—	75
Expense adjustments - unfavorable (favorable)		(3)	—	(13)	—	(1)	—	(17)
PPD reinstatement premiums - unfavorable (favorable)		(1)	(4)	—	1	(1)	—	(5)
PPD, gross of related adjustments - favorable (unfavorable)		683	91	103	93	28	(153)	845
CAY loss and loss expense ex CATs	B	$ 8,468	$ 2,591	$ 1,711	$ 4,547	$ 329	$ 5	$ 17,651
Policy acquisition costs and administrative expenses								
Policy acquisition costs and administrative expenses	C	$ 2,859	$ 1,234	$ 90	$ 3,534	$ 204	$ 319	$ 8,240
Expense adjustments - favorable (unfavorable)		3	—	13	—	1	—	17
Policy acquisition costs and administrative expenses, adjusted	D	$ 2,862	$ 1,234	$ 103	$ 3,534	$ 205	$ 319	$ 8,257
Denominator								
Net premiums earned	E	$ 12,922	$ 4,694	$ 1,795	$ 8,882	$ 654		$ 28,947
Reinstatement premiums (collected) expensed on catastrophe losses		—	11	—	4	(3)		12
Net premiums earned adjustments on PPD - unfavorable (favorable)		38	—	36	—	1		75
PPD reinstatement premiums - unfavorable (favorable)		(1)	(4)	—	1	(1)		(5)
Net premiums earned excluding adjustments	F	$ 12,959	$ 4,701	$ 1,831	$ 8,887	$ 651		$ 29,029
P&C Combined ratio								
Loss and loss expense ratio	A/E	63.5%	64.8%	90.1%	51.9%	53.9%		62.1%
Policy acquisition cost and administrative expense ratio	C/E	22.1%	26.3%	5.0%	39.7%	31.1%		28.5%
P&C Combined ratio		85.6%	91.1%	95.1%	91.6%	85.0%		90.6%
CAY P&C Combined ratio ex CATs								
Loss and loss expense ratio, adjusted	B/F	65.3%	55.1%	93.5%	51.2%	50.6%		60.8%
Policy acquisition cost and administrative expense ratio, adjusted	D/F	22.1%	26.3%	5.6%	39.7%	31.5%		28.4%
CAY P&C Combined ratio ex CATs		87.4%	81.4%	99.1%	90.9%	82.1%		89.2%
Combined ratio								
Combined ratio								90.6%
Add: impact of gains and losses on crop derivatives								—
P&C Combined ratio								90.6%

Note: The ratios above are calculated using whole U.S. dollars. Accordingly, calculations using rounded amounts may differ. Letters A, B, C, D, E and F included in the table are references for calculating the ratios above.

For the Year Ended December 31, 2018 (in millions of U.S. dollars except for ratios)		North America Commercial P&C Insurance	North America Personal P&C Insurance	North America Agricultural Insurance	Overseas General Insurance	Global Reinsurance	Corporate	Total P&C
Numerator								
Losses and loss expenses								
Losses and loss expenses		$ 8,000	$ 3,229	$ 1,111	$ 4,429	$ 479	$ 53	$ 17,301
Realized (gains) losses on crop derivatives		—	—	3	—	—	—	3
Adjusted losses and loss expenses	A	$ 8,000	$ 3,229	$ 1,114	$ 4,429	$ 479	$ 53	$ 17,304
Catastrophe losses and related adjustments								
Catastrophe losses, net of related adjustments		(579)	(637)	(21)	(206)	(183)	—	(1,626)
Reinstatement premiums collected (expensed) on catastrophe losses		—	(26)	—	—	22	—	(4)
Catastrophe losses, gross of related adjustments		(579)	(611)	(21)	(206)	(205)	—	(1,622)
PPD and related adjustments								
PPD, net of related adjustments - favorable (unfavorable)		610	(41)	110	212	50	(45)	896
Net premiums earned adjustments on PPD - unfavorable (favorable)		29	—	40	—	8	—	77
Expense adjustments - unfavorable (favorable)		7	—	(10)	—	(1)	—	(4)
PPD reinstatement premiums - unfavorable (favorable)		7	1	—	4	—	—	12
PPD, gross of related adjustments - favorable (unfavorable)		653	(40)	140	216	57	(45)	981
CAY loss and loss expense ex CATs	B	$ 8,074	$ 2,578	$ 1,233	$ 4,439	$ 331	$ 8	$ 16,663
Policy acquisition costs and administrative expenses								
Policy acquisition costs and administrative expenses	C	$ 2,795	$ 1,208	$ 70	$ 3,360	$ 203	$ 295	$ 7,931
Expense adjustments - favorable (unfavorable)		(7)	—	10	—	1	—	4
Policy acquisition costs and administrative expenses, adjusted	D	$ 2,788	$ 1,208	$ 80	$ 3,360	$ 204	$ 295	$ 7,935
Denominator								
Net premiums earned	E	$ 12,402	$ 4,593	$ 1,569	$ 8,612	$ 670		$ 27,846
Reinstatement premiums (collected) expensed on catastrophe losses		—	26	—	—	(22)		4
Net premiums earned adjustments on PPD - unfavorable (favorable)		29	—	40	—	8		77
PPD reinstatement premiums - unfavorable (favorable)		7	1	—	4	—		12
Net premiums earned excluding adjustments	F	$ 12,438	$ 4,620	$ 1,609	$ 8,616	$ 656		$ 27,939
P&C Combined ratio								
Loss and loss expense ratio	A/E	64.5%	70.3%	71.0%	51.4%	71.6%		62.1%
Policy acquisition cost and administrative expense ratio	C/E	22.5%	26.3%	4.5%	39.0%	30.2%		28.5%
P&C Combined ratio		87.0%	96.6%	75.5%	90.4%	101.8%		90.6%
CAY P&C Combined ratio ex CATs								
Loss and loss expense ratio, adjusted	B/F	64.9%	55.8%	76.7%	51.5%	50.5%		59.6%
Policy acquisition cost and administrative expense ratio, adjusted	D/F	22.4%	26.1%	4.9%	39.0%	31.1%		28.4%
CAY P&C Combined ratio ex CATs		87.3%	81.9%	81.6%	90.5%	81.6%		88.0%
Combined ratio								
Combined ratio								90.6%
Add: impact of gains and losses on crop derivatives								—
P&C Combined ratio								90.6%

Note: The ratios above are calculated using whole U.S. dollars. Accordingly, calculations using rounded amounts may differ. Letters A, B, C, D, E and F included in the table are references for calculating the ratios above.

Net Investment Income

(in millions of U.S. dollars, except for percentages)	**2019**	2018	2017
Average invested assets	**$ 104,074**	$ 101,453	$ 99,675
Net investment income [1]	**$ 3,426**	$ 3,305	$ 3,125
Yield on average invested assets	**3.3%**	3.3%	3.1%
Market yield on fixed maturities	**2.7%**	3.7%	2.9%

(1) Includes $161 million, $248 million and $332 million of amortization expense related to the fair value adjustment of acquired invested assets related to the Chubb Corp acquisition in 2019, 2018 and 2017, respectively.

Net investment income is influenced by a number of factors including the amounts and timing of inward and outward cash flows, the level of interest rates, and changes in overall asset allocation. Net investment income increased 3.6 percent in 2019 compared with 2018, primarily due to higher average invested assets, partially offset by a reduction in the usage of notional cash pooling programs and unfavorable foreign exchange. Net investment income increased 5.8 percent in 2018 compared with 2017, primarily due to higher reinvestment rates offset by lower private equity distributions. Refer to Note 3 g) to the Consolidated Financial Statements for additional information.

For private equities where we own less than three percent, investment income is included within Net investment income in the table above. For private equities where we own more than three percent, investment income is included within Other income (expense) in the Consolidated statements of operations. Excluded from Net investment income is the mark-to-market movement for private equities, which is recorded within either Other income (expense) or Net realized gains (losses) based on our percentage of ownership. The total mark-to-market movement for private equities excluded from Net investment income was as follows:

(in millions of U.S. dollars)	**2019**	2018
Total mark-to-market gain on private equity, pre-tax	**$ 449**	$ 298

Interest Expense

The following table presents our pre-tax interest expense for the years ended December 31, 2019 and 2018. Also presented below is our estimated pre-tax interest expense for the year ended December 31, 2020 based on our existing debt obligations as well as fees based on our expected usage of certain facilities, including letters of credit, collateral fees, and repurchase agreements.

	Estimated Interest Expense					Actual Interest Expense	
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Full Year	**Full Year**	Full Year
(in millions of U.S. dollars)	2020	2020	2020	2020	2020	**2019**	2018
Fixed interest expense based on outstanding debt	$ 123	$ 123	$ 122	$ 118	$ 486	**$ 488**	$ 520
Variable interest expense based on expected usage	18	18	18	18	72	**85**	154
Adjusted interest expense	$ 141	$ 141	$ 140	$ 136	$ 558	**$ 573**	$ 674
Amortization of the fair value of debt assumed in the Chubb Corp acquisition	(5)	(5)	(5)	(6)	(21)	**(21)**	(33)
Total interest expense, including amortization of the fair value of debt	$ 136	$ 136	$ 135	$ 130	$ 537	**$ 552**	$ 641

Estimated 2020 fixed interest expense assumes that the $1.3 billion 2.3 percent senior notes is fully paid in November 2020 at the maturity date. Estimated variable interest expense is based on expected usage and current interest rates and may fluctuate.

Net Realized and Unrealized Gains (Losses)

We take a long-term view with our investment strategy, and our investment managers manage our investment portfolio to maximize total return within certain specific guidelines designed to minimize risk. The majority of our investment portfolio is available for sale and reported at fair value. Our held to maturity investment portfolio is reported at amortized cost.

The effect of market movements on our fixed maturities portfolio impacts Net income (through Net realized gains (losses)) when securities are sold or when we record an Other-than-temporary impairment (OTTI) charge. For a further discussion related to how we assess OTTI for our fixed maturities, including credit-related OTTI, and the related impact on Net income, refer to Note 3 c) to the Consolidated Financial Statements. Additionally, Net income is impacted through the reporting of changes in the fair value of equity securities and private equity securities where we own less than three percent, and derivatives, including financial futures, options, swaps, and GLB reinsurance. Changes in unrealized appreciation and depreciation on available for sale securities resulting from the revaluation of securities held, changes in cumulative foreign currency translation adjustment, and unrealized postretirement benefit obligations liability adjustment, are reported as separate components of Accumulated other comprehensive income (loss) in Shareholders' equity in the Consolidated balance sheets. The following table presents our net realized and unrealized gains (losses):

	Year Ended December 31						
	2019			2018			2017
(in millions of U.S. dollars)	**Net Realized Gains (Losses)**	**Net Unrealized Gains (Losses)**	**Net Impact**	Net Realized Gains (Losses)	Net Unrealized Gains (Losses)	Net Impact	Net Realized Gains (Losses)
Fixed maturities	**$ (31)**	**$ 3,738**	**$ 3,707**	$ (302)	$ (1,996)	$ (2,298)	$ (31)
Fixed income and equity derivatives	**(435)**	**—**	**(435)**	(75)	—	(75)	(11)
Public equity							
Sales	**58**	**—**	**58**	70	—	70	16
Mark-to-market	**46**	**—**	**46**	(129)	—	(129)	—
Private equity (less than 3 percent ownership)							
Sales	**(5)**	**—**	**(5)**	121	—	121	(11)
Mark-to-market	**(15)**	**—**	**(15)**	(126)	—	(126)	—
Total investment portfolio	**(382)**	**3,738**	**3,356**	(441)	(1,996)	(2,437)	(37)
Variable annuity reinsurance derivative transactions, net of applicable hedges	**(142)**	**—**	**(142)**	(252)	—	(252)	103
Other derivatives	**(8)**	**—**	**(8)**	(3)	—	(3)	(5)
Foreign exchange	**7**	**13**	**20**	131	(802)	(671)	36
Other [(1)]	**(5)**	**(79)**	**(84)**	(87)	(321)	(408)	(13)
Net gains (losses), pre-tax	**$ (530)**	**$ 3,672**	**$ 3,142**	$ (652)	$ (3,119)	$ (3,771)	$ 84

(1) Net unrealized gains (losses) includes our postretirement programs of $(76) million, $(321) million, and $(16) million for the years ended December 31, 2019, 2018, and 2017, respectively.

For the years ended December 31, 2019 and 2018, other-than-temporary impairments in Net realized gains (losses) include $58 million and $49 million, respectively, for fixed maturities.

The variable annuity reinsurance derivative transactions resulted in realized gains (losses), due to the (increase) decrease in the fair value of GLB liabilities of $(4) million, $(248) million, and $364 million for the years ended December 31, 2019, 2018, and 2017, respectively. The realized losses in 2019 reflected an increase in the fair value of GLB liabilities due to lower interest rates and changes made to our valuation model relating to policyholder behavior which was partially offset by higher global equity market levels. The realized losses in 2018 reflected an increase in the fair value of GLB liabilities due to lower global equity market levels, the impact of discounting future claims for one less year and changes made to our valuation model relating to policyholder behavior. In addition, we maintain positions in derivative instruments that decrease in fair value when the S&P 500 index increases. During the years ended December 31, 2019, 2018, and 2017, we experienced realized losses of $138 million, $4 million, and $261 million, respectively, related to these derivative instruments.

Amortization of Purchased Intangibles and Other Amortization

Amortization expense related to purchased intangibles were \$305 million, \$339 million, and \$260 million for the years ended December 31, 2019, 2018, and 2017, respectively, and principally relates to the Chubb Corp acquisition. The decrease in amortization expense of purchased intangibles in 2019 compared to 2018 primarily reflects lower intangible amortization expense related to agency distribution relationships and renewal rights. The increase in 2018 compared to 2017 primarily reflects a lower amortization benefit from the fair value adjustment on unpaid losses and loss expenses. The amortization of purchased intangibles expense in 2020 is expected to be \$290 million, or approximately \$73 million each quarter.

Reduction of deferred tax liability associated with intangible assets related to Other intangible assets (excluding the fair value adjustment on Unpaid losses and loss expense)

At December 31, 2019, the deferred tax liability associated with the Other intangible assets (excluding the fair value adjustment on Unpaid losses and loss expenses) was \$1,347 million.

The following table presents at December 31, 2019, the expected reduction to the deferred tax liability associated with Other intangible assets (which reduces as agency distribution relationships and renewal rights, and other intangible assets amortize), at current foreign currency exchange rates for the next five years:

For the Years Ending December 31 (in millions of U.S. dollars)	Reduction to deferred tax liability associated with intangible assets
2020	$ 72
2021	67
2022	64
2023	60
2024	55
Total	$ 318

Amortization of the fair value adjustment on acquired invested assets and assumed long-term debt

The following table presents at December 31, 2019, the expected amortization expense of the fair value adjustment on acquired invested assets, at current foreign currency exchange rates, and the expected amortization benefit from the amortization of the fair value adjustment on assumed long-term debt for the next five years as follows:

	Amortization (expense) benefit of the fair value adjustment on	
For the Years Ending December 31 (in millions of U.S. dollars)	Acquired invested assets (1)	Assumed long-term debt (2)
2020	$ (130)	$ 21
2021	(110)	21
2022	(92)	21
2023	—	21
2024	—	21
Total	$ (332)	$ 105

(1) Recorded as a reduction to Net investment income in the Consolidated statements of operations.

(2) Recorded as a reduction to Interest expense in the Consolidated statements of operations.

The estimate of amortization expense of the fair value adjustment on acquired invested assets could vary materially based on current market conditions, bond calls, overall duration of the acquired investment portfolio, and foreign exchange.

Investments

Our investment portfolio is invested primarily in publicly traded, investment grade, fixed income securities with an average credit quality of A/Aa as rated by the independent investment rating services Standard and Poor's (S&P)/ Moody's Investors Service (Moody's). The portfolio is externally managed by independent, professional investment managers and is broadly diversified across geographies, sectors, and issuers. Other investments principally comprise direct investments, investment funds, and limited partnerships. We hold no collateralized debt obligations in our investment portfolio, and we provide no credit default protection. We have long-standing global credit limits for our entire portfolio across the organization. Exposures are aggregated, monitored, and actively managed by our Global Credit Committee, comprising senior executives, including our Chief Financial Officer, our Chief Risk Officer, our Chief Investment Officer, and our Treasurer. We also have well-established, strict contractual investment rules requiring managers to maintain highly diversified exposures to individual issuers and closely monitor investment manager compliance with portfolio guidelines. The average duration of our fixed income securities, including the effect of options and swaps, was 3.8 years and 3.7 years at December 31, 2019 and 2018, respectively. We estimate that a 100 basis point (bps) increase in interest rates would reduce the valuation of our fixed income portfolio by approximately $3.9 billion at December 31, 2019.

	December 31, 2019		December 31, 2018	
(in millions of U.S. dollars)	**Fair Value**	**Cost/ Amortized Cost**	Fair Value	Cost/ Amortized Cost
Fixed maturities available for sale	**$ 85,488**	**$ 82,580**	$ 78,470	$ 79,323
Fixed maturities held to maturity	**13,005**	**12,581**	13,259	13,435
Short-term investments	**4,291**	**4,291**	3,016	3,016
	102,784	**99,452**	94,745	95,774
Equity securities	**812**	**812**	770	770
Other investments	**6,062**	**6,062**	5,277	5,277
Total investments	**$ 109,658**	**$ 106,326**	$ 100,792	$ 101,821

The fair value of our total investments increased $8.9 billion during the year ended December 31, 2019, primarily due to unrealized appreciation driven by declining interest rates and the investing of both operating cash flows and net proceeds from debt issuance. This increase was partially offset by the payment of dividends on our Common Shares and share repurchases.

The following tables present the market value of our fixed maturities and short-term investments at December 31, 2019 and 2018. The first table lists investments according to type and the second according to S&P credit rating:

	December 31, 2019		December 31, 2018	
(in millions of U.S. dollars, except for percentages)	**Market Value**	**% of Total**	Market Value	% of Total
Treasury / Agency	**$ 4,630**	**5%**	$ 5,327	6%
Corporate and asset-backed	**34,259**	**33%**	29,091	31%
Mortgage-backed	**21,588**	**21%**	18,026	19%
Municipal	**12,824**	**12%**	16,327	17%
Non-U.S.	**25,192**	**25%**	22,958	24%
Short-term investments	**4,291**	**4%**	3,016	3%
Total	**$ 102,784**	**100%**	$ 94,745	100%
AAA	**$ 15,714**	**15%**	$ 14,571	15%
AA	**37,504**	**37%**	36,715	39%
A	**19,236**	**19%**	17,253	18%
BBB	**13,650**	**13%**	12,035	13%
BB	**9,474**	**9%**	8,363	9%
B	**6,897**	**7%**	5,596	6%
Other	**309**	**—**	212	—
Total	**$ 102,784**	**100%**	$ 94,745	100%

Corporate and asset-backed securities

The following table presents our 10 largest global exposures to corporate bonds by market value at December 31, 2019:

(in millions of U.S. dollars)	Market Value
Wells Fargo & Co	$ 637
Bank of America Corp	575
JP Morgan Chase & Co	568
Comcast Corp	461
HSBC Holdings Plc	396
AT&T Inc	392
Citigroup Inc	392
Verizon Communications Inc	381
Goldman Sachs Group Inc	369
Morgan Stanley	358

Mortgage-backed securities

	S&P Credit Rating					Market Value	Amortized Cost
December 31, 2019 (in millions of U.S. dollars)	AAA	AA	A	BBB	BB and below	Total	Total
Agency residential mortgage-backed (RMBS)	$ 187	$ 17,722	$ —	$ —	$ —	$ 17,909	$ 17,436
Non-agency RMBS	184	32	75	18	10	319	317
Commercial mortgage-backed	2,946	272	136	6	—	3,360	3,290
Total mortgage-backed securities	$ 3,317	$ 18,026	$ 211	$ 24	$ 10	$ 21,588	$ 21,043

Municipal

As part of our overall investment strategy, we may invest in states, municipalities, and other political subdivisions fixed maturity securities (Municipal). We apply the same investment selection process described previously to our Municipal investments. The portfolio is highly diversified primarily in state general obligation bonds and essential service revenue bonds including education and utilities (water, power, and sewers).

Non-U.S.

Our exposure to the Euro results primarily from Chubb European Group SE which is headquartered in France and offers a broad range of coverages throughout the European Union, Central, and Eastern Europe. Chubb primarily invests in Euro denominated investments to support its local currency insurance obligations and required capital levels. Chubb's local currency investment portfolios have strict contractual investment guidelines requiring managers to maintain a high quality and diversified portfolio to both sector and individual issuers. Investment portfolios are monitored daily to ensure investment manager compliance with portfolio guidelines.

Our non-U.S. investment grade fixed income portfolios are currency-matched with the insurance liabilities of our non-U.S. operations. The average credit quality of our non-U.S. fixed income securities is A and 49 percent of our holdings are rated AAA or guaranteed by governments or quasi-government agencies. Within the context of these investment portfolios, our government and corporate bond holdings are highly diversified across industries and geographies. Issuer limits are based on credit rating (AA—two percent, A—one percent, BBB—0.5 percent of the total portfolio) and are monitored daily via an internal compliance system. We manage our indirect exposure using the same credit rating based investment approach. Accordingly, we do not believe our indirect exposure is material.

The following table summarizes the market value and amortized cost of our non-U.S. fixed income portfolio by country/sovereign for non-U.S. government securities at December 31, 2019:

(in millions of U.S. dollars)	Market Value	Amortized Cost
Republic of Korea	$ 1,032	$ 920
United Kingdom	924	903
Canada	835	830
Federative Republic of Brazil	688	669
Kingdom of Thailand	652	558
Province of Ontario	644	634
United Mexican States	567	554
Province of Quebec	496	484
Commonwealth of Australia	365	324
Socialist Republic of Vietnam	362	277
Other Non-U.S. Government Securities	4,890	4,706
Total	$ 11,455	$ 10,859

The following table summarizes the market value and amortized cost of our non-U.S. fixed income portfolio by country/sovereign for non-U.S. corporate securities at December 31, 2019:

(in millions of U.S. dollars)	Market Value	Amortized Cost
United Kingdom	$ 2,316	$ 2,224
Canada	1,781	1,735
United States [(1)]	1,156	1,111
France	1,136	1,088
Australia	813	781
Netherlands	685	656
Japan	587	576
Germany	560	538
Switzerland	511	490
China	371	362
Other Non-U.S. Corporate Securities	3,821	3,673
Total	$ 13,737	$ 13,234

(1) The countries that are listed in the non-U.S. corporate fixed income portfolio above represent the ultimate parent company's country of risk. Non-U.S. corporate securities could be issued by foreign subsidiaries of U.S. corporations.

Below-investment grade corporate fixed income portfolio
Below-investment grade securities have different characteristics than investment grade corporate debt securities. Risk of loss from default by the borrower is greater with below-investment grade securities. Below-investment grade securities are generally unsecured and are often subordinated to other creditors of the issuer. Also, issuers of below-investment grade securities usually have higher levels of debt and are more sensitive to adverse economic conditions, such as recession or increasing interest rates, than investment grade issuers. At December 31, 2019, our corporate fixed income investment portfolio included below-investment grade and non-rated securities which, in total, comprised approximately 14 percent of our fixed income portfolio. Our below-investment grade and non-rated portfolio includes over 1,300 issuers, with the greatest single exposure being $149 million.

We manage high-yield bonds as a distinct and separate asset class from investment grade bonds. The allocation to high-yield bonds is explicitly set by internal management and is targeted to securities in the upper tier of credit quality (BB/B). Our minimum rating for initial purchase is BB/B. Twelve external investment managers are responsible for high-yield security selection and portfolio construction. Our high-yield managers have a conservative approach to credit selection and very low historical default experience. Holdings are highly diversified across industries and generally subject to a 1.5 percent issuer limit as a percentage of high-yield allocation. We monitor position limits daily through an internal compliance system. Derivative and structured securities (e.g., credit default swaps and collateralized loan obligations) are not permitted in the high-yield portfolio.

Asbestos and Environmental (A&E)

Asbestos and environmental (A&E) reserving considerations
For asbestos, Chubb faces claims relating to policies issued to manufacturers, distributors, installers, and other parties in the chain of commerce for asbestos and products containing asbestos. Claimants will generally allege damages across an extended time period which may coincide with multiple policies covering a wide range of time periods for a single insured.

Environmental claims present exposure for remediation and defense costs associated with the contamination of property as a result of pollution.

The following table presents count information for asbestos claims by causative agent and environmental claims by account, for direct policies only:

	Asbestos (by causative agent)		Environmental (by account)	
	2019	2018	**2019**	2018
Open at beginning of year	**1,838**	1,789	**1,361**	1,349
Newly reported/reopened	**173**	188	**140**	149
Closed or otherwise disposed	**287**	139	**284**	137
Open at end of year	**1,724**	1,838	**1,217**	1,361

Survival ratios are calculated by dividing the asbestos or environmental loss and allocated loss adjustment expense (ALAE) reserves by the average asbestos or environmental loss and ALAE payments for the three most recent calendar years (3-year survival ratio). The 3-year survival ratios for gross and net Asbestos loss and ALAE reserves were 5.8 years and 6.0 years, respectively. The 3-year survival ratios for gross and net Environmental loss and ALAE reserves were 4.0 years and 12.1 years, respectively. The net 3-year survival ratios were impacted by favorable reinsurance settlements in 2018. Excluding the settlements, the 3-year survival ratio for net Asbestos loss and ALAE reserves and net Environmental loss and ALAE reserves were 5.7 years and 4.5 years, respectively. Refer to the PPD section in Note 7 to the consolidated financial statements for additional information on the settlements. The survival ratios provide only a very rough depiction of reserves and are significantly impacted by a number of factors such as aggressive settlement practices, variations in gross to ceded relationships within the asbestos or environmental claims, and levels of coverage provided. Therefore, we urge caution in using these very simplistic ratios to gauge reserve adequacy.

Catastrophe Management

We actively monitor and manage our catastrophe risk accumulation around the world such as setting risk limits based on probable maximum loss (PML) and purchasing catastrophe reinsurance. The table below presents our modeled pre-tax estimates of natural catastrophe PML, net of reinsurance, at December 31, 2019, for Worldwide, U.S. hurricane and California earthquake events, based on our in-force portfolio at October 1, 2019 and reflecting the April 1, 2019 reinsurance program (see Natural Catastrophe Property Reinsurance Program section) as well as inuring reinsurance protection coverages. According to the model, for the 1-in-100 return period scenario, there is a one percent chance that our pre-tax annual aggregate losses incurred in any year from U.S. hurricane events could be in excess of $2,685 million (or 4.9 percent of our total shareholders' equity at December 31, 2019). These estimates assume that reinsurance recoverable is fully collectible.

	Modeled Net Probable Maximum Loss (PML) Pre-tax					
	Worldwide [1] Annual Aggregate		U.S. Hurricane [2] Annual Aggregate		California Earthquake [3] Single Occurrence	
(in millions of U.S. dollars, except for percentages)	**Chubb**	**% of Total Shareholders' Equity**	**Chubb**	**% of Total Shareholders' Equity**	**Chubb**	**% of Total Shareholders' Equity**
1-in-10	$ 1,873	3.4%	$ 1,089	2.0%	$ 129	0.2%
1-in-100	$ 3,804	6.9%	$ 2,685	4.9%	$ 1,338	2.4%
1-in-250	$ 6,227	11.3%	$ 4,698	8.5%	$ 1,513	2.7%

(1) Worldwide losses are comprised of losses arising only from hurricanes, typhoons, convective storms and earthquakes and do not include "non-modeled" perils such as wildfire and flood.

(2) U.S. Hurricane losses include losses from wind and storm-surge and exclude rainfall.

(3) California earthquakes include fire-following perils.

The above estimates of Chubb's loss profile are inherently uncertain for many reasons, including the following:

- While the use of third-party catastrophe modeling packages to simulate potential hurricane and earthquake losses is prevalent within the insurance industry, the models are reliant upon significant meteorology, seismology, and engineering assumptions to estimate catastrophe losses. In particular, modeled catastrophe events are not always a representation of actual events and ensuing additional loss potential;
- There is no universal standard in the preparation of insured data for use in the models, the running of the modeling software and interpretation of loss output. These loss estimates do not represent our potential maximum exposures and it is highly likely that our actual incurred losses would vary materially from the modeled estimates; and
- The potential effects of climate change add to modeling complexity.

Natural Catastrophe Property Reinsurance Program

Chubb's core property catastrophe reinsurance program provides protection against natural catastrophes impacting its primary property operations (i.e., excluding our Global Reinsurance and Life Insurance segments).

We regularly review our reinsurance protection and corresponding property catastrophe exposures. This may or may not lead to the purchase of additional reinsurance prior to a program's renewal date. In addition, prior to each renewal date, we consider how much, if any, coverage we intend to buy and we may make material changes to the current structure in light of various factors, including modeled PML assessment at various return periods, reinsurance pricing, our risk tolerance and exposures, and various other structuring considerations.

Chubb renewed its Global Property Catastrophe Reinsurance Program for our North American and International operations effective April 1, 2019 through March 31, 2020, with modest enhancements in coverage from the expiring program. The program consists of three layers in excess of losses retained by Chubb on a per occurrence basis. In addition, Chubb also renewed its terrorism coverage (excluding nuclear, biological, chemical and radiation coverage, with an inclusion of coverage for biological and chemical coverage for personal lines) for the United States from April 1, 2019 through March 31, 2020 with the same limits and retention and percentage placed except that the majority of terrorism coverage is on an aggregate basis above our retentions without a reinstatement.

Natural Catastrophe Property Reinsurance Program

Loss Location	Layer of Loss	Comments	Notes
United States (excluding Alaska and Hawaii)	$0 million – $1.0 billion	Losses retained by Chubb	(a)
United States (excluding Alaska and Hawaii)	$1.0 billion – $1.2 billion	All natural perils and terrorism	(b)
United States (excluding Alaska and Hawaii)	$1.2 billion – $2.2 billion	All natural perils and terrorism	(c)
United States (excluding Alaska and Hawaii)	$2.2 billion – $3.5 billion	All natural perils and terrorism	(d)
International (including Alaska and Hawaii)	$0 million – $175 million	Losses retained by Chubb	(a)
International (including Alaska and Hawaii)	$175 million – $1.175 billion	All natural perils and terrorism	(c)
Alaska, Hawaii, and Canada	$1.175 billion– $2.475 billion	All natural perils and terrorism	(d)

(a) Ultimate retention will depend upon the nature of the loss and the interplay between the underlying per risk programs and certain other catastrophe programs purchased by individual business units. These other catastrophe programs have the potential to reduce our effective retention below the stated levels.

(b) These coverages are partially placed with Reinsurers.

(c) These coverages are both part of the same Second layer within the Global Catastrophe Program and are fully placed with Reinsurers.

(d) These coverages are both part of the same Third layer within the Global Catastrophe Program and are fully placed with Reinsurers.

Chubb also has a property catastrophe bond in place that offers additional natural catastrophe protection for certain parts of the portfolio. The geographic scope of this coverage is from Virginia through Maine. The East Lane VI 2015 bond currently provides $250 million of coverage as part of a $427 million layer in excess of $2.0 billion retention through March 13, 2020.

Political Risk and Credit Insurance

Political risk insurance is a specialized coverage that provides clients with protection against unexpected, catastrophic political or macroeconomic events, primarily in emerging markets. We participate in this market through our wholly-owned subsidiary Sovereign Risk Insurance Ltd. (Sovereign), and through a unit of our London-based CGM operation. Chubb is one of the world's leading underwriters of political risk and credit insurance, has a global portfolio spread across more than 150 countries and is also a member of the Berne Union. Our clients include financial institutions, national export credit agencies, leading multilateral agencies, private equity firms and multinational corporations. CGM writes political risk and credit insurance business out of underwriting offices in London, United Kingdom; Hamburg, Germany; Sao Paulo, Brazil; Singapore; Tokyo, Japan; and in the U.S. in the following locations: Chicago, Illinois; New York, New York; Los Angeles, California; and Washington, D.C.

Our political risk insurance provides protection to commercial lenders against defaults on cross border loans, insulates investors against equity losses, and protects exporters against defaults on contracts. Commercial lenders, our largest client segment, are covered for missed scheduled loan repayments due to acts of confiscation, expropriation or nationalization by the host government, currency inconvertibility or exchange transfer restrictions, or war or other acts of political violence. In addition, in the case of loans to government-owned entities or loans that have a government guarantee, political risk policies cover scheduled payments against risks of non-payment or non-honoring of government guarantees. Private equity investors and corporations receive similar coverage to that of lenders, except their equity is protected against financial losses, inability to repatriate dividends, and physical damage to their operations caused by covered events. Our export contracts protection provides coverage for both exporters and their financing banks against the risk of contract frustration due to government actions, including non-payment by governmental entities.

CGM's credit insurance businesses cover losses due to insolvency, protracted default, and political risk perils including export and license cancellation. Our credit insurance product provides coverage to larger companies that have sophisticated credit risk management systems, with exposure to multiple customers and that have the ability to self-insure losses up to a certain level through excess of loss coverage. It also provides coverage to trade finance banks, exporters, and trading companies, with exposure to trade-related financing instruments. CGM also has limited capacity for Specialist Credit insurance products which provide coverage for project finance and working capital loans for large corporations and banks.

We have implemented structural features in our policies in order to control potential losses within the political risk and credit insurance businesses. These include basic loss sharing features that include co-insurance and deductibles, and in the case of trade credit, the use of non-qualifying losses that drop smaller exposures deemed too difficult to assess. Ultimate loss severity is also limited by using waiting periods to enable the insurer and insured to agree on recovery strategies, and the subrogation of the rights of the lender/exporter to the insurer following a claim. We have the option to pay claims over the original loan payment schedule, rather than in a lump sum in order to provide insureds and the insurer additional time to remedy problems and work towards full recoveries. It is important to note that political risk and credit policies are named peril conditional contracts, not financial guarantees, and claims are only paid after conditions and warranties are fulfilled. Political risk and credit insurance do not cover currency devaluations, bond defaults, movements in overseas equity markets, transactions deemed illegal, situations where corruption or misrepresentation has occurred, or debt that is not legally enforceable. In addition to assessing and mitigating potential exposure on a policy-by-policy basis, we also have specific risk management measures in place to manage overall exposure and risk. These measures include placing country, credit, and individual transaction limits based on country risk and credit ratings, combined single loss limits on multi-country policies, the use of reinsurance protection as well as quarterly modeling and stress-testing of the portfolio. We have a dedicated Country and Credit Risk management team that are responsible for the portfolio.

Crop Insurance

We are, and have been since the 1980s, one of the leading writers of crop insurance in the U.S. and have conducted that business through a managing general agent subsidiary of Rain and Hail. We provide protection throughout the U.S. on a variety of crops and are therefore geographically diversified, which reduces the risk of exposure to a single event or a heavy accumulation of losses in any one region. Our crop insurance business comprises two components - Multiple Peril Crop Insurance (MPCI) and crop-hail insurance.

The MPCI program, offered in conjunction with the U.S. Department of Agriculture’s Risk Management Agency (RMA), is a federal subsidized insurance program that covers revenue shortfalls or production losses due to natural causes such as drought, excessive moisture, hail, wind, freeze, insects, and disease. These Revenue Products are defined as providing both commodity price and yield coverages. Policies are available for various crops in different areas of the U.S. and generally have deductibles generally ranging from 10 percent to 50 percent of the insured's risk. The USDA's Risk Management Agency (RMA) sets the policy terms and conditions, rates and forms, and is also responsible for setting compliance standards. As a participant in the MPCI program, we report all details of policies to the RMA and are party to a Standard Reinsurance Agreement (SRA). The SRA sets out the relationship between private insurance companies and the Federal Crop Insurance Corporation (FCIC) concerning the terms and conditions regarding the risks each will bear including the pro-rata and state stop-loss provisions, which allows companies to limit the exposure of any one state or group of states on their underwriting results. In addition to the pro-rata and excess of loss reinsurance protections inherent in the SRA, we also purchase third-party proportional and stop-loss reinsurance for our MPCI business to reduce our exposure. We may also enter into crop derivative contracts to further manage our risk exposure.

Each year the RMA issues a final SRA for the subsequent reinsurance year (i.e., the 2020 SRA covers the 2020 reinsurance year from July 1, 2019 through June 30, 2020). There were no significant changes in the terms and conditions from the 2019 SRA and therefore, the new SRA does not impact Chubb's outlook on the crop program relative to 2020.

We recognize net premiums written as soon as estimable on our MPCI business, which is generally when we receive acreage reports from the policyholders on the various crops throughout the U.S. This allows us to best determine the premium associated with the liability that is being planted. The MPCI program has specific timeframes as to when producers must report acreage to us and in certain cases, the reporting occurs after the close of the respective reinsurance year. Once the net premium written has been recorded, the premium is then earned over the growing season for the crops. A majority of the crops that are covered in the program are typically subject to the SRA in effect at the beginning of the year. Given the major crops covered in the program, we typically see a substantial written and earned premium impact in the second and third quarters.

The pricing of MPCI premium is determined using a number of factors including commodity prices and related volatility (i.e., both impact the amount of premium we can charge to the policyholder). For example, in most states, the pricing for the MPCI Revenue Product for corn (i.e., insurance coverage for lower than expected crop revenue in a given season) includes a factor based on the average commodity price in February. If corn commodity prices are higher in February, compared to the February price in the prior year, and all other factors are the same, the increase in price will increase the corn premium year-over-year.

Pricing is also impacted by volatility factors, which measure the likelihood commodity prices will fluctuate over the crop year. For example, if volatility is set at a higher rate compared to the prior year, and all other factors are the same, the premium charged to the policyholder will be higher year-over-year for the same level of coverage.

Losses incurred on the MPCI business are determined using both commodity price and crop yield. With respect to commodity price, there are two important periods on a large portion of the business: The month of February when the initial premium base is set, and the month of October when the final harvest price is set. If the price declines from February to October, with yield remaining at normal levels, the policyholder may be eligible to recover on the policy. However, in most cases there are deductibles on these policies, therefore, the impact of a decline in price would have to exceed the deductible before a policyholder would be eligible to recover.

We evaluate our MPCI business at an aggregate level and the combination of all of our insured crops (both winter and summer) go into our underwriting gain or loss estimate in any given year. Typically, we do not have enough information on the harvest prices or crop yield outputs to quantify the preliminary estimated impact to our underwriting results until the fourth quarter.

Our crop-hail program is a private offering. Premium is earned on the crop-hail program over the coverage period of the policy. Given the very short nature of the growing season, most crop-hail business is typically written in the second and third quarters and the recognition of earned premium is also more heavily concentrated during this timeframe. We use industry data to develop our own rates and forms for the coverage offered. The policy primarily protects farmers against yield reduction caused by hail and/or fire, and related costs such as transit to storage. We offer various deductibles to allow the grower to partially self-insure for a reduced premium cost. We limit our crop-hail exposures through the use of township liability limits and third-party reinsurance on our net retained hail business.

Liquidity

Liquidity is a measure of a company's ability to generate cash flows sufficient to meet short-term and long-term cash requirements. As a holding company, Chubb Limited possesses assets that consist primarily of the stock of its subsidiaries and other investments. In addition to net investment income, Chubb Limited's cash flows depend primarily on dividends and other statutorily permissible payments. Historically, dividends and other statutorily permitted payments have come primarily from Chubb's Bermuda-based operating subsidiaries, which we refer to as our Bermuda subsidiaries. Our consolidated sources of funds consist primarily of net premiums written, fees, net investment income, and proceeds from sales and maturities of investments. Funds are used at our various companies primarily to pay claims, operating expenses, and dividends; to service debt; to purchase investments; and to fund acquisitions.

We anticipate that positive cash flows from operations (underwriting activities and investment income) should be sufficient to cover cash outflows under most loss scenarios for the near term. Should the need arise, we generally have access to capital markets and available credit facilities. Refer to “Credit Facilities” below for additional information. Our access to funds under the existing credit facility is dependent on the ability of the bank that is a party to the facility to meet its funding commitments. Should our existing credit provider experience financial difficulty, we may be required to replace credit sources, possibly in a difficult market. If we cannot obtain adequate capital or sources of credit on favorable terms, on a timely basis, or at all, our business, operating results, and financial condition could be adversely affected. To date, we have not experienced difficulty accessing our credit facility.

To further ensure the sufficiency of funds to settle unforeseen claims, we hold certain invested assets in cash and short-term investments. In addition, for certain insurance, reinsurance, or deposit contracts that tend to have relatively large and reasonably predictable cash outflows, we attempt to establish dedicated portfolios of assets that are duration-matched with the related liabilities. With respect to the duration of our overall investment portfolio, we manage asset durations to both maximize return given current market conditions and provide sufficient liquidity to cover future loss payments. At December 31, 2019, the average duration of our fixed maturities (3.8 years) is less than the average expected duration of our insurance liabilities (4.3 years).

Despite our safeguards, if paid losses accelerate beyond our ability to fund such paid losses from current operating cash flows, we might need to either liquidate a portion of our investment portfolio or arrange for financing. Potential events causing such a liquidity strain could include several significant catastrophes occurring in a relatively short period of time, large uncollectible reinsurance recoverables on paid losses (as a result of coverage disputes, reinsurers' credit problems, or decreases in the value of collateral supporting reinsurance recoverables) or increases in collateral postings under our variable annuity reinsurance business. Because each subsidiary focuses on a more limited number of specific product lines than is collectively available from the Chubb Group of Companies, the mix of business tends to be less diverse at the subsidiary level. As a result, the probability of a liquidity strain, as described above, may be greater for individual subsidiaries than when liquidity is assessed on a consolidated basis. If such a liquidity strain were to occur in a subsidiary, we could be required to liquidate a portion of our investments, potentially at distressed prices, as well as be required to contribute capital to the particular subsidiary and/or curtail dividends from the subsidiary to support holding company operations.

The payment of dividends or other statutorily permissible distributions from our operating companies are subject to the laws and regulations applicable to each jurisdiction, as well as the need to maintain capital levels adequate to support the insurance and reinsurance operations, including financial strength ratings issued by independent rating agencies. During 2019, we were able to meet all our obligations, including the payments of dividends on our Common Shares, with our net cash flows.

We assess which subsidiaries to draw dividends from based on a number of factors. Considerations such as regulatory and legal restrictions as well as the subsidiary's financial condition are paramount to the dividend decision. Chubb Limited received dividends of $200 million and $75 million from its Bermuda subsidiaries in 2019 and 2018, respectively.

The payment of any dividends from CGM or its subsidiaries is subject to applicable U.K. insurance laws and regulations. In addition, the release of funds by Syndicate 2488 to subsidiaries of CGM is subject to regulations promulgated by the Society of Lloyd's. Chubb Limited received no dividends from CGM in 2019 and 2018.

The U.S. insurance subsidiaries of Chubb INA may pay dividends, without prior regulatory approval, subject to restrictions set out in state law of the subsidiary's domicile (or, if applicable, commercial domicile). Chubb INA's international subsidiaries are also subject to insurance laws and regulations particular to the countries in which the subsidiaries operate. These laws and regulations sometimes include restrictions that limit the amount of dividends payable without prior approval of regulatory insurance authorities. Chubb Limited received no dividends from Chubb INA in 2019 and 2018. Debt issued by Chubb INA is serviced by statutorily permissible distributions by Chubb INA's insurance subsidiaries to Chubb INA as well as other group resources. Chubb INA received dividends of $3.7 billion and $5.2 billion from its subsidiaries in 2019 and 2018, respectively. At December 31, 2019, the amount of dividends available to be paid to Chubb INA in 2019 from its subsidiaries without prior approval of insurance regulatory authorities totals $3.1 billion.

In January 2020, Chubb INA Holdings Inc. paid $1.5 billion towards the series of intercompany loans involving its parents, Chubb Group Holdings Inc. and Chubb Limited. Additionally, Chubb Limited contributed $1.2 billion to a Bermuda subsidiary.

Cash Flows

Our insurance and reinsurance operations provide liquidity in that premiums are received in advance, sometimes substantially in advance, of the time claims are paid. Generally, cash flows are affected by claim payments that, due to the nature of our operations, may comprise large loss payments on a limited number of claims and which can fluctuate significantly from period to period. The irregular timing of these loss payments can create significant variations in cash flows from operations between periods. Refer to “Contractual Obligations and Commitments” for our estimate of future claim payments by period. Sources of liquidity include cash from operations, routine sales of investments, and financing arrangements. The following is a discussion of our cash flows for 2019, 2018, and 2017.

Operating cash flows reflect Net income for each period, adjusted for non-cash items and changes in working capital.

Operating cash flows were $6.3 billion in 2019, compared to $5.5 billion and $4.5 billion in 2018 and 2017, respectively. Operating cash flow was higher in 2019 compared to 2018, primarily due to higher underwriting cash flow, partially offset by higher taxes paid compared to 2018 principally due to the timing of tax payments. The increase in operating cash flows of $977 million in 2018 compared to 2017 was primarily due to higher premiums collected, net of higher catastrophe loss payments related to the 2017 catastrophe events, and lower taxes paid principally due to the timing of tax payments.

Cash used for investing was $5.9 billion in 2019, compared to $2.9 billion and $2.4 billion in 2018 and 2017, respectively. The increase in cash used for investing of $3.0 billion in 2019 was primarily due to net purchases of short-term investments of $1.1 billion in 2019 compared to net proceeds of $516 million in 2018. Additionally, the increase in 2019 was due to the purchase of an additional 10.9 percent ownership interest in Huatai Group for $580 million. Cash used for investing in 2018 was higher compared to 2017, due to higher net private equity contributions, net of distributions received, of $793 million.

Cash used for financing was $151 million in 2019, compared to $2.0 billion and $2.3 billion in 2018 and 2017, respectively. Cash used for financing was lower by $1.8 billion in 2019 compared to 2018 primarily due to higher net proceeds from the issuance of long-term debt (net of repayments) of $2.1 billion offset by higher share repurchases of $486 million. Cash used for financing in 2018 was lower by $328 million, primarily due to higher net repayments of long-term debt in 2017.

Both internal and external forces influence our financial condition, results of operations, and cash flows. Claim settlements, premium levels, and investment returns may be impacted by changing rates of inflation and other economic conditions. In many cases, significant periods of time, ranging up to several years or more, may lapse between the occurrence of an insured loss, the reporting of the loss to us, and the settlement of the liability for that loss.

We use repurchase agreements as a low-cost funding alternative. At December 31, 2019, there were $1.4 billion in repurchase agreements outstanding with various maturities over the next five months.

In addition to cash from operations, routine sales of investments, and financing arrangements, we have agreements with a third-party bank provider which implemented two international multi-currency notional cash pooling programs to enhance cash management efficiency during periods of short-term timing mismatches between expected inflows and outflows of cash by currency. The programs allow us to optimize investment income by avoiding portfolio disruption. In each program, participating Chubb entities establish deposit accounts in different currencies with the bank provider. Each day the credit or debit balances in every account are notionally translated into a single currency (U.S. dollars) and then notionally pooled. The bank extends overdraft credit to all participating Chubb entities as needed, provided that the overall notionally pooled balance of all accounts in each pool at the end of each day is at least zero. Actual cash balances are not physically converted and are not commingled between legal entities. Chubb entities may incur overdraft balances as a means to address short-term liquidity needs. Any overdraft balances incurred under this program by a Chubb entity would be guaranteed by Chubb Limited (up to $300 million in the aggregate). Our syndicated letter of credit facility allows for same day drawings to fund a net pool overdraft should participating Chubb entities withdraw contributed funds from the pool.

Capital Resources

Capital resources consist of funds deployed or available to be deployed to support our business operations.

(in millions of U.S. dollars, except for percentages)	**December 31 2019**	December 31 2018
Short-term debt	**$ 1,299**	$ 509
Long-term debt	**13,559**	12,087
Total financial debt	**14,858**	12,596
Trust preferred securities	**308**	308
Total shareholders' equity	**55,331**	50,312
Total capitalization	**$ 70,497**	$ 63,216
Ratio of financial debt to total capitalization	**21.1%**	19.9%
Ratio of financial debt plus trust preferred securities to total capitalization	**21.5%**	20.4%

Repurchase agreements are excluded from the table above and are disclosed separately from short-term debt in the Consolidated balance sheets. The repurchase agreements are collateralized borrowings where we maintain the right and ability to redeem the collateral on short notice, unlike short-term debt which comprises the current maturities of our long-term debt instruments.

Refer to Note 9 to the Consolidated Financial Statements for details about the debt issued and debt redeemed.

We believe our financial strength provides us with the flexibility and capacity to obtain available funds externally through debt or equity financing on both a short-term and long-term basis. Our ability to access the capital markets is dependent on, among other things, market conditions and our perceived financial strength. We have accessed both the debt and equity markets from time to time. We generally maintain the ability to issue certain classes of debt and equity securities via an unlimited Securities and Exchange Commission (SEC) shelf registration which is renewed every three years. This allows us capital market access for refinancing as well as for unforeseen or opportunistic capital needs. In October 2018, we filed an unlimited shelf registration which allows us to issue certain classes of debt and equity. This shelf registration expires in October 2021.

Securities Repurchases
From time to time, we repurchase shares as part of our capital management program. The Board of Directors (Board) has authorized share repurchase programs as follows:

- $1.0 billion of Chubb Common Shares from November 17, 2016 through December 31, 2017
- $1.0 billion of Chubb Common Shares from January 1, 2018 through December 31, 2018
- $1.5 billion of Chubb Common Shares from December 1, 2018 through December 31, 2019
- $1.5 billion of Chubb Common Shares from November 21, 2019 through December 31, 2020

Share repurchases may be made in the open market, in privately negotiated transactions, block trades, accelerated repurchases and/or through option or other forward transactions. In 2017, 2018 and 2019, we repurchased $830 million, $1.02 billion and $1.53 billion, respectively, of Common Shares in a series of open market transactions under the Board share repurchase authorizations. The $1.5 billion December 2018 Board authorization remained effective through December 31, 2019, and was used in advance of the $1.5 billion share repurchase authorized in November 2019. For the period January 1 through February 26, 2020, we repurchased 947,400 Common Shares for a total of $151 million in a series of open market transactions. At February 26, 2020, $1.30 billion in share repurchase authorization remained through December 31, 2020.

Common Shares
Our Common Shares had a par value of CHF 24.15 each at December 31, 2019.

As of December 31, 2019, there were 27,812,297 Common Shares in treasury with a weighted average cost of $134.98 per share.

Under Swiss law, dividends must be stated in Swiss francs though dividend payments are made by Chubb in U.S. dollars.

At our May 2018 annual general meeting, our shareholders approved an annual dividend for the following year of up to $2.92 per share, which was paid in four quarterly installments of $0.73 per share at dates determined by the Board after the annual general meeting by way of a distribution from capital contribution reserves, transferred to free reserves for payment.

At our May 2019 annual general meeting, our shareholders approved an annual dividend for the following year of up to $3.00 per share, expected to be paid in four quarterly installments of $0.75 per share after the annual general meeting by way of distribution from capital contribution reserves, transferred to free reserves for payment. The Board will determine the record and payment dates at which the annual dividend may be paid until the date of the 2020 annual general meeting, and is authorized to abstain from distributing a dividend at its discretion. The first three quarterly installments each of $0.75 per share, have been distributed by the Board as expected.

Dividend distributions on Common Shares amounted to CHF 2.94 ($2.98) per share for the year ended December 31, 2019. Refer to Note 11 to the Consolidated Financial Statements for additional information on our dividends.

Contractual Obligations and Commitments

The following table presents our future payments due by period under contractual obligations at December 31, 2019:

	Payments Due By Period				
(in millions of U.S. dollars)	Total	2020	2021 and 2022	2023 and 2024	Thereafter
Payment amounts determinable from the respective contracts					
Deposit liabilities [1]	$ 2,092	$ 21	$ 51	$ 131	$ 1,889
Purchase obligations [2]	411	159	223	29	—
Investments, including Limited Partnerships [3]	3,994	1,328	1,721	895	50
Huatai share acquisition deposits [4]	1,550	1,550	—	—	—
Operating leases	660	158	243	154	105
Repurchase agreements	1,416	1,416	—	—	—
Short-term debt	1,301	1,301	—	—	—
Long-term debt [5]	13,292	—	1,000	1,954	10,338
Trust preferred securities	309	—	—	—	309
Interest on debt obligations [5]	6,199	479	898	810	4,012
Total obligations in which payment amounts are determinable from the respective contracts	31,224	6,412	4,136	3,973	16,703
Payment amounts not determinable from the respective contracts					
Estimated gross loss payments under insurance and reinsurance contracts	62,713	17,601	17,200	8,731	19,181
Estimated payments for future policy benefits	20,645	916	1,885	1,541	16,303
Total contractual obligations and commitments	$ 114,582	$ 24,929	$ 23,221	$ 14,245	$ 52,187

(1) Refer to Note 1 k) to the Consolidated Financial Statements.

(2) Primarily comprises audit fees and agreements with vendors to purchase system software administration and maintenance services.

(3) Funding commitment primarily related to limited partnerships. The timing of the payments of these commitments is uncertain and may differ from the estimated timing in the table.

(4) Chubb entered into agreements to purchase incremental ownership interests in Huatai Insurance Group Company Limited through two separate purchases, a 15.3 percent ownership interest for approximately $1.1 billion and a 7.1 percent ownership interest for approximately $493 million. The purchases are contingent upon obtaining regulatory approvals and other important conditions, which are expected to be obtained by the end of 2021. The 7.1 percent purchase is also contingent upon receipt of Chinese insurance regulatory approval of the 15.3 percent purchase. In connection with these purchase agreements, in January 2020, we paid collateralized deposits totaling $1.550 billion to the selling shareholders, which are accounted for as loans.

(5) Subject to foreign exchange fluctuations on interest expense and principal.

The above table excludes the following items:

- Pension obligations: Minimum funding requirements for our pension obligations are immaterial. Subsequent funding commitments are apt to vary due to many factors and are difficult to estimate at this time. Refer to Note 13 to the Consolidated Financial Statements for additional information.
- Liabilities for unrecognized tax benefits: The liability for unrecognized tax benefits, excluding interest and offsetting tax credits, was $47 million at December 31, 2019. At December 31, 2019, we had accrued $8 million in liabilities for income tax-related interest and penalties in our Consolidated balance sheet. We are unable to make a reasonably reliable estimate for the timing of cash settlement with respect to these liabilities. Refer to Note 8 to the Consolidated Financial Statements for additional information.

We have no other significant contractual obligations or commitments not reflected in the table above. We do not have any off-balance sheet arrangements that are reasonably likely to have a material effect on our financial condition, revenues or expenses, results of operations, liquidity, capital expenditures, or capital resources.

Estimated gross loss payments under insurance and reinsurance contracts
We are obligated to pay claims under insurance and reinsurance contracts for specified loss events covered under those contracts. Such loss payments represent our most significant future payment obligation as a P&C insurance and reinsurance company. In contrast to other contractual obligations, cash payments are not determinable from the terms specified within the contract. For example, we do not ultimately make a payment to our counterparty for many insurance and reinsurance contracts (i.e., when a loss event has not occurred) and if a payment is to be made, the amount and timing cannot be determined from the contract. In the table above, we estimate payments by period relating to our gross liability for unpaid losses and loss expenses included in the Consolidated balance sheet at December 31, 2019, and do not take into account reinsurance recoverable. These estimated loss payments are inherently uncertain and the amount and timing of actual loss payments are likely to differ from these estimates and the differences could be material. Given the numerous factors and assumptions involved in both estimates of loss and loss expense reserves and related estimates as to the timing of future loss and loss expense payments in the table above, differences between actual and estimated loss payments will not necessarily indicate a commensurate change in ultimate loss estimates. The liability for Unpaid losses and loss expenses presented in our balance sheet is discounted for certain structured settlements, for which the timing and amount of future claim payments are reliably determinable, and certain reserves for unsettled claims. Our loss reserves are not discounted for the time value of money. Accordingly, the estimated amounts in the table exceed the liability for Unpaid losses and loss expenses presented in our balance sheet. Refer to Note 1 h) to the Consolidated Financial Statements for additional information.

Estimated payments for future policy benefits
We establish reserves for future policy benefits for life, long-term health, and annuity contracts. The amounts in the table are gross of fees or premiums due from the underlying contracts. The liability for Future policy benefits for life, long-term health, and annuity contracts presented in our balance sheet is discounted and reflected net of fees or premiums due from the underlying contracts. Accordingly, the estimated amounts in the table exceed the liability for Future policy benefits presented in our balance sheet. Payment amounts related to these reserves must be estimated and are not determinable from the contract. Due to the uncertainty with respect to the timing and amount of these payments, actual results could materially differ from the estimates in the table.

Credit Facilities

As our Bermuda subsidiaries are non-admitted insurers and reinsurers in the U.S., the terms of certain U.S. insurance and reinsurance contracts require them to provide collateral, which can be in the form of letters of credit (LOCs). LOCs may also be used for general corporate purposes.

On October 25, 2017, we entered into a credit facility that provides for up to $1.0 billion of availability, all of which may be used for the issuance of LOC and for revolving loans. We have the ability to increase the capacity to $2.0 billion under certain conditions, but any such increase would not raise the sub-limit for revolving loans above $1.0 billion. Our existing credit facility has a remaining term expiring in October 2022. At December 31, 2019, our LOC usage was $567 million.

Our access to funds under an existing credit facility is dependent on the ability of the banks that are a party to the facility to meet their funding commitments. In the event that such credit support is insufficient, we could be required to provide alternative security to clients. This could take the form of additional insurance trusts supported by our investment portfolio or funds withheld using our cash resources. The value of LOCs required is driven by, among other things, statutory liabilities reported by variable annuity guarantee reinsurance clients, loss development of existing reserves, the payment pattern of such reserves, the expansion of business, and loss experience of such business.

The facility noted above requires that we maintain certain covenants, all of which have been met at December 31, 2019. These covenants include:

(i) a minimum consolidated net worth of not less than $34.985 billion; and
(ii) a ratio of consolidated debt to total capitalization of not greater than 0.35 to 1.

At December 31, 2019, (a) the minimum consolidated net worth requirement under the covenant described in (i) above was $34.985 billion and our actual consolidated net worth as calculated under that covenant was $54.7 billion and (b) our ratio of debt to total capitalization, as calculated under the covenant which excludes the fair value adjustment of debt acquired through the Chubb Corp acquisition, was 0.21 to 1, which is below the maximum debt to total capitalization ratio of 0.35 to 1 as described in (ii) above.

Our failure to comply with the covenants under any credit facility would, subject to grace periods in the case of certain covenants, result in an event of default. This could require us to repay any outstanding borrowings or to cash collateralize LOCs under such facility. Our failure to repay material financial obligations, as well as our failure with respect to certain other events expressly identified, would result in an event of default under the facility.

Should our existing credit provider experience financial difficulty, we may be required to replace credit sources, possibly in a difficult market. If we cannot obtain adequate capital or sources of credit on favorable terms, on a timely basis, or at all, our business, operating results, and financial condition could be adversely affected. To date, we have not experienced difficulty accessing our credit facility.

Ratings

Chubb Limited and its subsidiaries are assigned credit and financial strength (insurance) ratings from internationally recognized rating agencies, including S&P, A.M. Best, Moody's, and Fitch. The ratings issued on our companies by these agencies are announced publicly and are available directly from the agencies. Our Internet site (investors.chubb.com, under Shareholder Resources/Rating Agency Ratings) also contains some information about our ratings, but such information on our website is not incorporated by reference into this report.

Financial strength ratings reflect the rating agencies' opinions of a company's claims paying ability. Independent ratings are one of the important factors that establish our competitive position in the insurance markets. The rating agencies consider many factors in determining the financial strength rating of an insurance company, including the relative level of statutory surplus necessary to support the business operations of the company. These ratings are based upon factors relevant to policyholders, agents, and intermediaries and are not directed toward the protection of investors. Such ratings are not recommendations to buy, sell, or hold securities.

Credit ratings assess a company's ability to make timely payments of principal and interest on its debt. It is possible that, in the future, one or more of the rating agencies may reduce our existing ratings. If one or more of our ratings were downgraded, we could incur higher borrowing costs, and our ability to access the capital markets could be impacted. In addition, our insurance and reinsurance operations could be adversely impacted by a downgrade in our financial strength ratings, including a possible reduction in demand for our products in certain markets. Also, we have insurance and reinsurance contracts which contain rating triggers. In the event the S&P or A.M. Best financial strength ratings of Chubb fall, we may be faced with the cancellation of premium or be required to post collateral on our underlying obligation associated with this premium. We estimate that at December 31, 2019, a one-notch downgrade of our S&P or A.M. Best financial strength ratings would result in an immaterial loss of premium or requirement for collateral to be posted.

ITEM 7A. Quantitative and Qualitative Disclosures about Market Risk

Market Sensitive Instruments and Risk Management

Market risk represents the potential for loss due to adverse changes in the fair value of financial instruments. We are exposed to potential losses from various market risks including changes in interest rates, equity prices, and foreign currency exchange rates. Further, through writing the GLB and GMDB products, we are exposed to volatility in the equity and credit markets, as well as interest rates. Our investment portfolio consists primarily of fixed income securities, denominated in both U.S. dollars and foreign currencies, which are sensitive to changes in interest rates and foreign currency exchange rates. The majority of our fixed income portfolio is classified as available for sale. The effect of market movements on our available for sale investment portfolio impacts Net income (through Net realized gains (losses)) when securities are sold or when we record an OTTI charge in Net income. Changes in interest rates and foreign currency exchange rates will have an immediate effect on Shareholders' equity and Comprehensive income and in certain instances, Net income. From time to time, we also use derivative instruments such as futures, options, swaps, and foreign currency forward contracts to manage the duration of our investment portfolio and foreign currency exposures and also to obtain exposure to a particular financial market. At December 31, 2019 and 2018, our notional exposure to derivative instruments was $4.9 billion and $9.1 billion, respectively. These instruments are recognized as assets or liabilities in our consolidated financial statements and are sensitive to changes in interest rates, foreign currency exchange rates, and equity security prices. As part of our investing activities, we purchase to be announced mortgage backed securities (TBAs). Changes in the fair value of TBAs are included in Net realized gains (losses) and therefore, have an immediate effect on both our Net income and Shareholders' equity.

We seek to mitigate market risk using a number of techniques, including maintaining and managing the assets and liabilities of our international operations consistent with the foreign currencies of the underlying insurance and reinsurance businesses, thereby limiting exchange rate risk to net assets denominated in foreign currencies.

The following is a discussion of our primary market risk exposures at December 31, 2019. Our policies to address these risks in 2019 were not materially different from 2018. We do not currently anticipate significant changes in our primary market risk exposures or in how those exposures are managed in future reporting periods based upon what is known or expected to be in effect in future reporting periods.

Interest rate risk – fixed income portfolio and debt obligations

Our fixed income portfolio and debt obligations have exposure to interest rate risk. Changes in investment values attributable to interest rate changes are mitigated by corresponding and partially offsetting changes in the economic value of our insurance reserves and debt obligations. We monitor this exposure through periodic reviews of our asset and liability positions.

The following table presents the impact at December 31, 2019 and 2018, on the fair value of our fixed income portfolio of a hypothetical increase in interest rates of 100 bps applied instantly across the U.S. yield curve (an immediate time horizon was used as this presents the worst case scenario):

(in billions of U.S. dollars, except for percentages)	**2019**	2018
Fair value of fixed income portfolio	**$ 102.8**	$ 94.7
Pre-tax impact of 100 bps increase in interest rates:		
Decrease in dollars	**$ 3.9**	$ 3.5
As a percentage of total fixed income portfolio at fair value	**3.8%**	3.7%

Changes in interest rates will have an immediate effect on Comprehensive income and Shareholders' equity but will not ordinarily have an immediate effect on Net income. Variations in market interest rates could produce significant changes in the timing of prepayments due to available prepayment options. For these reasons, actual results could differ from those reflected in the tables.

Although our debt and trust preferred securities (collectively referred to as debt obligations) are reported at amortized cost and not adjusted for fair value changes, changes in interest rates could have a material impact on their fair value, albeit there would be no impact on our consolidated financial statements.

The following table presents the impact at December 31, 2019 and 2018, on the fair value of our debt obligations of a hypothetical decrease in interest rates of 100 bps applied instantly across the U.S. yield curve (an immediate time horizon was used as this presents the worst case scenario):

(in millions of U.S. dollars, except for percentages)	**2019**	2018
Fair value of debt obligations, including repurchase agreements	**$ 18,238**	$ 14,524
Pre-tax impact of 100 bps decrease in interest rates:		
Increase in dollars	**$ 1,570**	$ 1,201
As a percentage of total debt obligations at fair value	**8.6%**	8.3%

Foreign currency management

As a global company, Chubb entities transact business in multiple currencies. Our policy is to generally match assets, liabilities and required capital for each individual jurisdiction in local currency, which would include the use of derivatives. We do not hedge our net asset non-U.S. dollar capital positions; however, we do consider hedging for planned cross border transactions.

The following table summarizes the net assets in non-U.S. currencies at December 31, 2019 and 2018:

	2019		2018		
(in millions of U.S. dollars, except for percentages)	**Value of Net Assets**	**Exchange rate per USD**	Value of Net Assets	Exchange rate per USD	2019 vs. 2018 % change in exchange rate per USD
Canadian dollar (CAD)	**$ 2,220**	**0.7698**	$ 2,114	0.7333	5.0 %
British pound sterling (GBP)	**2,024**	**1.3257**	1,901	1.2754	3.9 %
Euro (EUR)	**1,675**	**1.1213**	1,896	1.1467	(2.2)%
Australian dollar (AUD)	**1,100**	**0.7021**	1,149	0.7049	(0.4)%
Brazilian real (BRL)	**990**	**0.2485**	938	0.2577	(3.6)%
Mexican peso (MXN)	**942**	**0.0528**	729	0.0509	3.7 %
Korean won (KRW) (x100)	**788**	**0.0865**	726	0.0900	(3.9)%
Hong Kong dollar (HKD)	**653**	**0.1284**	362	0.1277	0.5 %
Thai baht (THB)	**606**	**0.0337**	459	0.0309	9.1 %
Chilean peso (CLP) (x100)	**489**	**0.1328**	28	0.1441	(7.8)%
Euro denominated debt [1]	**(4,804)**	**1.1213**	(2,016)	1.1467	(2.2)%
Other foreign currencies	**2,474**	**various**	2,106	various	NM
Value of net assets denominated in foreign currencies [2]	**$ 9,157**		$ 10,392		
As a percentage of total net assets	**16.6%**		20.7%		
Pre-tax decrease to Shareholders' equity of a hypothetical 10 percent strengthening of the U.S. dollar	**$ 832**		$ 945		

NM – not meaningful

(1) Refer to Note 9 to the Consolidated Financial Statements for additional information.

(2) At December 31, 2019, net assets denominated in foreign currencies comprised approximately 6 percent tangible assets and 94 percent intangible assets, primarily goodwill.

Effective July 1, 2018, Argentina was designated as a highly inflationary economy and therefore we changed the functional currency for our Argentine operations from the Argentine Peso to the U.S. dollar. Our net assets denominated in the Argentine Peso represented less than 0.1 percent of consolidated shareholders' equity. Therefore, this change in the functional currency of our Argentine operations did not have a material impact on our financial condition or results of operations.

Reinsurance of GMDB and GLB guarantees
Chubb views its variable annuity reinsurance business as having a similar risk profile to that of catastrophe reinsurance with the probability of long-term economic loss relatively small, at the time of pricing. Adverse changes in market factors and policyholder behavior will have an impact on both Life Insurance underwriting income and net income. When evaluating these risks, we expect to be compensated for taking both the risk of a cumulative long-term economic net loss, as well as the short-term accounting variations caused by these market movements. Therefore, we evaluate this business in terms of its long-term economic risk and reward.

Net income is directly impacted by changes in benefit reserves calculated in connection with reinsurance of variable annuity guarantees. In addition, net income is directly impacted by changes in the fair value of the GLB liability (FVL), which is classified as a derivative for accounting purposes. The FVL established for a GLB reinsurance contract represents the difference between the fair value of the contract and the benefit reserves. Benefit reserves and FVL calculations are directly affected by market factors, including equity levels, interest rate levels, credit risk, and implied volatilities, as well as policyholder behaviors, such as annuitization and lapse rates, and policyholder mortality.

The tables below are estimates of the sensitivities to instantaneous changes in economic inputs (e.g., equity shock, interest rate shock, etc.) or actuarial assumptions at December 31, 2019 of the FVL and of the fair value of specific derivative instruments held (hedge value) to partially offset the risk in the variable annuity guarantee reinsurance portfolio. The following assumptions should be considered when using the below tables:

- No changes to the benefit ratio used to establish benefit reserves at December 31, 2019.
- Equity shocks impact all global equity markets equally
    - Our liabilities are sensitive to global equity markets in the following proportions: 75 percent—85 percent U.S. equity, and 15 percent—25 percent international equity.
    - Our current hedge portfolio is sensitive only to U.S. equity markets.
    - We would suggest using the S&P 500 index as a proxy for U.S. equity, and the MSCI EAFE index as a proxy for international equity.
- Interest rate shocks assume a parallel shift in the U.S. yield curve
    - Our liabilities are also sensitive to global interest rates at various points on the yield curve, mainly the U.S. Treasury curve in the following proportions: 5 percent—15 percent short-term rates (maturing in less than 5 years), 25 percent—35 percent medium-term rates (maturing between 5 years and 10 years, inclusive), and 55 percent—65 percent long-term rates (maturing beyond 10 years).
    - A change in AA-rated credit spreads impacts the rate used to discount cash flows in the fair value model. AA-rated credit spreads are a proxy for both our own credit spreads and the credit spreads of the ceding insurers.
- The hedge sensitivity is from December 31, 2019 market levels and only applicable to the equity and interest rate sensitivities table below.
- The sensitivities are not directly additive because changes in one factor will affect the sensitivity to changes in other factors. The sensitivities do not scale linearly and may be proportionally greater for larger movements in the market factors. The sensitivities may also vary due to foreign exchange rate fluctuations. The calculation of the FVL is based on internal models that include assumptions regarding future policyholder behavior, including lapse, annuitization, and asset allocation. These assumptions impact both the absolute level of the FVL as well as the sensitivities to changes in market factors shown below. Actual sensitivity of our net income may differ from those disclosed in the tables below due to differences between short-term market movements and management judgment regarding the long-term assumptions implicit in our benefit ratios.
- In addition, the tables below do not reflect the expected quarterly run rate of net income generated by the variable annuity guarantee reinsurance portfolio if markets remain unchanged during the period. All else equal, if markets remain unchanged during the period, the Gross FVL will increase, resulting in a realized loss. This realized loss occurs primarily because the guarantees provided in the underlying contracts continue to become more valuable even when markets remain unchanged. We refer to this increase in Gross FVL as “timing effect”. The unfavorable impact of timing effect on our Gross FVL in a quarter is not reflected in the sensitivity tables below. For this reason, when using the tables below to estimate the sensitivity of Gross FVL in the first quarter 2020 to various changes, it is necessary to assume an additional $5 million to $45 million increase in Gross FVL and realized losses. The impact to Net income is partially mitigated because this realized loss is partially offset by the positive quarterly run rate of Life Insurance underwriting income generated by the variable annuity guarantee reinsurance portfolio if markets remain unchanged during the period. Note that both the timing effect and the quarterly run rate of Life Insurance underwriting income change over time as the book ages.

Sensitivities to equity and interest rate movements

(in millions of U.S. dollars)		Worldwide Equity Shock					
Interest Rate Shock		+10%	Flat	-10%	-20%	-30%	-40%
+100 bps	(Increase)/decrease in Gross FVL	$ 343	$ 207	$ 49	$ (138)	$ (357)	$ (604)
	Increase/(decrease) in hedge value	(63)	—	63	125	188	250
	Increase/(decrease) in net income	$ 280	$ 207	$ 112	$ (13)	$ (169)	$ (354)
Flat	(Increase)/decrease in Gross FVL	$ 156	$ —	$ (182)	$ (394)	$ (636)	$ (904)
	Increase/(decrease) in hedge value	(63)	—	63	125	188	250
	Increase/(decrease) in net income	$ 93	$ —	$ (119)	$ (269)	$ (448)	$ (654)
-100 bps	(Increase)/decrease in Gross FVL	$ (74)	$ (249)	$ (451)	$ (681)	$ (936)	$ (1,215)
	Increase/(decrease) in hedge value	(63)	—	63	125	188	250
	Increase/(decrease) in net income	$ (137)	$ (249)	$ (388)	$ (556)	$ (748)	$ (965)

Sensitivities to Other Economic Variables	AA-rated Credit Spreads		Interest Rate Volatility		Equity Volatility	
(in millions of U.S. dollars)	+100 bps	-100 bps	+2%	-2%	+2%	-2%
(Increase)/decrease in Gross FVL	$ 73	$ (81)	$ —	$ 1	$ (9)	$ 9
Increase/(decrease) in net income	$ 73	$ (81)	$ —	$ 1	$ (9)	$ 9

Sensitivities to Actuarial Assumptions	Mortality			
(in millions of U.S. dollars)	+20%	+10%	-10%	-20%
(Increase)/decrease in Gross FVL	$ 18	$ 9	$ (9)	$ (19)
Increase/(decrease) in net income	$ 18	$ 9	$ (9)	$ (19)

	Lapses			
(in millions of U.S. dollars)	+50%	+25%	-25%	-50%
(Increase)/decrease in Gross FVL	$ 101	$ 52	$ (57)	$ (120)
Increase/(decrease) in net income	$ 101	$ 52	$ (57)	$ (120)

	Annuitization			
(in millions of U.S. dollars)	+50%	+25%	-25%	-50%
(Increase)/decrease in Gross FVL	$ (498)	$ (264)	$ 298	$ 585
Increase/(decrease) in net income	$ (498)	$ (264)	$ 298	$ 585

Variable Annuity Net Amount at Risk

All our VA reinsurance treaties include annual or aggregate claim limits and many include an aggregate deductible which limit the net amount at risk under these programs. The tables below present the net amount at risk at December 31, 2019 following an immediate change in equity market levels, assuming all global equity markets are impacted equally. For further information on the net amount at risk, refer to Note 5 c) to the Consolidated Financial Statements.

a) Reinsurance covering the GMDB risk only

	Equity Shock					
(in millions of U.S. dollars)	+20%	Flat	-20%	-40%	-60%	-80%
GMDB net amount at risk	$ 271	$ 256	$ 442	$ 797	$ 817	$ 696
Claims at 100% immediate mortality	160	167	166	156	138	122

The treaty claim limits function as a ceiling as equity markets fall. As the shocks in the table above become incrementally more negative, the impact on the NAR and claims at 100 percent mortality begin to drop due to the specific nature of these claim limits, many of which are annual claim limits calculated as a percentage of the reinsured account value. There is also some impact due to a small portion of the GMDB reinsurance under which claims are positively correlated to equity markets (claims decrease as equity markets fall).

b) Reinsurance covering the GLB risk only

(in millions of U.S. dollars)	Equity Shock +20%	Flat	-20%	-40%	-60%	-80%
GLB net amount at risk	$ 724	$ 1,095	$ 1,738	$ 2,516	$ 3,021	$ 3,387

The treaty claim limits cause the net amount at risk to increase at a declining rate as equity markets fall.

c) Reinsurance covering both the GMDB and GLB risks on the same underlying policyholders

(in millions of U.S. dollars)	Equity Shock +20%	Flat	-20%	-40%	-60%	-80%
GMDB net amount at risk	$ 76	$ 91	$ 105	$ 117	$ 123	$ 123
GLB net amount at risk	305	415	560	723	888	985
Claims at 100% immediate mortality	16	16	17	17	17	17

The treaty limits control the increase in the GMDB net amount at risk as equity markets fall. The GMDB net amount at risk continues to grow as equity markets fall because most of these reinsurance treaties do not have annual claim limits calculated as a percentage of the underlying account value. The treaty limits cause the GLB net amount at risk to increase at a declining rate as equity markets fall.

ITEM 8. Financial Statements and Supplementary Data

The financial statements and supplementary data are included in this Form 10-K commencing on page F-1.

ITEM 9. Changes in and Disagreements with Accountants on Accounting and Financial Disclosure

None.

ITEM 9A. Controls and Procedures

Chubb’s management, with the participation of Chubb’s Chief Executive Officer and Chief Financial Officer, evaluated the effectiveness of Chubb’s disclosure controls and procedures as defined in Rule 13a-15(e) and Rule 15d-15(e) under the Securities Exchange Act of 1934 as of December 31, 2019. Based upon that evaluation, Chubb’s Chief Executive Officer and Chief Financial Officer concluded that Chubb’s disclosure controls and procedures are effective in allowing information required to be disclosed in reports filed under the Securities Exchange Act of 1934 to be recorded, processed, summarized, and reported within time periods specified in the rules and forms of the SEC, and that such information is accumulated and communicated to Chubb’s management, including its Chief Executive Officer and Chief Financial Officer, as appropriate to allow timely decisions regarding required disclosure.

In 2016, Chubb completed the acquisition of The Chubb Corporation. For the year ended December 31, 2019, we continued to integrate the information technology environments of the two companies.

There were no other changes to Chubb's internal controls over financial reporting for the year ended December 31, 2019 that have materially affected, or are reasonably likely to materially affect, Chubb's internal controls over financial reporting. Chubb's management report on internal control over financial reporting is included on page F-3 and PricewaterhouseCoopers LLP's audit report is included on pages F-4, F-5, and F-6.

ITEM 9B. Other Information

Item not applicable.

ITEM 10. Directors, Executive Officers and Corporate Governance

Information pertaining to this item is incorporated by reference to the sections entitled “Agenda Item 5 - Election of the Board of Directors”, “Corporate Governance - The Board of Directors - Director Nomination Process”, and “Corporate Governance - The Committees of the Board - Audit Committee” of the definitive proxy statement for the 2020 Annual General Meeting of Shareholders which will be filed with the SEC not later than 120 days after the close of the fiscal year pursuant to Regulation 14A. Also incorporated herein by reference is the text under the caption “Information about our Executive Officers” appearing at the end of Part I Item 1 of the Annual Report on Form 10-K.

Code of Ethics
Chubb has adopted a Code of Conduct, which sets forth standards by which all Chubb employees, officers, and directors must abide as they work for Chubb. Chubb has posted this Code of Conduct on its Internet site (investors.chubb.com, under Corporate Governance/Highlights and Governance Documents/The Chubb Code of Conduct). Chubb intends to disclose on its Internet site any amendments to, or waivers from, its Code of Conduct that are required to be publicly disclosed pursuant to the rules of the SEC or the New York Stock Exchange.

ITEM 11. Executive Compensation

This item is incorporated by reference to the sections entitled “Executive Compensation”, “Compensation Committee Report” and “Director Compensation” of the definitive proxy statement for the 2020 Annual General Meeting of Shareholders which will be filed with the SEC not later than 120 days after the close of the fiscal year pursuant to Regulation 14A.

ITEM 12. Security Ownership of Certain Beneficial Owners and Management and Related Stockholder Matters

Plan category	Number of securities to be issued upon exercise of outstanding options, warrants, and rights	Weighted-average exercise price of outstanding options, warrants, and rights [3]	Number of securities remaining available for future issuance under equity compensation plans
Equity compensation plans approved by security holders [1]	11,801,420	$ 116.79	12,575,263
Equity compensation plans not approved by security holders [2]	27,914		

[1] These totals include securities available for future issuance under the following plans:

(i) Chubb Limited 2016 Long-Term Incentive Plan (LTIP). A total of 19,500,000 shares are authorized to be issued pursuant to awards made as options, stock appreciation rights, stock units, performance shares, performance units, restricted stock, and restricted stock units. The maximum number of shares that may be delivered to participants and their beneficiaries under the LTIP shall be equal to the sum of: (x) 19,500,000 shares of stock; and (y) any shares of stock that have not been delivered pursuant to the ACE LTIP (as defined in clause (ii) of this footnote (1) below) and remain available for grant pursuant to the ACE LTIP, including shares of stock represented by awards granted under the ACE LTIP that are forfeited, expire or are canceled after the effective date of the LTIP without delivery of shares of stock or which result in the forfeiture of the shares of stock back to the Company to the extent that such shares would have been added back to the reserve under the terms of the ACE LTIP. As of December 31, 2019, a total of 5,288,553 option awards and 706,535 restricted stock unit awards are outstanding, and 10,789,285 shares remain available for future issuance under this plan.

(ii) ACE Limited 2004 Long-Term Incentive Plan (ACE LTIP). As of December 31, 2019, a total of 5,496,523 option awards and 72,075 restricted stock unit awards are outstanding. No additional grants will be made pursuant to the ACE LTIP.

(iii) The Chubb Corporation Long-Term Incentive Plan (2014) (Chubb Corp. LTIP). As of December 31, 2019, a total of 99,759 option awards, 3,433 restricted stock unit awards, nil performance unit awards (representing 100% of the aggregate target in accordance with the Chubb Corp. merger agreement) and 83,173 deferred stock unit awards are outstanding. No additional grants will be made pursuant to the Chubb Corp. LTIP.

(iv) ESPP. A total of 6,500,000 shares have been authorized for purchase at a discount. As of December 31, 2019, 1,785,978 shares remain available for future issuance under this plan.

(2) These plans are the Chubb Corp. CCAP Excess Benefit Plan (CCAP Excess Benefit Plan) and the Chubb Corp. Deferred Compensation Plan for Directors, under which no Common Shares are available for future issuance other than with respect to outstanding rewards. The CCAP Excess Benefit Plan is a nonqualified, defined contribution plan and covers those participants in the Capital Accumulation Plan of The Chubb Corporation (CCAP) (Chubb Corp.'s legacy 401(k) plan) and Chubb Corp.'s legacy employee stock ownership plan (ESOP) whose total benefits under those plans are limited by certain provisions of the Internal Revenue Code. A participant in the CCAP Excess Benefit Plan is entitled to a benefit equaling the difference between the participant's benefits under the CCAP and the ESOP, without considering the applicable limitations of the Code, and the participant's actual benefits under such plans. A participant's excess ESOP benefit is expressed as Common Shares. Payments under the CCAP Excess Benefit Plan are generally made: (i) for excess benefits related to the CCAP, in cash annually as soon as practical after the amount of excess benefit can be determined; and (ii) for excess benefits related to the ESOP, in Common Shares as soon as practicable after the participant's termination of employment. Allocations under the ESOP ceased in 2004. Accordingly, other than dividends, no new contributions are made to the ESOP or the CCAP Excess Benefit Plan with respect to excess ESOP benefits.

(3) Weighted average exercise price excludes shares issuable under performance unit awards and restricted stock unit awards.

ITEM 13. Certain Relationships and Related Transactions and Director Independence

This item is incorporated by reference to the sections entitled "Corporate Governance - What Is Our Related Party Transactions Approval Policy And What Procedures Do We Use To Implement It?", "Corporate Governance - What Related Party Transactions Do We Have?", and "Corporate Governance - The Board of Directors - Director Independence" of the definitive proxy statement for the 2020 Annual General Meeting of Shareholders which will be filed with the SEC not later than 120 days after the close of the fiscal year pursuant to Regulation 14A.

ITEM 14. Principal Accounting Fees and Services

This item is incorporated by reference to the section entitled "Agenda Item 4 – Election of Auditors – 4.2 – Ratification of appointment of PricewaterhouseCoopers LLP (United States) as independent registered public accounting firm for purposes of U.S. securities law reporting" of the definitive proxy statement for the 2020 Annual General Meeting of Shareholders which will be filed with the SEC not later than 120 days after the close of the fiscal year pursuant to Regulation 14A.

ITEM 15. Exhibits, Financial Statement Schedules

(a) Financial Statements, Schedules, and Exhibits

Other schedules have been omitted as they are not applicable to Chubb, or the required information has been included in the Consolidated Financial Statements and related notes.

3. Exhibits

		Incorporated by Reference			
Exhibit Number	Exhibit Description	Form	Original Number	Date Filed	Filed Herewith
3.1	Articles of Association of the Company, as amended and restated	8-K	3.1	May 18, 2018	
3.2	Organizational Regulations of the Company as amended	8-K	3.1	November 21, 2016	
4.1	Articles of Association of the Company, as amended and restated	8-K	4.1	May 18, 2018	
4.2	Organizational Regulations of the Company as amended	8-K	3.1	November 21, 2016	
4.3	Specimen share certificate representing Common Shares	8-K	4.3	July 18, 2008	
4.4	Indenture, dated March 15, 2002, between ACE Limited and Bank One Trust Company, N.A.	8-K	4.1	March 22, 2002	
4.5	Senior Indenture, dated August 1, 1999, among ACE INA Holdings, Inc., ACE Limited and Bank of New York Mellon Trust Company, N.A. (as successor), as trustee	S-3 ASR	4.4	December 10, 2014	

Exhibit Number	Exhibit Description	Incorporated by Reference Form	Original Number	Date Filed	Filed Herewith
4.6	Indenture, dated November 30, 1999, among ACE INA Holdings, Inc. and Bank One Trust Company, N.A., as trustee	10-K	10.38	March 29, 2000	
4.7	Indenture, dated December 1, 1999, among ACE INA Holdings, Inc., ACE Limited and Bank One Trust Company, National Association, as trustee	10-K	10.41	March 29, 2000	
4.8	Amended and Restated Trust Agreement, dated March 31, 2000, among ACE INA Holdings, Inc., Bank One Trust Company, National Association, as property trustee, Bank One Delaware Inc., as Delaware trustee and the administrative trustees named therein	10-K	4.17	March 16, 2006	
4.9	Common Securities Guarantee Agreement, dated March 31, 2000	10-K	4.18	March 16, 2006	
4.10	Capital Securities Guarantee Agreement, dated March 31, 2000	10-K	4.19	March 16, 2006	
4.11	Form of 2.70 percent Senior Notes due 2023	8-K	4.1	March 13, 2013	
4.12	Form of 4.15 percent Senior Notes due 2043	8-K	4.2	March 13, 2013	
4.13	First Supplemental Indenture dated as of March 13, 2013 to the Indenture dated as of August 1, 1999 among ACE INA Holdings, Inc., as Issuer, ACE Limited, as Guarantor, and The Bank of New York Mellon Trust Company, N.A., as Successor Trustee	8-K	4.3	March 13, 2013	
4.14	Form of 3.35 percent Senior Notes due 2024	8-K	4.1	May 27, 2014	
4.15	Form of 3.150 percent Senior Notes due 2025	8-K	4.1	March 16, 2015	
4.16	Form of 2.30 percent Senior Notes due 2020	8-K	4.1	November 3, 2015	
4.17	Form of 2.875 percent Senior Notes due 2022	8-K	4.2	November 3, 2015	
4.18	Form of 3.35 percent Senior Notes due 2026	8-K	4.3	November 3, 2015	
4.19	Form of 4.35 percent Senior Notes due 2045	8-K	4.4	November 3, 2015	
4.20	First Supplemental Indenture to the Chubb Corp Senior Indenture dated as of January 15, 2016 to the Indenture dated as of October 25, 1989 among ACE INA Holdings, Inc., as Successor Issuer, ACE Limited, as Guarantor, and The Bank of New York Mellon Trust Company, N.A., as Trustee	8-K	4.1	January 15, 2016	
4.21	Second Supplemental Indenture to the Chubb Corp Junior Subordinated Indenture dated as of January 15, 2016 to the Indenture dated as of March 29, 2007 among ACE INA Holdings, Inc., as Successor Issuer, ACE Limited, as Guarantor, and The Bank of New York Mellon Trust Company, N.A., as Trustee	8-K	4.2	January 15, 2016	
4.22	Chubb Corp Senior Indenture (incorporated by reference to Exhibit 4(a) to Chubb Corp's Registration Statement on Form S-3 filed on October 27, 1989) (File No. 33-31796)	S-3	4(a)	October 27, 1989	
4.23	Chubb Corp Junior Subordinated Indenture (incorporated by reference to Exhibit 4.1 to Chubb Corp's Current Report on Form 8-K filed on March 30, 2007) (File No. 001-08661)	8-K	4.1	March 30, 2007	

Exhibit Number	Exhibit Description	Incorporated by Reference Form	Original Number	Date Filed	Filed Herewith
4.24	First Supplemental Indenture to the Chubb Corp Junior Subordinated Indenture dated as of March 29, 2007 between the Chubb Corporation and The Bank of New York Trust Company, N.A., as Trustee (incorporated by reference to Exhibit 4.2 to Chubb Corp's Current Report on Form 8-K filed on March 30, 2007) (File No. 001-08661)	8-K	4.2	March 30, 2007	
4.25	Form of 5.75 percent Chubb Corp Senior Notes due 2018 (incorporated by reference to Exhibit 4.1 to Chubb Corp's Current Report on Form 8-K filed on May 6, 2008) (File No. 001-08661)	8-K	4.1	May 6, 2008	
4.26	Form of 6.60 percent Chubb Corp Debentures due 2018 (incorporated by reference to Exhibit 4(a) to Chubb Corp's Registration Statement on Form S-3 filed on October 27, 1989) (File No. 33-31796)	S-3	4(a)	October 27, 1989	
4.27	Form of 6.80 percent Chubb Corp Debentures due 2031 (incorporated by reference to Exhibit 4(a) to Chubb Corp's Registration Statement on Form S-3 filed on October 27, 1989) (File No. 33-31796)	S-3	4(a)	October 27, 1989	
4.28	Form of 6.00 percent Chubb Corp Senior Notes due 2037 (incorporated by reference to Exhibit 4.1 to Chubb Corp's Current Report on Form 8-K filed on May 11, 2007) (File No. 001-08661)	8-K	4.1	May 11, 2007	
4.29	Form of 6.50 percent Chubb Corp Senior Notes due 2038 (incorporated by reference to Exhibit 4.2 to Chubb Corp's Current Report on Form 8-K filed on May 6, 2008) (File No. 001-08661)	8-K	4.2	May 6, 2008	
4.30	Form of debenture for the 6.375 percent Chubb Corp DISCs (incorporated by reference to Exhibit 4.3 to Chubb Corp's Current Report on Form 8-K filed on March 30, 2007) (File No. 001-08661)	8-K	4.3	March 30, 2007	
4.31	Procedures regarding the registration of shareholders in the share register of Chubb Limited	10-K	4.32	February 28, 2017	
4.32	Form of Officer's Certificate related to the 1.550% Senior Notes due 2028 and 2.500% Senior Notes due 2038	8-K	4.1	March 6, 2018	
4.33	Form of Global Note for the 1.550% Senior Notes due 2028	8-K	4.2	March 6, 2018	
4.34	Form of Global Note for the 2.500% Senior Notes due 2038	8-K	4.3	March 6, 2018	
4.35	Form of Officer's Certificate related to the 0.875% Senior Notes due 2027 and 1.400% Senior Notes due 2031	8-K	4.1	June 17, 2019	
4.36	Form of Global Note for the 0.875% Senior Notes due 2027	8-K	4.2	June 17, 2019	
4.37	Form of Global Note for the 1.400% Senior Notes due 2031	8-K	4.3	June 17, 2019	
4.38	Form of Officer’s Certificate related to the 0.300% Senior Notes due 2024 and 0.875% Senior Notes due 2029	8-K	4.1	December 5, 2019	
4.39	Form of Global Note for the 0.300% Senior Notes due 2024	8-K	4.2	December 5, 2019	
4.40	Form of Global Note for the 0.875% Senior Notes due 2029	8-K	4.3	December 5, 2019	

Exhibit Number	Exhibit Description	Incorporated by Reference			Filed Herewith
		Form	Original Number	Date Filed	
4.41	Description of the Registrant's Securities				X
10.1*	Form of Indemnification Agreement between the Company and the directors of the Company, dated August 13, 2015	10-K	10.1	February 26, 2016	
10.2	Credit Agreement for $1,000,000,000 Senior Unsecured Letter of Credit Facility, dated as of November 6, 2012, among ACE Limited, and certain subsidiaries and Wells Fargo Bank, National Association as Administrative Agent, the Swingline Bank and an Issuing Bank	10-K	10.13	February 28, 2013	
10.3*	Employment Terms dated October 29, 2001, between ACE Limited and Evan Greenberg	10-K	10.64	March 27, 2003	
10.4*	Employment Terms dated November 2, 2001, between ACE Limited and Philip V. Bancroft	10-K	10.65	March 27, 2003	
10.5*	Executive Severance Agreement between ACE Limited and Philip Bancroft, effective January 2, 2002	10-Q	10.1	May 10, 2004	
10.6*	Letter Regarding Executive Severance between ACE Limited and Philip V. Bancroft	10-K	10.17	February 25, 2011	
10.7*	Employment Terms dated April 10, 2006, between ACE and John Keogh	10-K	10.29	February 29, 2008	
10.8*	Executive Severance Agreement between ACE and John Keogh	10-K	10.30	February 29, 2008	
10.9*	ACE Limited Executive Severance Plan as amended effective May 18, 2011	10-K	10.21	February 24, 2012	
10.10*	Form of employment agreement between the Company (or subsidiaries of the Company) and executive officers of the Company to allocate a percentage of aggregate salary to the Company (or subsidiaries of the Company)	8-K	10.1	July 16, 2008	
10.11*	Outside Directors Compensation Parameters				X
10.12*	ACE Limited Elective Deferred Compensation Plan (as amended and restated effective January 1, 2005)	10-K	10.24	March 16, 2006	
10.13*	ACE USA Officer Deferred Compensation Plan (as amended through January 1, 2001)	10-K	10.25	March 16, 2006	
10.14*	ACE USA Officer Deferred Compensation Plan (as amended and restated effective January 1, 2011)	10-Q	10.7	October 30, 2013	
10.15*	ACE USA Officer Deferred Compensation Plan (as amended and restated effective January 1, 2009)	10-K	10.36	February 27, 2009	
10.16*	First Amendment to the Amended and Restated ACE USA Officers Deferred Compensation Plan	10-K	10.28	February 25, 2010	
10.17*	Form of Swiss Mandatory Retirement Benefit Agreement (for Swiss-employed named executive officers)	10-Q	10.2	May 7, 2010	
10.18*	ACE Limited Supplemental Retirement Plan (as amended and restated effective July 1, 2001)	10-Q	10.1	November 14, 2001	
10.19*	ACE Limited Supplemental Retirement Plan (as amended and restated effective January 1, 2011)	10-Q	10.6	October 30, 2013	

Exhibit Number	Exhibit Description	Incorporated by Reference Form	Original Number	Date Filed	Filed Herewith
10.20*	Amendments to the ACE Limited Supplemental Retirement Plan and the ACE Limited Elective Deferred Compensation Plan	10-K	10.38	February 29, 2008	
10.21*	ACE Limited Elective Deferred Compensation Plan (as amended and restated effective January 1, 2009)	10-K	10.39	February 27, 2009	
10.22*	ACE Limited Elective Deferred Compensation Plan (as amended and restated effective January 1, 2011)	10-Q	10.5	October 30, 2013	
10.23*	Deferred Compensation Plan amendments, effective January 1, 2009	10-K	10.40	February 27, 2009	
10.24*	Amendment to the ACE Limited Supplemental Retirement Plan	10-K	10.39	February 29, 2008	
10.25*	Amendment and restated ACE Limited Supplemental Retirement Plan, effective January 1, 2009	10-K	10.42	February 27, 2009	
10.26*	ACE USA Supplemental Employee Retirement Savings Plan (see exhibit 10.6 to Form 10-Q filed with the SEC on May 15, 2000)	10-Q	10.6	May 15, 2000	
10.27*	ACE USA Supplemental Employee Retirement Savings Plan (as amended through the Second Amendment)	10-K	10.30	March 1, 2007	
10.28*	ACE USA Supplemental Employee Retirement Savings Plan (as amended through the Third Amendment)	10-K	10.31	March 1, 2007	
10.29*	ACE USA Supplemental Employee Retirement Savings Plan (as amended and restated)	10-K	10.46	February 27, 2009	
10.30*	First Amendment to the Amended and Restated ACE USA Supplemental Employee Retirement Savings Plan	10-K	10.39	February 25, 2010	
10.31*	The ACE Limited 1995 Outside Directors Plan (as amended through the Seventh Amendment)	10-Q	10.1	August 14, 2003	
10.32*	ACE Limited 1998 Long-Term Incentive Plan (as amended through the Fourth Amendment)	10-K	10.34	March 1, 2007	
10.33*	ACE Limited 2004 Long-Term Incentive Plan (as amended through the Fifth Amendment)	8-K	10	May 21, 2010	
10.34*	ACE Limited 2004 Long-Term Incentive Plan (as amended through the Sixth Amendment)	8-K	10.1	May 20, 2013	
10.35*	ACE Limited Rules of the Approved U.K. Stock Option Program (see exhibit 10.2 to Form 10-Q filed with the SEC on February 13, 1998)	10-Q	10.2	February 13, 1998	
10.36*	Form of Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-K	10.54	February 27, 2009	
10.37*	Form of Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-K	10.55	February 27, 2009	
10.38*	Director Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.1	November 9, 2009	
10.39*	Form of Restricted Stock Unit Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.1	May 8, 2008	

		Incorporated by Reference			
Exhibit Number	Exhibit Description	Form	Original Number	Date Filed	Filed Herewith
10.40*	Form of Restricted Stock Unit Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.2	May 8, 2008	
10.41*	Form of Restricted Stock Unit Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-K	10.60	February 27, 2009	
10.42*	Form of Restricted Stock Unit Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.2	October 30, 2013	
10.43*	Form of Restricted Stock Unit Award Terms under the ACE Limited 2004 Long-Term Incentive Plan for Chief Executive Officer, Chief Financial Officer and the General Counsel	10-K	10.56	February 28, 2014	
10.44*	Form of Incentive Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan	8-K	10.4	September 13, 2004	
10.45*	Form of Incentive Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.4	May 8, 2008	
10.46*	Form of Incentive Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-K	10.63	February 27, 2009	
10.47*	Form of Incentive Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.3	October 30, 2013	
10.48*	Form of Non-Qualified Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan	8-K	10.5	September 13, 2004	
10.49*	Form of Non-Qualified Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.3	May 8, 2008	
10.50*	Form of Non-Qualified Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.4	October 30, 2013	
10.51*	Form of Performance Based Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan, as updated through May 4, 2006	10-Q	10.3	May 5, 2006	
10.52*	Revised Form of Performance Based Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.2	November 8, 2006	
10.53*	Revised Form of Performance Based Restricted Stock Award Terms under The ACE Limited 2004 Long-Term Incentive Plan	10-K	10.65	February 25, 2011	
10.54*	Form of Performance Based Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-K	10.67	February 28, 2014	
10.55*	Form of Performance Based Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan for Chief Executive Officer, Chief Financial Officer and the General Counsel	10-K	10.68	February 28, 2014	
10.56*	Form of Restricted Stock Unit Award Terms (for outside directors) under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.2	November 7, 2007	
10.57*	Form of Restricted Stock Unit Award Terms (for outside directors) under the ACE Limited 2004 Long-Term Incentive Plan	10-Q	10.2	August 7, 2009	

Exhibit Number	Exhibit Description	Incorporated by Reference Form	Original Number	Date Filed	Filed Herewith
10.58*	Form of Incentive Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan for Messrs. Greenberg and Cusumano	10-Q	10.1	August 4, 2011	
10.59*	Form of Non-Qualified Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan for Messrs. Greenberg and Cusumano	10-Q	10.2	August 4, 2011	
10.60*	Form of Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan for Messrs. Greenberg and Cusumano	10-Q	10.3	August 4, 2011	
10.61*	ACE Limited Employee Stock Purchase Plan, as amended	8-K	10.1	May 22, 2012	
10.62*	Form of Performance Based Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan for Messrs. Greenberg and Cusumano	10-K	10.72	February 24, 2012	
10.63*	Form of Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.68	February 27, 2015	
10.64*	Form of Performance Based Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.69	February 27, 2015	
10.65*	Form of Restricted Stock Unit Award Terms under the ACE Limited 2004 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.70	February 27, 2015	
10.66*	Form of Incentive Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.71	February 27, 2015	
10.67*	Form of Non-Qualified Stock Option Terms under the ACE Limited 2004 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.72	February 27, 2015	
10.68*	Form of Executive Management Non-Competition Agreement	8-K	10.1	May 22, 2015	
10.69	Commitment Increase Agreement to increase the credit capacity under the Credit Agreement originally entered into on November 6, 2012 to $1,500,000,000 under the Senior Unsecured Letter of Credit Facility, dated as of December 11, 2015, among ACE Limited, and certain subsidiaries, and Wells Fargo Bank, National Association as Administrative Agent, the Swingline Bank and an Issuing Bank	10-K	10.72	February 26, 2016	
10.70*	Form of Performance Based Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan	10-K	10.73	February 26, 2016	
10.71*	Form of Performance Based Restricted Stock Award Terms under the ACE Limited 2004 Long-Term Incentive Plan for Special Award for Messrs. Greenberg and Keogh	10-K	10.74	February 26, 2016	
10.72*	Chubb Limited 2016 Long-Term Incentive Plan	S-8	4.4	May 26, 2016	
10.73*	Form of Incentive Stock Option Terms under the Chubb Limited 2016 Long-Term Incentive Plan	10-Q	10.2	August 5, 2016	
10.74*	Form of Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan	10-Q	10.3	August 5, 2016	

Exhibit Number	Exhibit Description	Incorporated by Reference			Filed Herewith
		Form	Original Number	Date Filed	
10.75*	Form of Restricted Stock Unit Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan	10-Q	10.4	August 5, 2016	
10.76*	Form of Non-Qualified Stock Option Terms under the Chubb Limited 2016 Long-Term Incentive Plan	10-Q	10.5	August 5, 2016	
10.77*	Form of Incentive Stock Option Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-Q	10.6	August 5, 2016	
10.78*	Form of Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-Q	10.7	August 5, 2016	
10.79*	Form of Restricted Stock Unit Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-Q	10.8	August 5, 2016	
10.80*	Form of Non-Qualified Stock Option Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-Q	10.9	August 5, 2016	
10.81*	Form of Performance Based Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.84	February 28, 2017	
10.82*	Form of Performance Based Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan	10-K	10.85	February 28, 2017	
10.83*	Chubb Limited Employee Stock Purchase Plan, as amended and restated	S-8	4.4	May 25, 2017	
10.84*	Director Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan	10-Q	10.1	August 3, 2017	
10.85	Amended and Restated Credit Agreement for $1,000,000 Senior Unsecured Letter of Credit Facility, dated as of October 25, 2017, among Chubb Limited, and certain subsidiaries and Wells Fargo Bank, National Association as Administrative Agent, the Swingline Bank and an Issuing Bank	10-K	10.88	February 23, 2018	
10.86*	Form of Incentive Stock Option Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Executive Officers	10-K	10.89	February 23, 2018	
10.87*	Form of Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Executive Officers	10-K	10.90	February 23, 2018	
10.88*	Form of Performance Based Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Executive Officers	10-K	10.91	February 23, 2018	
10.89*	Form of Non-Qualified Stock Option Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Executive Officers	10-K	10.92	February 23, 2018	
10.90*	Form of Restricted Stock Unit Award Terms under the Chubb Limited 2016 Long-Term Plan for Executive Officers	10-K	10.93	February 23, 2018	
10.91*	Form of Incentive Stock Option Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.94	February 23, 2018	
10.92*	Form of Non-Qualified Stock Option Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.95	February 23, 2018	

Exhibit Number	Exhibit Description	Incorporated by Reference Form	Original Number	Date Filed	Filed Herewith
10.93*	Form of Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.96	February 23, 2018	
10.94*	Form of Restricted Stock Unit Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.97	February 23, 2018	
10.95*	Form of Performance Based Restricted Stock Award Terms under the Chubb Limited 2016 Long-Term Incentive Plan for Swiss Executive Management	10-K	10.98	February 23, 2018	
10.96*	Chubb Limited Clawback Policy	10-K	10.99	February 23, 2018	
21.1	Subsidiaries of the Company				X
23.1	Consent of Independent Registered Public Accounting Firm				X
31.1	Certification Pursuant to Section 302 of The Sarbanes-Oxley Act of 2002				X
31.2	Certification Pursuant to Section 302 of The Sarbanes-Oxley Act of 2002				X
32.1	Certification Pursuant to 18 U.S.C. Section 1350, As Adopted Pursuant to Section 906 of The Sarbanes-Oxley Act of 2002				X
32.2	Certification Pursuant to 18 U.S.C. Section 1350, As Adopted Pursuant to Section 906 of The Sarbanes-Oxley Act of 2002				X
101	The following financial information from Chubb Limited's Annual Report on Form 10-K for the year ended December 31, 2019, formatted in Inline XBRL: (i) Consolidated Balance Sheets at December 31, 2019 and 2018; (ii) Consolidated Statements of Operations and Comprehensive Income for the years ended December 31, 2019, 2018, and 2017; (iii) Consolidated Statements of Shareholders' Equity for the years ended December 31, 2019, 2018, and 2017; (iv) Consolidated Statements of Cash Flows for the years ended December 31, 2019, 2018, and 2017; and (v) Notes to the Consolidated Financial Statements				X
104	The Cover Page Interactive Data File formatted in Inline XBRL (The cover page XBRL tags are embedded in the Inline XBRL document and included in Exhibit 101)				

* Management contract, compensatory plan or arrangement

ITEM 16. Form 10-K Summary

None.

SIGNATURES

Pursuant to the requirements of Section 13 or 15(d) of the Securities Exchange Act of 1934, the registrant has duly caused this report to be signed on its behalf by the undersigned, thereunto duly authorized.

CHUBB LIMITED

By: /s/ Philip V. Bancroft

Philip V. Bancroft
Executive Vice President and Chief Financial Officer

February 27, 2020

Pursuant to the requirements of the Securities Exchange Act of 1934, this report has been signed below by the following persons on behalf of the registrant and in the capacities and on the dates indicated.

Signature	Title	Date
/s/ Evan G. Greenberg **Evan G. Greenberg**	Chairman, President, Chief Executive Officer, and Director	February 27, 2020
/s/ Philip V. Bancroft **Philip V. Bancroft**	Executive Vice President and Chief Financial Officer (Principal Financial Officer)	February 27, 2020
/s/ Paul B. Medini **Paul B. Medini**	Chief Accounting Officer (Principal Accounting Officer)	February 27, 2020
/s/ Michael G. Atieh **Michael G. Atieh**	Director	February 27, 2020
/s/ Sheila P. Burke **Sheila P. Burke**	Director	February 27, 2020
/s/ James I. Cash **James I. Cash**	Director	February 27, 2020
/s/ Mary A. Cirillo **Mary A. Cirillo**	Director	February 27, 2020
/s/ Michael P. Connors **Michael P. Connors**	Director	February 27, 2020

Signature	Title	Date
/s/ John Edwardson **John Edwardson**	Director	February 27, 2020
/s/ Robert M. Hernandez **Robert M. Hernandez**	Director	February 27, 2020
/s/ Kimberly Ross **Kimberly Ross**	Director	February 27, 2020
/s/ Robert W. Scully **Robert W. Scully**	Director	February 27, 2020
/s/ Eugene B. Shanks, Jr. **Eugene B. Shanks, Jr.**	Director	February 27, 2020
/s/ Theodore E. Shasta **Theodore E. Shasta**	Director	February 27, 2020
/s/ David Sidwell **David Sidwell**	Director	February 27, 2020
/s/ Olivier Steimer **Olivier Steimer**	Director	February 27, 2020

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LETTER

DERMATOLOGIC THERAPY WILEY

COVID-19 and SARS: Differences and similarities

Dear Editor

SARS-CoV (causative pathogen of Severe Acute Respiratory Syndrome or SARS) and SARS-CoV-2 (causative pathogen of Coronavirus Disease 2019 or COVID-19) are positive-sense RNA viruses belonging to the family of Coronaviridae, able to cause severe respiratory diseases.[1-4]

Despite some similarities, they have many differences, especially in terms of epidemiology. The main differences and similarities are summarized in Table 1.

Genomic characterization has shown that SARS-CoV-2 share almost 80% of the genome with SARS-CoV but it contains additional gene regions (10b, 13, 14).[5]

SARS originated in China's Guangdong province on November 27, 2002. It presented as a respiratory disease caused by the SARS coronavirus (SARS-CoV). At the end of the epidemic in June, the infection affected 8422 individuals leading to 916 deaths and a case-fatality ratio of 10.9% across 29 countries.[2]

On the other hand, COVID-19 began in Wuhan (China), the largest city in Hubei province, in central China in the last week of December 2019. To date, a cumulative 512 701 cases with 23 495 deaths (case-fatality ratio of 4,6%) were reported across 202 countries[6] and, based on available data, the transmission rate might be higher for COVID-19 than for SARS.

The incubation period for SARS was from 2 to 10 days (with mean of 4-5 days) while the average incubation period for COVID-19 is 5.1 days, with a range of 1 to14 days. The average latency of COVID is slightly longer than SARS.[4]

The World Health Organization (WHO) estimates an average basic reproduction number (R0) of COVID-19 of 1.4 to 2.5, with a median of 1.95. In other words, each patient transmits the infection to an additional 1.95 people. The R0 of the SARS epidemic were approximately 3.[3] In contrast with these values, a study shows that the COVID-19 is already more widespread than SARS because its real average R0 is 3.28.[7] This data indicates that COVID-19 may be more transmissible than SARS.

There was a predominance of female patients affected by SARS, with a male to female ratio of 1:1.25. Instead COVID-19 is much more prevalent among males, with a male to female ratio of 2.7:1.[8] Data show that the COVID-19 patients' median age is 59 years, with a range of 15 to 89 years while the median age of patients with SARS was 35 years, with a range of 0 to 92 years and the highest age-specific incidence was in patients with 65-69 years.[2]

The early symptoms of SARS and COVID-19 are very similar, including fever, cough, headache, shortness breath and breathing difficulties. Diarrhea was reported in about 20-25% of patients with SARS, while intestinal symptoms were rarely described in patients with COVID-19. In addition, most patients with SARS and COVID-19 developed lymphopenia with high-levels of proinflammatory cytokines including interleukin (IL)-1b and IL-6.[2]

TABLE 1 Main aspects of coronavirus disease 2019 (COVID-19) and severe acute respiratory syndrome (SARS)

	COVID-19	SARS
Location of first detection	Wuhan, China	Guangdong, China
Start date	December 2019	November 2002
Incubation period	2-10 years (mean of 4-5 days)	1–14 years (mean of 5.1 days)
Global cumulative incidence	512 701 cases (to date)	8422 cases
Deaths	23 595 (to date)	916
Mortality	4.6%	10.8%
Median age	59 years (range of 15 to 89 years)	35 years (range of 0 to 92 years)
Male to female ratio	2.7:1	1:1.25
Possible natural reservoir	Bat	Bat
Possible intermediate host	Pangolins	Civet cats
R0	1.4 to 2.5 (median of 1.95)	3
Intestinal Symptoms	rare	20%-25% of cases
Predominant cellular receptor	ACE2	ACE2

Abbreviation: ACE = Angiotensin-converting enzyme.

The possible pathogens are both derived from wild animals: SARS-CoV was transmitted from civet cats to humans. Previous studies showed that bats were the most likely reservoir for SARS-CoV-2 as it is very similar to a bat coronavirus.[8] However, there are no evidences of direct bat-human transmission; instead pangolins are the possible intermediate host for COVID-19. The common aspect is that SARS and COVID-19 infect lung alveolar epithelial cells using receptor-mediated endocytosis via the angiotensin-converting enzyme II (ACE2) as an entry receptor.[9]

The rapid development of this pandemic requires comparisons with previous epidemic, to analyze infection trends and to find the right prevention and treatment measures, as was done in the past for similar cases.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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EMERGING INFECTIOUS DISEASES®

Emerg Infect Dis. 2004 Nov; 10(11): e26. PMCID: PMC3329048
doi: 10.3201/eid1011.040797_02: 10.3201/eid1011.040797_02

SARS, the First Pandemic of the 21st Century[1]

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Keywords: SARS, 21st Century Pandemic

The 2003 outbreak of severe acute respiratory syndrome (SARS) shocked the world as it spread swiftly from continent to continent, resulting in >8,000 infections, with approximately 10% mortality, and a devastating effect on local and regional economies. Three laboratories—one each in Hong Kong, Germany, and the Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia, USA—nearly simultaneously isolated an apparently new coronavirus as the cause of SARS. Through traditional virus isolation and molecular techniques, CDC's team recovered the virus from specimens and characterized it as a novel coronavirus. Specific nucleotide sequences of the new virus were identified in specimens from SARS patients, and an immune response to the agent was demonstrated in patients' sera.

The potential for global spread of SARS was quickly recognized by the World Health Organization (WHO). The Global Outbreak Alert and Response Network was activated to help identify and deploy volunteers from around the world to assist the most severely affected nations, and WHO rapidly issued several recommendations to help nations control outbreaks and prevent spread.

Hong Kong was among the first cities affected by SARS, and its healthcare community suffered greatly from the disease. Some lessons from their experiences included recognition of the value of real-time information in a rapidly progressing epidemic with a large number of cases and the need for frequent patient updates, challenges of national efforts to maintain entry and exit health screening among international travelers, and implementation of home quarantine as an effective tool to interrupt SARS transmission.

In Toronto, Ontario, Canada, the public health department had responsibility for SARS surveillance and case reporting, investigation and management of possible cases, identification and quarantine of contacts, health risk assessment, and communications, and they were a liaison with hospitals regarding infection control. These were massive responsibilities. Serious practical and legal challenges were encountered as the department successfully implemented quarantine measures for the first time in more than half a century. Daunting challenges were also overcome in disease surveillance and reporting; meeting the needs for accurate, timely information and guidance; and implementing effective infection control practices in healthcare facilities. One of the most important lessons was an awareness of the psychosocial problems among healthcare workers directly involved in facing SARS.

Footnotes

Suggested citation for this article: LeDuc JW, Barry MA. SARS, the first pandemic of the 21st century. Emerg Infect Dis [serial on the Internet]. 2004 Nov [*date cited*].http://dx.doi.org/10.3201/eid1011.040797_02

[1]Presented at the International Conference on Emerging Infectious Diseases, Atlanta, Georgia, February 29 – March 3, 2004, by William Bellini, Centers for Disease Control and Prevention; Guenael Rodier, World Health Organization; Thomas Tsang, Department of Health, Hong Kong, China; and Barbara Yaffe, Toronto Public Health.

FORMS - FILED JULY 6, 2006

FROM: LARRY PODOSHEN, SENIOR ANALYST

COMMERCIAL PROPERTY LI-CF-2006-175

NEW ENDORSEMENTS FILED TO ADDRESS EXCLUSION OF LOSS DUE TO VIRUS OR BACTERIA

This circular announces the submission of forms filings to address exclusion of loss due to disease-causing agents such as viruses and bacteria.

BACKGROUND

Commercial Property policies currently contain a pollution exclusion that encompasses contamination (in fact, uses the term *contaminant* in addition to other terminology). Although the pollution exclusion addresses contamination broadly, viral and bacterial contamination are specific types that appear to warrant particular attention at this point in time.

ISO ACTION

We have submitted forms filing CF-2006-OVBEF in all ISO jurisdictions and recommended the filing to the independent bureaus in other jurisdictions. This filing introduces new endorsement CP 01 40 07 06 - Exclusion Of Loss Due To Virus Or Bacteria, which states that there is **no coverage for loss or damage caused by or resulting from any virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease**.

Note: In Alaska, District of Columbia, Louisiana*, New York and Puerto Rico, we have submitted a different version of this filing, containing new endorsement CP 01 75 07 06 in place of CP 01 40. The difference relates to lack of implementation of the mold exclusion that was implemented in other jurisdictions under a previous multistate filing.

Both versions of CF-2006-OVBEF are attached to this circular.

* In Louisiana, the filing was submitted as a recommendation to the Property Insurance Association of Louisiana (PIAL), the independent bureau with jurisdiction for submission of property filings.

PROPOSED EFFECTIVE DATE

Filing CF-2006-OVBEF was submitted with a proposed effective date of January 1, 2007, in accordance with the applicable effective date rule of application in each state, with the exception of various states for which the insurer establishes its own effective date.

Upon approval, we will announce the actual effective date and state-specific rule of effective date application for each state.

RATING SOFTWARE IMPACT

New attributes being introduced with this revision:

- A new form is being introduced.

CAUTION

This filing has not yet been approved. If you print your own forms, do not go beyond the proof stage until we announce approval in a subsequent circular.

RELATED RULES REVISION

We are announcing in a separate circular the filing of a corresponding rules revision. Please refer to the **Reference(s)** block for identification of that circular.

REFERENCE(S)

LI-CF-2006-176 (7/6/06) - New Additional Rule Filed To Address Exclusion Of Loss Due To Virus Or Bacteria

ATTACHMENT(S)

- Multistate Forms Filing CF-2006-OVBEF
- State-specific version of Forms Filing CF-2006-OVBEF (Alaska, District of Columbia, Louisiana, New York, Puerto Rico)

We are sending these attachments only to recipients who asked to be put on the mailing list for attachments. If you need the attachments for this circular, contact your company's circular coordinator.

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Amendatory Endorsement - Exclusion Of Loss Due To Virus Or Bacteria

About This Filing

This filing addresses exclusion of loss due to disease-causing agents such as viruses and bacteria.

New Form

We are introducing:

- Endorsement **CP 01 40 07 06 -** Exclusion Of Loss Due To Virus Or Bacteria

Related Filing(s)

Rules Filing CF-2006- OVBER

Introduction

The current pollution exclusion in property policies encompasses contamination (in fact, uses the term *contaminant* in addition to other terminology). Although the pollution exclusion addresses contamination broadly, viral and bacterial contamination are specific types that appear to warrant particular attention at this point in time.

An example of bacterial contamination of a product is the growth of listeria bacteria in milk. In this example, bacteria develop and multiply due in part to inherent qualities in the property itself. Some other examples of viral and bacterial contaminants are rotavirus, SARS, influenza (such as avian flu), legionella and anthrax. The universe of disease-causing organisms is always in evolution.

Disease-causing agents may render a product impure (change its quality or substance), or enable the spread of disease by their presence on interior building surfaces or the surfaces of personal property. When disease-causing viral or bacterial contamination occurs, potential claims involve the cost of replacement of property (for example, the milk), cost of decontamination (for example, interior building surfaces), and business interruption (time element) losses.

Current Concerns

Although building and personal property could arguably become contaminated (often temporarily) by such viruses and bacteria, the nature of the property itself would have a bearing on whether there is actual property damage. An allegation of property damage may be a point of disagreement in a particular case. In addition, pollution exclusions are at times narrowly applied by certain courts. In recent years, ISO has filed exclusions to address specific exposures relating to contaminating or harmful substances. Examples are the mold exclusion in property and liability policies and the liability exclusion addressing silica dust. Such exclusions enable elaboration of the specific exposure and thereby can reduce the likelihood of claim disputes and litigation.

While property policies have not been a source of recovery for losses involving contamination by disease-causing agents, the specter of pandemic or hitherto unorthodox transmission of infectious material raises the concern that insurers employing such policies may face claims in which there are efforts to expand coverage and to create sources of recovery for such losses, contrary to policy intent.

In light of these concerns, we are presenting an exclusion relating to contamination by disease-causing viruses or bacteria or other disease-causing microorganisms.

Features Of New Amendatory Endorsement

The amendatory endorsement presented in this filing states that there is **no coverage for loss or damage caused by or resulting from any virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease**. The exclusion (which is set forth in Paragraph B of the endorsement) applies to property damage, time element and all other coverages; introductory Paragraph A prominently makes that point. Paragraphs C and D serve to avoid overlap with other exclusions, and Paragraph E emphasizes that other policy exclusions may still apply.

Copyright Explanation

Important Note

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THIS ENDORSEMENT CHANGES THE POLICY. PLEASE READ IT CAREFULLY.

EXCLUSION OF LOSS DUE TO VIRUS OR BACTERIA

This endorsement modifies insurance provided under the following:

COMMERCIAL PROPERTY COVERAGE PART
STANDARD PROPERTY POLICY

A. The exclusion set forth in Paragraph **B.** applies to all coverage under all forms and endorsements that comprise this Coverage Part or Policy, including but not limited to forms or endorsements that cover property damage to buildings or personal property and forms or endorsements that cover business income, extra expense or action of civil authority.

B. We will not pay for loss or damage caused by or resulting from any virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease.

However, this exclusion does not apply to loss or damage caused by or resulting from "fungus", wet rot or dry rot. Such loss or damage is addressed in a separate exclusion in this Coverage Part or Policy.

C. With respect to any loss or damage subject to the exclusion in Paragraph **B.**, such exclusion supersedes any exclusion relating to "pollutants".

D. The following provisions in this Coverage Part or Policy are hereby amended to remove reference to bacteria:

1. Exclusion of "Fungus", Wet Rot, Dry Rot And Bacteria; and
2. Additional Coverage - Limited Coverage for "Fungus", Wet Rot, Dry Rot And Bacteria, including any endorsement increasing the scope or amount of coverage.

E. The terms of the exclusion in Paragraph **B.**, or the inapplicability of this exclusion to a particular loss, do not serve to create coverage for any loss that would otherwise be excluded under this Coverage Part or Policy.

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Amendatory Endorsement - Exclusion Of Loss Due To Virus Or Bacteria

About This Filing

This filing addresses exclusion of loss due to disease-causing agents such as viruses and bacteria.

New Form

We are introducing:

- Endorsement **CP 01 75 07 06 -** Exclusion Of Loss Due To Virus Or Bacteria

Related Filing(s)

Rules Filing CF-2006-OVBER

Introduction

The current pollution exclusion in property policies encompasses contamination (in fact, uses the term *contaminant* in addition to other terminology). Although the pollution exclusion addresses contamination broadly, viral and bacterial contamination are specific types that appear to warrant particular attention at this point in time.

An example of bacterial contamination of a product is the growth of listeria bacteria in milk. In this example, bacteria develop and multiply due in part to inherent qualities in the property itself. Some other examples of viral and bacterial contaminants are rotavirus, SARS, influenza (such as avian flu), legionella and anthrax. The universe of disease-causing organisms is always in evolution.

Disease-causing agents may render a product impure (change its quality or substance), or enable the spread of disease by their presence on interior building surfaces or the surfaces of personal property. When disease-causing viral or bacterial contamination occurs, potential claims involve the cost of replacement of property (for example, the milk), cost of decontamination (for example, interior building surfaces), and business interruption (time element) losses.

Current Concerns

Although building and personal property could arguably become contaminated (often temporarily) by such viruses and bacteria, the nature of the property itself would have a bearing on whether there is actual property damage. An allegation of property damage may be a point of disagreement in a particular case. In addition, pollution exclusions are at times narrowly applied by certain courts. In recent years, ISO has filed exclusions to address specific exposures relating to contaminating or harmful substances. Examples are the mold exclusion in property and liability policies and the liability exclusion addressing silica dust. Such exclusions enable elaboration of the specific exposure and thereby can reduce the likelihood of claim disputes and litigation.

While property policies have not been a source of recovery for losses involving contamination by disease-causing agents, the specter of pandemic or hitherto unorthodox transmission of infectious material raises the concern that insurers employing such policies may face claims in which there are efforts to expand coverage and to create sources of recovery for such losses, contrary to policy intent.

In light of these concerns, we are presenting an exclusion relating to contamination by disease-causing viruses or bacteria or other disease-causing microorganisms.

Features Of New Amendatory Endorsement

The amendatory endorsement presented in this filing states that there is **no coverage for loss or damage caused by or resulting from any virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease**. The exclusion (which is set forth in Paragraph B of the endorsement) applies to property damage, time element and all other coverages; introductory Paragraph A prominently makes that point. Paragraph C serves to avoid overlap with another exclusion, and Paragraph D emphasizes that other policy exclusions may still apply.

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THIS ENDORSEMENT CHANGES THE POLICY. PLEASE READ IT CAREFULLY.

EXCLUSION OF LOSS DUE TO VIRUS OR BACTERIA

This endorsement modifies insurance provided under the following:

COMMERCIAL PROPERTY COVERAGE PART
STANDARD PROPERTY POLICY

A. The exclusion set forth in Paragraph **B.** applies to all coverage under all forms and endorsements that comprise this Coverage Part or Policy, including but not limited to forms or endorsements that cover property damage to buildings or personal property and forms or endorsements that cover business income, extra expense or action of civil authority.

B. We will not pay for loss or damage caused by or resulting from any virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease.

However, this exclusion does not apply to loss or damage caused by or resulting from fungus. Such loss or damage is addressed in a separate exclusion in this Coverage Part or Policy.

C. With respect to any loss or damage subject to the exclusion in Paragraph **B.**, such exclusion supersedes any exclusion relating to "pollutants".

D. The terms of the exclusion in Paragraph **B.**, or the inapplicability of this exclusion to a particular loss, do not serve to create coverage for any loss that would otherwise be excluded under this Coverage Part or Policy.

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World Health Organization

< Go back to all Coronavirus disease 2019 Q&As

Coronavirus disease (COVID-19): How is it transmitted?

23 December 2021 | Q&A

The English version was updated on 23 December 2021.

How does COVID-19 spread between people?

We know that the disease is caused by the SARS-CoV-2 virus, which spreads between people in several different ways.

- **Current evidence suggests that the virus spreads mainly between people who are in close contact with each other, for example at a conversational distance. The virus can spread from an infected person's mouth or nose in small liquid particles when they cough, sneeze, speak, sing or breathe. Another person can then contract the virus when infectious particles that pass through the air are inhaled at short range (this is often called short-range aerosol or short-range airborne transmission) or if infectious particles come into direct contact with the eyes, nose, or mouth (droplet transmission).**
- **The virus can also spread in poorly ventilated and/or crowded indoor settings, where people tend to spend longer periods of time. This is because aerosols can remain suspended in the air or travel farther than conversational distance (this is often called long-range aerosol or long-range airborne transmission).**
- **People may also become infected when touching their eyes, nose or mouth after touching surfaces or objects that have been contaminated by the virus.**

Further research is ongoing to better understand the spread of the virus and which settings are most risky and why. Research is also under way to study virus variants that are emerging and why some are more transmissible. For updated information on SARS-CoV-2 variants, please read the weekly epidemiologic updates.

When do infected people transmit the virus?

What is the difference between people who are asymptomatic or pre-symptomatic? Don't they both mean someone without symptoms?

Are there certain settings where COVID-19 can spread more easily?

How can I reduce my risk of getting COVID-19?

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VIRUS

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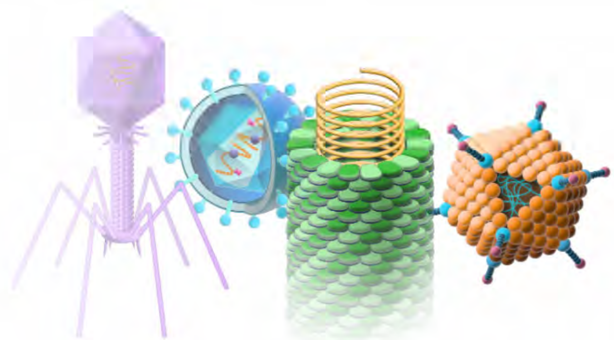

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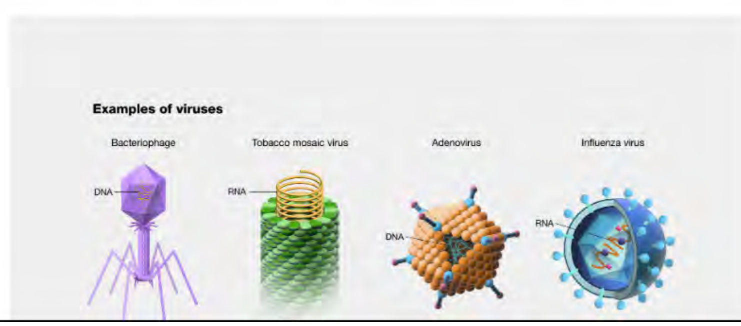
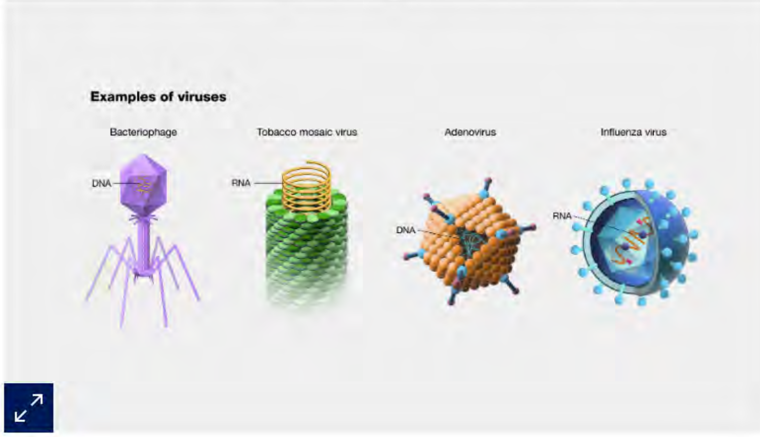
Definition

00:00 00:39

A virus is an infectious microbe consisting of a segment of nucleic acid (either DNA or RNA) surrounded by a protein coat. A virus cannot replicate alone; instead, it must infect cells and use components of the host cell to make copies of itself. Often, a virus ends up killing the host cell in the process, causing damage to the host organism. Well-known examples of viruses causing human disease include AIDS, COVID-19, measles and smallpox.





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Narration

00:00 01:15

Virus. Well, we all have learned a lot more about viruses in the last two years with the Covid-19 outbreak/global pandemic. Viruses infect humans. But, in fact, viruses infect many organisms, so you'll have viruses that infect fungi, viruses that infect bacteria, and we can learn a lot about how viruses maintain themselves by studying viruses that infect a whole host of species. That really does help us to understand human disease. But the viruses that infect humans are only a small fraction of the viruses that you find in the world. The greatest abundance of viruses would be those that infect bacteria that are sometimes called phage. And they have shared a lot of the same properties but they are much more abundant. A lot of future research will unravel the ways in which viruses infect humans and what we might find as potential ways of stopping viral replication within human cells.

Julie Segre, Ph.D.
Chief and Senior Investigator
Translational and Functional Genomics Branch

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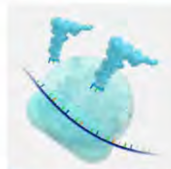
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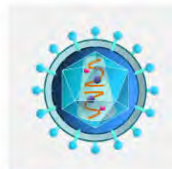
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Science Brief: SARS-CoV-2 and Surface (Fomite) Transmission for Indoor Community Environments

Updated Apr. 5, 2021

> COVID-19 Science Briefs provide a summary of the scientific evidence used to inform specific CDC guidance and recommendations. The Science Briefs reflect the scientific evidence, and CDC's understanding of it, on a specific topic at the time of the Brief's publication. Though CDC seeks to update Science Briefs when and as appropriate, given ongoing changes in scientific evidence an individual Science Brief might not reflect CDC's current understanding of that topic. As scientific evidence and available information on COVID-19 change, Science Briefs will be systematically archived as historic reference materials.
>
> Page First Published March 24, 2021

The principal mode by which people are infected with SARS-CoV-2 (the virus that causes COVID-19) is through exposure to respiratory droplets carrying infectious virus. It is possible for people to be infected through contact with contaminated surfaces or objects (fomites), but the risk is generally considered to be low.

Background

SARS-CoV-2, the virus that causes COVID-19, is an enveloped virus, meaning that its genetic material is packed inside an outer layer (envelope) of proteins and lipids. The envelope contains structures (spike proteins) for attaching to human cells during infection. The envelope for SARS-CoV-2, as with other enveloped respiratory viruses, is labile and can degrade quickly upon contact with surfactants contained in cleaning agents and under environmental conditions. The risk of fomite-mediated transmission is dependent on:

- The infection prevalence rate in the community
- The amount of virus infected people expel (which can be substantially reduced by wearing masks)
- The deposition of expelled virus particles onto surfaces (fomites), which is affected by air flow and ventilation
- The interaction with environmental factors (e.g., heat and evaporation) causing damage to virus particles while airborne and on fomites
- The time between when a surface becomes contaminated and when a person touches the surface
- The efficiency of transference of virus particles from fomite surfaces to hands and from hands to mucous membranes on the face (nose, mouth, eyes)
- The dose of virus needed to cause infection through the mucous membrane route

Because of the many factors affecting the efficiency of environmental transmission, the relative risk of fomite transmission of SARS-CoV-2 is considered low compared with direct contact, droplet transmission, or airborne transmission [1, 2]. However, it is not clear what proportion of SARS-CoV-2 infections are acquired through surface transmission. There have been few reports of COVID-19 cases potentially attributed to fomite transmission [1, 2]. Infections can often be attributed to multiple transmission pathways. Fomite transmission is difficult to prove definitively, in part because respiratory transmission from asymptomatic people cannot be ruled out [3, 4, 5]. Case reports indicate that SARS-CoV-2 is transmitted between people by touching surfaces an ill person has recently coughed or sneezed on, and then directly touching the mouth, nose, or eyes [3, 4, 5]. Hand hygiene is a barrier to fomite transmission and has been associated with lower risk of infection [6].

Quantitative microbial risk assessment (QMRA) studies have been conducted to understand and characterize the relative risk of SARS-CoV-2 fomite transmission and evaluate the need for and effectiveness of prevention measures to reduce risk. Findings of these studies suggest that the risk of SARS-CoV-2 infection via the fomite transmission route is low, and generally less than 1 in 10,000, which means that each contact with a contaminated surface has less than a 1 in 10,000 chance of causing an infection [7, 8, 9]. Some studies estimated exposure risks primarily using outdoor environmental SARS-CoV-2 RNA quantification data. They noted that their QMRA estimates are subject to uncertainty that can be reduced with additional data to improve the accuracy and precision of information that is entered into the models. Concentrations of infectious SARS-CoV-2 on outdoor surfaces could be expected to be lower than indoor surfaces because of air dilution and movement, as well as harsher environmental conditions, such as sunlight. One QMRA study also evaluated the effectiveness of prevention measures that reduce the risk of fomite transmission and found that hand hygiene could substantially reduce the risk of SARS-CoV-2 transmission from contaminated surfaces, while surface disinfection once- or twice-per-day had little impact on reducing estimated risks [9].

Surface survival

Numerous researchers have studied how long SARS-CoV-2 can survive on a variety of porous and non-porous surfaces [10, 11, 12, 13, 14, 15]. On porous surfaces, studies report inability to detect viable virus within minutes to hours; on non-porous surfaces, viable virus can be detected for days to weeks. The apparent, relatively faster inactivation of SARS-CoV-2 on porous compared with non-porous surfaces might be attributable to capillary action within pores and faster aerosol droplet evaporation [16].

Data from surface survival studies indicate that a 99% reduction in infectious SARS-CoV-2 and other coronaviruses can be expected under typical indoor environmental conditions within 3 days (72 hours) on common non-porous surfaces like stainless steel, plastic, and glass [10, 11, 12, 13, 15]. However, experimental conditions on both porous and non-porous surfaces do not necessarily reflect real-world conditions, such as initial virus amount (e.g., viral load in respiratory droplets) and factors that can remove or degrade the virus, such as ventilation and changing environmental conditions [8, 9]. They also do not account for inefficiencies in transfer of the virus between surfaces to hands and from hands to mouth, nose, and eyes [8, 9]. In fact, laboratory studies try to optimize the recovery of viruses from surfaces (e.g., purposefully swabbing the surface multiple times or soaking the contaminated surface in viral transport medium before swabbing). When accounting for both surface survival data and real-world transmission factors, the risk of fomite transmission after a person with COVID-19 has been in an indoor space is minor after 3 days (72 hours), regardless of when it was last cleaned [8, 9, 10, 11, 12, 13, 15].

Effectiveness of cleaning and disinfection

Both cleaning (use of soap or detergent) and disinfection (use of a product or process designed to inactivate SARS-CoV-2) can reduce the risk of fomite transmission. Cleaning reduces the amount of soil (e.g., dirt, microbes and other organic agents, and chemicals) on surfaces, but efficacy varies by the type of cleaner used, cleaning procedure, and how well the cleaning is performed. No reported studies have investigated the efficacy of surface cleaning (with soap or detergent not containing a registered disinfectant) for reducing concentrations of SARS-CoV-2 on non-porous surfaces. From studies of cleaning focused on other microbes, a 90–99.9% reduction of microbe levels could be possible depending on the cleaning method and the surface being cleaned [17, 18]. In addition to physical removal of SARS-CoV-2 and other microbes, surface cleaning can be expected to degrade the virus. Surfactants in cleaners can disrupt and damage the membrane of an enveloped virus like SARS-CoV-2 [19, 20, 21].

To substantially inactivate SARS-CoV-2 on surfaces, the surface must be treated with a disinfectant product registered with the Environmental Protection Agency's (EPA's) List N or technology that has been shown to be effective against the virus [22]. Disinfectant products might also contain cleaning agents, so they are designed to clean by both removing soil and inactivating microbes. Cleaners and disinfectants should be used safely, following the manufacturer guidance. There have been increases in poisonings and injuries from unsafe use of cleaners and disinfectants since the start of the COVID-19 pandemic [23]. Some types of disinfection applications, particularly those including fogging or misting, are neither safe nor effective for inactivating the virus unless properly used [24].

Surface disinfection has been shown to be effective for preventing secondary transmission of SARS-CoV-2 between an infected person and other people within households [25]. However, there is little scientific support for routine use of disinfectants in community settings, whether indoor or outdoor, to prevent SARS-CoV-2 transmission from fomites. In public spaces and community settings, available epidemiological data and QMRA studies indicate that the risk of SARS-CoV-2 transmission from fomites is low—compared with risks from direct contact, droplet transmission or airborne transmission [8, 9]. Routine cleaning performed effectively with soap or detergent, at least once per day, can substantially reduce virus levels on surfaces. When focused on high-touch surfaces, cleaning with soap or detergent should be enough to further reduce the relatively low transmission risk from fomites in situations when there has not been a suspected or confirmed case of COVID-19 indoors. In situations when there has been a suspected or confirmed case of COVID-19 indoors within the last 24 hours, the presence of infectious virus on surfaces is more likely and therefore high-touch surfaces should be disinfected [26].

Response to a case in an indoor environment

When a person with suspected or confirmed COVID-19 has been indoors, virus can remain suspended in the air for minutes to hours. The length of time virus remains suspended and is infectious depends on numerous factors, including viral load in respiratory droplets or in small particles, disturbance of air and surfaces, ventilation, temperature, and humidity [27, 28, 29, 30, 31]. Wearing masks consistently and correctly can substantially reduce the amount of virus indoors, including the amount of virus that lands on surfaces [32].

Based on limited epidemiologic and experimental data, the risk of infection from entering a space where a person with COVID-19 has been is low after 24 hours. During the first 24 hours, the risk can be reduced by increasing ventilation and waiting as long as possible before entering the space (at least several hours, based on documented airborne transmission cases), and using personal protective equipment (including any protection needed for the cleaning and disinfection products) to reduce risk. Certain techniques can improve the fit and filtration effectiveness of masks [32].

After a person with suspected or confirmed COVID-19 has been in an indoor space, the risk of fomite transmission from any surfaces is minor after 3 days (72 hours). Researchers have found that 99% reduction in infectious SARS-CoV-2 on non-porous surfaces can occur within 3 days [8, 9, 10, 11, 12, 13]. In indoor settings, risks can be reduced by wearing masks (which reduces droplets that can be deposited on surfaces), routine cleaning, and consistent hand hygiene.

Conclusion

People can be infected with SARS-CoV-2 through contact with surfaces. However, based on available epidemiological data and studies of environmental transmission factors, surface transmission is not the main route by which SARS-CoV-2 spreads, and the risk is considered to be low. The principal mode by which people are infected with SARS-CoV-2 is through exposure to respiratory droplets carrying infectious virus. In most situations, cleaning surfaces using soap or detergent, and not disinfecting, is enough to reduce risk. Disinfection is recommended in indoor community settings where there has been a suspected or confirmed case of COVID-19 within the last 24 hours. The risk of fomite transmission can be reduced by wearing masks consistently and correctly, practicing hand hygiene, cleaning, and taking other measures to maintain healthy facilities.

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COVID-19

Scientific Brief: SARS-CoV-2 Transmission

Updated May 7, 2021

COVID-19 Science Briefs provide a summary of the scientific evidence used to inform specific CDC guidance and recommendations. The Science Briefs reflect the scientific evidence, and CDC's understanding of it, on a specific topic at the time of the Brief's publication. Though CDC seeks to update Science Briefs when and as appropriate, given ongoing changes in scientific evidence an individual Science Brief might not reflect CDC's current understanding of that topic. As scientific evidence and available information on COVID-19 change, Science Briefs will be systematically archived as historic reference materials.

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SARS-CoV-2 is transmitted by exposure to infectious respiratory fluids

The principal mode by which people are infected with SARS-CoV-2 (the virus that causes COVID-19) is through exposure to respiratory fluids carrying infectious virus. Exposure occurs in three principal ways: (1) inhalation of very fine respiratory droplets and aerosol particles, (2) deposition of respiratory droplets and particles on exposed mucous membranes in the mouth, nose, or eye by direct splashes and sprays, and (3) touching mucous membranes with hands that have been soiled either directly by virus-containing respiratory fluids or indirectly by touching surfaces with virus on them.

People release respiratory fluids during exhalation (e.g., quiet breathing, speaking, singing, exercise, coughing, sneezing) in the form of droplets across a spectrum of sizes.[1-9] These droplets carry virus and transmit infection.

- The largest droplets settle out of the air rapidly, within seconds to minutes.
- The smallest very fine droplets, and aerosol particles formed when these fine droplets rapidly dry, are small enough that they can remain suspended in the air for minutes to hours.

Infectious exposures to respiratory fluids carrying SARS-CoV-2 occur in three principal ways (not mutually exclusive):

1. **Inhalation** of air carrying very small fine droplets and aerosol particles that contain infectious virus. Risk of transmission is greatest within three to six feet of an infectious source where the concentration of these very fine droplets and particles is greatest.
2. **Deposition** of virus carried in exhaled droplets and particles onto exposed mucous membranes (i.e., "splashes and sprays", such as being coughed on). Risk of transmission is likewise greatest close to an infectious source where the concentration of these exhaled droplets and particles is greatest.
3. **Touching** mucous membranes with hands soiled by exhaled respiratory fluids containing virus or from touching inanimate surfaces contaminated with virus.

The risk of SARS-CoV-2 infection varies according to the amount of virus to which a person is exposed

Once infectious droplets and particles are exhaled, they move outward from the source. The risk for infection decreases with increasing distance from the source and increasing time after exhalation. Two principal processes determine the amount of virus to which a person is exposed in the air or by touching a surface contaminated by virus:

1. **Decreasing concentration of virus in the air** as larger and heavier respiratory droplets containing virus fall to the ground or other surfaces under the force of gravity and the very fine droplets and aerosol particles that remain in the airstream progressively mix

with, and become diluted within, the growing volume and streams of air they encounter. This mixing is not necessarily uniform and can be influenced by thermal layering and initial jetting of exhalations.

2. **Progressive loss of viral viability and infectiousness** over time influenced by environmental factors such as temperature, humidity, and ultraviolet radiation (e.g., sunlight).

Transmission of SARS-CoV-2 from inhalation of virus in the air farther than six feet from an infectious source can occur

With increasing distance from the source, the role of inhalation likewise increases. Although infections through inhalation at distances greater than six feet from an infectious source are less likely than at closer distances, the phenomenon has been repeatedly documented under certain preventable circumstances.[10-21] These transmission events have involved the presence of an infectious person exhaling virus indoors for an extended time (more than 15 minutes and in some cases hours) leading to virus concentrations in the air space sufficient to transmit infections to people more than 6 feet away, and in some cases to people who have passed through that space soon after the infectious person left. Per published reports, factors that increase the risk of SARS-CoV-2 infection under these circumstances include:

- **Enclosed spaces with inadequate ventilation or air handling** within which the concentration of exhaled respiratory fluids, especially very fine droplets and aerosol particles, can build-up in the air space.
- **Increased exhalation** of respiratory fluids if the infectious person is engaged in physical exertion or raises their voice (e.g., exercising, shouting, singing).
- **Prolonged exposure** to these conditions, typically more than 15 minutes.

Prevention of COVID-19 transmission

The infectious dose of SARS-CoV-2 needed to transmit infection has not been established. Current evidence strongly suggests transmission from contaminated surfaces does not contribute substantially to new infections. Although animal studies[22-24] and epidemiologic investigations[25] (in addition to those described above) indicate that inhalation of virus can cause infection, the relative contributions of inhalation of virus and deposition of virus on mucous membranes remain unquantified and will be difficult to establish. Despite these knowledge gaps, the available evidence continues to demonstrate that existing recommendations to prevent SARS-CoV-2 transmission remain effective. These include physical distancing, community use of well-fitting masks (e.g., barrier face coverings, procedure/surgical masks), adequate ventilation, and avoidance of crowded indoor spaces. These methods will reduce transmission both from inhalation of virus and deposition of virus on exposed mucous membranes. Transmission through soiled hands and surfaces can be prevented by practicing good hand hygiene and by environmental cleaning.

Summary of Updates

Updates from Previous Content

As of May 7, 2021

- This science brief has been updated to reflect current knowledge about SARS-CoV-2 transmission and reformatted to be more concise.
- Modes of SARS-CoV-2 transmission are now categorized as inhalation of virus, deposition of virus on exposed mucous membranes, and touching mucous membranes with soiled hands contaminated with virus.
- Although how we understand transmission occurs has shifted, the ways to prevent infection with this virus have not. All prevention measures that CDC recommends remain effective for these forms of transmission.

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air

atmospheric gas

Written and fact-checked by The Editors of Encyclopaedia Britannica
Last Updated: Article History

Key People: Carl von Linde • Henry Cavendish • Robert Boyle • Anaximenes Of Miletus • Ctesibius Of Alexandria

Related Topics: chemical element • atmosphere • air-cushion machine • hydrogen • compressed air

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air, mixture of gases comprising the Earth's atmosphere. The mixture contains a group of gases of nearly constant concentrations and a group with concentrations that are variable in both space and time. The atmospheric gases of steady concentration (and their proportions in percentage by volume) are as follows:

nitrogen (N_2)	78.084
oxygen (O_2)	20.946
argon (Ar)	0.934
neon (Ne)	0.0018
helium (He)	0.000524
methane (CH_4)	0.0002
krypton (Kr)	0.000114
hydrogen (H_2)	0.00005
nitrous oxide (N_2O)	0.00005
xenon (Xe)	0.0000087

The uniformity of composition is maintained by mixing associated with atmospheric motions; but, above a height of about 90 km (55 miles), diffusional processes become more important than mixing, and the lighter gases (hydrogen and helium, in particular) are more abundant above that level.

Of the gases present in variable concentrations, water vapour, ozone, carbon dioxide, sulfur dioxide, and nitrogen dioxide are of principal importance. The typical concentration ranges of these gases (in percentage by volume) are as follows:

water vapour (H_2O)	0 to 7
carbon dioxide (CO_2)	0.01 to 0.1 (average about 0.032)
ozone (O_3)	0 to 0.01
sulfur dioxide (SO_2)	0 to 0.0001
nitrogen dioxide (NO_2)	0 to 0.000002

Although present in relatively small amounts, these variable constituents may be very important for maintaining life on Earth's surface. Water vapour is the source for all forms of precipitation and is an important absorber and emitter of infrared radiation. Carbon dioxide, besides being involved in the process of photosynthesis, is also an important absorber and emitter of infrared radiation. Ozone, which is present mainly in the atmospheric region 10 to 50 km (6 to 30 miles) above the Earth's surface, is an effective absorber of ultraviolet radiation from the Sun and effectively shields the Earth from all radiation of wavelengths less than 3,000 angstroms.

PNAS RESEARCH ARTICLE | CHEMISTRY MICROBIOLOGY OPEN ACCESS

The dynamics of SARS-CoV-2 infectivity with changes in aerosol microenvironment

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Understanding the factors that influence the airborne survival of viruses such as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in aerosols is important for identifying routes of transmission and the value of various mitigation strategies for preventing transmission. We present measurements of the stability of SARS-CoV-2 in aerosol droplets (∼5 to 10 μm equilibrated radius) over timescales spanning 5 s to 20 min using an instrument to probe survival in a small population of droplets (typically 5 to 10) containing ∼1 virus/droplet. Measurements of airborne infectivity change are coupled with a detailed physicochemical analysis of the airborne droplets containing the virus. A decrease in infectivity to ∼10% of the starting value was observable for SARS-CoV-2 over 20 min, with a large proportion of the loss occurring within the first 5 min after aerosolization. The initial rate of infectivity loss was found to correlate with physical transformation of the equilibrating droplet; salts within the droplets crystallize at relative humidities (RHs) below 50%, leading to a near-instant loss of infectivity in 50 to 60% of the virus. However, at 90% RH, the droplet remains homogenous and aqueous, and the viral stability is sustained for the first 2 min, beyond which it decays to only 10% remaining infectious after 10 min. The loss of infectivity at high RH is consistent with an elevation in the pH of the droplets, caused by volatilization of CO_2 from bicarbonate buffer within the droplet. Four different variants of SARS-CoV-2 were compared and found to have a similar degree of airborne stability at both high and low RH.

aerosol | SARS-CoV-2 | airborne transmission | microphysics | environmental conditions

Significance

The aerosol microenvironment is dynamic, exposing pathogens, such as severe acute respiratory syndrome coronavirus 2 virus, when exhaled in respiratory aerosol to extreme conditions of solute concentration, pH, and evaporative cooling. Yet surviving this environment is a key step in the transmission of such pathogens. Understanding the impact that airborne transport has on pathogens and the influence of environmental conditions on pathogen survival can inform the implementation of strategies to mitigate the spread of diseases such as coronavirus disease 2019. We report changes in the infectivity of the airborne virus over timescales from 5 s to 20 min and demonstrate the role of two microphysical processes in this infectivity loss, namely, particle crystallization and aerosol droplet pH change.

The ongoing coronavirus disease 2019 (COVID-19) pandemic has demonstrated the requirement for an improved understanding of the factors that govern the relative importance of different modes of transmission of respiratory pathogens, including the parameters that influence droplet, fomite, and airborne transmission. Indeed, shortcomings in our understanding have prolonged the debate surrounding the likelihood of airborne transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (1–3), with consequences for the implementation of nonpharmaceutical interventions and mitigation strategies such as physical distancing, the wearing of face coverings, and the use of ultraviolet (UV) germicidal irradiation. Currently, epidemiological evidence (4–7), air sampling studies (8), and animal-model studies (9) are broadly consistent with transmission dominated by the inhalation of infectious aerosol (<100-μm diameter). Transmission over distances beyond 2 m has been documented and tends to be under preventable circumstances (10), such as occurring after prolonged exposure in poorly ventilated rooms (11, 12).

Reports of the airborne stability of SARS-CoV-2 consistently indicate that the half-life associated with the decay in viral infectivity is on the order of hours in surrogates of respiratory aerosols (13–16). However, a detailed understanding of the processes that govern the airborne longevity of viruses, and how infectivity is affected by basic environmental conditions such as relative humidity (RH) and temperature, is required. More specifically, there is little clarity on the impact of environmental conditions on the microenvironment within an airborne droplet and the interplay between this microenvironment and the stability of pathogens. Improved models of the physicochemical properties of respiratory aerosol and the processes that transform particle size, moisture content, composition, and phase are essential to provide clearer insights into the relative risks of airborne transmission in different environments and the potential benefits of mitigation measures to reduce transmission. Indeed, it should be recognized that transformation processes lead to transient changes in properties (e.g., surface enrichment in salts during evaporation following droplet exhalation) that can have impacts on infectivity distinct from the steady state equilibrium properties that persist

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over longer time periods during airborne transport (e.g., an equilibrated salt concentration).

The microenvironment within an airborne droplet is multifarious and notoriously difficult to study (17) and is further complicated by the presence of organic macromolecules and microorganisms (18). While the vast majority of indoor aerosols originate from sources such as candles, dust, outdoor air pollution, and food cookers (19), respiratory pathogens are transmitted in exhaled aerosol that can span from 100-nm to 100-μm diameter and have emission rates as low as 10 particles s^{-1} when humans breathe (20, 21). Regardless of the expiratory activity that generates respiratory aerosols [e.g., coughing, speaking (21, 22)], the high surface area-to-volume ratio of the emitted particles facilitates rapid equilibration to the surrounding gas phase composition (*SI Appendix*, Fig. S1*A*) (23). In particular, the equilibration of the water activity within the droplet to the surrounding RH impacts the physicochemical conditions experienced by microorganisms present within the aerosol. Aqueous respiratory droplets at the point of exhalation start with a very high water activity (∼0.995) (24) consistent with equilibration with the high RH within the respiratory tract (25) but must adjust to equilibrate with the indoor humidity, which is typically within the range 20 to 60% (26–28). Under most conditions, exhaled aerosol droplets rapidly lose both moisture and heat through evaporation, with large concomitant changes in volume and temperature as they establish an equilibrium with the indoor environment.

Not only does the loss in water lead to an increase in solute concentrations during evaporation but also the absence of heterogenous nucleation sites (i.e., a surface) leads to supersaturated solute concentrations that cannot be achieved in the bulk solution phase or in sessile droplets deposited on surfaces. At sufficiently low RH (e.g., below 45% for saline solution droplets), the supersaturation of solutes can be sufficient to induce homogenous nucleation (29–31) of the salt fraction, leading to efflorescence (crystallization) of the droplet and the formation of a dryer particle. Furthermore, during the initial period of droplet evaporation, the rates of diffusion of microorganisms within the droplet can be significantly slower than the rate at which the droplet surface recedes, leading to their exclusion to the near-surface region of the droplet. Given that the physicochemical conditions at the surface of the droplet can be different to the core (e.g., surface enrichment in solute concentration), establishing the distribution of microorganisms within a particle may be crucial to understanding the impact of aerosol microphysics on their longevity.

Once the moisture content of the aerosol has decreased to establish equilibrium with the ambient environment, the decay in microorganism survival may be regulated by steady-state microphysical properties. In particular, the typical range in ambient RH is consistent with equilibrated solute concentrations that are supersaturated in the exhaled aerosol. Although the mechanism remains unclear, high salt concentrations may inactivate viruses by damaging the viral nucleic acid (32, 33). With high contents of organic macromolecules, phase-separated particles with organic- and inorganic-rich domains or amorphous particles containing trapped moisture may form, potentially enhancing viral and bacterial survival. Furthermore, the pH of aerosol particles is RH, size, and composition dependent, and the pH of aerosol droplet surfaces may be different from the droplet bulk (34). Indeed, predicting the evolving aerosol pH is challenging, particularly when the facile partitioning of water-soluble acidic and basic components from the ambient environment is considered, even before the influence of aerosol pH on microorganism survival is considered (35).

Laboratory strategies to assess the airborne stability of a pathogen must either be capable of simulating every aspect of the real-world environment in which transmission occurs or sufficient control over the conditions must be achieved such that the influence of individual processes and properties on survival can be assessed independently. Goldberg rotating drums (36) have been widely used over many decades to assess airborne pathogen stability and have been used to investigate the airborne survival of SARS-CoV-2. More specifically, studies have examined the dependence of infectivity on time (20 min to 16 h), RH (40 to 70%), and the presence of UVC light with measurements in aerosols composed of cell culture media (Dulbecco's modified Eagle medium [DMEM] and minimal essential media [MEM]) and artificial saliva (13–16, 37). All studies concentrate on equilibrated particle sizes of ∼5 μm (mass median aerodynamic diameter). A nebulizer is used to generate a cloud of aerosolized pathogen that is suspended by the rotation of the drum. The initial environmental conditions within the drum can be controlled by mixing the output of the nebulizer with a flow of humidity- and temperature-controlled air. However, operation with stable environmental conditions can be challenging; for example, as the droplets evaporate and equilibrate to the set humidity, the water they release can cause the humidity within the drum to increase [see for example the report of Smither et al. (14)]. In addition, dynamic changes in liquid water content within the freshly nebulized aerosol cloud do not replicate the very rapid changes that can accompany the extremely low concentrations of the exhaled aerosol. This precludes any study of short-term decreases in pathogen viability that may be critical to understanding close contact transmission and the immediate consequences of exhalation on microbe survival.

We have previously reported a unique approach to the study of infectious aerosol and the interplay between aerosol microphysics and pathogen survival, using complementary aerosol analysis techniques to assess the underlying mechanisms that govern the airborne longevity of pathogens (38, 39). The aerosol stability of viruses and bacteria is investigated using the CELEBS (controlled electrodynamic levitation and extraction of bioaerosols onto a substrate) technique (38–40). In CELEBS (*SI Appendix*, Fig. S1*B*), a small population (<20) of near-identical monodisperse droplets containing bacteria or viruses are trapped within an electric field, while a constant flow of air prevents the accumulation of released water around the droplets. Loading droplets into the CELEBS takes <0.1 s, and there is no physical loss of droplets over time. Thus, an assessment of the viability of suspended microbes within droplets can be made after periods of suspension varying between less than 5 s to many hours. These longevity measurements can then be contextualized with detailed measurements of the dynamic changes in the physicochemical properties of droplets generated the exact same way in an instrument referred to as the comparative kinetic-electrodynamic balance (CK-EDB) (38, 41–45). The CK-EDB uses the same piezoelectric droplet-on-demand dispensers as the CELEBS to generate droplets, with particles captured in the path of a laser within a flow of humidity and temperature-controlled air (*SI Appendix*, Fig. S1*C*). The elastic light scattering pattern can be used to infer the size and structure of these droplets within the same environmental conditions as those used in CELEBS.

By coupling the time-sensitive measurements of the physicochemical properties of the droplets (CK-EDB) with the downstream biological effects (CELEBS) on the same timescale, the systematic exploration of hypotheses regarding the inactivation

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mechanisms of viruses and bacteria is possible. In this study, we apply this approach to the study of SARS-CoV-2 survival in airborne droplets of cell culture medium, examining the survival over timescales spanning from <20 s, commensurate with the evaporation of freshly exhaled aerosol, through to 20 min. By studying the physicochemical changes that take place in the droplet and exploring how these changes impact the infectivity of the virus, we elucidate the effect of the airborne environment on SARS-CoV-2. This study provides insights into the potential influence of environmental conditions on COVID-19 transmission.

Results

The Airborne Infectivity of SARS-CoV-2 Declines over the First 20 min following Aerosolization. The infectivity of SARS-CoV-2 contained in droplets of MEM with 2% vol/vol fetal bovine serum (MEM 2% FBS) was measured over the course of 20 min of levitation in CELEBS at both low (40%) and high (90%) RH (Fig. 1*A*). A decrease in infectivity (in this work, defined as the proportion of virus remaining able to induce cytopathic effect) at low RH occurs almost immediately, falling to an average of 54% within 5 s of generation. Interestingly, although the initial loss in infectivity at low RH is almost instant, the virus infectivity then remains more stable, only decreasing an average of 19% over the next 5 min. At high RH, the reduction in infectivity following aerosolization is more gradual with a steady loss of infectivity of 48% within the first 5 min. The decay in survival appears to plateau at both RHs after 10 min, and the difference between infectivity in aerosol particles suspended at the two RHs diminishes over time, until survival at the two RHs is indistinguishable after 20 min. Further research will be required to explore for how long the apparent plateau continues, but it is possible that this slowing down of the viral decay is responsible for the longer half-lives reported in previous Goldberg rotating drum studies (15). It is unlikely that the rapid initial decay in virus infectivity would be observable in a rotating drum due to the relatively long times required to load the drum.

To more fully characterize the dependence of the infectivity of SARS-CoV-2 on RH, the RH was varied from 30 to 90% and the infectivity remaining at 2 min measured. Previous studies have reported little dependence of the infectivity decay rate on RH within the uncertainty of the measurements (14, 16). However, we observe a clear relationship between the short-term viability of SARS-CoV-2 and RH (Fig. 1*B*). Between 30 and 50% RH, the infectivity typically declines within this short time frame to between 30% and 40% after 2 min of levitation. At RHs of 80% and above, the virus is far more stable, with infectivity rarely falling below 80% after 2 min. The residual infectivity between 60% and 70% RH is highly variable, sometimes falling to similar levels to those observed at the lower RHs and sometimes showing almost no decrease; we shall return to this variability in a later section.

The rapid decay in infectivity reported here, with an observed half-life of on the order of seconds to minutes, has not been reported previously. However, consistent with the majority of previous studies, these survival decays have been measured in virus culture directly and it should be remembered that the aerosol composition (MEM 2% FBS) is different from real exhaled respiratory fluids, including saliva, alveolar lung fluid, and other respiratory secretions. Thus, we now investigate the causative mechanisms driving the decay of SARS-CoV-2 in airborne MEM 2% FBS in order to better understand the relevance of these measurements to the transmission of SARS-CoV-2.

Airborne Droplets of MEM Show Complex Phase Behavior during Evaporation. To provide insight into the underlying mechanisms that drive the observed airborne loss of SARS-CoV-2 infectivity, the microphysical changes (depicted in *SI Appendix*, Fig. S1*A*) taking place in the droplets hosting the virus were explored in real time and in situ using the CK-EDB with a time resolution of <100 ms (38, 41–45). For context, the phase changes that occur during the evaporation of aqueous sodium chloride at an RH below the efflorescence threshold are

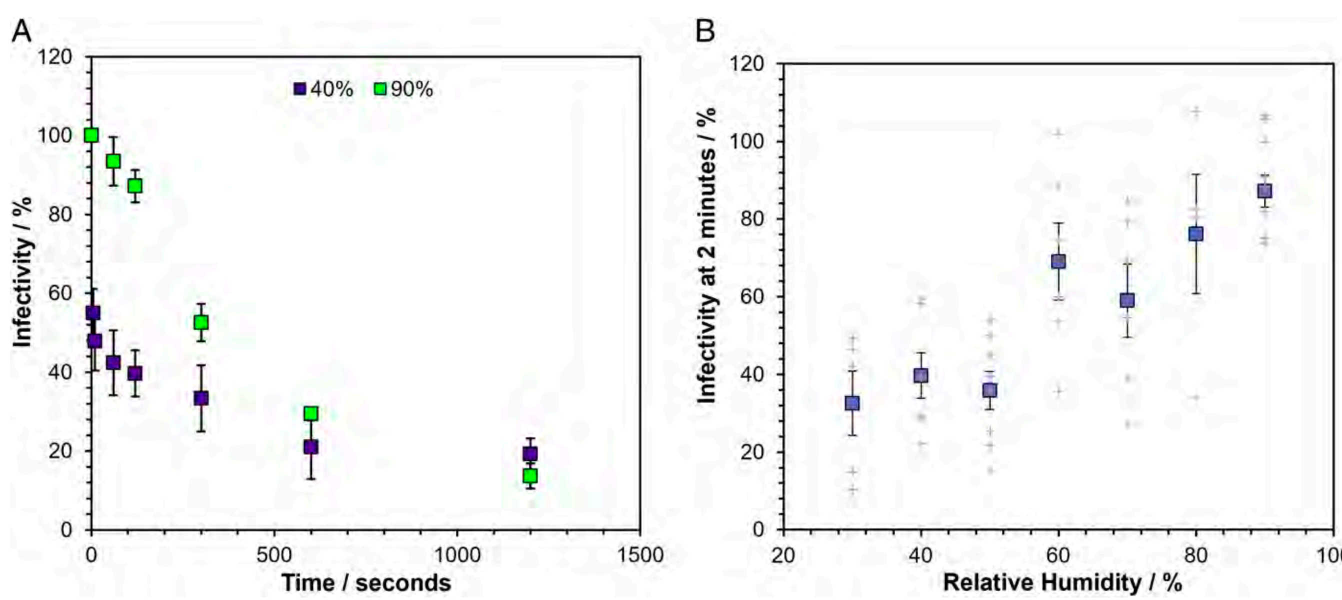

Fig. 1. The short-term airborne decay of SARS-CoV-2. Datapoints are the mean of several measurements (typically >4), and error bars show the standard error. Measurements were carried out at room temperature at 18 to 21°C. (*A*) The percentage infectivity of SARS-CoV-2 REMRQ0001 as a function of time levitated in CELEBS at 40% RH (purple) and 90% RH (green). (*B*) Curve showing the impact of RH on the percentage infectivity of SARS-CoV-2 REMRQ0001 after 2 min of levitation in CELEBS. The larger colored square points show the mean, with the error bars showing the standard error. Gray crosses show the results of individual measurements.

shown in *SI Appendix*, Fig. S2. When efflorescence occurs at low RH, the crystallization of the salt is exothermic, resulting in a transient increase in the droplet temperature and a concomitant increase in the evaporation rate. This increase in evaporation rate characteristic of efflorescence is best observed in changes in the intensity of the total light scattered by the particle. By comparison, Mie scattering calculations from the angularly resolved light scattering pattern can be used for precise estimation of the droplet size and can provide other insights into the physical transformations of the particle, such as the formation of numerous submicron crystals dispersed within the host liquid droplet and the point at which the particle ceases to be spherical (46).

For the viral longevity measurements in this study, the virus was suspended in MEM 2% FBS, which was the tissue culture medium used in the initial growth of the virus on Vero cells. The relatively low viral titers obtained with SARS-CoV-2 culture (, 47) prevented dilution into other solutions, constraining longevity experiments to the starting stock solution. We avoided concentrating the virus stocks using methods such as ultracentrifugation and tangential flow filtration to avoid any impact these processes might have on the stability of the virus, which could then introduce ambiguity into the interpretation of the longevity data. MEM is a complex solution containing a range of inorganic salts and organic components such as proteins, amino acids, and various sugars. The composition is made more complicated and uncertain through the addition of an animal extract (FBS). Saliva and lung fluid are also complex mixtures of inorganic and organic components, with many solutes at similar concentrations to those found in MEM. For example, MEM contains 3.3 g/L of sodium, 0.2 g/L of potassium, and 1.6 g/L of bicarbonate. For human saliva, these concentrations range from 0.26 to 5 g/L for sodium (48), 0.1 to 0.7 g/L for potassium (48), and 0.5 to 2 g/L for bicarbonate (49), putting the concentrations in MEM within the expected ranges for saliva. It should be noted though that the composition of saliva can vary significantly from individual to individual, with sampling conditions, and over the course of a respiratory infection (50–54).

To better understand the response of aerosols, formed from the complex mixture of components typical of cell culture media and respiratory secretions, to the airborne environment, the drying kinetics of droplets containing MEM 2% FBS were studied using the CK-EDB. Evaporation curves for droplets of MEM 2% FBS levitated at a range of RHs are shown in Fig. 2*A*. From the evaporation rates reported here, it is possible to estimate that the change in droplet temperature driven by evaporative cooling will not exceed a transient reduction of 5.5 °C, which is unlikely to influence viral infectivity. At an RH of 51% and below, changes in the overall light scatter intensity typical of efflorescence were observed (*SI Appendix*, Fig. S3), with the droplets crystallizing in less than 5 s from generation. At a measurement RH of 67%, efflorescence was not observed, although the recorded Mie scattering profile indicates that the particles are no longer spherical, potentially forming inhomogeneous amorphous semisolid particles (Fig. 2*A*). Indeed, at 78% RH, variability in the outcome of the dynamics and phase transformation of the aerosol was observed; particles initially underwent a phase change (possibly with the formation of inclusions) that was sometimes reversible, reforming a homogenous spherical particle at a later time. At RHs of 85% and above, particles mostly remained homogenous aqueous spheres. The dependence of the apparent final particle structure on RH is summarized in Fig. 2*B*. At the extremes of RH, particles of consistent phase were formed following drying and equilibration, with crystalline or spherical homogenous solution droplets resulting at low and high RH, respectively. At intermediate RHs, variability in the physical state of the equilibrated particle was observed, mirroring the greater variability in the remaining infectivity of SARS-CoV-2 at 2 min across these RHs (Fig. 1*B*). We shall return to a fuller explanation of the phase behavior of the droplets at these intermediate RHs in a later section.

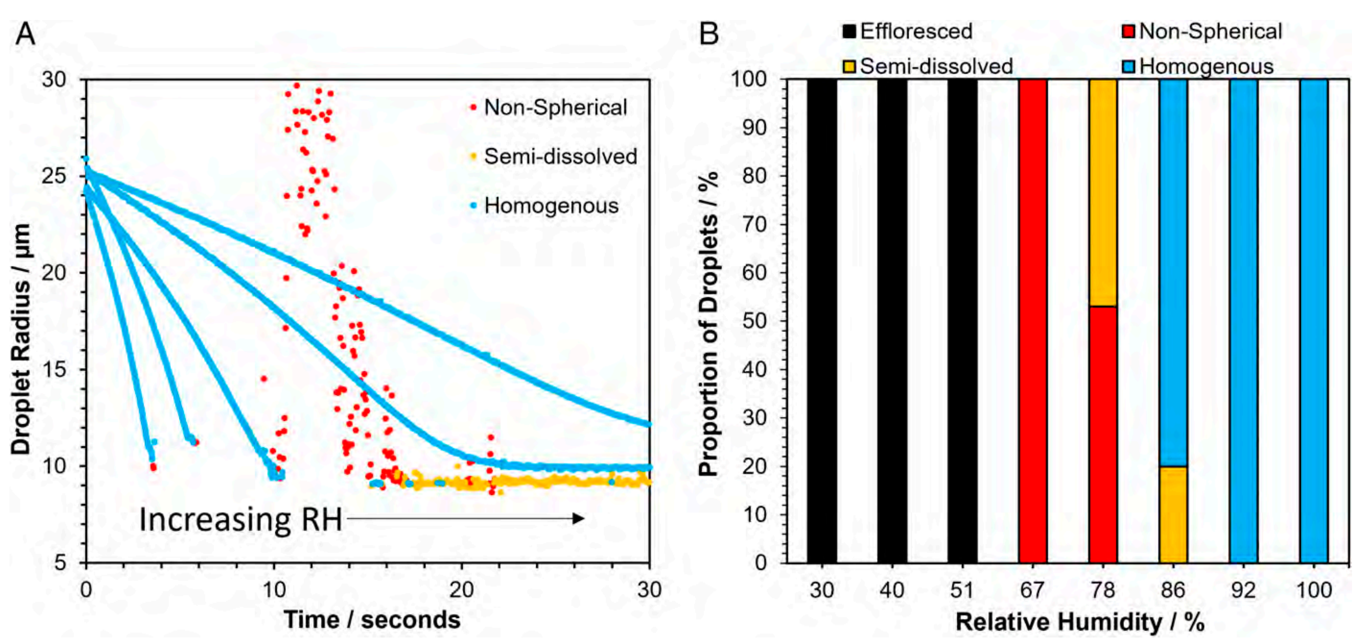

Fig. 2. The microphysics of airborne MEM droplets. (*A*) Mie scatter evaporation profiles of MEM 2% FBS generated by a droplet dispenser and levitated in the CK-EDB at different RHs (51, 66.8, 78.2, 86, 92, *Left* to *Right*). Blue indicates a homogenous spherical droplet, yellow indicates the presence of inclusions within the droplet, and red indicates a nonspherical particle (note that size estimates become inaccurate for nonspherical particles). (*B*) Proportion of particle morphologies formed by MEM 2% FBS at different RHs. The frequency of the formation of each particle type is shown for the RHs studied, with black indicating efflorescence, red indicating a nonspherical particle, yellow indicating a semi dissolved particle, and blue indicating an aqueous homogenous particle.

The relationships between the RH, the rate of evaporation, and the volume change during drying for aqueous MEM droplets are shown in *SI Appendix*, Fig. S4. The solute molarities increase from their initial values by around 10-fold when droplets evaporate into a gas phase at 92% RH and 25-fold at 78.2%, as reflected by the change in droplet radius and, thus, volume. Below this RH, inclusion formation (likely by some of the solute components crystallizing from solution) precludes an accurate estimation of the degree of supersaturation achieved within the remaining liquid phase. Although equilibration timescales are size dependent (smaller droplets would be expected to reach equilibrium much faster), the overall increase in solute concentration is size independent.

During equilibration to the ambient RH, the surface of an evaporating droplet can become enriched with larger solutes and suspended matter if the rate at which the surface is receding (κ, $m^2\ s^{-1}$) is faster than the rate of diffusional mixing (reflected in the diffusion constant, D_i, $m^2\ s^{-1}$) (55, 56). This competition is characterized by the Peclet number, Pe_i, for component i:

$$Pe_i = \frac{\kappa}{8D_i}. \qquad [1]$$

By comparing the evaporation rates reported in Fig. 2*A* (and *SI Appendix*, Fig. S4) with the previously reported diffusion coefficient for a typical virus in water (57, 58), the Pe_i for SARS-CoV-2 in MEM 2% FBS can be estimated. In all cases and for all temperatures studied here, the initial Pe_i for SARS-CoV-2 at the starting droplet water activity can be assumed to be in the range 0.5 to 5, showing marginal surface enrichment at most (59). As the water content diminishes during evaporation, particularly when drying into low RH, the increasing solute concentrations may slow the diffusion of the virus and may lead to surface segregation, although we do not account for this here. Indeed, Pe_is for more highly diffusing solutes will be $\ll$1 and can be assumed to show only marginal surface enrichment at the lowest RHs and highest temperatures; for example, at a Pe_i of 0.2, drying aqueous sodium chloride droplets show a transient enrichment in surface salt concentration of ~20% above the droplet core concentration for similarly sized droplets (60).

Efflorescence Enhances the Loss of Infectivity in Aerosol at Low RH. The loss of infectivity at low RHs appears to be consistent with observations of a change in phase state for the airborne droplet with a reproducible decrease in infectivity observed when efflorescence occurs. However, it remains unclear whether the efflorescence event itself impacts the infectivity of the virus. To confirm the correlation with phase behavior, the RH was cycled above (75% RH) and below (40% RH) the efflorescence threshold twice during a 2-min levitation (Fig. 3*A*). The infectivity for three out of the four levitations fell below the detection limit, indicating a >90% loss of infectivity. This loss of infectivity was far greater than during 2-min levitations where the RH was maintained at either a constant 40% RH, resulting in a single efflorescence event and an average infectivity of 40%, or at 70% RH for which no efflorescence would occur, which resulted in an average infectivity of 59%. A more detailed account of this measurement can be seen in *SI Appendix*, Fig. S5, with infectivity measured before and after each efflorescence event.

A CK-EDB measurement of a levitated MEM droplet, in which the RH was cycled between the same values as in the CELEBS survival measurement, is shown in Fig. 3*B*. These data confirm that a cycle of evaporation and efflorescence, redissolution, efflorescence, and redissolution occurs as the RH is cycled between 75, 45, 75, 45, and 75%. As in previous CK-EDB measurements of MEM, the particles were predominantly aqueous at the higher RH but with some solid inclusion content. For the cycled RH measurements in Fig. 3*A* (and *SI Appendix*, Fig. S5), the droplets were deposited at high RH ensuring they were in a dissolved solution phase on sampling. This indicates that the efflorescence-driven loss in infectivity did not arise from a physical sequestration of the virus in non-dissolving salt crystals but reflected an infectivity impairing alteration to the virus itself.

The consistency in the infectivity reduction induced on efflorescence, even when multiple efflorescence events take place in the same droplet population, demonstrates that there is no inherent property of individual virions that protects them from the crystallization event. The factor that determines whether an individual virion retains infectivity postefflorescence must instead depend on the local conditions in the vicinity of each individual virion. It was possible to image the evaporation and efflorescence of airborne MEM 2% FBS at 40% RH using a falling droplet column (Fig. 3*C*). In flight, there is considerable variability in the morphology of the MEM particle immediately after crystallization, which is apparent also in the dried MEM 2% FBS droplets collected and imaged with scanning electron microscopy (SEM) (also Fig. 3*C*). These images of the effloresced media reveal that some of the particle is crystalline while some is not. Thus, it is possible that whether or not the virus is in the crystallized fraction of a particle determines its stability following efflorescence. Interestingly, the salt crystals formed are smaller and more numerous as the RH is lowered (*SI Appendix*, Fig. S6), consistent with previous work that has shown that there is a greater propensity for nucleation when droplets are dried at higher rates leading to more nucleation events and smaller final crystals forming a larger composite particle (61).

Changing the temperature of the air around the droplets while maintaining the RH below the efflorescence point does not significantly impact the observed loss of infectivity (Fig. 3*D*). This provides further evidence that the mechanism driving the loss of infectivity is a physical process such as efflorescence rather than a thermodynamically driven chemical process, such as the rate at which the solute concentrations increase during the evaporation process. The temperature change marginally alters the timepoint at which efflorescence occurs, but the droplets all effloresce within 25 s for all three temperatures reported here, well before the 5-min point at which droplets were sampled and infectivity measured.

Airborne Longevity Appears Similar for Different SARS-CoV-2 Variants. Most measurements in this study were carried out using SARS-CoV-2 isolated early in the pandemic (SARS-CoV-2/human/Liverpool/REMRQ0001/2020 [REMRQ0001]). We compared the data from this variant with CELEBS measurements with three others to determine if changes in the structure of SARS-CoV-2 could have an impact on its response to the airborne environment. At 5 min, a decrease in infectivity was observed both at 40 and 90% RH for REMRQ0001, providing the optimum time to resolve any differences in aerostability. At both 40 and 90% RH, no significant difference was observed between REMRQ0001, B.1.1.7 (the Alpha variant), a mutant of the SARS-CoV-2 isolate England/2/2020 that has the same Spike protein sequence as REMRQ0001 except that the furin cleavage site is deleted (designated BriSΔ) (62, 63), and B.1.351 (the Beta variant) (Fig. 4). It is possible that if this comparison is expanded to cover a broader range of times and conditions, differences between these variants will be observable. However,

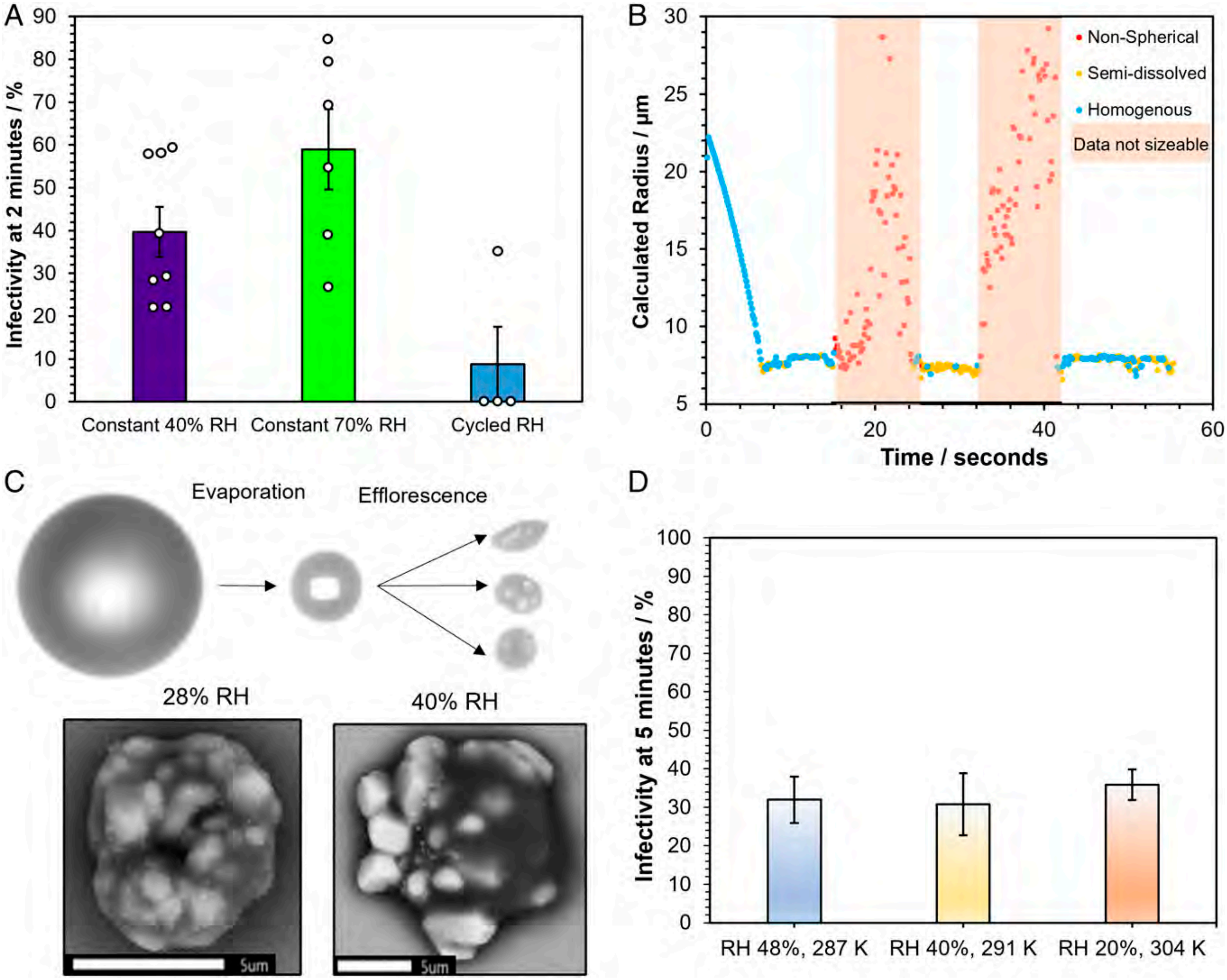

Fig. 3. The role of efflorescence in SARS-CoV-2 airborne loss of infectivity. (*A*) Comparison of the infectivity from Fig. 1*B* after 2-min levitations at constant 40% RH (purple bar) and 70% RH (green bar) with levitations where the RH has been cycled between 75 and 40% RH in one levitation (blue bar labelled cycled RH). The bars show the average % infectivity with error bars showing the standard error; the white circles show the % infectivity from the individual measurements. (*B*) CK-EDB measurements showing the phase behavior of levitated MEM droplets as the RH is cycled between 75 and 40%. RH is initially set at 75%, lowered to 40% at 14 s, raised to 75% at 24 s, lowered to 40% at 32 s, and finally raised to 75% at 41 s. Structural information about the droplet is denoted by the color of the data points as per Fig. 2*A*. (*C*) Images showing the changes in particle morphology that take place while MEM 2% FBS is airborne. The *Top* images are from the falling droplet column and showing the initial droplet generated by the dispenser on the *Left*, the droplet after 1.6 s of evaporation at 28% RH in the *Center*, and three different particles after they have undergone phase change on the *Right*. The *Bottom* shows two SEM images of droplets effloresced at 28% RH (*Left*) and 40% RH (*Right*). The scale bar is 5 µm long. (*D*) Percent Infectivity of SARS-CoV-2 (REMRQ0001) measured after levitation for 5 min at three different temperatures and RHs. Bars show the mean of five measurements with error bars showing the standard error.

based on these measurements, it does not appear that the deletion in BriSΔ, or the array of mutations throughout B.1.1.7 and B.1.351, result in readily observable changes in the airborne longevity of the virus when compared with REMRQ0001. There is no reason to believe that the measurements in this study using REMRQ0001 are not representative of later-circulating variants of the virus.

Droplet pH, Carbon Dioxide Partitioning, and the Rate of the Loss of Infectivity at High RH. Replicating the physicochemical conditions that exist in the aerosol phase through bulk phase measurements is not possible except for conditions equivalent to the very highest RH. Under typical ambient conditions in the range 20 to 60% RH, solute concentrations are heavily supersaturated in equilibrated aerosols. In addition, the high surface-to-volume ratio in aerosol cannot be replicated, diminishing the potentially significant role of surface processes at the gas–liquid boundary and ignoring the influence of the rapid microphysical dynamics including the coupling of heat and mass transfer. However, certain elements of the airborne change in droplet composition can be replicated in the bulk phase by simulating the concentrations of various components in the droplet at concentrations equivalent to equilibration at high RH. The steady concentrations of solutes when the aerosol is equilibrated at 90% RH are approximately a factor of 10 higher than in the starting droplets at a water activity of 0.995 (*SI Appendix*, Fig. S4), which is a concentration that can be replicated in the bulk. However, exposing SARS-CoV-2 to a 10-fold higher MEM concentration did not result in any observable loss of viral infectivity within 20 min (*SI Appendix*, Fig. S7). This suggests that this increased concentration of culture medium solutes is unable to account for the rate of the loss of infectivity in the aerosol phase.

In addition to changes in the concentration of solutes that occur on equilibration to the ambient RH, it is possible that the pH of aerosol droplets containing MEM can change

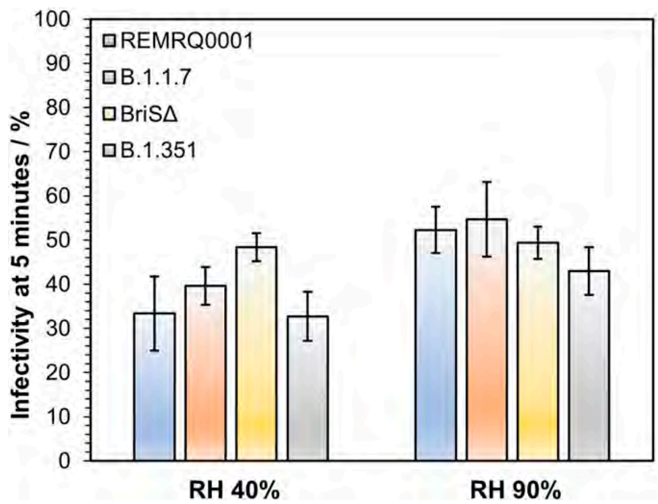

Fig. 4. The influence of SARS-CoV-2 strain on airborne stability. Infectivity of four different variants of SARS-CoV-2 (blue bars for REMRQ0001, orange bars for B.1.1.7, yellow bars for BriSΔ, gray bars for B.1.351). Infectivity is compared after 5 min of levitation at 40 and 90% RH, 18°C. At 40% RH, N = 5 for REMRQ0001, N = 8 for B.1.1.7, N = 4 for BriSΔ, and N = 10 for B.1.351. At 90% RH, N = 7 for REMRQ0001, N = 11 for B.1.1.7, N = 7 for BriSΔ, and N = 13 for B.1.351. Bars show the mean; error bars show the standard error.

rapidly. Although the sensitivity of SARS-CoV-2 infectivity both to high and to low pH has been reported (37, 64), these studies do not report measurements on a timescale relevant to the rapid loss of infectivity reported here in the aerosol phase. To investigate whether there is a loss of infectivity with the change in pH on a similar timescale, SARS-CoV-2 was suspended in tissue culture media at varying pH for 20 min, before dilution into neutral media and plating onto cells for infectivity quantification (*SI Appendix*, Fig. S8). Although no significant decrease in infectivity was observed after 20 min at pH ranging from 5.6 to 9, the average infectivity was diminished considerably above pH 9.5 so that only 7% of the virus remained infectious after 20 min at pH 11.2. The effect of pH was further explored by suspending SARS-CoV-2 in solutions of pH 9 and 11 for 30 min (Fig. 5*A*), with neutralization and quantification being carried out every 10 min. In this experiment, the virus remained stable in the pH 9 solution, but at pH 11, the infectivity fell to a similar level as in the 90% RH levitations, also seeming to plateau once 90% of the virus had been deactivated. These bulk phase studies suggest that the pH would have to increase to around 11 to explain the deactivation observed in the aerosol phase at 90% RH after 20 min. We therefore considered whether such a high pH could be present in the aerosol droplets at high RH conditions.

The equilibration between dissolved bicarbonate anions and gaseous CO_2 is particularly important to consider for many respiratory secretions as well as the tissue culture media often used in experimental studies of airborne viral survival (65). A set of coupled equilibria is established with a bicarbonate concentration that responds to changes in the level of gas phase CO_2, typically at an elevated gas phase concentration for cell culture and 50,000 ppmv in exhaled air, specifically,

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons CO_2.H_2O_{(l)},$$
$$CO_2.H_2O_{(l)} \rightleftharpoons HCO_3{}^-{}_{(aq)} + H^+{}_{(aq)},$$
$$HCO_3{}^-{}_{(aq)} \rightleftharpoons H^+{}_{(aq)} + CO_3{}^{2-}{}_{(aq)}.$$

Cell culture media typically contain 20 to 50 mM bicarbonate (50, 51) to buffer the aqueous solution at a pH ~7.4 when gas

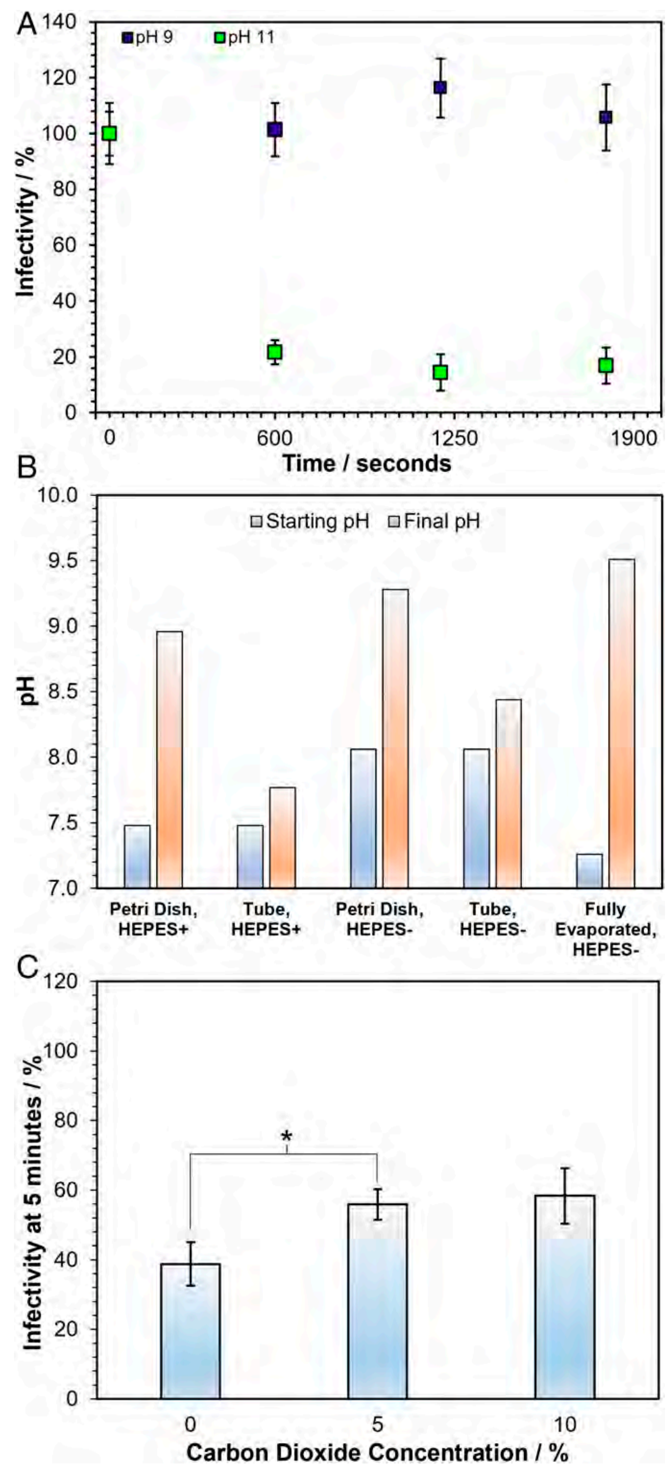

Fig. 5. The role of pH in SARS-CoV-2 airborne loss of infectivity. (*A*) Bulk % infectivity of SARS-CoV-2 (B.1.351) after a 30-min incubation in DMEM 2% FBS altered to either pH 9 (purple datapoints) or 11 (green datapoints), diluted back into neutral media and plated onto cells every 10 min. Datapoints are the mean of three measurements for pH 11 and five measurements for pH 9, with error bars showing the standard error. (*B*) The pH changes that tissue culture media (in this case DMEM) underwent when exposed to open air. DMEM was left in an open petri dish or 50-mL tube both with and without HEPES and the initial pH (blue bar) and the pH after 20 min (orange bar) was measured. The same measurement was carried out using thin layers of DMEM that were allowed to evaporate to 10% of their original volume over the course of 24 h (labelled fully evaporated). (*C*) The 5-min levitations were carried out with SARS-CoV-2 (B.1.351) at 90% RH with varying CO_2 concentrations mixed into the gas flow. Bars show the mean of 15 measurements for 0% CO_2, 16 measurements for 5% CO_2, and 6 measurements for 10% CO_2 with the error bars showing the standard error. *$P < 0.03$ between 0% and 5% CO_2.

phase CO_2 is at an elevated concentration, 4 to 5% by volume. For bicarbonate in exhaled salivary aerosol (66), the lower gas phase CO_2 concentration in the environment after exhalation (0.04%) results in a change in the equilibrium concentration of bicarbonate in the aerosol by shifting the equilibria toward $CO_2{\cdot}H_2O_{(l)}$ and eventually $CO_{2(g)}$, leading to particle-to-gas phase partitioning of CO_2. Indeed, for laboratory studies of airborne survival, the aerosol is often generated in an environment devoid of CO_2, as is the case here, leading to irreversible evaporation of dissolved CO_2 into the gas phase. As evaporation occurs, the available H^+ concentration diminishes, and the pH can be expected to rise.

As a bulk analog experiment, bulk tissue culture medium was exposed to ambient air for an extended time period (Fig. 5*B*). After 20 min in an open petri dish, the pH of DMEM (formulated with the same concentration of bicarbonate as the MEM used in the levitations) rises from 8 to 9.3. Adding HEPES reduces the initial pH of the medium, but the pH was still found to increase significantly after exposure to air, increasing from 7.4 to 9. When the DMEM solution was kept in an open 50-mL tube rather than a petri dish, decreasing the surface area for interaction, the rate of the rise in pH also decreased. A final experiment was carried out in which thin layers of DMEM were placed in petri dishes and allowed to evaporate to 10% of the starting volume over the course of 24 h, replicating both the CO_2 and H_2O equilibration that takes place in airborne droplets. The combination of CO_2 equilibration and volume loss resulted in the greatest pH rise, increasing from 7.25 to 9.5. The particle-gas partitioning can be expected to occur more rapidly than in any of these bulk examples because of facile transport across a droplet surface with a high surface-to-volume ratio. While the presence of bicarbonate buffers biological fluids such as saliva (66) when they are in the respiratory tract (or in a CO_2 supplied incubator), the decrease in the concentration of dissolved bicarbonate through the irreversible loss of CO_2 following their aerosolization will cause droplets to become more alkaline.

Sodium bicarbonate accounts for ~20% of the solute mass in MEM with ~65% sodium chloride by mass. With the loss of bicarbonate from MEM solution droplets, through irreversible evaporation of CO_2, the reduction in solute mass should lead to a reduction in the wet equilibrated size of the droplet with less solute able to sustain less water in the condensed phase. Indeed, it was possible to observe a long-time slow loss of CO_2 and dissolved solute using the CK-EDB for MEM solution droplets (*SI Appendix*, Fig. S9) and for mixtures of NaCl and $NaHCO_3$ (*SI Appendix*, Fig. S10), the two dominant salts. Droplets of both MEM and sodium bicarbonate continue to decrease in size for longer than the time required for the water activity to equilibrate to the gas phase RH. Indeed, the vapor pressures inferred from the data in *SI Appendix*, Fig. S10 with varying RH (0.0092, 0.014, and 0.052 Pa at 60, 75, and 90% RH) are consistent with calculations using the E-AIM model (www.aim.env.uea.ac.uk/aim/aim.php) (67) for the vapor pressure of CO_2 above supersaturated carbonate solutions at the same water activities (~0.01 Pa and increasing with increase in RH). By contrast, the vapor pressure of CO_2 from bicarbonate solutions at the same RHs are considerably higher (~100 kPa) and the particle-gas partitioning can be expected to occur extremely rapidly in ≪1 s following aerosol droplet exhalation or generation, a process that can be expected to already be completed by the time the aerosol droplets are captured by CELEBS or the CK-EDB.

During the evaporation of water, as the moisture content of the aerosol equilibrates, the solutes surpass solubility limits for various salts. The initial water activity of the starting droplets can be estimated as 0.9952 by considering the dominant ionic species alone (Na^+, Ca^{2+}, Cl^-, and HCO_3^-) using the E-AIM model (67). Calcium carbonate is particularly insoluble and becomes supersaturated from very early on in the evaporation process, successively followed by other binary and mixed salts, specifically $CaNa_2(CO_3)_2 0.5H_2O(s)$, $Na_2Ca(CO_3)_2 0.2H_2O(s)$, $NaHCO_3(s)$, and finally NaCl(s) as water activity decreases. The droplet becomes saturated with respect to the first two salts above a water activity of 0.9, sodium bicarbonate at ~0.9, and NaCl below 0.8. Indeed, we observe the precipitation of salts during the droplet equilibration process as the water activity transitions through to the final equilibrated value, with significant supersaturation required for each before crystallization occurs (Fig. 2*B*). Until the crystallization of NaCl(s), which only occurs at the very lowest RHs of 50% and below, a partially deliquesced particle containing crystalline inclusions along with an aqueous phase leads to considerable variability in the remaining infectivity of the virus (Fig. 1*B*).

It can be hypothesized that increasing the concentration of $CO_{2(g)}$ around the droplet would reduce the irreversible loss of bicarbonate from the droplet and could mitigate a pH-driven loss of infectivity. $CO_{2(g)}$ was added to the airflow during CELEBS levitations at high RH and the infectivity of SARS-CoV-2 measured after 5 min (Fig. 5*C*). The elevation to a gas phase concentration of 5% by volume CO_2 (equivalent to 50,000 ppmv) around the droplet at 90% RH results in a small but significant increase in the remaining infectivity of SARS-CoV-2 after 5 min when compared with ambient $CO_{2(g)}$ (0.04%). Increasing the steady $CO_{2(g)}$ concentration around the trapped droplet cannot mitigate the loss of infectivity from pH changes during the initial travel of the droplet to the trapping region. While it is possible that elevated $CO_{2(g)}$ around the droplet may have other physicochemical effects on the droplet in addition to decreasing the pH, this measurement provides further evidence that increased droplet pH is at least partly responsible for the observed falls in viral infectivity at high RH.

The influence of pH on infectivity is expected to be relevant in respiratory aerosols as the underlying physicochemical properties of exhaled aerosol (saliva) and MEM are similar, and numerous studies have demonstrated that exhaled breath condensate is alkaline (68–71). This dynamic is in stark contrast to environmental aerosols such as sea spray where, following generation, the pH of the sea spray droplets become more acidic through the uptake of acidic gases such as HCl and SO_x (72). Exhaled aerosol is generated in an environment with an extremely high concentration of an acidic gas (4 to 5% by volume CO_2) that can only be reduced once exhaled. This contrast in pH behavior following generation is clear when comparing studies of collected sea spray pH (72, 73) with those of collected exhaled breath condensate (69–71, 74). In short, while the vast majority of ambient aerosol may be acidic, exhaled aerosol can be expected to be alkaline. The pH of exhaled and model respiratory aerosols is an area in need of further study, with a need for measurements across a broad range of timescales, droplet compositions (saliva, sputum, MEM, DMEM), and environmental conditions (RH, $[CO_{2(g)}]$).

Comparison with Rotating Drum Studies of SARS-CoV-2. A motivation of our combined approach using CELEBS and CK-EDB is to identify the fundamental physicochemical parameters that dictate viral infectivity in the aerosol phase, progressing beyond general associations such as those between RH and infectivity, and to address the more challenging and informative questions allowing the identification of mechanistic causation rather than just correlation. By taking this approach, it has been shown that SARS-CoV-2 undergoes a rapid deactivation in the first few minutes following droplet generation and that this deactivation occurs on efflorescence at low RH and possibly by an increase in droplet pH at high RH resulting from irreversible partitioning of CO_2 into the gas phase. There have been several reports of the aerostability of SARS-CoV-2 using the Goldberg rotating drum (14–16). However, given the relatively short timescale over which the majority of this deactivation occurs, which drum experiments cannot observe, and the importance of the physicochemical properties of the droplet in driving the deactivation, it is unsurprising that data collected from rotating drums report a longer lifetime for the virus in the aerosol phase.

Rotating drums have a poorly defined time-zero, meaning that the benchmark infectivity to which later time data are compared is poorly defined. The number of droplets suspended, their initial size, and viral units per droplet are both variable and uncontrolled and thus must be inferred offline. RH profiles, while they appear to be commonly collected in rotating drum experiments, are rarely reported in their entirety, with many drum studies only reporting a single RH value for each measurement (15). The location of the RH probe within the experiment, and whether the value is taken at a particular time or is an average across their experiment, is not always reported. Regardless, the RH recorded by a probe is likely unrelated to the RH trajectory that an aerosol droplet experiences as it passes from the nebulization source into the rotating vessel. Indeed, the nebulization of a cloud of aerosol at a high number concentration likely leads to some buffering of the RH in the gas phase, sustaining a higher value that would be typical of the very low respiratory aerosol concentrations actually generated (21). These uncertainties may make the influence of processes such as efflorescence on infectivity challenging to infer.

Comparisons of the time dependence and precision of the CELEBS measurements with those from rotating drum studies are reported in *SI Appendix*, Figs. S11 and S12. The time-resolution of the drum measurements make the initial decrease in infectivity challenging to identify. Indeed, the times of the indicated points (*SI Appendix*, Fig. S11) should not be taken as the time-resolution as discussed above. In addition, the average relative SD (RSD) from the CELEBS measurements is 0.37 (*SI Appendix*, Fig. S12), compared with 0.66 from van Doremalen et al. and 1.03 from Smither et al. (14) Two further papers do not report sufficient information to estimate RSDs (15, 16). The smaller RSD from the CELEBS is likely the result of the more stable environmental conditions, a more reproducible monodisperse droplet generation process, and improved methodology for viral infectivity quantification (39). Furthermore, CELEBS experiments are more straightforward to perform, allowing for more repeat measurements for each condition and leading to a high degree of confidence in the mean percentage infectivity values reported.

The nebulization of bicarbonate-buffered solutions into a confined volume results in the elevation of the CO_2 gas concentration (*SI Appendix*, Fig. S13). The magnitude of this elevation is dependent on many variables, including the pH of the nebulized solution, the nebulization time, and the drum volume. A survey of the literature failed to identify a single article where the CO_2 levels within a rotating drum was reported. As reported (Fig. 5*C*), CO_2 in the gas phase reduces the degradation of the virus likely by limiting the rise in droplet pH. CO_2 cannot be removed selectively during a rotating drum study, and the conditions likely support greater SARS-CoV-2 longevity. Accumulation of CO_2 is not an issue in CELEBS due to the constant flow of compositionally controlled air being maintained over the trapped droplets. In addition to potential issues with the pH of the airborne droplets in the rotating drum, it is also possible that the pH of the solution within the nebulizer may increase during the nebulization process (*SI Appendix*, Fig. S14), directly affecting the viral infectivity prior to nebulization (Fig. 5*A*).

Discussion

A combination of measurement strategies to probe the changes in airborne viral infectivity with time and the physicochemical transformation dynamics of the host aerosol is crucial to improve our understanding of the influence of environmental (such as RH, temperature) and biological (such as spike protein mutations) parameters on the transmission of viruses in the aerosol phase. While the current consensus is that the half-life of SARS-CoV-2 in the aerosol phase is between 1 and 2 h, if not longer, we report an initial rapid decline in infectivity within a few seconds to minutes of aerosol generation. Under all conditions measured, the majority of SARS-CoV-2 is inactivated within 10 min of aerosolization. Further research is required to determine for how long the remaining fraction persists, how this may depend on the viral load in the aerosol, and the influence of chemical composition. The high-time resolution infectivity measurements reported here are uniquely accessible to the CELEBS technology and can only be understood once the detailed aerosol microphysics are fully explored. Although we do not report measurements in artificial or real saliva, the culture media used do have many of the same characteristics of real respiratory secretions, particularly the high concentration of inorganic ions that dominate the phase behavior and water content of the aerosol, along with bicarbonate ions that partition CO_2 into the gas phase on aerosolization. In addition, the initial water activity of the aerosol is consistent with the high RH of the respiratory tract, and the aerosol generation process generates isolated droplets that must respond rapidly to the surrounding environmental conditions, which is typical of the very low concentrations of aerosol exhaled in infected individuals.

The aerostability data reported here are consistent with a view that the risk of SARS-CoV-2 transmission is greatest closer to the source of infection. Often, the assumption is that short distance transmission is caused by large droplets that fall to the ground more quickly and therefore do not travel as far. The rapid loss of infectivity demonstrated in these measurements provides an alternative explanation for a short transmission distance, with rapid airborne losses of viral infectivity possibly making transmission decreasingly likely as distance from the particle source is increased, even if the particles that contain the virus are small and able to travel long distances. This loss in infectivity is compounded by the considerable dilution in aerosol concentration that results following exhalation and transport beyond the short range. However, the rapid loss of infectivity must also be considered in combination with the large variability in aerosol emission rate between individuals [up to a factor of 10^3 between individuals when breathing (75)] and viral titer in the exhaled aerosol [which could be as much as 10^4 if variations in sampled saliva are indicative (76)].

We do not observe the characteristic "V-shape" relationship between RH and virus stability, where maximum virus loss occurs around RH = 50%. Rather, the largest loss of infectivity was observed at the lowest RHs. Previously, Goldberg drum studies have not identified a strong dependence for SARS-CoV-2 survival on RH (14). However, following the initial loss of infectivity, the virus within the now dry particle appears to be somewhat stable when compared with the higher RH. Thus, if the initial rapid decrease in infectivity is not accounted for when reporting RH stability data, a V-shape relationship may be identifiable. However, not accounting for changes in viral infectivity that take place immediately after particle generation prevents the accurate coupling of airborne stability measurements with measurements of initial virus shedding, limiting the value of the V-shape relationship.

The rapid loss of SARS-CoV-2 infectivity through droplet efflorescence at an RH of <45% suggests that dry air may help to limit overall exposure. However, investigation of the impact that lowering RH has on particle transport in the exhalation jet is required to confirm this. The large impact of efflorescence on SARS-CoV-2 infectivity indicates that measuring the impact of environmental conditions on phase change in respiratory secretion aerosols may provide useful insights into COVID-19 transmission. Further research is needed to confirm with more certainty the degree to which pH is involved in the airborne loss of SARS-CoV-2 infectivity at high RH and to determine the exact mechanism by which the pH rise is deactivating the virus. The importance of elucidating of the role of pH in the survival of SARS-CoV-2 in the aerosol phase cannot be understated. A literature survey found no manuscripts indicating that the alkaline nature of exhaled aerosol may affect viral infectivity. Contrarily, it has been reported that viruses may be inactivated by acid in the aerosol phase (77).

Elevation of CO_2 levels within a room is taken as a clear sign of occupancy and poor ventilation. There has been increasing discussion surrounding the use of CO_2 monitors as a means of determining the relative risk of COVID-19 transmission in various settings. The data from this study give further credence to this approach. Not only is elevated CO_2 an indication of a densely occupied, poorly ventilated space but it could also be indicative of an environment in which SARS-CoV-2 is more stable in the air. The precise elevation in CO_2 required for an observable increase in SARS-CoV-2 transmissibility is unknown and requires further investigation (5% CO_2 is not a concentration reached in typical indoor environments), but it is possible that this is an additional risk presented by poorly ventilated, densely occupied settings. If so, CO_2 monitors may present an immensely valuable means of assessing the relative risk of different indoor environments. Additionally, the apparent role of pH elevation in the deactivation of airborne virus suggests a currently unexplored role of condensable acid vapors, such as nitric acid (78, 79), in the role of infectivity. It is possible that the condensation of acidic components into exhaled aerosol may help to neutralize the initial rapid pH increase, lowering the pH and increasing the airborne stability of the virus.

The approach taken here has clearly demonstrated the value of a combined approach that considers both the aerosol microphysics and biological processes in tandem and on the same timescale, demonstrating that underlying parameters that drive SARS-CoV-2 inactivation in the aerosol phase are particle phase and pH. In further research, we intend to explore these processes over an even wider range of times, conditions, and virus variants. There also remain unanswered questions as to exactly how phase change and high pH deactivate the virus. Do these processes rupture the viral envelope or impart an irreversible modification to the spike protein? Is the effect of pH the result of direct deprotonation of viral molecules or is it an indirect effect caused by alterations to the solubility of other components within the droplet? Answering such questions would provide key insights into the physicochemical and biomolecular processes governing SARS-CoV-2 transmission and airborne pathogen transmission more broadly. It is only by pushing the limits of aerobiology to this deeper level that we can hope to understand how best to prevent the airborne spread of disease.

Materials and Methods

Details of virus strains and methodologies for virus and cell culture, viral infectivity quantification, bulk stability measurements, CK-EDB measurements, and falling droplet column measurements can be found in *SI Appendix*, *Extended Materials and Methods*.

Generation and Trapping of Droplets. The reservoir of a droplet-on-demand dispenser (MicroFab) is filled with MEM 2% FBS. The application of a square waveform to the piezoelectric crystal results in a compression wave that passes through the dispenser's orifice and initiates the formation of a jet that forms droplets of uniform size with each pulse. A direct current voltage is applied to an induction electrode, positioned 2 to 3 mm from the dispenser tip, which leads to an ion imbalance in the jet, resulting in a droplet with a net charge (~5 fC). Using the Gouy-Chapman model (80), a salt containing droplets with this level of net charge can be predicted to have an electric field strength of 0 V/m throughout its core, with the outer most shell (with a depth of ~3 nm) having an electric field strength of 3 V/m. The presence of this net charge interacting with the electrodynamic field of the CELEBS/CK-EDB leads to confinement of the droplet within the null field point.

CELEBS Airborne Longevity Measurements. The environmental conditions were set by adjusting the Peltier voltage and polarity to set the temperature and the ratio of dry to wet air to set the humidity. SARS-CoV-2 suspension is drawn into a 1-mL syringe which is then attached to the instrument and used to feed the virus solution to the droplet dispenser via a remotely operated motor. Droplets are then generated and trapped as described above. Once the desired time is reached, an isolation plate is retracted causing the electric field to be set to zero; then, the droplets are pulled down into a plate containing 5 to 10 mL of DMEM 2% FBS so that the remaining virus can be quantified (*SI Appendix*, *Extended Materials and Methods*). For each measurement, two levitations are carried out. First, a short levitation of <5 s at 90% RH was used to measure the initial infectious unit per droplet number, and then a second levitation was used for which the droplets are kept in the trap for the conditions and length of time being investigated. Infectious units per droplet are normalized to the average of the short, high humidity levitations from that experiment, such that the levitation data can be presented as percentage infectivity.

Data Availability. The txt file data has been deposited in data.bris, the University of Bristol Research Data repository (81).

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Long-distance airborne dispersal of SARS-CoV-2 in COVID-19 wards

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Evidence suggests that SARS-CoV-2, as well as other coronaviruses, can be dispersed and potentially transmitted by aerosols directly or via ventilation systems. We therefore investigated ventilation openings in one COVID-19 ward and central ducts that expel indoor air from three COVID-19 wards at Uppsala University Hospital, Sweden, during April and May 2020. Swab samples were taken from individual ceiling ventilation openings and surfaces in central ducts. Samples were subsequently subjected to rRT-PCR targeting the N and E genes of SARS-CoV-2. Central ventilation HEPA filters, located several stories above the wards, were removed and portions analyzed in the same manner. In two subsequent samplings, SARS-CoV-2 N and E genes were detected in seven and four out of 19 room vents, respectively. Central ventilation HEPA exhaust filters from the ward were found positive for both genes in three samples. Corresponding filters from two other, adjacent COVID-19 wards were also found positive. Infective ability of the samples was assessed by inoculation of susceptible cell cultures but could not be determined in these experiments. Detection of SARS-CoV-2 in central ventilation systems, distant from patient areas, indicate that virus can be transported long distances and that droplet transmission alone cannot reasonably explain this, especially considering the relatively low air change rates in these wards. Airborne transmission of SARS-CoV-2 must be taken into consideration for preventive measures.

Abbreviations

ACH	Air changes per hour
CoV	Coronavirus
COVID-19	Coronavirus infectious disease 2019
Ct	Cycle threshold
HFNC	High flow nasal cannula
Hpi	Hour post infection
HVAC	Heating Ventilation Air-condition
MERS	Middle eastern respiratory syndrome
RNA	Ribonucleic acid
rRT-PCR	Real time reverse transcriptase polymerase chain reaction
SARS	Severe acute respiratory syndrome

During the coronavirus infectious disease 19 (COVID-19) pandemic, droplet transmission has been considered the most significant transmission route for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), although other routes such as aerosol, fecal–oral, and indirect transmission via fomites may contribute to the rapid global dissemination of the virus[1,2]. The relative importance of aerosols versus droplets in the transmission of respiratory infections is difficult to distinguish, since particles of both aerosol and droplet size are generated for example when talking[3,4]. Aerosols are smaller than droplets, traditionally defined as smaller than 5 µm in diameter, and are thought to remain airborne longer, enabling transmission at greater distances and over longer periods of time[5]. This definition has been challenged and may very well be an over-simplification and it may be precarious to rigidly differentiate the two categories[3,6,7].

Previously, other coronaviruses have been shown to disperse via aerosols and ventilation, and have been determined to cause HVAC (heating, ventilation, air conditioning) associated and nosocomial infections as well as extensive hospital outbreaks[8–13]. In recent studies, extensive environmental contamination of SARS-CoV-2 in

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Figure 1. (**A**) Overview of the 19 investigated COVID-19 ward rooms (ward 1). Dots indicate approximate placing of ceiling vent openings. Red dots indicate openings that where SARS-CoV-2 RNA was detected in at least one of two samplings, blue dots openings negative in both samplings. (**B**) Lateral view of the hospital building. Ward levels: red; COVID-19 outpatient clinic, yellow and blue; COVID-19 wards 1 and 2, with 19 rooms each, purple; eighth floor with central ventilation fans and HEPA filters. Individual ceiling vent openings were investigated on the second-floor ward (yellow) seen in (**A**).

hospital settings has been demonstrated, and viral RNA has been found both in air samples and in samples from air vent openings in isolation rooms[14–18]. Also, the potential for the aerosol transmission route of SARS-CoV-2 is supported by other recent studies[17,19–21]. The increased risk for infection in indoor environments, as well as superspreading events, could be explained by airborne transmission[22–26]. In this context it is therefore vital to understand the amount of SARS-CoV-2 in confined spaces and the distances at which virus can be passively dispersed. Hospital rooms where COVID-19 patients are treated are obviously venues in which airborne transmission is both of great importance to understand, as well as a suitable environment to study this phenomenon. In this study from a COVID-19 infectious disease ward at Uppsala University Hospital, Sweden, we investigated if SARS-CoV-2 RNA could be detected in and near air vent openings in isolation rooms and in filters in the central ventilation system situated on the eighth (top) floor of the hospital building. As RNA was detected at substantial distances from patient areas, fluid sample collections were performed in an attempt to determine the potential infective ability of SARS-CoV-2 detected in the systems. Our findings may suggest both airborne dispersal of SARS-CoV-2 and possible long-distance dissemination of SARS-CoV-2 via ventilation air flow.

Materials and methods

Sampling strategy. Sampling was performed on separate occasions during April and May 2020. In the first two occasions, 17 and 28 April, surfaces of exit vent openings in all 19 patient rooms in ward 1 (Fig. 1a) were swabbed as described below. When repeated on April 28, the internal surfaces of the central ventilation ducts, on the top floor were also swabbed and filter sections removed, as described further below. Due to the detection of SARS-CoV-2 RNA in the ventilation system (see "Results"), a further sample collection was performed using fluid traps, both at the terminal end of the ducts prior to the exhaust filters (at the same area where swabs were taken on April 28) as well as under the ceiling vent openings in the ward rooms (ward 1, see Fig. 1b), in an attempt to determine the infective ability of any collected virus.

Swab samples. Surfaces were swabbed using sterile nylon flocked swabs (Copan eSwab, Copan Italia SpA, Italy) moistened in sterile viral transport medium (VTM), containing Hank's balanced salt solution (Gibco, UK) supplemented with 2% fetal bovine serum (Gibco, USA), 100 µg/ml Gentamicin, and 0.5 µg/ml Amphotericin B[27]. Round ceiling vent openings were swabbed around the inside of the entire opening (circumference ca 25 cm). Swabs were placed in tubes containing 750 µl viral transport medium and stored at 4 °C until analysis within 24–72 h. Sampling was performed on April 17 and 28, 2020. Indoor relative air humidity and temperature were 30–31% and 20–21 °C, respectively.

Filter samples. Exit ventilations from each of the eight stories in the investigated hospital building, (Fig. 1b), lead to separate HEPA filter systems, located on the eighth (top) floor. Consequently, we could identify ducts and exhaust filters collecting air from individual floors not merging airflows. We chose to examine exhaust filters from three floors in the building that had been specifically designated for COVID-19 patients; two COVID-19 wards and a COVID-19 out-patient clinic. In addition, we examined exhaust filters from one story with per-

Corresponding floor	Exit airflow from ward (m^3/s)	Approximate distance from ward to top floor filters (m)	Sample	PCR results (Ct value)	
				N gene	E gene
Top floor air vent samples					
Covid-19 outpatient clinic	2.45	56	Ventilation shaft swab	Negative	Negative
			Air vent filter sample 1	37.13	37.30
			Air vent filter sample 2	Negative	Negative
			Air vent filter sample 3	38.79	36.96
			Cell medium in petri dish	Negative	Negative
Covid-19 ward 1	2.27	53	Ventilation shaft swab 1	Negative	Negative
			Ventilation shaft swab 2	Negative	Negative
			Air vent filter sample 1	36.86	34.91
			Air vent filter sample 2	36.31	34.87
			Air vent filter sample 3	35.32	35.41
			Cell medium in petri dish	Negative	33.00
Covid-19 ward 2	2.55	49	Ventilation shaft swab	Negative	Negative
			Air vent filter sample 1	37.42	38.70
			Air vent filter sample 2	35.72	33.85
			Air vent filter sample 3	36.72	36.08
			Cell medium in petri dish	35.32	33.16
Ground level non-patient care area	3.48	60	Air vent filter sample × 3 (negative control)	Negative	Negative

Table 1. rRT-PCR analysis of samples from filters and swabs in the ventilation system at the 8th floor, top level of the hospital building. Samples not exhibiting fluorescence above threshold level after 45 PCR cycles are labeled "negative". Ct: cycle threshold, N gene: SARS-CoV-2 Nucleocapsid gene, E gene: SARS-CoV-2 Membrane Small Envelope gene.

sonnel areas and a cafeteria, as a negative control. The distance between the COVID-19 wards and the exhaust filters and inspection hatches was 49, 53 and 56 m respectively for each COVID-19 ward (Table 1). The four stories located between the COVID-19 wards and the central ventilation in the top of the building (Fig. 1b) only sporadically harbored COVID-19 patients and were therefore not investigated. Adjacent inspection hatches upstream from (prior to) the HEPA filters were opened, and internal 30 × 30 cm surfaces swabbed as described above. Furthermore, one (out of six) 60 × 60 cm laminate F7 HEPA filter sections was removed from each system (filtering air from one ward or floor) and three filter samples (3 × 3 cm) were randomly cut out of the filters using sterilized scissors, placed in vials containing 2.5 ml of viral transport medium (described above), and stored at 4 °C until analysis within 72 h. The removed filters had been routinely replaced one month prior to collection.

Fluid samples. Fluid sample collection was performed near air entrances (ward rooms) and exits (directly prior to exhaust filters) in the ventilation system by placing open, 10 cm diameter petri dishes with 10 ml of DMEM (Dulbecco's Modified Eagle's medium (cell medium); Gibco) diluted 1 to 5 with autoclaved water, suspended 15 cm below ceiling vent openings (in ward rooms) for 24 h, or placed within central vent ducts via inspection hatches for 3 h. DMEM was diluted to ensure appropriate salt balance for the cells and no osmotic effect on the virus after evaporation of water during the collection process. We used DMEM instead of water only to be able to add the whole volume of sample onto cells without a dilution effect of the cell medium. These points were chosen in an attempt to determine if virus found entering and/or exiting the ventilation ducts retained infective ability, in response to the PCR results from vent opening and exhaust filters. The suspended petri dishes in the ward rooms were placed within what we expected to be the normal air flow to ventilation ducts, as well as placing the dishes as far from the patients as possible, in order to avoid contamination by coughing induced droplets or other patient or personnel activity in the rooms. An open petri dish containing cell medium was exposed to air in the biosafety level (BSL)-2 area of the laboratory for 24 h and used as a negative control, along with non-exposed DMEM and viral transport medium. DMEM and VTM spiked with synthetic oligonucleotides (gBlocks, IDT, Belgium) based on N and E gene sequences with introduced 5 base pair deletions were used as positive controls (Suppl. Table 1). DMEM exposed to air in 19 ward rooms were combined to three pools. Pooling was performed when we could establish that a large number of rooms were occupied by non-contagious patients (seven rooms), patients with suspected COVID-19 but not confirmed (five rooms) and only six rooms were occupied by contagious COVID-19 patients (May 13, 2020) (Suppl. Table 1). Due to evaporation during collection, the final concentration of DMEM in the petri dishes after collection was equivalent to undiluted cell medium. The entire pooled volume ranging from 5 to 10 ml was subsequently applied to Vero E6 cells in T25 flasks and incubated up to 13 days. Samples were subsequently collected and subject to rRT-PCR. Petri dishes with 10 ml DMEM exposed to air outside of patient areas for 24 h were used as negative control.

Ward conditions. All exit vent openings in the ward rooms are situated in the ceiling and are approximately 3 to 5 m from the head end of the beds (fresh air input openings are at 0 to 50 cm above floor level). Seven of the 19 openings are situated in adjacent washing rooms (see Fig. 1a) and are up to approximately 5 to 6 m from beds. Total air changes per hour (ACH) for each patient room varied between 1.5 and 2.6 in ward 1, and 2.1 to 2.7 in ward 2, between 2.8 and 3.2 in the outpatient clinic, (measured December 2017). Air flow in the central ventilation shafts, from each story, ranged between 2.27 and 3.48 m^3/s (Table 1). Pressure differences in rooms in ward 1 varied, − 6 to − 8.1 Pa between corridor and anterooms and + 5.5 to + 18 Pa between anterooms and patient rooms (measured March 2020). Hence, the anterooms were under negative pressure compared to the adjacent ward corridor as well as patient rooms.

RNA extraction and rRT-PCR. RNA was extracted using 280 µl of samples and QIAamp viral RNA kit (Qiagen, Hilden, Germany), according to manufacturer's protocol. Portions of the SARS-CoV-2 nucleocapsid (N) and envelope small membrane protein (E) genes were amplified by rRT-PCR, using primers (Thermo Fisher Scientific, Waltham, MA, USA) previously described[28–30] and the SuperScript III OneStep RT-PCR System with Platinum Taq DNA Polymerase kit (Invitrogen, Carlsbad, CA, USA). In brief, the two reaction mixtures (25 µl) contained 12.5 µl reaction buffer (a buffer containing 0.4 mM of each dNTP, 3.2 mM $MgSO_4$), 1 µl of enzyme solution (SuperScript III RT/Platinum Taq Mix), 1.25 µl of probe primers solution (10 µM stock concentration) 3 µl magnesium sulfate (50 nM), and 7.25 µl of RNA. The cycling conditions were as follows: cDNA synthesis at 55 °C for 30 min (min) and 50 °C for 2 min followed by 45 cycles of denaturation at 95 °C for 15 s (s), extension at 57 °C for 30 s and collecting the fluorescence signal at 68 °C for 30 s. Target 1 (E gene) forward primer ACA GGTACGTTAATAGTTAATAGCGT; reverse primer TGTGTGCGTACTGCTGCAATAT; and probe 5′-FAM-ACACTAGCCATCCTTACTGCGCTTCG-TAMRA-3′. Target 2 (N gene) forward primer GGGGAACTTCTC CTGCTAGAAT; reverse primer CAGCTTGAGAGCAAAATGTCTG; and probe 5′-FAM-TTGCTGCTGCTT GACAGATT-TAMRA-3′. As positive controls, double stranded DNA fragments (gBlocks, IDT, Belgium) with a five-nucleotide deletion in the targeted part of the E (10^2 copies/µl) and N (10^3 copies/µl) gene were used. Positive control Ct vales were 31.67 ± 0.68 and 28.07 ± 2.66 respectively. All PCR products with a Ct value < 45 were confirmed by Sanger sequencing (Macrogen, the Netherlands). Negative controls (swabs) were performed on non-exposed VTM (Suppl. Table 1).

Inoculation. Vero E6 cells (green monkey kidney cells (ATCC CRL-1586)) were seeded into T-25 flasks and grown in DMEM (Gibco, 41966) supplemented with 10% FBS (Gibco, USA) and 1 × Penicillin–Streptomycin (Sigma-Aldrich, PA333). The flasks were incubated (37 °C, 5% CO2) until cells confluency reached approximately 90%, after which the cell media was substituted with 9 ml of pooled samples supplemented with 2% FBS and 1 × Penicillin–Streptomycin. Potential cytopathic effect (CPE) was observed daily. Increase in viral load was determined by rRT-PCR, using 100 µl of supernatant from each T-25 flask at 0 (base line for comparison), 24 and 120 h post infection (hpi). rRT-PCR was also performed on DMEM exposed to air in a BSL-2 laboratory for 24 h (see section "Fluid samples"), non-exposed DMEM and DMEM spiked with SARS-CoV-2 synthetic oligonucleotide control sequence as negative and positive controls, respectively (Suppl. Table 1). Eleven days post inoculation, supernatants from the pooled samples (1 ml) were passed once into new flasks seeded with Vero E6 cells and containing 4 ml of cell media. Two days after the passage, samples were taken as described above for quantification by rRT-PCR. All procedures involving live virus were performed in a BSL-3 laboratory.

Ethical approval. Approval for accessing patient information was granted from the Swedish Ethical Review Authority DNR 2020-01787. As this retrospective data collection was considered completely anonymized by the Ethics committee, the need for patient consent was waived by the Swedish Ethical Review Authority. The study was conducted according to good clinical and scientific practices and following the ethical principles of the Declaration of Helsinki.

Results

SARS-CoV-2 RNA detection from ward samples. In two consecutive surface sampling rounds, performed on April 17 and 28, 2020, both SARS-CoV-2 N and E gene RNA were detected in seven (36.8%) out of 19 vent openings, while 11 days later, four vents (21%) were positive for both genes. Ct values varied between 33.77 and 39.78 (Table 2) and sequences were confirmed by Sanger sequencing. All three pooled cell medium samples from patient room ceilings were positive for both genes; Ct values ranged between 33.41 and 36.64. Pool 1 (Fluid traps from 7 rooms occupied by confirmed COVID-19 patients) N gene 35.47 and E gene 36.4, Pool 2 (6 suspected COVID-19 patient rooms) N gene 33.41 and E gene 36.64; Pool 3, (5 suspected non-contagious patient rooms), N gene 34.07 and E gene 36.64). Despite the attempt to arrange the potentially most infective samples in pools 1 and 2, a retrospective overview of patient diagnostics revealed that PCR-positive patients occupied rooms generating samples in all three pools (Suppl. Table 2).

SARS-CoV-2 RNA detection in central ventilation samples. Samples extracted from the main exhaust filters, located on the eighth (top) floor of the investigated hospital building (Fig. 1b), from each separate ventilation system for the three investigated COVID-19 wards were positive for both genes in eight (88.9%) out of nine samples (Table 2). Swabs taken from internal surfaces of three central ventilation channels at the top floor were all negative (Ct values > 45) (Table 1). Petri dishes containing cell medium, placed in inspection hatches in the central ventilation system prior to the exhaust filters, were found to contain SARS-CoV-2 RNA (both N and E genes) in one (33.3%) out of three specimens from ward 2 (Ct values 35.32 and 33.16 for N and E

		Patient details						Ventilation opening	
			SARS-CoV-2 PCR			Respiratory support		PCR results (Ct value)	
				PCR results (Ct value)					
Room	Sample set	Days since onset of symptoms	Patient sample date	N gene	E gene	Current	Last 24 h	N gene	E gene
1	1	17	April 1, 2020	23.51	22.22	Oxygen	Oxygen	Negative	Negative
	2	8	April 21, 2020	19.14	18.64	HFNC	HFNC	Negative	Negative
2	1	11	April 15, 2020	31.68	32.55	Oxygen	Oxygen	35.33	33.77
	2	12	April 18, 2020	13.3	13.91	Oxygen	Oxygen	Negative	Negative
3*	1	10	April 12, 2020	16.89	16.86	Oxygen	Oxygen	37.94	37.90
		Unoccupied							
	2	16	April 15, 2020	25.47	25.43	None	Oxygen	38.82	37.76
		9	April 21, 2020	14.96	14.98	HFNC	Oxygen/HFNC		
4*	1	15	April 7, 2020	25.98	25.33	HFNC	HFNC	39.55	38.71
		Unoccupied							
	2	20	April 13, 2020	19.72	19.11	Oxygen	Oxygen/HFNC	Negative	Negative
		29	April 5, 2020	17.16	16.59	None	Oxygen		
5*	1	*Unoccupied*						Negative	Negative
		7	April 14, 2020	25.38	25.33	HFNC	HFNC		
	2	*Unoccupied*						Negative	Negative
		8	April 23, 2020	Negative	Negative	Oxygen	Oxygen		
6*	1	8	April 11, 2020	17.91	16.88	Oxygen	Oxygen	36.24	36.70
		20	March 31, 2020	25.18	24.1	HFNC	HFNC		
	2	5	April 25, 2020	Negative	Negative	None	None	Negative	36.78
		Unoccupied							
7*	1	7	April 16, 2020	22.84	22.5	None	None	39.28	Negative
		Unoccupied							
	2	*Unoccupied*						Negative	Negative
		16	April 22, 2020	32.19	Negative	Oxygen	Oxygen		
8*	1	*Unoccupied*						Negative	Negative
		1	April 17, 2020	Negative	Negative	None	None		
	2	*Unoccupied*						Negative	Negative
		15	April 21, 2020	16.09	15.99	None	Oxygen		
9	1	8	April 16, 2020	17.22	17.88	Oxygen	Oxygen	Negative	Negative
	2	12	April 24, 2020	23.76	23.7	None	None	Negative	Negative
10	1	20	April 5, 2020	21.95	21.57	HFNC	HFNC	Negative	Negative
	2	8	April 27, 2020	Negative	Negative	Oxygen	Oxygen	Negative	Negative
11	1	12	April 11, 2020	10.08	9.65	HFNC	Oxygen/HFNC	Negative	Negative
	2	*Unoccupied*						38.61	37.55
12	1	*Unoccupied*						39.77	38.95
	2	12	April 21, 2020	16.09	15.99	None	Oxygen	39.78	Negative
13	1	5	April 15, 2020	24.87	25	Oxygen	Oxygen/HFNC	Negative	Negative
	2	11	April 28, 2020	30.74	Negative	HFNC	HFNC	Negative	Negative
14	1	7	April 17, 2020	Negative	Negative	Oxygen	Oxygen	Negative	Negative
	2	8	April 26, 2020	23.55	22.04	HFNC	HFNC	38.75	38.45
15*	1	*Unoccupied*						Negative	Negative
		Unoccupied							
	2	15	April 20, 2020	14.95	14.83	Oxygen	Oxygen	Negative	Negative
		Unoccupied							
16*	1	13	April 13, 2020	15.95	15.47	Oxygen	Oxygen	37.26	36.14
		Unoccupied							
	2	23	April 14, 2020	17.91	17.58	HFNC	HFNC	Negative	Negative
		Unoccupied							
17*	1	18	April 16, 2020	31.03	36.18	None	None	Negative	Negative
		8	April 13, 2020	16.94	15.95	None	Oxygen		
	2	15	April 18, 2020	29.23	28.38	HFNC	HFNC	Negative	38.63
		30	April 8, 2020	25.31	25.44	Oxygen	Oxygen		

Continued

Room	Sample set	Patient details						Ventilation opening	
			SARS-CoV-2 PCR			Respiratory support		PCR results (Ct value)	
		Days since onset of symptoms	Patient sample date	PCR results (Ct value) N gene	PCR results (Ct value) E gene	Current	Last 24 h	N gene	E gene
18*	1	*Unoccupied*						Negative	37.76
		18	April 6, 2020	19.02	17.62	Oxygen	Oxygen		
	2	*Unoccupied*						Negative	Negative
		Unoccupied							
19	1	14	April 6, 2020	14.28	13.58	Oxygen	Oxygen	37.56	35.28
	2	19	April 18, 2020	17.16	15.87	HFNC	HFNC	36.78	35.31

Table 2. Overview of results from the 19 investigated COVID-19 ward rooms (ward 1), including patient details regarding duration of symptoms, date when clinical sample was collected for PCR-diagnosis, PCR-result from clinical sample and ongoing oxygen therapies when ventilation samples were collected. Rooms marked with an * can accommodate two patients, and thus patient data is supplied for two patients for each sample occasion. Sample set 1: April 17, 2020. Sample set 2: April 28, 2020. Samples not exhibiting fluorescence above threshold level after 45 PCR cycles are labeled "negative". No O_2: No ongoing patient oxygen therapy, O_2: conventional nasal cannula or mask, HFNC: High Flow Nasal Cannula, Ct: cycle threshold, N gene: SARS-CoV-2 Nucleocapsid gene, E gene: SARS-CoV-2 Membrane Small Envelope gene.

genes respectively), while one (33.3%) of the three specimens from ward 1 contained only the E gene (Ct value 33.00) (Table 1).

Infectivity in Vero E6 cells. No significant CPE nor decrease in rRT-PCR Ct values were seen compared to baseline values (see "Results" above for Ct values) after 24 or 120 hpi on Vero E6 cells from samples retrieved from ward vent openings or central ventilation ducts or filters.

Discussion

Several aspects during the COVID-19 pandemic support the risk of aerosol transmission of SARS-CoV-2. First, mounting evidence for pre- and asymptomatic transmission, where the spread of droplets through coughing and sneezing cannot be a major factor, must raise questions about aerosol transmission[31]. Second, aerosols generated by speech could theoretically contain enough SARS-CoV-2 virus particles to support transmission, and these aerosols can remain airborne for up to ten minutes[20]. In addition, coronaviruses can be emitted in aerosols through normal breathing[32]. Third, field studies in hospital wards have detected SARS-CoV-2 RNA both in vent openings and in the air[14–17]. These findings are not unexpected seeing as similar observations have been made for both SARS and Middle East Respiratory Syndrome (MERS)[8,33,34].

In this study, we found SARS-CoV-2 RNA in vent openings in ward rooms harboring COVID-19 patients. Viral RNA was also detected in fluid placed in open dishes suspended below vent openings. Similar levels of viral RNA were detected in exhaust filters and open petri dishes with cell medium at least 44 to 56 m from the three investigated COVID-19 wards. Only a small fraction of each filter was analyzed implying that a large number of particles emanating from COVID-19 wards can disperse to greater distances than can be explained by droplet transmission routes. In previous studies, the effect of ventilation has not shown any obvious impact on the risk for spread of droplet-transmitted diseases, probably since droplets are more governed by gravity[35]. Furthermore, the ventilation system in the investigated hospital building has a relatively low air flow; between 1.7 and 3 total air changes per hour (ACH) for each room, depending on room volumes. The recommendation for airborne infection isolation rooms is 12 ACH in most guidelines[35]. Notably, the relative air humidity in the investigated environment was low, between 30 and 31%. Low air humidity has recently been suggested to increase the risk of airborne SARS-CoV-2 dispersal[36,37].

We initiated this study by performing rRT-PCR on numerous surface and filter samples. Detection of SARS-CoV-2 as well as other coronavirus RNA in ventilation openings has been reported before[10,15,38]. However, the detection of viral RNA in the exhaust filters over 50 m from patient care areas was unexpected. In response to these findings, we found it vital to rapidly address the question of infective ability in order to determine the immediate risk of infection for uninfected patients, personnel working in the investigated wards and service personnel that might be exposed while working with the ventilation systems. We therefore employed the ad hoc methods described above in an attempt to determine the infective ability of the samples. We are aware that there are several potential limitations to the employed sampling methods in fluid traps; the likelihood of viral particles being deposited in fluids by gravity, the length of time the viral particles retain infective ability, concentration and increased osmolarity of the cell medium by evaporation as well as pH increase due to oxygen exposure during sampling. We have not determined whether the detected RNA could be from viral particles that have been inactivated by antibodies, seeing as a majority of the patients admitted to at least one of the wards were in later phases of COVID-19 disease at both collection dates (Table 2), and may have likely developed an immune response. Even though we could not determine infective capability of virus collected in cell medium, we repeatedly detected

SARS-CoV-2 RNA using this method. The placement of the petri dishes, either just below the ceiling in ward rooms or at distances around at least 50 m from patients in central vent ducts indicates that dispersal by means other than larger droplets must occur, since larger droplets are considered to precipitate by gravity within one or two meters from a source[5]. Although RNA could be detected in samples from ward rooms and central ventilation ducts, no infectivity was seen after inoculating samples on susceptible cells. This collection method was adopted in order to rapidly address the question as to what threat the RNA findings may infer in a clinical setting. Several explanations for these results may be identified. First, the Ct values are close to the detection limit, indicating that there were few viral copies in theses samples. Also, many of the admitted patients at this time point (later than other samplings in this study) were in late phases of COVID-19 or cleared of infection. We chose to report this as we could detect SARS-CoV-2 RNA in these samples, and that droplets do not appear to be a plausible explanation for these findings as droplets could unlikely follow a ballistic pathway from patient into the petri dished at 2.5 m height, and in all three pools. It is important to continue to develop effective sampling methods in order to determine infective ability of SARS-CoV-2 as well as differentiating between patients in early and late phases of disease. Since we are aware of these technical limitations, we have recommended service personnel to take adequate protective measures while working with the ventilation systems as we cannot definitively repudiate the risk of infection from contaminated air.

Ongoing oxygenation therapies, such as High Flow Nasal Cannula (HFNC) oxygenation, in each room did not apparently correlate to detection, or Ct values, of SARS-CoV-2 RNA in vent openings (Table 2). This raises the question if the risk for airborne transmission should be considered in more situations than during potentially aerosol generating procedures such as HFNC[6]. This is further corroborated by the studies on aerosols generated when speaking and breathing[20,32]. Results differed in ward rooms between the two samplings of vent openings, which could be due to varying disease progression for the occupying patients. Some vent openings were positive for both N and E genes despite the rooms having been evacuated and routinely cleaned (Table 2). This suggests that detection also could result from viral shedding by previous patients and calls for further studies on how long SARS-CoV-2 RNA can be detected in the environment, with the accompanying risk for transmission via fomites. Alternatively, detection of viral RNA in the ventilation systems could arise from such activities as handling bed linens or cleaning which may disturb viral particles from textiles or surfaces and displace them into the air, and that these virions have dried and been rendered inactive. On the other hand, RNA deterioration after inactivation could limit the extent of this source of RNA found in HVAC systems.

In this study we could not demonstrate infectious capability of the virus, when inoculated on Vero E6 cells, from samples in either vent openings, exhaust filters or by collection directly in cell medium. This is likely due to the pathogens rapidly drying in the vents or inadequate amounts of virus collected near vent openings or in front of exhaust filters. Also, collection directly in cell medium does not appear to have been performed previously and these results should be interpreted cautiously. Furthermore, admitted patients in the ward were between day 5 and 23 after symptom onset (Table 2). There is accumulating evidence that COVID-19 contagiousness peaks shortly prior to symptom onset[2,31,39]. This implies that the patients in this study may be in a less contagious phase of COVID-19 disease, which is consistent with the findings that SARS-CoV-2 infectivity appears to be low eight days after symptom onset[39,40]. Nevertheless, during dispersal from a patient to ventilation, and over considerable distances, the virus may still retain infective capability. RNA was also detected in containers placed at ceiling level, demonstrating that viral particles were airborne during these specific periods, at not only deposited on fomites over longer, uncertain duration. We speculate that the risk of infection by exposure to ventilation system air is presumably very low, due to dilution of viral load and drying. Nevertheless, the apparent capability of the virus to be transported in air, as we present here, should raise concerns for the risk of infection in smaller, confined spaces in close proximity to contagious patients, i.e. all air in patients rooms, intensive care units, etc. during care for COVID-19 patients[41]. This may be even more important concerning patients in earlier phases of disease, in which contagiousness may be high. This includes both symptomatic and asymptomatic SARS-CoV-2 infected persons in any confined space, such as homes, public transportation, restaurants, etc. The presented findings indicate airborne dissemination of SARS-CoV-2, especially considering the distance SARS-CoV-2 RNA was dispersed. However, further investigations, preferably discriminating between patients in early and later phases of SARS-CoV-2 disease as well as direct sampling of expiratory air from COVID-19 patients will be needed to resolve this question.

Conclusions

Detection of coronavirus RNA, including SARS-CoV-2, in hospital and other ventilation systems has been reported, as well as nosocomial and HVAC associated outbreaks[8–13]. In particular, MERS coronavirus, closely related to SARS-CoV-2, has caused major hospital associated outbreaks[9–12]. Also, growing concern about aerosol transmission of SARS-CoV-2 has recently been ventilated[42]. Here we present further evidence for SARS-CoV-2 ability to disperse from patients to ward vent openings as well as detection of viral RNA in ventilation exhaust filters located at least 50 m from patient room vent openings. Although we could not conclude that the viral samples in this collection retained infective ability, the distance at which we detected RNA suggests that there may be a risk for airborne dissemination and transmission, especially at much closer distances to contagious persons in confined spaces, both in and outside hospital environments. We therefore find it reasonable to take precautionary measures against airborne transmission and that further investigations are necessary.

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Long distance airborne transmission of SARS-CoV-2: rapid systematic review

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Abstract

OBJECTIVES
To evaluate the potential for long distance airborne transmission of SARS-CoV-2 in indoor community settings and to investigate factors that might influence transmission.

DESIGN
Rapid systematic review and narrative synthesis.

DATA SOURCES
Medline, Embase, medRxiv, Arxiv, and WHO COVID-19 Research Database for studies published from 27 July 2020 to 19 January 2022; existing relevant rapid systematic review for studies published from 1 January 2020 to 27 July 2020; and citation analysis in Web of Science and Cocites.

ELIGIBILITY CRITERIA FOR STUDY SELECTION
Observational studies reporting on transmission events in indoor community (non-healthcare) settings in which long distance airborne transmission of SARS-CoV-2 was the most likely route. Studies such as those of household transmission where the main transmission route was likely to be close contact or fomite transmission were excluded.

DATA EXTRACTION AND SYNTHESIS
Data extraction was done by one reviewer and independently checked by a second reviewer. Primary outcomes were SARS-CoV-2 infections through long distance airborne transmission (>2 m) and any modifying factors. Methodological quality of included studies was rated using the quality criteria checklist, and certainty of primary outcomes was determined using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) framework. Narrative synthesis was themed by setting.

RESULTS
22 reports relating to 18 studies were identified (methodological quality was high in three, medium in five, and low in 10); all the studies were outbreak investigations. Long distance airborne transmission was likely to have occurred for some or all transmission events in 16 studies and was unclear in two studies (GRADE: very low certainty). In the 16 studies, one or more factors plausibly increased the likelihood of long distance airborne transmission, particularly insufficient air replacement (very low certainty), directional air flow (very low certainty), and activities associated with increased emission of aerosols, such as singing or speaking loudly (very low certainty). In 13 studies, the primary cases were reported as being asymptomatic, presymptomatic, or around symptom onset at the time of transmission. Although some of the included studies were well conducted outbreak investigations, they remain at risk of bias owing to study design and do not always provide the level of detail needed to fully assess transmission routes.

CONCLUSION
This rapid systematic review found evidence suggesting that long distance airborne transmission of SARS-CoV-2 might occur in indoor settings such as restaurants, workplaces, and venues for choirs, and identified factors such as insufficient air replacement that probably contributed to transmission. These results strengthen the need for mitigation measures in indoor settings, particularly the use of adequate ventilation.

SYSTEMATIC REVIEW REGISTRATION
PROSPERO CRD42021236762.

WHAT IS ALREADY KNOWN ON THIS TOPIC
The risk of SARS-CoV-2 transmission is likely to be greatest when in close proximity (<2 m) to someone who is infected

The potential for long distance airborne transmission (>2 m) is unclear, although widespread reporting of superspreader events suggests it may occur

Emission rates of respiratory particles released vary considerably between individuals but are generally higher for singing and speaking compared with breathing and tend to increase with loudness of vocalisation

WHAT THIS STUDY ADDS
The findings from this rapid systematic review suggest that long distance airborne transmission of SARS-CoV-2 might happen in indoor settings such as restaurants, public transport, workplaces, or choir venues

These results show that factors such as insufficient air replacement, directional air flow, and activities associated with increased emissions of respiratory particles (eg, singing or speaking loudly) might contribute to long distance airborne transmission

Well conducted epidemiological investigations can provide critical insight into transmission routes, especially when other types of studies are not feasible; the question of what level of public health evidence is sufficient to support decision making for a novel infection warrants further consideration

Introduction
Since the early stages of the covid-19 pandemic and the first reports of superspreader events,[1 2] the body of evidence suggesting airborne transmission of SARS-CoV-2 in the absence of aerosol generating procedures has grown. However, despite the publication of numerous opinion pieces and narrative reviews in support of airborne transmission of SARS-CoV-2,[3-9] scientific consensus on the relative importance of this route of transmission is lacking. Part of the controversy arises from differences in terminology, definitions, and size thresholds for respiratory particles.[10]

Traditionally, close contact transmission was assumed to occur through droplets with ballistic trajectory that directly deposit on mucous membranes, whereas airborne transmission was assumed to occur over longer distances via smaller particles (aerosols) that remained suspended in the air and were subsequently inhaled.[10 11] Limitations of this dichotomy are well illustrated by the challenge in defining a size range to characterise particles that are droplets or aerosols.[6 7 10 12] For example, the World Health Organization threshold is set at 5-10 microns[13] whereas in the UK the threshold is based on the work by Milton[14] and set to 100 microns.[15] This is also complicated by the role of evaporation, as a particle will get smaller as it moves from human sources.

Regardless of terminology and definitions, it is now understood that short range transmission can occur through both droplets and aerosols and that the concentration of respiratory particles is higher at short range than over longer distances.[7 11 16 17] Consensus is, however, still lacking on the risk for long distance airborne transmission in indoor settings in the community such as hospitality venues, leisure facilities, workplaces, or apartment blocks. This lack of consensus also reflects the challenging nature of the evidence base, and high quality review level evidence is still needed; some systematic reviews have relied on environmental sampling studies, which only provide indirect evidence of the potential risk of airborne transmission,[18-20] whereas systematic reviews that have included a wider range of study designs (epidemiological, environmental, and modelling) and settings (healthcare and community) remain inconclusive.[21-24]

This gap needs to be addressed from a public health perspective, focusing on long distance transmission (>2 m) in indoor community settings. As evidence on the biological plausibility of long distance airborne transmission is available from environmental and experimental studies,[18 21 22] we focused on epidemiological observational studies to assess where and when human-to-human transmission are likely to occur. In this rapid review we systematically identified and examined such studies to evaluate the potential for long distance airborne transmission of SARS-CoV-2 in indoor community settings and to assess the impact of potential modifying factors.

Methods

We used a rapid systematic review approach, following streamlined systematic methodologies to accelerate the review process,[25] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.[26] The protocol for this review was registered on PROSPERO before screening took place.[27]

Data sources and searches

We identified primary studies through two sources. Firstly, we screened studies included in the rapid systematic review by Comber et al for those published from 1 January 2020 to 27 July 2020.[21] This systematic review, assessed to be of moderate quality using the AMSTAR 2 (A MeaSurement Tool to Assess systematic Reviews, revised) critical appraisal tool,[28] contains a comprehensive search strategy and wider inclusion criteria than the current rapid review (studies related to all airborne transmission of SARS-CoV-2) and was the only relevant review available at the time we wrote our protocol.

Secondly, we conducted electronic searches in Ovid Medline, Ovid Embase, medRxiv, Arxiv, and WHO COVID-19 Research Database for studies published from 27 July 2020 to 19 January 2022. The initial search was conducted on 8 February 2021 and last updated on 19 January 2022. The search strategy was drafted by an information scientist and peer reviewed by a second information scientist. Supplementary material 1 (section 1) shows the full search strategy.

Using the studies that met our inclusion criteria, we performed a citation analysis on 1 February 2022 on Web of Science and Cocites (co-citation analysis, forward and backwards snowballing). Although this was not part of the search strategy outlined in the protocol, it was agreed a posteriori by the review team to increase the chance of additional relevant studies being retrieved.

Eligibility criteria for study selection

Our eligibility criteria for study selection were published articles, accepted manuscripts, and preprints reporting on the potential for airborne transmission of SARS-CoV-2 in indoor community (non-healthcare) settings at a distance >2 m (the 2 m threshold is based on UK regulations; we also considered for inclusion non-UK studies that used thresholds based on their respective national recommendations, such as 1.5 m or 6 feet/1.8 m). The aim was to include all observational studies (outbreak investigations and epidemiological case series, cohort, case-control, and cross sectional studies) of any human population in non-healthcare settings. We excluded systematic or narrative reviews, guidelines, opinion pieces, intervention studies, modelling studies, environmental sampling studies without epidemiological investigation, laboratory or virology studies, and animal studies. We also excluded observational studies in which close contact or fomite were the most likely transmission routes (eg, studies reporting on transmission in households).

Screening was performed using Rayyan Systems, a freely available online screening tool.[29] Two reviewers independently screened the first 10% of records retrieved from the initial search on title and abstract, with substantial agreement (97.7%; Cohen's κ=0.61). A single reviewer screened the remainder, and two reviewers independently screened a further 10% (of the total number of records), with almost perfect agreement (99.6%; Cohen's κ=0.92). All records selected were screened at full text by one reviewer and checked by a second reviewer, with any discrepancies resolved by discussion with a third reviewer.

Outcomes

The primary outcomes were SARS-CoV-2 infections through long distance airborne transmission (at a distance >2 m), and any factors that might have modified the risk of transmission under these conditions. Included measures for SARS-CoV-2 infections were number of covid-19 cases; secondary attack rates; risk, rate, or odds of transmission over the stipulated distances; or any other reported measure related to transmission rate. For the modifying factors, we considered narrative on the type of effect and any potentially relevant information to be acceptable.

Additional outcomes extracted, when available, were time spent in the setting and distance over which airborne transmission was thought to have occurred.

Data extraction and synthesis

We developed a data extraction table to gather information on methods, participants, settings, outcomes, key findings, and any additional relevant information (eg, whether participants wore face coverings). Data extraction was completed for each included study by one reviewer and independently checked by a second reviewer, with discrepancies resolved by discussion. Only evidence directly relevant to the review question was extracted. For example, if studies reported on different outbreaks or on onward transmission that might have happened in different settings, we only extracted the results of outbreaks or settings when distance and transmission routes could be assessed.

A narrative summary of results according to indoor setting was produced.

Quality assessment and certainty of evidence

We used a quality criteria checklist for primary research to assess the methodological quality of each included study.[30] This checklist tool is composed of 10 questions, four of which are considered critical (questions on selection bias, group comparability, description of exposure/assessment of transmission routes, and validity of outcome measurements). Strict criteria were used to assess the two critical questions related to exposure and outcome assessment. In particular, a cluster of covid-19 cases in the setting of interest had to be confirmed with viral genomic sequencing to be considered as low risk of bias for validity of outcome measurements. Supplementary material 1 (section 2) lists the 10 questions of the quality criteria checklist.

A study was rated as high methodological quality if the answers were yes to the four critical questions plus at least one of the remaining questions. A study was rated as low methodological quality if answers were no to ≥50% of the critical questions. Otherwise, the study was rated as medium methodological quality. Each study was assessed independently in duplicate, with disagreements resolved by consensus.

Certainty of the evidence was assessed using a variation of the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) framework for systematic reviews without meta-analysis.[31] We assessed each of the five GRADE domains (methodological limitations of the studies, indirectness, imprecision, inconsistency, and likelihood of publication bias) and classified them as no limitation or not serious (not important enough to warrant downgrading), serious (downgrading the certainty rating by one level), or very serious (downgrading the certainty rating by two levels). We then classified the body of evidence for a specific outcome as high certainty, moderate certainty, low certainty, or very low certainty.

Patient and public involvement

Patients and members of the public were not involved in this rapid systematic review mainly because of time restrictions. The review question was, however, developed with the input of several public health experts and stakeholders.

Results

Study selection

After removal of duplicates, 7439 records were screened for relevance on title and abstract, with 90 reports assessed for eligibility (fig 1). Fifty six additional reports identified from the Comber et al rapid review[21] and by citation analysis were also assessed. From these 146 reports, 124 were excluded (see supplementary material 1 (section 3) for list of reasons for exclusion), and 22 reports[1 32-52] relating to 18 studies were included. When two or more reports related to the same study, we considered the most comprehensive report as the main publication.

All the studies investigated outbreaks of clusters of SARS-CoV-2 infections, and one study had an analytical component.[36] Eight studies were conducted in Asia,[34-40 45] five in Europe,[41 43 44 47 48] three in Oceania,[32 33 46] and two in the United States.[1 42] Three studies reported on transmission between flats in apartment blocks,[38-40] two in quarantine hotels,[32 33] two in restaurants,[34 35] two in buses,[36 37] one in a food processing factory,[41] one in a courtroom,[43] one in an office,[44] one in a fitness facility,[42] one in a department store,[45] and four during singing events.[1 46-48] All the outbreaks occurred in 2020, except for one in January 2021 in South Korea[40] (before vaccine rollout started in this country) and one in July 2021 in a quarantine hotel in New Zealand.[33]

Table 1 and table 2 summarise the studies by setting. Supplementary material 2 provides detailed information on each study.

Quality assessment

Figure 2 provides details of the methodological quality ratings: three studies were rated as high quality,[33 35 46] five as medium quality,[32 34 36 41 47] and 10 as low quality.[1 37-40 42-45 48] These ratings represent the methodological quality of descriptive studies.

Transmission settings

Quarantine hotels

Two outbreaks of covid-19 in quarantine hotels were identified, both in New Zealand and involving cases part of the same genomic cluster who had quarantined

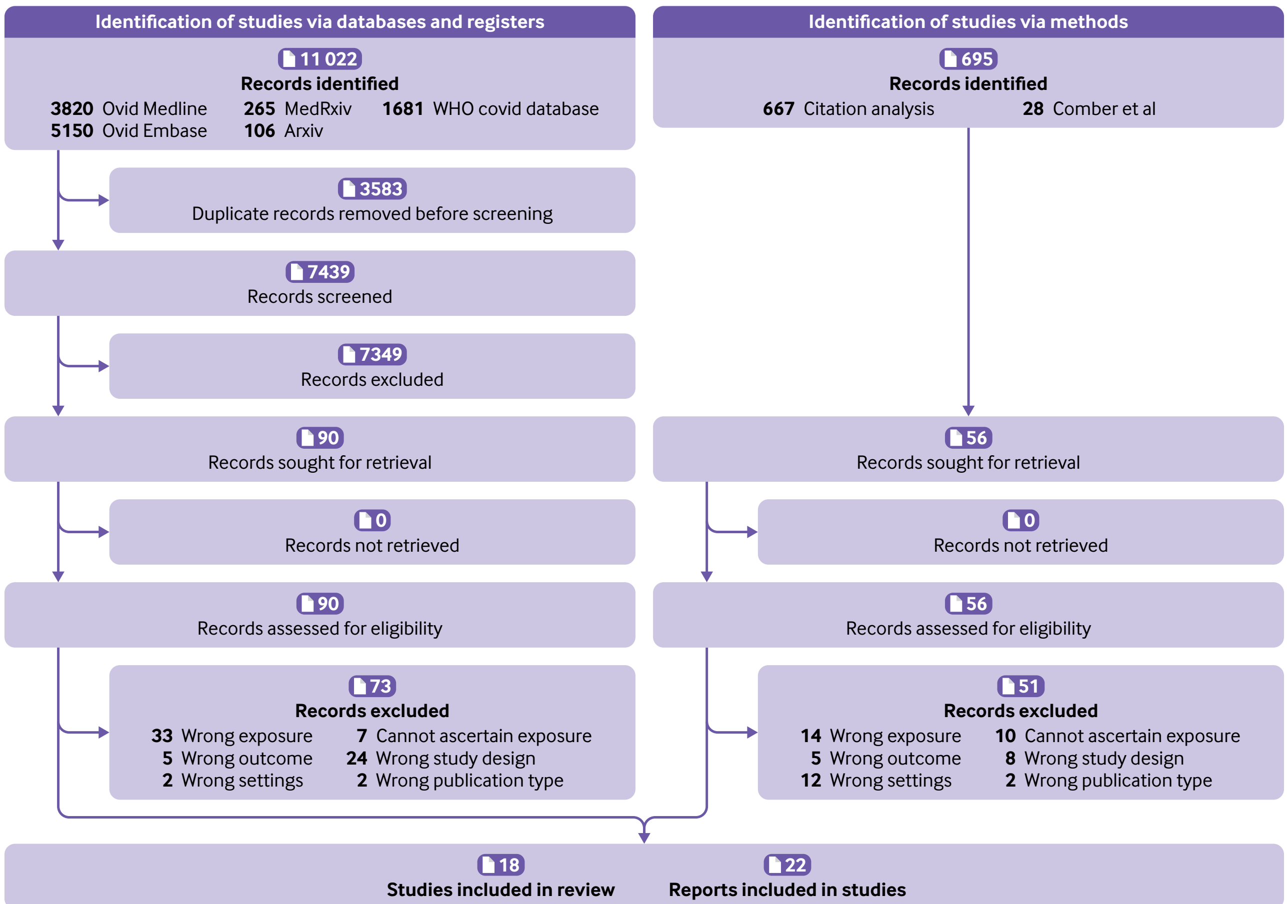

Fig 1 | Flow of articles through the review

in separate rooms. The first outbreak, reported by Eichler et al[32] (rated as medium methodological quality) occurred in September 2020, and although primary and secondary cases had travelled on the same flight, transmission is believed to have happened in the hotel on day 12 of quarantine, after the primary case had developed symptoms on day 10. No information was provided on the measures in place at this quarantine hotel (eg, use of face coverings). The second outbreak, reported by Fox-Lewis et al[33] (rated as high methodological quality) occurred in July 2021. The primary case (asymptomatic) and secondary cases had travelled on different flights and arrived at the hotel on different days. Staff members, all vaccinated, wore full personal protective equipment and were regularly tested. Participants were asked to wear surgical masks when opening doors, but this could not be validated in the investigation. None of the cases (primary or secondary) were vaccinated; the only person who was vaccinated tested negative despite being part of the same travel group as the secondary cases.

Close contact and fomite transmission were ruled out by video analysis in both studies, although in the outbreak reported by Eichler et al[32] fomite transmission through a communal bin—although unlikely, cannot be ruled out. Video analysis showed that in both outbreaks the doors of the rooms had been opened simultaneously for a short period during which infected respiratory particles could have moved between rooms. Both investigations included a review of the ventilation systems and found that pressure differences between rooms and corridors could support this hypothesis. Long distance airborne transmission between a primary case and at least one secondary case was therefore considered to be the most likely route in both outbreaks.

Restaurants

Two separate outbreaks of covid-19 in restaurants were identified. The first outbreak, in China in January 2020, was mainly reported by Li et al[34] (rated as medium methodological quality), with additional evidence provided in two other reports.[49 50] This outbreak involved a primary case (with symptom onset later that day) and at least two secondary cases who were seated on tables between 1.4 and 4.6 m away from the primary case. The second outbreak, reported by Kwon et al[35] (rated as high methodological quality), occurred in June 2020 in South Korea and involved three people with confirmed covid-19 who belonged to the same genomic cluster. The primary case, which was presymptomatic at the time, sat 6.5 m from one secondary case for five minutes, and 4.8 m from the other secondary cases for 21 minutes, all at different tables.

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Table 1 | Summary of included studies, in chronological order by setting: quarantine hotels, restaurants, buses, and apartment blocks

Reference (quality rating)	Transmission event, setting, date	No of cases	Outcome and exposure assessment	Potential for other transmission routes	Potential for airborne transmission >2 m*	Modifying factors
Li et al,[34] Lu et al,[49] Zhang et al[50] (medium)	Restaurant, China, January 2020	Ten confirmed cases from three tables	No genomic sequencing. Epidemiological data, video recording, on-site visit, design of air conditioning and ventilation system, experiments to assess airflow and ventilation rates	Close contact or fomite transmission unlikely (except for cases in same household). Transmission from outside event possible for some cases	Possible airborne transmission between primary case and at least two secondary cases; up to 1.4 m (53 min) and 4.6 m (75 min) from primary case	Insufficient air replacement. Directional air flow through air circulation units
Shen et al[36] (medium)	Buses, China, January 2020	Twenty four confirmed cases	No genomic sequencing. Questionnaires and interviews, contact tracing data, bus design, and ventilation system	Close contact, fomite transmission, or transmission from outside event possible for some cases	Possible airborne transmission >2 m from primary case (50 min)	Insufficient air replacement. Directional air flow from central heating system
Luo et al,[37] Ou et al[51] (low)	Buses, China, January 2020	Nine confirmed cases	No genomic sequencing. Epidemiological data, information on loading and unloading stops of all passengers, and seating positions, ventilation systems, tracer gas experiments	Close contact unlikely. Fomite transmission or transmission from outside event possible for some cases	Possible airborne transmission >2 m for some cases (1 hour to 2.5 hours)	Insufficient air replacement. Directional air flow due to exhaust system
Lin et al[38] (low)	Apartment block, China, January 2020	Nine confirmed cases from three households	No whole genome sequencing (partial S gene only). Interviews with cases, CCTV of lift, tracer gas and wind speed experiments	Close contact or fomite transmission unlikely (except for cases in same household); transmission from outside event possible for some cases	Possible airborne transmission between cases in one flat to two different flats (up to 10 floors from flat of primary case)	Insufficient air replacement. Directional air flow through drainage and exhaust system
Kwon et al[35] (high)	Restaurant, South Korea, June 2020	Three confirmed cases	Genomic sequencing. Contact tracing, interviews, credit card records, video recording, mobile phone location data, on-site visits, air flow measurement, environmental sampling	Close contact, fomite transmission, or transmission from outside event unlikely	Possible airborne transmission between cases seated 4.8 m (21 min) and 6.5 m (5 min) from the primary case	Insufficient air replacement. Directional air flow through air circulation units
Hwang et al[39] (low)	Apartment block, South Korea, August 2020	Ten confirmed cases from seven households	No genomic sequencing. Epidemiological data, surface sampling, building assessment	Close contact or fomite transmission unlikely (except for cases in same household). Transmission from outside event possible	Possible airborne transmission through ventilation ducts across floors for some secondary cases	Directional air flow through vertical air duct or floor drain. Insufficient air replacement (unclear)
Eichler et al[32] (medium)	Quarantine hotel, New Zealand, August-September 2020	Nine confirmed cases, with one secondary case considered for long distance transmission	Genomic sequencing. Epidemiological data, surveillance video, review of ventilation system in hotel	Close contact or fomite transmission unclear. Transmission from outside event unlikely	Possible airborne transmission from hotel room of the primary case to doorway or corridor for one secondary case	Insufficient air replacement. Directional air flow
Han et al[40] (low)	Apartment block, South Korea, January 2021	Five secondary cases (three households) considered for long distance transmission	Genomic sequencing. Epidemiological data, interviews, mobile phone location tracking, surface sampling	Close contact or fomite transmission unlikely (except for cases in same household). Transmission from outside event unlikely	Possible airborne transmission through floor drains across three floors for two secondary cases	Insufficient air replacement. Directional air flow through vertical floor drain
Fox-Lewis et al[33](high)	Quarantine hotel, New Zealand, July 2021	Five confirmed cases in two rooms	Genomic sequencing. Epidemiological data, surveillance video, review of ventilation system in hotel	Close contact, fomite transmission, or transmission from outside of event unlikely	Possible airborne transmission from hotel room of primary case to hotel room for at least one secondary case (2.1 m)	Insufficient air replacement. Directional air flow

This review's assessment of likelihood of airborne transmission of SARS-CoV-2 over distances >2 m is based on likelihood of it occurring in some, but not necessarily all, transmission events.
*Exposure distance and time are stated when known; if not stated they are categorised as not clear or not specified.

After extensive epidemiological and environmental investigations, both studies suggested that the most plausible route was long distance airborne transmission, which could have been facilitated by air circulation units generating a directional air flow from the primary to secondary cases combined with lack of air replacement. In both outbreaks close contact and fomite transmission were ruled out based on video surveillance analysis.

Buses and coaches

Two separate outbreaks of covid-19 on buses in China in January 2020 were identified, one on a journey to and from a worship event among lay Buddhists[36] and one on a long distance journey using a public coach and minibus.[37 51]

The outbreak at a worship event was reported by Shen et al[36] who conducted a retrospective epidemiological investigation with an analytical component (rated as medium methodological quality). Thirty one of the 300 participants tested positive for SARS-CoV-2 of whom seven were likely to have been infected by close contact transmission during the religious event. The other 23 cases had travelled to the event in the same bus as the primary case and were thought to have been mainly infected during the bus journey, throughout

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Table 2 | Summary of included studies, in chronological order by setting: department store, singing events, meat processing plant, fitness facility, courtroom, and office

Reference (quality rating)	Transmission event, setting, date	No of cases	Outcome and exposure assessment	Potential for other transmission routes	Potential for airborne transmission >2 m*	Modifying factors
Jiang et al[45] (low)	Department store, China, January 2020	Twenty four cases, with 12 secondary cases considered for long distance transmission	No genomic sequencing. Epidemiological data, surveillance video, assessment of ventilation conditions	Close contact, fomite transmission, or transmission from outside event all possible	Unclear airborne transmission across different sections of the store	Not applicable
Hamner et al,[1] Miller et al[52] (low)	Singing event, USA, March 2020	Fifty two: 32 confirmed cases, 20 probable cases	No genomic sequencing. Telephone interviews	Close contact or transmission from outside event possible for some cases. Fomite transmission unlikely	Possible airborne transmission >2 m for some cases, owing to high secondary attack rate (2.5 hours)	Insufficient air replacement. Increased aerosol emission—singing
Charlotte et al[48] (low)	Singing event, France, March 2020	Nineteen: seven confirmed cases, 12 probable cases	No genomic sequencing. Questionnaire and telephone interviews	Close contact possible for some cases. Fomite transmission unlikely. Transmission from outside event possible for at least two cases	Possible airborne transmission >2 m for some cases, owing to high secondary attack rate (2 hours)	Insufficient air replacement. Increased aerosol emission—singing
Gunther et al[41] (medium)	Meat processing plant, Germany, May-June 2020	Thirty one confirmed cases	Genomic sequencing. On-site visit (work condition and ventilation system) and information provided by employer on housing, commuting, and workplaces of employees	Close contact and fomite transmission possible for some cases. Transmission from outside event unlikely	Possible airborne transmission for some cases on the production line, up to 12 m from the primary case	Insufficient air replacement. Directional air flow from air circulation system. Increased aerosol emission—physical work (unclear)
Groves et al[42] (low)	Fitness facility, USA, June 2020	Twenty one confirmed cases, with10 secondary cases considered for long distance transmission	No genomic sequencing. Questionnaire and on-site assessment	Close contact possible for some cases. Fomite transmission unclear. Transmission from outside event unlikely	Possible airborne transmission >2 m for some cases, owing to high secondary attack rate (1 hour)	Insufficient air replacement. Directional air flow from air fan. Increased aerosol emission—shouting
Katelaris et al[46] (high)	Singing event, Australia, July 2020	Thirteen confirmed cases	Genomic sequencing. Interviews with cases, video recording, on-site visit (ventilation system)	Close contact or fomite transmission unlikely (except for five cases in same household). Transmission from outside event unlikely	Possible airborne transmission with secondary cases seated 1-15 m from the primary case (1 hour)	Insufficient air replacement. Increased aerosol emission—singing
Vernez et[43] (low)	Courtroom, Switzerland, September 2020	Five confirmed cases	No genomic sequencing. Court records, contact tracing data, and field measurements	Close contact cannot be ruled out, especially for the two secondary cases at 1.5 m from the primary case. Fomite transmission unlikely. Transmission from outside event likely for one secondary case	Possible long distance airborne transmission for three secondary cases (1.5-3 m; 3 hours)	Insufficient air replacement
Shah et al[47] (medium)	Five singing events, Netherlands, September-October 2020	Fifty: 48 confirmed cases and two probable cases	Genomic sequencing for seven cases. Phone and email correspondence, questionnaires, epidemiological data, aerosol transmission model	Close contact possible for some cases. Fomite transmission unlikely (except for one event). Transmission from outside event possible for some cases, but unlikely in others	Possible airborne transmission >1.5 m for some cases (1 hour to 2.5 hours)	Increased aerosol emission—singing. Directional air flow (unclear). Insufficient air replacement (unclear)
Sarti et al[44] (low)	Office, Italy, November 2020	Five confirmed cases	No genomic sequencing. Telephone interviews	Close contact, fomite transmission, or transmission from outside event possible	Unclear airborne transmission between coworkers	Not applicable

The review's assessment of likelihood of airborne transmission of SARS-CoV-2 over distances >2 m is based on likelihood of it occurring in some, but not necessarily all, transmission events.
*Exposure distance and time are stated when known; if not stated they are categorised as not clear or not specified.

which no one wore face coverings. Those travelling on the bus with the primary case were 11 times more likely to develop covid-19 compared with the other participants (relative risk 11.4, 95% confidence interval 5.1 to 25.4; P<0.01) and 42 times more likely compared with those travelling in the other bus (42.2, 2.6 to 679.3; P<0.01). Close contact transmission, fomite transmission, and transmission from outside the event cannot be ruled out for some of the cases but are unlikely to have accounted for all 23 secondary cases.

The second outbreak, reported by Luo et al[37] (rated as low methodological quality) with additional environmental investigations conducted by Ou et al,[51] involved one primary case (symptom onset occurred on the day of the event) who had travelled without wearing a face covering on a coach for 2.5 hours with 48 other individuals and then on a minibus for one hour with 12 other individuals. Nine secondary cases were identified, resulting in a secondary attack rate of 15% (95% confidence interval 6% to 24%), with most seated >2 m from the primary case: up to 4.5 m based

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Reference	QCC questions* 1	2†	3†	4	5	6†	7†	8	9	10	Quality rating
Charlotte 2020[48]	Yes	Yes	Not applicable	Yes	Not applicable	No	No	Not applicable	Yes	Yes	Low
Eichler 2021[32]	Yes	Yes	Not applicable	Not applicable	Not applicable	Unclear	Yes	Not applicable	No	Yes	Medium
Fox-Lewis 2022[33]	Yes	Yes	Not applicable	Not applicable	Not applicable	Yes	Yes	Not applicable	Yes	Yes	High
Groves 2021[42]	Yes	Yes	Not applicable	Unclear	Not applicable	No	No	Not applicable	Yes	Yes	Low
Gunther 2020[41]	Yes	Yes	Not applicable	Yes	Not applicable	Unclear	Yes	Not applicable	Yes	Yes	Medium
Hamner 2020[1,52]	Yes	Yes	Not applicable	Yes	Not applicable	No	No	Not applicable	Yes	Yes	Low
Han 2022[40]	Yes	No	Not applicable	Unclear	Not applicable	No	Yes	Not applicable	No	Yes	Low
Hwang 2021[39]	Yes	Yes	Not applicable	Yes	Not applicable	No	No	Not applicable	Yes	Yes	Low
Jiang 2021[45]	Yes	Unclear	Not applicable	Not applicable	Not applicable	No	No	Not applicable	No	Yes	Low
Katelaris 2021[46]	Yes	Yes	Not applicable	Yes	Not applicable	Yes	Yes	Not applicable	Yes	Yes	High
Kwon 2020[35]	Yes	Yes	Not applicable	Unclear	Not applicable	Yes	Yes	Not applicable	Yes	Yes	High
Li 2021[34,49,50]	Yes	Yes	Not applicable	Not applicable	Not applicable	Yes	No	Not applicable	Yes	Yes	Medium
Lin 2021[38]	Yes	No	Not applicable	Unclear	Not applicable	Unclear	Unclear	Not applicable	Yes	Yes	Low
Luo 2020[37,51]	Yes	Yes	Not applicable	Yes	Not applicable	No	No	Not applicable	Yes	Yes	Low
Sarti 2021[44]	Yes	Yes	Not applicable	Yes	Not applicable	No	No	Not applicable	No	Yes	Low
Shah 2021[47]	Yes	Yes	Not applicable	Yes	Not applicable	Unclear	Unclear	Not applicable	Yes	Yes	Medium
Shen 2020[36]	Yes	Yes	Yes	Yes	Not applicable	Unclear	No	No	Yes	Yes	Medium
Vernez 2021[43]	Yes	Yes	Not applicable	Not applicable	Not applicable	No	No	Not applicable	Yes	Yes	Low

Yes Unclear No Not applicable

Fig 2 | Quality assessment. *Assessments using quality criteria checklist (QCC) for primary research (see supplementary material 1). †Critical questions: 2 on selection bias, 3 on group comparability, 6 on description of exposure/assessment of transmission routes, and 7 on validity of outcome measurements

on one report[37] and up to 9.5 m based on the other report.[51] Genomic sequencing was not performed and, based on symptom onset dates, it is plausible that more than one primary case was present, reducing our confidence in the distances reported. However, even taking into account all potential primary cases, it is possible that airborne transmission occurred for some secondary cases seated >2 m from a primary case. Some passengers wore face coverings, but none of the secondary cases did.

In both outbreaks, insufficient air replacement and directional airflow from the heating system were hypothesised as promoting long distance airborne transmission, supported by tracer gas experiments in the buses involved in one of the outbreaks.[51]

Apartment blocks

Three outbreaks of covid-19 in three separate residential apartment blocks were identified. The study by Lin et al[38] (rated as low methodological quality) investigated an outbreak involving nine people who tested positive for SARS-CoV-2 in three flats of a 29 storey apartment block in China. The nine cases, identified between 27 January and 13 February 2020, lived in flats that shared drain and sewer pipes connected via an exhaust pipe to the roof. Except for cases in the same household, close contact and fomite transmission were ruled out based on interviews with the cases and partial video analysis (lift only). Some but not all of the cases reported wearing face coverings in the communal areas of the building.

The two other outbreaks were in South Korea. The first, reported by Hwang et al[39] (rated as low methodological quality), occurred in August 2020 in an apartment block of 267 flats and involved 10 cases from seven households located around two ventilation ducts (eight cases around one, two around another). The second outbreak, reported by Han et al[40] (rated as low methodological quality), occurred in January 2021 in a complex of 260 flats, in which cases located in three flats along the same drainpipe and ventilation duct could not be explained by close contact or fomite transmission. For both outbreaks, transmission routes were mainly investigated through interviews with cases, and therefore recall bias (no video analysis) was possible. All cases reported wearing face coverings in the communal areas of the buildings.

For all three outbreaks, long distance airborne transmission between flats through vertical air ducts or floor drains was deemed possible for at least some of the secondary cases, although environmental investigation (tracer gas experiment) to support this hypothesis was conducted in only one[38] of the three studies. In two of the three studies,[38 40] the ventilation ducts were found to be malfunctioning, which could have contributed to transmission risk. However, only one of these studies[39] tested all residents and only one conducted whole genome sequencing,[40] which reduces confidence in the results.

Other indoor settings

The other outbreaks identified in this review occurred in a food processing factory,[41] fitness facility,[42] courtroom,[43] office,[44] and department store.[45]

Gunther et al[41] (rated as medium methodological quality) reported on an outbreak in a meat processing plant in Germany in May and June 2020 in which 31 out of the 140 workers on the same shift had tested positive for SARS-CoV-2 and were part of the same genomic cluster. Although close contact or fomite transmission in other areas of the processing plant and outside the factory (some workers shared accommodation and carpools) was possible for some cases, the spatial distribution of the cases suggested that transmission was likely to have occurred on the processing line at distances up to 12 m from the primary case who was asymptomatic. The authors hypothesised that factors such as increased respiratory rates (from physically demanding work), lack of air replacement, and continuous recirculation of cooled unfiltered air might have promoted long distance airborne transmission, but these were not investigated further. Some covid-19 measures were in place, including increased distance between workers and use of single layer face coverings, but adherence was not assessed as part of the study.

Groves et al[42] (rated as low methodological quality) reported on an outbreak involving two fitness instructors at classes taught in three different facilities in June and July 2020, although the investigation suggested that close contact and fomite transmission were likely to have occurred in all classes but one. The class in which long distance airborne transmission might have happened was a one hour static cycling class in which bikes were placed at least 1.8 m apart, with doors and windows closed and three large fans directed towards the class participants. The instructor, who had shouted instructions while facing the participants, was identified as being the primary case (with symptom onset the next day) and all 10 class participants had tested positive for SARS-CoV-2 three to six days after the class. Face coverings had not been used during the class.

In an outbreak in a courtroom in Switzerland reported by Vernez et al[43] (study rated as low methodological quality), five out of the 10 participants at a three hour hearing held on the 30 September 2020 tested positive for SARS-CoV-2. The use of face coverings was mandatory in the building, but not when seated, and social distancing measures were in place, with a minimum of 1.5 m between each seat. Long distance airborne transmission (1.5-3 m) was likely to have happened between a primary case (with symptom onset on that day) and three secondary cases, although close contact or fomite transmission after the hearing or in the bathroom cannot be ruled out. The hypothesis that a lack of air replacement (doors and windows were closed and there was no mechanical ventilation) might have promoted long distance airborne transmission was supported by field measurements and modelling.

Sarti et al[44] (rated as low methodological quality) reported on an outbreak in an office in Italy in which five of six coworkers were identified as cases. One of the five coworkers was identified as the primary case, and transmission happened before symptom onset. The sixth coworker, who was not infected, was not present in the office for the two days before symptom onset of the primary case. This transmission event happened in November and December 2020 when mitigation measures were in place, including social distancing, acrylic panels between desks, hand hygiene, and use of a face covering except when seated at a desk. The office was not well ventilated (no air conditioning and windows were closed), which could have promoted long distance airborne transmission. On the basis of the investigation, however, close contact, fomite transmission, and transmission from outside the event cannot be ruled out, so it is unclear as to whether long distance airborne transmission was the most likely route.

Jiang et al[45] (rated as low methodological quality) reported on an outbreak linked to a department store that occurred in January 2020 in Tianjin, China, involving 24 cases (six staff and 18 customers). Airborne transmission was considered as the most likely route of transmission between a primary case and 12 secondary cases, which might have been promoted by a lack of air replacement (doors were closed) and high density of people in the store. As genomic sequencing of SARS-CoV-2 was not performed, however, transmission from outside this event cannot be ruled out and, based on symptom onset dates, it is possible that several primary cases were present. On the basis of this investigation, it is unclear whether long distance airborne transmission had occurred in the store.

Singing events

In addition to transmission events associated with specific settings, four epidemiological investigations reporting on outbreaks linked to singing events were identified.

Katelaris et al[46] (rated as high methodological quality) reported on an outbreak in Sydney, Australia, linked to a series of four church services held between 15 and 17 July 2020. The probable primary case, a choir member, had sung at each of these one hour services, and 12 secondary cases were identified (2.4% secondary attack rate across the four services), who had sat in the same section of the church, between 1 m and 15 m from the primary case. Viral genomic sequencing of the primary case and 10 secondary cases showed a single genomic cluster, suggesting that transmission had occurred during the church services.

The second epidemiological investigation[47] (rated as medium methodological quality; preprint) reported on five singing events held between September and October 2020 in the Netherlands. At the time, national recommendations were in place to reduce covid-19 transmission, and although singing in groups was allowed, physical distancing (>1.5 m) and ventilation were recommended. Each singing event had between nine and 21 attendees, and attack rates of between 53% and 74% were observed. Fomite transmission was deemed unlikely in all but one event, but close contact transmission was considered possible for some of the secondary cases in three of the five events. However, owing to the high secondary attack rates, it is possible that at least some of the secondary cases had been infected via long distance airborne transmission and, even though ventilation through open doors or windows was reported for all events, air exchange rates were likely to have been low in at least three of the five events.

The two other outbreaks occurred in March 2020—that is, during the early stage of the pandemic when no mitigation measures were in place. One of them (70% attack rate, including probable cases) happened in France during a two hour choral rehearsal in a narrow, indoor, non-ventilated space[48] (study rated as low methodological quality). The second outbreak (87% secondary attack rate, including probable cases) after a 2.5 hour choral rehearsal on 10 March 2020 in Washington (USA) was initially reported by Hamner et al[1] (rated as low methodological quality) and further discussed by Miller et al.[52] For both outbreaks, close contact and fomite transmission were only assessed through interviews and cannot be fully ruled out. The high secondary attack rate, however, suggests that long distance airborne transmission might have occurred for at least some of the cases.

The results from the four studies suggest that long distance airborne transmission was likely to have occurred for at least some of the transmission events, and that singing may have increased the amount of aerosol generated by the primary cases, which is consistent with modelling results reported by some of these authors.[52 53]

Summary and critical analysis of results

Seven of the outbreaks identified[1 34 36-38 45 48] occurred in the early stage of the pandemic (January-March 2020) when knowledge of covid-19 was limited, especially the incubation period and the extent of asymptomatic or presymptomatic transmission. As a result, most of these studies only conducted symptomatic testing and considered potential secondary cases to be participants with symptom onset soon after the potential exposure event, including the next day. In addition, for the studies conducted in January 2020 in China and in March 2020 in Europe or the US, it is possible that community transmission was higher than perceived at the time.

Therefore, in an outbreak such as the one reported by Luo et al[37] where no genomic sequencing was conducted and three of the nine secondary cases developed symptoms or tested positive for SARS-CoV-2 one or two days after exposure, it is plausible that more than one primary case was present and that transmission occurred through means other than long distance airborne transmission. In two of the studies reporting on singing events,[1 48] genomic sequencing and asymptomatic testing were not carried out and some of the secondary cases developed symptoms in the days after exposure but because of the high attack rates reported for these outbreaks, it is possible that long distance airborne transmission had happened for at least some of the transmission events. Long distance airborne transmission was also considered possible for two other early studies as a result of detailed epidemiological investigations.[34 36] However, the plausibility of long distance airborne transmission for the outbreak in the department store was unclear as other transmission routes could not be ruled out.[45]

Among the other studies, four[33 35 41 46] provided convincing evidence for long distance airborne transmission as a result of detailed epidemiological investigations combined with genomic sequencing. Eichler et al[32] also conducted genomic sequencing but their reporting of the epidemiological investigation was not sufficiently exhaustive to exclude other transmission routes (close contact or fomite) for the only secondary cases who could have been infected by long distance airborne transmission. The investigations by Shah et al,[47] Hwang et al,[39] Groves et al,[42] Han et al,[40] and Vernez et al[43] suggested that long distance airborne transmission was possible for at least some of the transmission events (close contact or fomite could not be fully ruled out), but stronger conclusions could not be drawn owing to methodological limitations (including the absence of genomic sequencing and risk of selection bias). Finally, the likelihood of long distance airborne transmission was unclear in the outbreak in the office reported by Sarti et al[44] as, despite the covid-19 measures in place, close contact and fomite transmission could not be completely ruled out on the basis of the investigation.

Eleven of the 18 studies reported on the use of face coverings.[33 35-44] Overall, the information provided was limited, and two of these studies only mentioned that face coverings were compulsory in the settings of interest (quarantine hotel[33] and food processing factory[41]) without reporting on adherence or behaviour (eg, whether workers wore face coverings correctly for the duration of their shift). Based on this limited information, we found no evidence of long distance airborne transmission where participants were known to have worn face coverings for the duration of exposure.

Only one of the outbreaks[33] identified occurred at a time when covid-19 vaccines were available, although in this outbreak the primary and secondary cases were not vaccinated.

Grading of the evidence

Table 3 provides the grading of the evidence for each of the primary outcomes: SARS-CoV-2 infection via

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airborne transmission at a distance >2 m, insufficient air replacement (modifying factor), directional air flow (modifying factor), and increased aerosol emission when singing, speaking loudly, or doing intense physical work (modifying factor). Assessment of modifying factors was considered not applicable for the two outbreaks where the likelihood of long distance airborne transmission had been judged as unclear.

For all four outcomes, the evidence was judged as having methodological limitations owing to study design and to be at serious risk of imprecision owing to small numbers of participants as well as some risk of bias in exposure or outcome assessment, or both. However, the risks of inconsistency and indirectness were judged as not serious as the results were consistent across studies conducted in a range of settings and with different populations and provide evidence of direct relevance to the public health question of interest. The risk of publication bias was judged to be serious for the outcome of SARS-CoV-2 infection through airborne transmission at a distance >2 m and for the modifying factor of activities associated with increased emission of aerosols, but not serious for the modifying factors of insufficient air replacement and directional air flow. As a result, the certainty of evidence was judged as very low for all outcomes.

Because of high heterogeneity between studies, the additional outcomes of time spent in the transmission setting and distance over which airborne transmission was thought to have occurred could not be summarised or graded using the GRADE framework. Exposure timings ranged from five minutes to three hours, and distances were up to 15 m.

Discussion

Evidence from the outbreak investigations discussed in this review suggests that airborne transmission of SARS-CoV-2 from an infectious individual to others located >2 m away can occur in different indoor non-healthcare settings. The results of this review show that when long distance transmission occurred, one or more factors were thought to have contributed. Modifying factors such as insufficient air replacement and singing are likely to result in an increased concentration of infectious respiratory particles within the indoor space, whereas factors such as directional air flow are likely to allow viable virus to travel further in a certain direction, which could potentially infect someone downstream of a primary case. The results of this review therefore confirm the importance of the role of ventilation to mitigate the risk of long distance aerosol transmission.[54-57]

A total of eight events (from four studies) in which singing may have contributed to long distance airborne transmission were identified.[1 46-48] These results are in line with experimental and modelling studies that have reported on singing and aerosol generation, suggesting that more virus-containing respiratory particles tend to be emitted when singing compared with speaking or breathing.[53 58] More generally, the quantity of respiratory particles emitted increases with loudness of vocalisation,[59 60] which was thought to have contributed to long distance aerosol transmission in a fitness facility.[42]

In 13 out of 18 studies identified,[33-37 41-48] suspected primary cases were asymptomatic, presymptomatic, or near the time of symptom onset when transmission occurred. This finding is consistent with wider evidence that people with asymptomatic or presymptomatic SARS-CoV-2 infection can contribute to the community spread of covid-19,[61-63] including from long distance airborne transmission.

Although the evidence on face coverings was limited, no outbreaks in which participants had been wearing face coverings for the duration of the exposure were identified. Evidence suggests that face coverings can reduce the number of respiratory particles emitted from the nose and mouth.[64] However, it is not possible to deduce from the evidence assessed in this review if wearing a face covering can prevent or reduce the risk of long distance transmission of SARS-CoV-2.

Most of the outbreaks we identified occurred at a time when population immunity was limited, either naturally acquired or vaccine mediated. This limits the applicability of our findings to the current context, although there is evidence that transmission of SARS-CoV-2 after vaccination does occur.[65] While the lack of evidence identified in vaccinated populations may to some extent reflect the successes of vaccine rollout, there may also be a time lag in publication of outbreak reports since vaccine programmes were initiated. There may also be less interest in publishing reports on SARS-CoV-2 associated outbreaks over time.

The evidence from our rapid systematic review was deemed to be of very low certainty based on 18 studies. The relatively small number of studies identified could suggest that outbreaks related to long distance airborne transmission are rare, although also likely to result from difficulties in identifying such events or to under-reporting—for example, in countries without sufficient contact tracing. It can also be partly explained by the level of detail needed to assess transmission routes. Indeed, even outbreak investigations that follow reporting guidelines such as the Outbreak Reports and Intervention studies Of Nosocomial infection (ORION) statement published by the Canada Communicable Disease Report[66] are not necessarily thorough enough to be able to fully rule out other transmission routes. As a result, several outbreaks in which long distance airborne transmission may have happened were excluded on full text, including a few reports on clusters in aeroplanes that did not properly consider transmission routes during boarding and disembarking.[67-70] Finally, the wider challenges of the pandemic should be acknowledged, including the limited resources in public health teams to conduct detailed epidemiological investigations.

The outcomes were rated as being of very low certainty using the GRADE framework, although this reflects the principles of GRADE rather than a lack of quality of the included studies because in traditional evidence hierarchies, outbreak investigations are

Table 3 | Summary of findings using Grading of Recommendations, Assessment, Development, and Evaluation approach

Outcome	Effect	No of studies	Certainty in the evidence
SARS-CoV-2 infection through airborne transmission over a distance >2 m	Sixteen studies suggested that long distance airborne transmission was the main transmission route for at least some of the transmission events in the reported outbreaks. Unclear in two studies	18	Very low owing to methodological limitations of the studies and serious risk of imprecision and publication bias
Modifying factor: insufficient air replacement	Fourteen studies suggested that insufficient air replacement had increased the likelihood of long distance airborne transmission. Unclear in two studies	16	Very low owing to methodological limitations of the studies and serious risk of imprecision
Modifying factor: directional air flow	Eleven studies suggested that directional air flow might have increased the likelihood of long distance airborne transmission. Unclear in one study	12	Very low owing to methodological limitations of the studies and serious risk of imprecision
Modifying factor: activities associated with increased emission of aerosols	Five studies (reporting on nine events) suggested that singing and speaking loudly might have increased the likelihood of long distance airborne transmission. Unclear in one study (intense physical work)	6	Very low owing to methodological limitations of the studies and serious risk of imprecision and publication bias

classed as a low level of evidence. However, some of the included studies were well conducted investigations of covid-19 outbreaks and their contribution to this particular research question should not be underestimated—they provide critical insight where other types of study are just not feasible.[71] The GRADE framework was developed to inform clinical practice where randomised controlled trials are feasible, and linear causal pathways are more often the norm. Public health research does not always fit easily within this framework and the question of what level of public health evidence is sufficient to support decision making for a novel infection warrants further consideration.

Comparison with other studies

These findings are an important addition to the wider body of evidence that supports the biological plausibility of airborne transmission as a potentially important route of transmission in certain scenarios. The wider evidence includes experimental evidence from animal studies[72] as well as experimental studies that have shown that SARS-CoV-2 can remain viable in artificially generated aerosols for up to 16 hours, and that the stability and viability depends on environmental factors such as temperature, humidity, and exposure to sunlight.[22] Similarly, biological monitoring studies have shown that SARS-CoV-2 RNA can be detected in exhaled breath and environmental air samples, but the evidence on viable virus remains limited to a few studies that mostly detected infectious virus in air samples collected at <2 m from the infectious individual.[22-24] These experimental and biological studies provide evidence that SARS-CoV-2 can be viable in aerosols and therefore support the epidemiological evidence from this rapid review, and from others[22 23] that suggest that airborne transmission can happen in some settings.

Strengths and limitations of this review

This rapid systematic review critically assessed the likelihood of long distance airborne transmission of SARS-CoV-2 using only direct real world evidence from observational studies from indoor non-healthcare settings. The application of inclusion criteria that focused the critical appraisal on those studies, which involved comprehensive investigations, is a key strength of our approach: some of these studies not only included epidemiological data, but also genomic analysis, video surveillance, analysis of seating arrangements, and environmental hypothesis testing.

The main limitation of selecting studies of only real world human-to-human transmission events is that scenarios where transmission has not occurred were not included, and likewise where transmission events have not been detected by contact tracing systems, which could be seen as a form of publication bias. All the evidence is from retrospective epidemiological investigations of outbreaks and therefore this review cannot make inferences on the extent to which long distance airborne transmission occurs or the contribution it may have on community rates of transmission: these remain critical questions for policy and practice. In addition, most of the outbreaks occurred before vaccine rollouts and it is unclear how these results apply to populations with a high level of immunity to infection. Finally, and as with all reviews assessing evidence related to covid-19, this rapid review is limited by the fact that the evidence assessed is from an emerging specialty.

Future work and policy implications

Well conducted outbreak investigations continue to be needed to assess the potential for long distance airborne transmission in vaccinated populations, and with more transmissible SARS-CoV-2 variants such as omicron. To assess transmission routes, such outbreak investigations should deploy robust and mixed methods, ranging from genomic analysis to environmental assessment, and they should be conducted as early as possible to reduce recall bias.

The results from this rapid systematic review highlight the need to ensure measures to mitigate SARS-CoV-2 long distance transmission in indoor settings, especially in poorly ventilated spaces. Identification of poorly ventilated public spaces should be undertaken and improvements made. Other factors such as directional air flow or singing that could increase the risk for long distance airborne transmission should also be considered in risk mitigation.

A need also exists to develop a new framework, or to adapt the existing GRADE framework, to support a pragmatic and consistent approach to the collation, interpretation, and synthesis of epidemiological investigations, especially when other types of studies are not feasible. The question of what level of public health evidence is sufficient to support decision making for a novel infection warrants further consideration.

Conclusion

This rapid review found evidence suggesting that long distance (>2 m) airborne transmission of SARS-CoV-2 might happen in indoor non-healthcare settings, and that it can occur from people who are asymptomatic or presymptomatic. All transmission events identified occurred alongside factors believed to have contributed to this type of transmission, including lack of air replacement (absence or little ventilation with fresh air), directional air flow (mainly through air circulation systems), and activities such as singing that increased aerosol emission. In the review, we found no evidence of long distance airborne transmission occurring without one or more of these factors present.

Based on the results from this review, indoor non-healthcare settings that might be at risk of long distance airborne transmission include hospitality settings such as restaurants, public transport, and workplaces with inadequate ventilation, as well as settings where activities resulting in increased aerosol emission, such as singing or speaking loudly are carried out.

These results highlight the importance of assessing ventilation, especially in indoor spaces where people meet others from outside their household. Particular attention should be given to ventilation in settings with activities that might increase the number of respiratory particles, for example, singing. Where ventilation is assessed to be inadequate, improvements should be made.

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Data sharing: Data are from published research and therefore are in the public domain. Extracted data are available in supplementary material 2.

The manuscript's guarantor (RC) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Dissemination to participants and related patient and public communities: This paper will be shared widely within the UK Health Security Agency and used to inform relevant guidance. It will also be shared with relevant stakeholders, policy makers, and other public health agencies within the United Kingdom and internationally. Further dissemination will include our website https://ukhsalibrary.koha-ptfs.co.uk/covid19rapidreviews/ and through colleagues working in covid-19 evidence synthesis.

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Supplementary information: supplementary material 1: search strategy, quality criteria checklist, and list of excluded studies

Supplementary information: supplementary material 2: data extraction of included studies

Indoor Air and COVID-19 Key References and Publications

This page lists some of the technical publications addressing the science related to aerosol transmission of SARS-CoV-2 and related topics. Key publications about actions that can reduce the likelihood of this type of transmission are also listed.
The following links exit the site

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* workshop reports, agency reports, and other sources that do not undergo a standard peer-review

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Ecosystems supported by Lake Balkhash in Kazakhstan are in jeopardy as desertification increases.

Edited by **Jennifer Sills**

Save Kazakhstan's shrinking Lake Balkhash

Kazakhstan is home to Lake Balkhash, one of the largest inland drainless lakes in the world. Estimated to be more than 35,000 years old (*1*), this lake has cultural, historical, and ecological value. However, since 1970, a substantial decrease in the Ili river runoff has led to a drawdown of water reaching the lake [(*2*), p. 18], leading to a decrease in water depth. Out of the original 16 lake systems around Lake Balkhash, only 5 remain (*1*). Preserving this lake ecosystem is crucial to halting the desertification process, which has already claimed a third of the lake and will have devastating effects on the diverse flora and fauna that depend on it.

Lake Balkhash's varying degrees of water mineralization support a wide variety of species; the western basin is freshwater, whereas the eastern basin is salty (*3*). The lake serves as a habitat for 20 species of fish, 6 of which live only in this lake (*3*), and 60 species of plants that don't grow anywhere else [(*4*), pp. 304–310]. More than 120 bird species rely on the lake [(*2*), pp. 24–26], 12 of which are listed in Kazakhstan's Red Book of endangered species [(*4*), p. 305]. Because the lake is located in a desert area, without runoff and with a dry continental climate and very little precipitation, these species will have nowhere else to go if their water source disappears.

To protect Lake Balkhash, local legislation that regulates industrial exploitation of the lake water area should be updated and enforced. The media should actively promote environmental awareness among the population of Kazakhstan. Designating Lake Balkhash a national treasure would increase the social significance of the lake in Kazakhstan as well as abroad. Kazakhstan should monitor the lake and provide public access to up-to-date data on its parameters (especially the current volume of water). The country should also clearly define areas of responsibility among the states that are responsible for water resources management. Given rising water security risks in Kazakhstan, Lake Balkhash needs an international collaboration to provide urgent and effective protection. It is crucial that local and national policy-makers, law enforcement authorities, scientists, the public sector, socially responsible businesses, and the world community work together to protect this ancient lake.

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Airborne transmission of SARS-CoV-2

There is overwhelming evidence that inhalation of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) represents a major transmission route for coronavirus disease 2019 (COVID-19). There is an urgent need to harmonize discussions about modes of virus transmission across disciplines to ensure the most effective control strategies and provide clear and consistent guidance to the public. To do so, we must clarify the terminology to distinguish between aerosols and droplets using a size threshold of 100 µm, not the historical 5 µm (*1*). This size more effectively separates their aerodynamic behavior, ability to be inhaled, and efficacy of interventions.

Viruses in droplets (larger than 100 µm) typically fall to the ground in seconds within 2 m of the source and can be sprayed like tiny cannonballs onto nearby individuals. Because of their limited travel range, physical distancing reduces exposure to these droplets. Viruses in aerosols (smaller than 100 µm) can remain suspended in the air for many seconds to hours, like smoke, and be inhaled. They are highly concentrated near an infected person, so they can infect people most easily in close proximity. But aerosols containing infectious virus (*2*) can also travel more than 2 m and accumulate in poorly ventilated indoor air, leading to superspreading events (*3*).

Individuals with COVID-19, many of

whom have no symptoms, release thousands of virus-laden aerosols and far fewer droplets when breathing and talking (*4–6*). Thus, one is far more likely to inhale aerosols than be sprayed by a droplet (*7*), and so the balance of attention must be shifted to protecting against airborne transmission. In addition to existing mandates of mask-wearing, social distancing, and hygiene efforts, we urge public health officials to add clear guidance about the importance of moving activities outdoors, improving indoor air using ventilation and filtration, and improving protection for high-risk workers (*8*).

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COMPETING INTERESTS

K.A.P. is Director of the National Science Foundation Center for Aerosol Impacts on Chemistry of the Environment. L.C.M. is a member of the Science Advisory Board and holds stock options for Phylagen and is a paid reviewer for the Alfred P. Sloan Foundation. R.T.S. is a member of the Gilead Sciences Scientific Advisory Board and chairs Data Safety and Monitoring Boards for VIR, Gilead, and Merck. Honoraria for these activities are paid to the Regents of the University of California. R.T.S. has served as a scientific consultant to Pfizer and to AbbVie. M.A.M. is the unpaid Chair of the National Academy of Medicine Committee on Personal Protective Equipment for Workplace Safety and Health.

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Deliberate poisoning of Africa's vultures

Between September 2019 and March 2020, more than 2000 Critically Endangered (*1*) hooded vultures (*Necrosyrtes monachus*) were killed across eastern Guinea-Bissau. Investigations revealed that the vultures were intentionally poisoned to collect their heads for belief-based use. Locals sighted bait placed where vultures died and reported a demand for vulture heads in Senegal (*2*, *3*). Toxicological analysis of carcasses confirmed poisoning with methiocarb (*3*), a carbamate pesticide banned in Europe (*4*) but still used in Guinea-Bissau. If unchecked, these poisonings are likely to continue, leading to further declines in the population of this imperiled species.

Old World vultures are among the most threatened groups of birds worldwide (*5*). In Africa, the illicit trade in vulture parts accounts for 29% of reported vulture deaths (*6*). In West Africa, up to 61 and 70% (inside and outside parks, respectively) of vultures disappeared in just 30 years (*7*). Hundreds of hooded vultures are traded yearly for belief-based use, and their heads are considered good luck charms (*8*). Prices are rising as they become more rare (*8*, *9*). Guinea-Bissau is home to about 22% of the world's 197,000 hooded vultures (*10*, *11*).

Hooded vultures (*Necrosyrtes monachus*) in Guinea-Bissau could be driven to extinction.

This blow to vulture conservation requires urgent action. Local stakeholders need to be made aware of the loss of critical ecosystem functions, such as waste removal and the likely control of disease (*5*, *12*). African governments should raise awareness about existing anti-poisoning legislation among residents, authorities, and police and invest the human and financial resources required to effectively enforce these laws. In addition, the governments should curb cross-border and local trade. International partners must help West African countries develop and implement national action plans to conserve vultures and avoid their looming extinction.

Mohamed Henriques[1]*, Ralph Buij[2,3], Hamilton Monteiro[4,5], Joãozinho Sá[4,6], Francisco Wambar[4], José Pedro Tavares[7], Andre Botha[8], Geoffroy Citegetse[9], Miguel Lecoq[10], Paulo Catry[11], Darcy Ogada[2,12]

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COMPETING INTERESTS

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Airborne transmission of SARS-CoV-2

Jennifer Sills, Kimberly A. Prather, Linsey C. Marr, Robert T. Schooley, Melissa A. McDiarmid, Mary E. Wilson, and Donald K. Milton

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Indirect Virus Transmission in Cluster of COVID-19 Cases, Wenzhou, China, 2020

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To determine possible modes of virus transmission, we investigated a cluster of coronavirus disease cases associated with a shopping mall in Wenzhou, China. Data indicated that indirect transmission of the causative virus occurred, perhaps resulting from virus contamination of common objects, virus aerosolization in a confined space, or spread from asymptomatic infected persons.

[1]These authors contributed equally to this article.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the causative agent of coronavirus disease (COVID-19), is presumed to spread primarily via respiratory droplets and close contact. However, these transmission modes do not explain all cases. To determine how the virus may have spread among a cluster of COVID-19 cases associated with a shopping mall in Wenzhou (a city with 8 million residents), China, we monitored and traced close contacts and hypothesized possible transmission modes. We analyzed clinical and laboratory data for cases by using real-time reverse transcription PCR (*1*). The study was approved with written consent from the Ethics Committee of Wenzhou Central Hospital and written informed consent from all case-patients.

On January 20, 2020, a 23-year-old man (patient E) sought care at a hospital after 11 days of fever and headache. On January 21, COVID-19 was confirmed for patient E and his co-worker, patient G. The Wenzhou Center for Disease Control and Prevention traced and tested their contacts, and by January 28, COVID-19 was confirmed for 7 persons (patients A–G) from the same office (on floor 7).

Patient A, a 30-year-old woman, the only case-patient who indicated that she had been in Wuhan, China, returned from Wuhan on December 18, 2019. On January 15–16, 2020, she had a fever, but symptoms resolved without treatment. Despite symptom resolution, on January 30 she was confirmed to have SARS-CoV-2 infection. If patient A is the index patient, infected in Wuhan, her incubation period would have been 28 days, which would be extremely long, according to updated information (W.J. Guan et al., unpub. data, https://www.medrxiv.org/content/10.1101/2020.02.06.20020974v1). Asymptomatic carrier transmission has been reported for SARS-CoV-2 (*2*); hence, patient A could have been screened as a close contact during her incubation period and then hospitalized on the basis of a positive test (PCR) result only. However, her clinical symptoms did not appear until after hospitalization. Because persons with asymptomatic COVID-19 can spread the virus, patient A also could have been an asymptomatic carrier with a persistent infection (*3*).

On January 22, the mall was shut down. During January 19–February 9, COVID-19 was diagnosed for 7 mall staff from floors B1–3 and for 10 mall customers. Close contacts associated with the mall were traced, and COVID-19 was confirmed for 11 persons. Sixteen patients had had direct contact with other patients or had gone shopping in the mall. The average incubation period was 7.3 (range 1–17) days.

The mall has 8 floors above ground and several basement levels; floors B1 to 6 are commercial

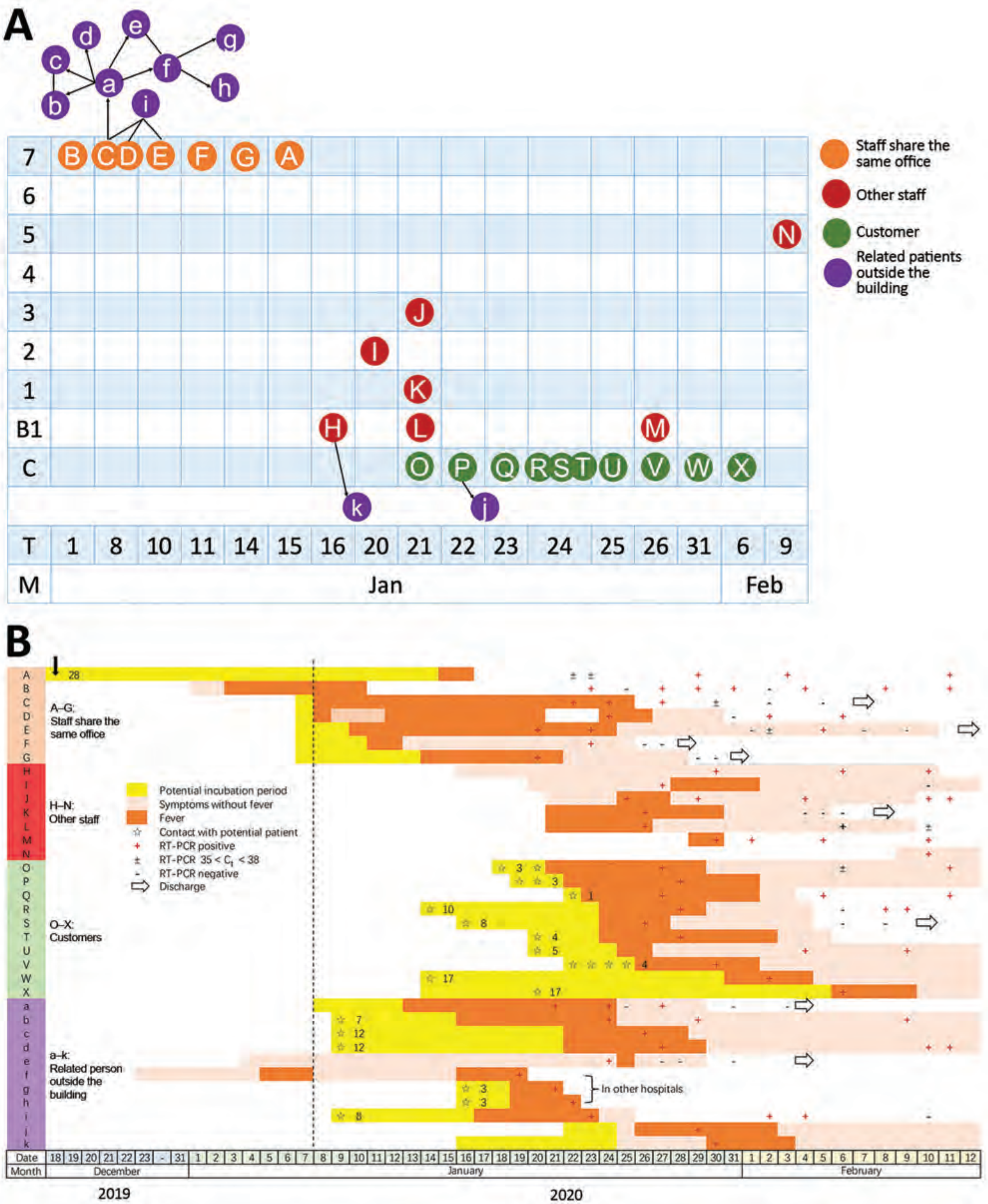

Figure. Cluster of COVID-19 cases associated with a shopping mall in Wenzhou, China. A) Distribution of COVID-19 case-patients by mall floor, time, and internal relationship. B) Dates of symptom onset, confirmed test results, and hospitalization information. Numbers within yellow bars indicate length of incubation period. Black vertical arrow indicates date when patient A returned from Wuhan, China. B1–7, mall floors; C, customer; COVID-19 coronavirus disease; C_t, cycle threshold; T, date of symptom onset; M, month; RT-PCR, reverse transcription PCR.

shopping space, and floor 7 contains shopping and office space. We created an illustration showing the floors where the eventual COVID-19 case-patients worked or shopped, along with dates of symptom onset, potential incubation periods, symptom durations, confirmed times of positive diagnosis, and times of discharge (Figure 1, panel A).

Except for those who had been on floor 7, all other case-patients denied direct close contact with other case-patients. The possibility of customers being infected from other sources cannot be excluded. However, most customers reported early symptom onset in a concentrated time frame (Figure 1, panel B). We found no convincing evidence of definitive transmission pathways in this building. Patients A–G (Figure 1, panel A) worked in the same room on floor 7. Other case-patients who had been on other floors denied any direct contact with confirmed patients from floor 7, but they shared common building facilities (e.g., restrooms, elevators). Also, staff from floor 7 visited shops on other floors daily.

Until now, no evidence has shown that SARS-CoV-2 can survive outside the body for long. However, Middle East respiratory syndrome coronavirus demonstrates high robustness and a strong capability to survive outside the body and can remain infectious for up to 60 minutes after aerosolization (*4*). Hence, the rapid spread of SARS-CoV-2 in our study could have resulted from spread via fomites (e.g., elevator buttons or restroom taps) or virus aerosolization in a confined public space (e.g., restrooms or elevators). All case-patients other than those on floor 7 were female, including a restroom cleaner, so common restroom use could have been the infection source. For case-patients who were customers in the shopping mall but did not report using the restroom, the source of infection could have been the elevators. The Guangzhou Center for Disease Control and Prevention detected the nucleic acid of SARS-CoV-2 on a doorknob at a patient's house (*5*), but Wenzhou Center for Disease Control and Prevention test results for an environmental sample from the surface of a mall elevator wall and button were negative.

We cannot exclude the possibility of unknown infected persons (e.g., asymptomatic carriers) spreading the virus. However, according to screening protocols implemented by the Wenzhou Center for Disease Control and Prevention, we traced all close contacts and included all patients with positive PCR results, including the asymptomatic carrier (patient A), in this study. Our findings appear to indicate that low intensity transmission occurred without prolonged close contact in this mall; that is, the virus spread by indirect transmission.

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Dr. Cai is deputy chief physician and deputy director of the comprehensive internal medicine department. Her major research interest focuses on infectious diseases and gastrointestinal diseases.

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U.S. Department of Homeland Security

Estimated Surface Decay of SARS-CoV-2 (virus that causes COVID-19)

on surfaces under a range of temperatures, relative humidity, and UV Index

Use the sliders to select the UV index (select either 0 or a value between 1.5 and 12), temperature and relative humidity of interest. Information on how long SARS-CoV-2 would be expected to remain stable on surfaces will be displayed in the table below. Users can find the environmental conditions for a specific location by accessing general weather resources online.

SARS-CoV-2 Surface Decay Calculator

UV Index: 0 10

UV Index: 2

Temperature: 74 95

Temperature: 68 °F / 23.3°C

Relative Humidity: 20 60

Relative Humidity: 20 %

* Note: Temperature (68°F) and relative humidity (20%) input cannot be changed for UV values greater than 0.

COVID Stability:

% Virus Decay	Hours	Days
50% (half-life):	5.32	0.22
99.99%:	70.71	2.95
99.9999%:	106.07	4.42
99.999999%:	141.42	5.89

Relative humidity, temperature, and sunlight (UV) can be used to provide an estimated half-life for SARS-CoV-2 with this model with some degree of certainty. The predictive power is limited to temperature between 74-95°F and relative humidity between 20-60% for a UV index of 0, and a temperature of 68°F and 20% relative humidity for a UV index between 1.5 and 12. The formula below was developed in °C, but has been modified in the web calculator to use °F.

Examples of Applying Surface Stability Model to Estimate SARS-CoV-2 Stability on Indoor Surfaces

Equation:

$t_{1/2}(T,RH) = 32.43 - 0.62T - 0.15RH$

Examples:

$t_{1/2}(28,30) = 32.43 - 0.62(28) - 0.15(30)$

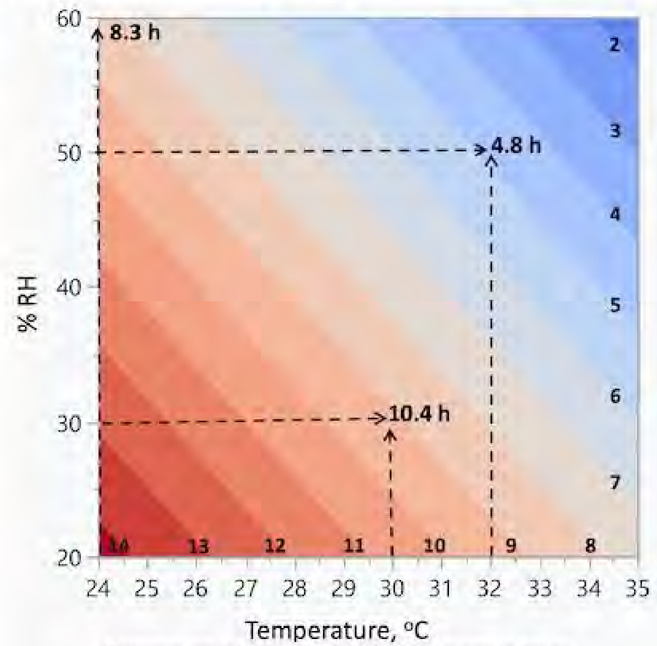
$t_{1/2}(28,30) = 10.4$ h

$t_{1/2}(24,60) = 32.43 - 0.62(24) - 0.15(60)$

$t_{1/2}(24,60) = 8.3$ h

$t_{1/2}(32,50) = 32.43 - 0.62(32) - 0.15(50)$

$t_{1/2}(32,50) = 4.8$ h



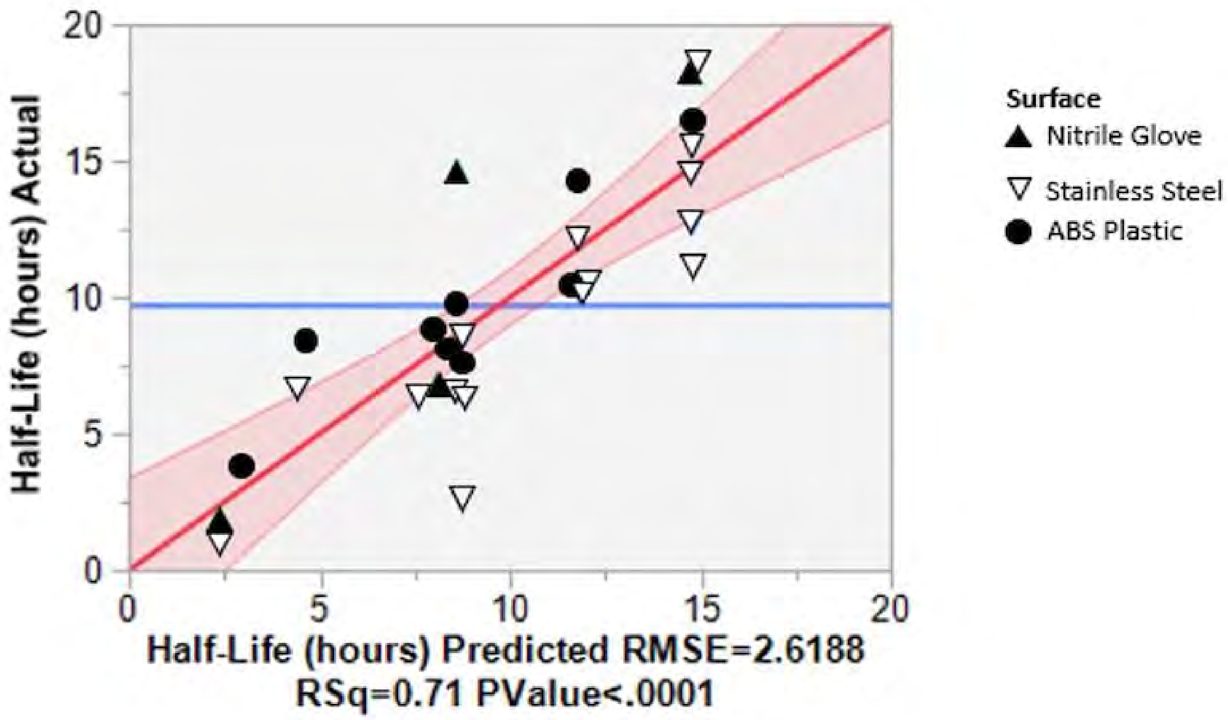
Contours are labeled with half-life estimates in hours

Close all Open all

Background

- Preventing person-to-person spread of SARS-CoV-2 is the only means to reduce the impact of COVID-19 in the absence of an effective therapeutic.
- Transmission occurs primarily through respiratory droplets produced by talking, coughing and sneezing.
- Contact with contaminated surfaces and objects may also contribute to spread.
- SARS-CoV-2 will survive in saliva and respiratory fluids on surfaces for extended periods of time under certain conditions.
- DHS S&T has studied the stability of SARS-CoV-2 in simulated saliva, using droplets of varying size deposited on a non-porous surface under a range of temperature and RH conditions.
- Viral survival on surfaces is driven by temperature, relative humidity (RH), sunlight (UV), and matrix (e.g., bodily fluids).
- These data have been used to develop a predictive model to estimate virus decay under a limited range of environmental conditions.
- Testing performed on non-porous surfaces, specifically stainless steel, ABS plastic, and nitrile rubber.
- There was no significant difference found in the decay of the virus found between stainless steel ABS plastic, and nitrile rubber.
- For additional information and details on methodology for the research on the impact of temperature and relative humidity on SARS-CoV-2 decay on surfaces, please see the article titled, "Increasing Temperature and Relative Humidity Accelerates Inactivation of SARS-CoV-2 on Surfaces" published in the American Society for Microbiology journal (https://www.dhs.gov/now-leaving?external_url=https%3A%2F%2Fmsphere.asm.org%2Fcontent%2F5%2F4%2Fe00441-20%23%3A~%3Atext%3DThe%20results%20show%20that%20SARS%2Cnot%20significantly%20impact%20decay%20rate.&back_url=https%3A%2F%2Fwww.dhs.gov%2Fs and-technology%2Fsars-calculator) .
- Research to determine impact of UV exposure on SARS-CoV-2 decay on surfaces was conducted at one temperature/relative humidity parameter. For additional information and details on methodology, please see the article titled, "Simulated Sunlight Rapidly Inactivates SARS-CoV-2 on Surfaces" published in the Journal of Infectious Diseases (https://www.dhs.gov/now-leaving?external_url=https%3A%2F%2Facademic.oup.com%2Fjid%2Farticle%2F222%2F2%2F214%2F5841129&back_url=https%3A%2F%2Fwww.dhs.gov%2Fscience-and-technology%2Fsars-calculator) .

Model Caveats



- Infectious dose is unknown (how much makes a person sick)
- Virus shedding is unknown (how much a sick person puts into the environment)
- Contact Hazard (how much virus comes off from touching surfaces)

This tool is valid for the following ranges of conditions:

- Without exposure to sunlight (UV 0): temperature (74°F to 95°F) and relative humidity from 20-60%.
- With exposure to sunlight (UV 1.5-12): temperature 68°F and relative humidity 20%.

S&T is partnering with CWMD to develop a tool that is easily accessible could be used by Occupational Safety and Health (OSH) professionals to support risk assessment, cleaning and disinfection in accordance with guidance provided by CDC and EPA including Guidance for Cleaning and Disinfecting: Public Spaces, Workplaces, Businesses, Schools, and Homes (https://www.cdc.gov/coronavirus/2019-ncov/community/pdf/reopening_america_guidance.pdf) . *(PDF, 9 pgs., 235 KB)*

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REVIEW

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Stability and transmissibility of SARS-CoV-2 in the environment

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Abstract

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus causing the ongoing global coronavirus disease 2019 (COVID-19) pandemic, is believed to be transmitted primarily through respiratory droplets and aerosols. However, reports are increasing regarding the contamination of environmental surfaces, shared objects, and cold-chain foods with SARS-CoV-2 RNA and the possibility of environmental fomite transmission of the virus raises much concern and debate. This study summarizes the current knowledge regarding potential mechanisms of environmental transmission of SARS-CoV-2, including the prevalence of surface contamination in various settings, the viability and stability of the virus on surfaces or fomites, as well as environmental factors affecting virus viability and survival such as temperature and relative humidity. Instances of fomite transmission, including cold-chain food transmission, and the importance of fomite transmission in epidemics, are discussed. The knowledge gaps regarding fomite transmission of SARS-CoV-2 are also briefly analyzed.

KEYWORDS

cold-chain transmission, environmental stability, fomite transmission, SARS-CoV-2, surface contamination, survivability

1 | INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2, family *Coronaviridae*, genus *Betacoronavirus*, species *severe acute respiratory syndrome-related coronavirus*) is the causative agent of coronavirus disease 2019 (COVID-19). SARS-CoV-2 is highly contagious as evidenced by its spread to nearly all countries worldwide within a very short time.[1] However, the viral determinants for the high transmissibility of SARS-CoV-2 are still unclear, and routes by which the virus can effectively spread through the population remain debating.

Respiratory viruses are transmitted between individuals when virus is released from the respiratory tract of infected individuals and is transferred to the environment, leading to infection of the respiratory tract of exposed and susceptible people.[2] It is recognized that respiratory viruses spread via four transmission routes: droplet, aerosol, direct contact, and indirect transmission.[2,3] SARS-CoV-2 was initially recognized to transmit mainly via respiratory droplets from an infected host. Aerosol transmission of SARS-CoV-2 was subsequently proven to be the predominant transmission mode.[4–6] Transmission through droplets and aerosols are both classified as airborne transmission.[3] Droplets and aerosols are conventionally distinguished by size (5 μm), delineating distinct characteristics such as dispersion efficiency, residence time in the air, and deposition patterns along the human respiratory tract.[5] Direct contact transmission refers to direct virus transfer from an infected to a susceptible individual (e.g., via contaminated hands), and indirect transmission occurs via contaminated environmental surfaces or fomites that serve as vectors for virus transmission.[2,3] Direct transmission of SARS-CoV-2 has been confirmed after tracing case clusters. However, the role of indirect SARS-CoV-2 transmission through intermediate surfaces or fomites remains under discussion, with considerable controversy.[7,8]

For contaminated surfaces or fomites to play a role in transmission, a respiratory pathogen must be shed into the environment, possess the capacity to survive on surfaces, be transferred to hands or other objects at a concentration above the minimum infective dose, and be able to initiate infection through contact with the eyes, nose, mouth or by re-inhalation into the respiratory tract.[2,9] In this study, we review current new evidence on these topics, including the shedding of SARS-CoV-2, contamination of environmental surfaces in various settings, stability and viability of SARS-CoV-2 on environmental surfaces and objects including cold foods, and current evidence for and against the importance of fomite transmission. We aim to summarize the findings regarding the transmissibility of environmental SARS-CoV-2 and relative importance of indirect environmental transmission in COVID-19 spread. We also identify ongoing research gaps and opportunities. The information provided herein will help in establishing practical and effective protocols to interrupt indirect environmental transmission of SARS-CoV-2 and mitigate its associated risks.

2 | SHEDDING AND DISSEMINATION OF SARS-CoV-2 FROM INFECTED INDIVIDUALS

Viral shedding is the first step of virus transmission from infected to susceptible individuals. Respiratory virus shedding occurs after airway epithelial cells excrete virions to extracellular fluid in the respiratory tract, especially the upper respiratory tract, through sneezing, breathing, talking, singing, coughing, and other aerosol-generating activities.[2]

Studies show that shedding of SARS-CoV-2 can begin before symptom onset,[10–13] peak in the first week of illness.[12,13] In contrast to SARS and MERS but similar to influenza, COVID-19 exhibits high viral shedding at an early stage of infection, when virus carriers display no or mild symptoms.[14,15] Most studies attempting virus isolation from respiratory samples have also successfully cultured viable virus within the first week of illness whereas live virus is rarely isolated from patients beyond 9 days of symptomatic illness.[15] When SARS-CoV-2 RNA screening was carried out in communities, more than half of the residents with positive test results were asymptomatic at the time of testing.[16–19] The rapid dissemination of COVID-19 may be attributed to the existence of presymptomatic and asymptomatic patients with active virus shedding, as these patients are harder to identify and control. The relative contribution of asymptomatic transmission was much higher in regions where case-based interventions were stringent.[20]

The viral load in infected individuals is an important factor affecting their transmissibility. Studies found that the viral load in patients' nasopharyngeal swabs is positively correlated with viral loads emitted in both droplets and aerosols, and with environmental contamination.[21–23] Multivariate analyses have identified that viral load (viral RNA) larger than 10^7 copies/ml (OR = 14.7) is independently associated with isolation of infectious virus from respiratory tract samples.[13] Numerous studies have demonstrated that higher SARS-CoV-2 viral load in the upper airway of an infected person is associated their increased infectivity.[24–26]

Using quantitative RT-PCR assay, Pan et al. determined viral loads in sputum and throat swab samples of 80 patients. The median viral load was 7.52×10^5 copies/ml and 7.99×10^4 copies/ml; the highest load was 1.34×10^{11} copies/ml and $>10^8$ copies/ml, respectively.[12] Studies have found that SARS-CoV-2 viral load in respiratory samples is similar in symptomatically and asymptomatically infected persons. Yang et al. showed that the distribution of SARS-CoV-2 viral load in 1405 asymptomatic individuals fits under a log-normal distribution centered around the mean of 2.1×10^7 virions/ml, while the highest viral load found in saliva was 6.1×10^{12} copies/ml.[27] Comparing with H1N1 influenza A, the standard deviation of the overall respiratory viral load distribution for COVID-19 was significantly higher, showing that the heterogeneity in viral load was indeed broader for SARS-CoV-2 infected persons.[28] This indicates that some patients shed virions at very high concentrations, for example, the highest viral load found in H1N1 influenza A patients was 1×10^{10}copies/ml, while the highest viral load in SARS-CoV-2 infected individuals can reach 6.1×10^{12} copies/ml.[28] Approximately 2% of individuals with SARS-CoV-2 have a viral load $>10^{10}$ copies/ml.[27] Further analysis found that just these 2% of individuals carry 90% of the virions circulating within communities, serving as viral "supercarriers."[27]

The heterogeneity in transmissibility among infected individuals may be associated with dissimilarity of viral shedding. The supercarriers shed virions at very high concentrations, making them highly infectious and more likely to contaminate the environment. Analyses of such individuals suggest heterogeneity associated with superspreading events as an intrinsic viral factor facilitating greater overdispersion of SARS-CoV-2 during the COVID-19 pandemic than influenza A during the 2009 influenza pandemic.[27,28]

In addition to respiratory tract specimens, viable SARS-CoV-2 has been detected in other biological samples, including stool and urine.[29] The detection of viable SARS-CoV-2 in diverse bodily fluids and secretions indicates various other potential sources of environmental contamination.

3 | ENVIRONMENTAL CONTAMINATION OF SARS-CoV-2

SARS-CoV-2 environmental contamination occurs through the release of nasal mucus, sputum, saliva, and other biological fluids by infected individuals into their surroundings. Infected individuals can contaminate surfaces and objects to create fomites by either shedding onto their hands and then touching a surface or by expelling respiratory particles when coughing, speaking, or even breathing, which then fall onto a surface.[6,30,31] Aerosolized droplets from an infected person can easily settle and persist on immediate surfaces for extended periods, especially in poorly ventilated indoor spaces with a continual affluence of people.[6,32]

3.1 | Presence of SARS-CoV-2 in clinical settings

Studies have found extensive SARS-CoV-2 contamination of surfaces in hospitals dedicated to patients with COVID-19. In airborne infection isolation rooms where COVID-19 patients were hospitalized in Singapore, 56.7% of rooms were found have at least one contaminated environmental surface, and high-touch surface contamination was found in the rooms of 10 (66.7%) of 15 patients during the first week of their illness.[33] In a study at six acute care hospitals in Toronto, 125 (26%, 125/474) surface samples from 42 (57%, 42/74) patient rooms were positive for SARS-CoV-2 RNA.[34] In another study, swabs taken from hospital air exhaust outlets yielded positive test results, suggesting that small virus-laden droplets may be displaced by airflows and deposited on equipment, such as vents.[22]

Some patients with SARS-CoV-2 infection appear to cause more extensive environmental contamination than others. In addition to higher viral load in respiratory samples, multivariable analysis indicates that hypoxia at admission, higher Charlson comorbidity score, and the time from illness onset to the sampling date are significantly associated with the presence of SARS-CoV-2 RNA on surface samples.[23,34]

In outpatient health care facilities, surface contamination has also been found, including on dental chairs, sinks, keyboards, ophthalmoscopes, laboratory equipment, and door handles. Places with greater contact had higher positive rates.[30,33] Toilet bowl and sink samples have tested positive for SARS-CoV-2, suggesting possible viral shedding in stool.[22]

3.2 | Presence of SARS-CoV-2 on surfaces in households

Households have been important sites of transmission throughout the COVID-19 pandemic. SARS-CoV-2 has been detected in the household environment of individuals with COVID-19, notably on surfaces in areas where there is close, prolonged contact with persons who have recently tested positive for SARS-CoV-2.[35,36] SARS-CoV-2 RNA appears to be able to sustain on environmental surfaces for a long time. One study found that a month after symptom subsidence, 46% of surfaces in the home had detectable levels of SARS-CoV-2.[36] Some surfaces found to be SARS-CoV-2 positive, such as home HVAC filters, floors, and the top of televisions, are common reservoirs for dust build-up and might be infrequently touched.[36] In contrast to hospitals and health care settings, there are limited data on environmental contamination with SARS-CoV-2 in households.

3.3 | Prevalence of SARS-CoV-2 on high-touch surfaces in community settings

During the ongoing pandemic, emerging evidence shows that SARS-CoV-2 is present in different community environments. Longitudinal monitoring of SARS-CoV-2 RNA on high-touch surfaces was carried out in Massachusetts, United States during a COVID-19 outbreak. SARS-CoV-2 RNA was found on various surfaces in 10 of 12 locations sampled; the overall positive rate among surface samples was 8.3% (29/348).[37] In a densely populated urban area of Brazil, SARS-CoV-2 RNA was detected in 5.3% (49/933) of swab samples collected from public surfaces, including metal and concrete, and in distinct places, mainly around hospital care units and public squares.[38] The viral RNA concentrations detected on surfaces in both studies ranged between <0.1 and 40 gc/cm^2 (gene copies per cm^2) and 2.5–102 gc/cm^2, respectively.

SARS-CoV-2 viral RNA has also been detected on environmental surfaces in playgrounds,[39] supermarkets,[40] cruise ship surfaces,[41] public transport vehicles,[42] tourist recreational facilities,[43] retail stores, and workplaces.[37] Surfaces in public areas that are exposed to human crowding or that are frequently touched by the hands (e.g., ATMs in public facilities) are frequently found to be positive for SARS-CoV-2 RNA contamination.[30]

3.4 | Presence of SARS-CoV-2 in cold foods

During the pandemic, workers in labor-intensive workplaces such as seafood processing and food manufacturing plants or slaughterhouses, have had high COVID-19 infection rates.[44,45] Processed foods and their packaging can be contaminated by infected workers with mild or no symptoms through falling respiratory droplets or hand contact. SARS-CoV-2 RNA has been detected many times in cold-chain aquatic products imported to China and their packaging materials.[46] In September 2020, the contamination status of imported frozen seafood from a cargo ship in Qingdao was investigated; the positive rate of SARS-CoV-2 RNA in frozen seafood was 11.53% (106/919).[47]

4 | VIABILITY AND STABILITY OF SARS-CoV-2 IN THE ENVIRONMENT

Assessment of the risks posed by SARS-CoV-2 on surfaces requires data on viability and stability of the virus on environmental surfaces as well as how virus viability is affected by environmental variables, such as air temperature and relative humidity.

4.1 | Viability of SARS-CoV-2 isolated from surface samples in natural settings

Many studies have attempted to assess the viability and infectivity of SARS-CoV-2 present on surfaces or objects. Using cell culture

TABLE 1 Viable severe acute respiratory syndrome coronavirus 2 isolated from various surfaces

Settings	Sample source	Culture cell	Virus *Ct* (or concentration) of the swab from surface	References
Patient room	Bathroom door, bed and switch, phone, table and chair, toilet and sink	Vero E6	NA	[34]
Household	Nightstand	Vero CCL-81	26.4	[35]
Quarantine unit	Windowsill	Vero E6	0.65 copies/μl	[48]
Patient room	Windowsill	Vero E6	>102 copies/μl	[48]
Negative-pressure isolation rooms	Endotracheal tube, floor, bed rails, bedsheet, ambu mask/NIV, bedside table, remote controller	Vero E6	30.9-34.3	[49]
Imported food	Frozen cod package	Vero E6	NA	[50]

Abbreviations: Ct, cycle threshold of real-time PCR; NA, not available; NIV, noninvasive ventilation.

systems, viable SARS-CoV-2 virus has been isolated from various environmental settings,[34,35,48,49] as well as frozen food packaging[50] (Table 1). These studies provide direct evidence supporting SARS-CoV-2 survival in fomites for a length of time consistent with the possibility of onward transmission.

4.2 | Stability of SARS-CoV-2 on skin, environmental surfaces, and in cold foods

4.2.1 | Stability of SARS-CoV-2 on the skin

Human hands are considered critical vectors in direct contact and indirect transmission of SARS-CoV-2. To understand how long SARS-CoV-2 can remain viable on the hands and evaluate the importance of hand hygiene, two experimental studies evaluated SARS-CoV-2 stability on the skin. In one study, 50 μl of SARS-CoV-2 virus at a starting titer of 4.5 ± 0.5 log10 PFU (plaque-forming unit) was deposited onto swine skin with the hair removed. The virus remained viable on skin samples for 8 h at 37°C, at least 96 h at 22°C, and for 14 days at 4°C.[51] In another study on human skin, Hirose et al. compared the stability of SARS-CoV-2 and influenza A virus and found that SARS-CoV-2 could survive approximately 9 h on skin, significantly longer than the survival time of influenza A virus (approximately 1.8 h), indicating that the stability of SARS-CoV-2 is markedly higher. However, the survival and half-life times of both SARS-CoV-2 and influenza A virus were significantly shorter on human skin than on other surfaces, indicating that the hands are less suitable for virus survival.[52]

4.2.2 | Stability of SARS-CoV-2 on inanimate surfaces

Several in-vitro studies have evaluated the survivability of SARS-CoV-2 when inoculated onto dry surfaces and shown that SARS-CoV-2 is relatively stable.[53–60] Using large initial viral concentrations and under optimized environmental conditions, SARS-CoV-2 can remain viable on solid surfaces such as plastic, glass, stainless steel, and polymer banknotes for up to 28 days at 20°C (Table 2).

Some researchers have controversed the results because of much higher amount of virus used in these studies than that in actual contamination. Considering that a portion of infected individuals have a viral load >10^{10} copies/ml in saliva,[27] and the most infectious saliva and cough specimens exhibited virus loads approaching 10^6 PFU/ml,[61] the initial viral concentrations used in these studies are plausible. In fact, SARS-CoV-2 shows an exponential decay in virus titer across all experimental conditions, as indicated by a linear decrease in the log10 TCID50/ml (50% tissue-culture infectious dose per ml) on surfaces over time.[53,54] When decimal reduction time (*D* value), the time of a 1-log reduction in viability (or infectivity), was used to gauge the stability of SARS-CoV-2, the virus inactivation rate on environmental surfaces was independent of initial loading.[54] Paton et al.[55] compared the viability of SARS-CoV-2 on stainless steel coupons between two starting titers, and found that the virus could be recovered after 4 days at the lower titer of 4×10^3 PFU/ml and 7 days at the higher titer of 4×10^5 PFU/ml, suggesting that the virus can remain viable on stainless steel for several days even with a lower initial viral load. Sun et al.[62] also reported that at 22°C the virus with a low starting titer of 10^4 TCID50 on stainless steel and plastic bag maintained infectious for 3 days.[62] These findings suggest high stability of SARS-CoV-2 on certain surfaces.

A comparison of SARS-CoV-2 and SARS-CoV-1 showed that these viruses have similar levels of stability on dry surfaces under the same experimental circumstances. However, the survival and half-life of SARS-CoV-2 was significantly longer than that of influenza A virus across different inanimate surface types, suggesting that SARS-CoV-2 is more stable.[53] Therefore, SARS-CoV-2 may pose a higher risk of transmission through fomites than influenza A virus.

4.2.3 | Stability of SARS-CoV-2 in cold foods

Unlike regular surfaces or fomites, cold foods are generally characterized by conditions that promote viral particle survival, such as high protein and moisture levels, temperatures below 4°C, and a lack of exposure to direct sunlight. Numerous studies have found that

TABLE 2 Studies on the survival of severe acute respiratory syndrome coronavirus 2 on dry surfaces

Surface type	Virus titer	Loading volume (μl/cm²)	Medium	Relative humidity (%)	Temperature	Time of virus decay	References
Stainless steel, plastic, cardboard, copper	1.78×10^5 TCID50/ml	50	Cell culture medium	65	21°C–23°C	3 days, 3 days, 1 day, 4 h	[53]
Stainless steel	4×10^3PFU/ml, 4×10^5 PFU/ml		Cell culture medium	45	21.5°C	4 days, 7 days	[54]
Plastic, aluminum, glass	10^6 TCID50/ml	50	None or BSA	45–55	19°C–21°C	4 days	[55]
Plastic, cotton, stainless steel, nitrile gloves	7.58×10^7 TCID50/ml		Organic soil	30–40	20°C	21 days, 0–4 h, 14 days, 7 days	[56]
Stainless steel, plastic, rubber glove	3.38×10^7 TCID50/ml	10	Simulated saliva	50	20°C	28 days	[57]
Cotton cloth						14 days	
Stainless steel, Plastic, glass, Banknote, surgical mask, cloth, wood, tissue paper	6.31×10^6 TCID50/ml	5	Cell culture medium	65	22°C	4 days, 4 days, 2 days, 2 days, 7 days, 1 day, 1 day, 30 mins–3 h	[58]
Salmon	3.16×10^6 TCID50/ml	soaked	Cell culture medium	NA	25°C, 4°C	2 days, 8 days	[59]
Plastic, metal coupons	10^6 PFU/ml		Cell culture medium	50	22°C	3 days, 3 days	[60]

Abbreviations: NA, not available; TCID50, 50% tissue-culture infectious dose; PFU, plaque-forming unit.

in cold foods contaminated with SARS-CoV-2 RNA, the viability and stability of virions within the foods, as a marker for transmission, raises much concern.

A laboratory study demonstrated that SARS-CoV-2 on contaminated fish with a titer of 3.16×10^6 TCID50/ml can survive for 2 days at 25°C and for 8 days at 4°C.[59] In an experiment involving contamination of pork, beef, and salmon meat with low virus concentrations close to the actual concentration in respiratory secretions, SARS-CoV-2 retained viability for 3 days at 4°C and for 7 days at −20°C.[63]

Similar to raw meats and seafood, deli foods that are high in protein, fats, and moisture can maintain infectivity of SARS-CoV-2 for up to 3 weeks when stored at refrigeration temperature (4°C).[64,65] However, processed meat, such as salami, and some fresh produce have exhibited antiviral effects.[65]

Under refrigeration (4°C) and freezing (−10°C to −80°C) conditions, the virus can remain infectious for more than 21 days in some foods.[59,66] Because under globalized logistics networks, imported and exported cold foods are usually transported in a low-temperature (e.g., 0°C to −4°C) environment from one country or region to another within a few days, contaminated food may serve as a vector for international transmission of SARS-CoV-2.

4.3 | Environmental factors affecting the viability of SARS-CoV-2

The survival and persistence of SARS-CoV-2 on surfaces appears to be influenced by many environmental factors, of which the following are particularly important.

(1) Types of surface and medium or metrics

The stability and viability of SARS-CoV-2 on surfaces is highly dependent on surface materials (Table 2). In general, coronaviruses are inactivated more rapidly on porous materials (i.e., containing pores/cavities) than nonporous materials. Longer persistence is observed on less absorbent or hydrophobic porous surfaces, particularly hydrophobic synthetic items, such as surgical masks, compared with hydrophilic natural fibers like cotton. It is hypothesized that dryness accelerates the inactivation of SARS-CoV-2 on paper and other porous solids; conversely, droplets of water remaining on waterproof surfaces protects the virus from dryness.[54,67]

Experimental studies show that the stability of SARS-CoV-2 on surfaces is also affected by its surrounding matrix; the suspending medium used to dry the virus onto surfaces is another important factor influencing survival times.[53,68] Several studies have demonstrated that the addition of a moderate amount of protein, like bovine serum albumin or mucus, to the inoculating suspension when loading onto a surface increases SARS-CoV-2 infectivity, indicating that additional protein provides a protective effect for the virus during and after drying on surfaces.[55–58] These results suggest that a protein-rich medium, like airway secretions, could protect the virus when it is expelled and may enhance its persistence and transmission via contaminated fomites.

(2) Temperature

Temperature is a critical environmental factor that affects SARS-CoV-2 survival. Like other known viruses, the stability of SARS-CoV-2 either in solution or on a dry surface is inversely correlated with temperature.

The half-life of SARS-CoV-2 infectivity is 1.7–2.7 days at 20°C and decreases to a few hours at 40°C on common surfaces.[57] SARS-CoV-2 can persist for 14 days in Dulbecco's modified Eagle medium at 4°C whereas the persistence time is dramatically reduced to 10 min and 1 min when the temperature is increased to 56°C and 70°C, respectively.[58] Because viruses are sensitive to temperature, heating is one method used for virus inactivation, including for SARS-CoV-2.

Using low virus concentrations close to the actual concentration of viral particles in the environment, SARS-CoV-2 has been shown to be more stable and infectious after storage at −20°C than at 4°C.[69] Infectious SARS-CoV-2 can persist for at least 60 days on cold-chain food packaging (kept at less than −18°C).[70] These foods are produced, transported, stored, and sold in a cold chain to keep them fresh, which also helps the virus to retain its viability and infectivity for a longer time.

(3) Humidity and moisture status

In contrast to dry surfaces, moist surfaces are more likely to be positive for SARS-CoV-2 RNA, and the duration of environmental surface contamination is associated with the moisture status of the sampling site.[23,66] Studies have found that water cups are the most frequently contaminated site in the hospital rooms of patients with COVID-19, and SARS-CoV-2 RNA can be detected in the water cup in room-temperature environments for 48 days after the infected patient has left the room, suggesting that water in the cup may play an important role in virus persistence.[23,70]

Relative humidity is associated with viability of airborne respiratory viruses. Biryukov and colleagues[71] found that SARS-CoV-2 on dry surfaces can decay more rapidly with increased humidity. However, contradictory findings have been obtained regarding SARS-CoV-2 viability and relative humidity. One study found that the rate of viral decay was most rapid at 65% relative humidity and slower with either lower (40%) or higher (75%) humidity.[72] Further studies found that there is an interaction effect between temperature and humidity on viral viability on surfaces. When the relative humidity was increased from 20% to 80%, the virus half-life changed from 18.6 to 6.3 h at room temperature (24°C) and from 8.9 to 1.0 h at 35°C.[71] The rate of inactivation increases with increased temperature and shows a U-shaped dependence on relative humidity.[72]

5 | OCCURRENCE OF SARS-CoV-2 INFECTIONS THROUGH INDIRECT TRANSMISSION

Extensive surface contamination of SARS-CoV-2 around asymptomatically and symptomatically infected individuals has been documented, and increasing evidence shows that SARS-CoV-2 can remain viable on surfaces, from several hours to 21 days. Thus, contaminated surfaces and fomites may result in exposing a larger number of susceptible individuals to potential infection.

5.1 | Fomite transmission estimated using mathematical models

Several mathematical model-based epidemiological investigations have evaluated the relative importance of different modes of virus transmission. Modeling of the Diamond Princess Cruise ship outbreak suggested that short-range (droplets), long-range (aerosols), and fomite transmission modes contributed to 35%, 35%, and 30% of infected cases, respectively, across the entire simulation period. The estimated contribution of fomite transmission before the start of quarantine on the cruise ship was higher than that after quarantine began.[73] Higher relative risks associated with SARS-CoV-2 fomite transmission were also reported in studies modeling child daycare centers[74] and hospital and health care settings.[75,76] However, studies of the infection risk via fomites using different mathematical models have had surprisingly divergent outcomes, with extremely low substantial risk estimates being reported.[37,77] This discrepancy could be explained by bias introduced from data on viral exposure and persistence generated in simulated laboratory conditions and those observed in naturally contaminated real-life scenarios.

5.2 | Fomite transmission demonstrated in animal experiments

Direct evidence for fomite transmission is still lacking because of difficulty in distinguishing between cases arising from fomite transmission and those involving droplet and aerosol transmission. A hamster model provided robust evidence to support fomite transmission, although airborne transmission was found to be more efficient. Hamsters were infected after being exposed to 40 µl of 8×10^4 TCID50 viruses in a propylene dish for 24 h.[78] Hamsters exposed to fomite SARS-CoV-2 displayed delayed replication kinetics in the respiratory tract and less severe lung pathology in comparison with hamsters exposed via aerosol inoculation.[78] Other studies using hamster models also demonstrated SARS-CoV-2 transmission via fomites in the absence of direct contact, droplets, and aerosols, in which naive hamsters were placed in cages where infected hamsters had lived and became infected.[79,80]

Rhesus macaques can be infected with SARS-CoV-2 through direct conjunctival inoculation but develop less severe pulmonary disease than macaques inoculated via an intra-tracheal route, implying that an extra-respiratory route of SARS-CoV-2 infection and hand contamination pose an increased risk of virus infection.[81]

5.3 | Occurrence of COVID-19 through fomite and cold-chain transmission

Because conventional epidemiologic studies cannot distinguish between competing transmission pathways (e.g., droplet, aerosol, direct, or fomite) acting simultaneously, reports on COVID-19 related to the transmission of SARS-CoV-2 from contaminated surfaces are rare.[82,83] Even in the few instances that appear to have been caused by surface transmission, aerosol transmission cannot be ruled out, and debate continues regarding the importance of fomite transmission of SARS-CoV-2.[7,8]

However, several outbreaks and sporadic cases in China have been demonstrated to be associated with transmission from imported cold-chain foods (Table 3).[46,50,84–86] The first outbreak speculated to originate from contaminated imported cold-chain foods occurred at Xinfadi Market in Beijing in June 2020. The index case emerged after 56 days with no community transmission in Beijing, and the possibility of contact with overseas personnel was ruled out based on epidemiological investigations. Subsequent field investigations and an on-site simulation experiment suggested that the virus spread from contaminated foods to humans in the market.[84] In September 2020, an outbreak occurred among dock workers in Qingdao, Shandong Province.[50] Apart from epidemiological evidence that the index case had no exposure to any COVID cases, more convincing evidence involved viable SARS-CoV-2 isolated from the outer packaging of frozen cod to which the workers were exposed.[50] Similar connections have been found in re-emerged COVID-19 outbreaks in the Chinese coastal cities of Dalian, Tianjin, and Guangzhou (Table 3). Investigation results documented the possibility that imported cold foods and their packaging can serve as vectors for the reintroduction of SARS-CoV-2 into areas with controlled transmission. The evidence from these outbreaks supports that cold-chain logistics transmission of SARS-CoV-2 is biologically plausible.

However, it has been nearly impossible to identify cases of infection via cold-chain food transmission during the pandemic when infections are primarily attributed to close-proximity transmission. Fomite transmission can be easily identified during the period of epidemic near-eradication, with the absence of explanatory source cases in the community.[87] With the near elimination of SARS-CoV-2 in China during 2020–2021, it became possible to exclude transmission via close contact with a known case and to distinguish unusual transmissions from single cases.

6 | IMPLICATION OF SARS-CoV-2 INFECTIONS VIA INDIRECT TRANSMISSION AND KNOWLEDGE GAP

Although it is estimated that the transmission of SARS-CoV-2 via fomites is rare, the possibility of fomite transmission cannot be ruled out. The debate over fomite transmission has shifted to the implications of this transmission mode.[7]

6.1 | Implication of SARS-CoV-2 infections via indirect transmission

During 2020–2021, although most Western countries were gradually lifting their border controls and quarantine measures, the Western Pacific Region, including in China, retained the elimination strategy aiming for "zero COVID-19." When stringent quarantine measures were implemented for travelers to control the introduction of infectious diseases, several outbreaks occurred in cities where COVID-19 was close to elimination via imported frozen foods or

TABLE 3 COVID-19 outbreak or sporadic infection initiated by cold chain food

Location, China	Starting date	Related cold chain food (COVID-19 RNA positive)	Period since the last infection (consecutive days)	References
Beijing	June, 2020	Imported salmon	59	[84]
Dalian	July, 2020	Frozen seafood products	111	[85]
Qingdao	September, 2020	Frozen cod packages	151	[50]
Tianjin	November, 2020	Frozen pork packages	125	[86]
Dalian	December, 2020	Imported cold food	NA	[46]
Yingkou	May, 2021	Frozen cod	NA	[46]
LiuAn	May, 2021	Frozen cod	NA	[46]

Abbreviation: NA, not available.

packaging.[46,50,84–86] In these cases, fomite transmission constituted a critical problem, by posing the risk of reintroducing the virus into a region that achieved local epidemic elimination.

Fomite transmission can occur over long distances, when contaminated objects are transported from one site to another. The development of e-commerce and express delivery services has made it possible for fomite transmission to cause intercity, interregional, and international virus spread, thereby sustaining the pandemic. Different from other infectious disease pandemics over the past century, the COVID-19 pandemic represents the first time that modern logistics have been emphasized as a possible vector for virus transmission and a serious concern.

Another concern is that some items contaminated with the virus, such as food products, have been stocked in cold storage during the global pandemic. These frozen items will likely be thawed and consumed over the next years, releasing the viable virus and posing the risk of human reinfection.

6.2 | Knowledge gaps in environmental transmission of COVID-19

The debate over the risks and control measures of fomite transmission is expected to continue until the mechanisms involved are fully understood. Among the many knowledge gaps regarding this transmission mode, the following are of greatest concern: (1) the way via which virus deposited on surfaces is re-transferred to humans is unknown. In addition to transferring virus from fomites to the hands and subsequently to mucous membranes of the mouth, nose, or eyes, there may be alternative routes via which the virus is transferred to humans from fomites. A plausible route could be via “aerosolized fomites,” in which live virus on surfaces is taken up into the air and inhaled.[7,88,89] In living and workplace settings, contaminated objects can generate aerosols, such as when transporting and processing frozen foods.[89] (2) The minimum infective dose required to cause an infection via a specific transmission mode is unknown. Recent studies report that respiratory tract samples from COVID-19 with only 14–30 PFU[28] or a minimum infective dose as low as 1 TCID50 caused illness in Syrian hamsters.[90] Nevertheless, it remains a challenge to identify the minimum infective dose of fomite transmission, making it difficult to quantitatively estimate the risks associated with exposure to fomites. (3) Emergence of the SARS-CoV-2 Omicron strain has raised concerns about whether its increased infectivity is owing to altered contamination/persistence on surfaces and/or a gain in airborne transmissibility.[91–93] Currently, viral factors provide inadequate explanation for its high transmissibility. Further molecular epidemiologic data may help to address this question.

7 | CONCLUSION

There is now extensive evidence supporting the contamination of surfaces and objects caused by individuals infected with SARS-CoV-2. SARS-CoV-2 showed high stability and viability in environment, surviving for hours to days depending on the surface, temperature, and humidity as key factors in viral survival. Studies have isolated viable virions from contaminated surfaces, including dry surfaces and frozen fish. Experimental animal models proved that infections can occur via the fomite transmission route. More importantly, several outbreaks and sporadic cases in China have been demonstrated to be associated with transmission from imported cold-chain foods. It is worth noting for international community that indirect transmission of SARS-CoV-2 through fomite may constitute problems by posing the risks of long distance transmission, reintroducing the virus into an area that achieved local epidemic elimination, and extending the duration of the pandemic. Strengthening the inspection and quarantine of cold-chain foods from high-epidemic areas should be an effective measure for COVID-19 prevention. Personal protective measures including washing hands and regular disinfection practices should reduce environmental contamination and the possibilities of environmental transmission of the virus.

AUTHOR CONTRIBUTIONS

Yansheng Geng and Youchun Wang conceived and wrote the manuscript. Youchun Wang contributed to the modification and revision of the manuscript. Both authors approved the submitted versions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available on request from the authors.

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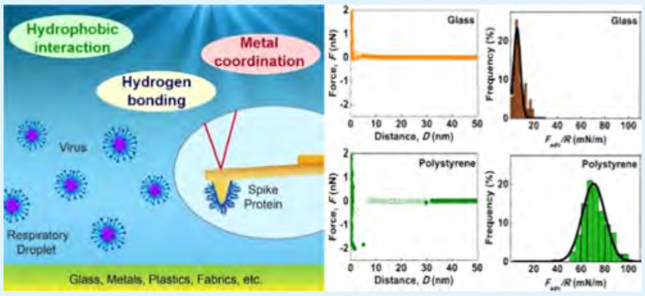
ABSTRACT: The SARS-CoV-2 virus that causes the COVID-19 epidemic can be transmitted via respiratory droplet-contaminated surfaces or fomites, which urgently requires a fundamental understanding of intermolecular interactions of the coronavirus with various surfaces. The corona-like component of the outer surface of the SARS-CoV-2 virion, named spike protein, is a key target for the adsorption and persistence of SARS-CoV-2 on various surfaces. However, a lack of knowledge in intermolecular interactions between spike protein and different substrate surfaces has resulted in ineffective preventive measures and inaccurate information. Herein, we quantified the surface interaction and adhesion energy of SARS-CoV-2 spike protein with a series of inanimate surfaces via atomic force microscopy under a simulated respiratory droplet environment. Among four target surfaces, polystyrene was found to exhibit the strongest adhesion, followed by stainless steel (SS), gold, and glass. The environmental factors (e.g., pH and temperature) played a role in mediating the spike protein binding. According to systematic quantification on a series of inanimate surfaces, the adhesion energy of spike protein was found to be (i) 0−1 mJ/m^2 for hydrophilic inorganics (e.g., silica and glass) due to the lack of hydrogen bonding, (ii) 2−9 mJ/m^2 for metals (e.g., alumina, SS, and copper) due to the variation of their binding capacity, and (iii) 6−11 mJ/m^2 for hydrophobic polymers (e.g., medical masks, safety glass, and nitrile gloves) due to stronger hydrophobic interactions. The quantitative analysis of the nanomechanics of spike proteins will enable a protein−surface model database for SARS-CoV-2 to help generate effective preventive strategies to tackle the epidemic.



KEYWORDS: *spike protein, intermolecular interaction, surface adhesion, COVID-19, surface forces*

1. INTRODUCTION

Since December 2019, the COVID-19 outbreak caused by SARS-CoV-2 has led to over 70 million of confirmed cases and over 1.6 million deaths in 218 countries.[1−5] The main transmission routes of SARS-CoV-2 indicate that this respiratory disease can spread by inhalation and/or direct contact with droplets of infected people as well as indirect contact with contaminated surfaces that carry respiratory droplets from infected persons.[1−5] While social distancing is proved to be an effective approach to inhibit the human−human transmission through direct routes, infections through indirect contact remain challenging to combat, owing to the invisible spreading paths and unclear surface behaviors of the new coronavirus.[5−8] Therefore, identifying the surface interactions of SARS-CoV-2 has become essential for prohibiting virus transmission via surface contaminations. The Munster group evaluated the persistence of SARS-CoV-2 by accessing virus decay rates in aerosols and on several typical substrates,[9] and similar studies were also conducted on other respiratory viruses such as SARS,[9,10] MERS,[11,12] and Ebola,[13] as shown in Table 1. Despite the significant progress achieved, it remains unclear in terms of the intermolecular interactions involved, such as adsorption and binding strengths of the virus on typical substrates, which are critical for evaluating viral loads on those target surfaces. Thus, detailed studies toward the nanomechanics of the virus-contaminated surfaces are urgently needed to determine the interaction mechanisms at the nanoscale, as well as their influences on viral persistence.

Spike protein refers to a class I fusion protein that is located at the surface of a coronavirus virion (illustrated in Figure 1A).[14−16] Consisting of more than 1000 amino acids, the spike protein can assemble into crownlike nanoarchitecture that allows the viral binding and fusion to host cell membranes through molecular recognition.[17−19] With regard to the structure of the new coronavirus, there are two main subunits in the spike protein named S1 and S2, the former of which is

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Table 1. Persistence of Selected Coronaviruses on Typical Inanimate Surfaces

virus type	inanimate surfaces	environment	persistence	references
SARS-CoV-2	copper	21−23 °C; 40% humidity	4 h	9
	cardboard	21−23 °C; 40% humidity	24 h	9
	SS	21−23 °C; 40% humidity	48 h	9
	plastic	21−23 °C; 40% humidity	72 h	9
MERS-CoV	SS	20 °C	48 h	11,12
	plastic	20 °C	48 h	11,12
Ebola-CoV	SS	21−27 °C; 40−80% humidity	11−27 h	13
	plastic	21−27 °C; 40−80% humidity	11−43 h	13
	Tyvek	21−27 °C; 40−80% humidity	15−52 h	13
SARS-CoV	copper	21−23 °C; 40% humidity	8 h	9
	cardboard	21−23 °C; 40% humidity	8 h	9
	SS	21−23 °C; 40% humidity	48 h	9
	plastic	21−23 °C; 40% humidity	72 h	9
	metal	room temperature	5 days	10
	wood	room temperature	4 days	10
	paper	room temperature	24 h	10
	glass	21 °C	4 days	10

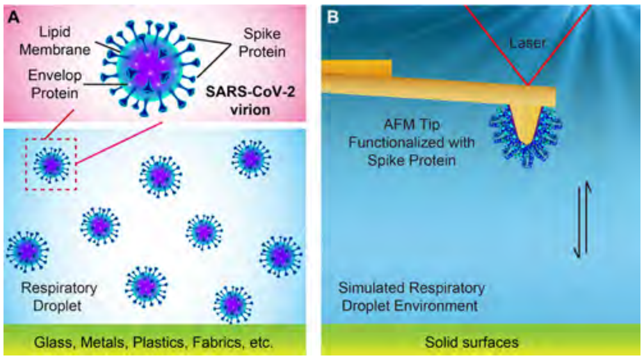

Figure 1. (A) Schematic of SARS-CoV-2 virions in respiratory droplets contaminating solid substrates such as glass, metals, plastics, and fabrics (down), and the zoomed-in structure of the SARS-CoV-2 virion (up). (B) Schematic of the experimental setup for measuring the interaction forces between the spike protein-functionalized AFM tip and various solid surfaces in simulated respiratory droplet environments.

responsible for ACE2 receptor binding using its receptor-binding domain, while the latter is managing the subsequent membrane fusion.[16,17,20] Considering the critical role of the spike protein in viral infection, characterizing the adsorption behavior and adhesion strength of spike protein can shed light on the molecular mechanism how the new coronavirus contaminates the surfaces of inanimate substrates. The active subunit S1 has been recognized as a good candidate to understand the adsorption and adhesion of spike protein at the molecular level owing to its representative structure and function.[17−19] Being the powerful nanomechanical techniques, atomic force microscopy (AFM) and surface force apparatus (SFA) have been widely employed to quantitatively characterize the intermolecular interactions, including adhesion and single-molecule binding, of a variety of biological molecules in vapor or liquid media.[21−32] As compared to SFA that requires molecularly smooth surfaces with at least one surface being transparent, AFM is more versatile to quantify the interaction forces of the materials that cannot be easily accessed by SFA. The unique, flexibility, and accuracy of AFM make it feasible to access the interaction mechanism of spike protein at the nanoscale.

To systematically investigate the adsorption behavior and interaction mechanism of COVID-19 spike protein, herein, a direct and quantitative analysis of surface interactions of spike protein was presented with respect to adsorption, kinetics, and intermolecular forces in the pico/nanonewton range (schematic illustrated in Figure 1B). A series of inanimate surfaces, including glass, plastics, metals, fabrics, and so forth, were applied to systematically evaluate the adsorption behaviors of the spike protein. In particular, we focused on four targeted surfaces (i.e., glass, gold, stainless steel (SS), and polystyrene-(PS)), which represent the most commonly used materials ranging from inorganics and organics to metals and composites/hybrids. We also discussed the key factors affecting the spike protein binding and explored the protein−surface interaction mechanisms under simulated respiratory droplets, as well as proposed feasible strategies to modulate the binding of spike protein with inanimate surfaces. This work will improve the fundamental understanding associated with the adsorption and adhesion mechanisms of spike protein on various solid substrates, thereby providing guidelines for developing preventive/protective equipment and optimizing current public measures against COVID-19 pandemic.

2. RESULTS AND DISCUSSION

2.1. Adsorption of Spike Protein on Various Surfaces. Figure 2 shows the AFM topography images of glass, gold, SS, and PS surfaces before and after the adsorption of spike protein. The bare glass, gold, SS, and PS surfaces exhibit a root-mean-square (RMS) roughness of 0.3−0.7 nm, and such smooth surfaces allow the accurate observation of protein adsorption. It is noted that the uniform grainlike pattern on bare metal (i.e., gold and SS) surfaces is arising from their metal particles. After spike protein adsorption, all the surfaces become rough with the obvious binding of spike protein as indicated by the white dots shown in Figure 2. The spike protein adsorbed on glass is sparsely distributed with a considerable size. In contrast, the size of the spike protein adsorbed on gold and SS is relatively small, and the distribution of the adsorbed spike protein is much denser for SS. However on PS, the size of the adsorbed protein becomes even smaller, and an ultra-dense distribution of protein pattern is observed (2×2 μm^2 image shown in Figure S1). The smaller size and denser distribution of the adsorbed spike protein reveal the preferential binding of spike protein with the surface instead of self-aggregation. Therefore, spike protein most preferentially adsorbs on PS followed by SS and gold. On the other hand, the adsorption of spike protein on glass is relatively weaker, as compared to the other three substrates.

2.2. Quantitative Force Measurements. To unravel the nanomechanics of spike protein interacting with various solid surfaces, the gold-coated AFM probe (including the AFM tip, cantilever, and cantilever base) is self-assembled with 11-mercaptoundecanoic acid, which subsequently covalently

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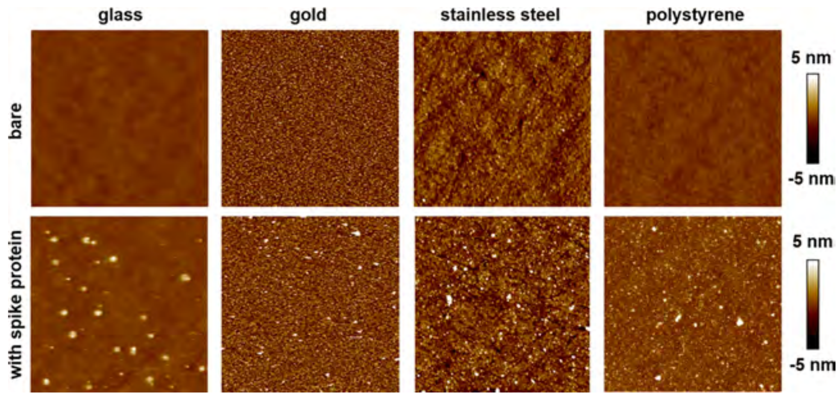

Figure 2. AFM topography images ($5 \times 5\ \mu m^2$) of glass, gold, SS, and PS before and after the adsorption of spike protein.

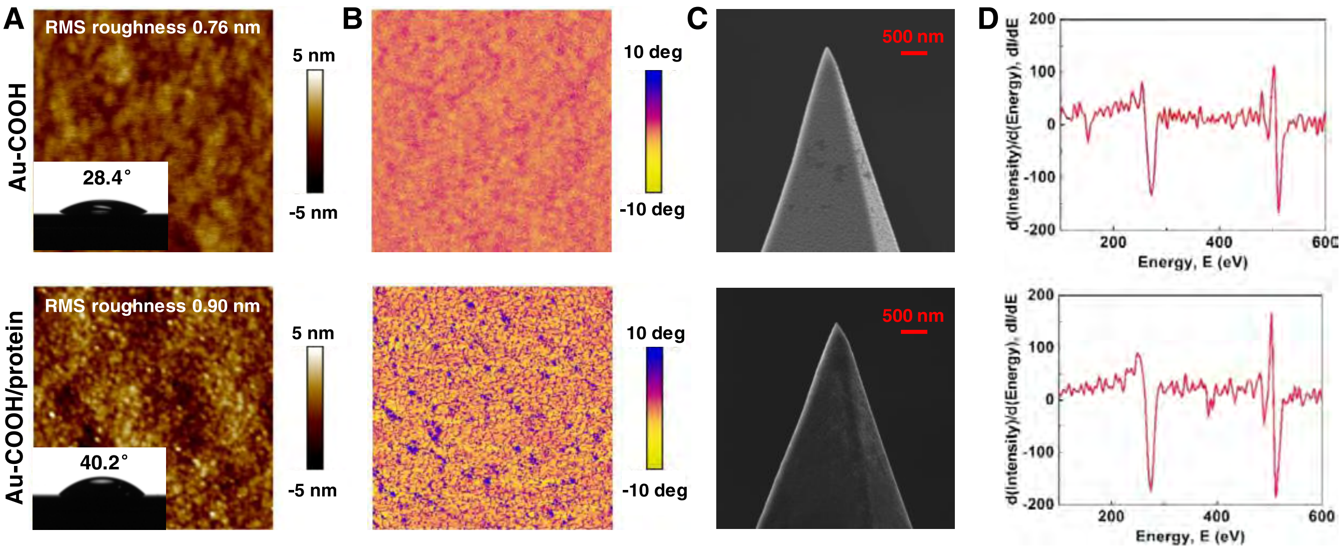

Figure 3. Characterization of the gold-coated AFM probe functionalized with carboxyl groups (up) and spike protein (down): (A) AFM topography image ($2 \times 2\ \mu m^2$) with the water contact angle (inset) on the cantilever base of the AFM probe, (B) phase image ($2 \times 2\ \mu m^2$) of the cantilever base of the AFM probe, (C) HIM on the AFM tip, and (D) Auger electron microscopy on the AFM tip.

bonds with spike protein via the carbodiimide crosslinking strategy.[21,33] The prepared AFM probe was characterized by AFM imaging, contact angle measurements, helium ion microscopy (HIM), and Auger electron spectroscopy (AES). As demonstrated in Figure 3A,B, the AFM probe without and with protein coating displays distinct morphologies and phase images, with spike protein closely and uniformly packing on the AFM probe that enhances RMS roughness from 0.76 to 0.90 nm. Meanwhile, the water contact angle increases from 28.4° ± 0.6° for the AFM probe without protein modification to 40.2° ± 0.8° for the protein-functionalized AFM probe (inset of Figure 3A), which suggests that the AFM probe becomes relatively hydrophobic after the protein modification. HIM is a unique surface-sensitive imaging technique that enables the high-resolution imaging of insulating proteins adsorbed at subnanometer resolution.[34] As shown in Figure 3C and Figure S2, the tip of the COOH-functionalized AFM probe displays the grainlike pattern of gold; instead, an evident coverage of nonconductive substances is detected for the tip of the protein-functionalized AFM probe. AFM imaging, water contact angle measurement, and HIM imaging all reveal the successful grafting of spike protein on the AFM probe, which is also further confirmed by the AES analysis where an additional nitrogen Auger peak at ~369 eV appears for the protein-functionalized AFM tip (Figure 3D).

The adsorption and adhesion of the virus outer protein on the surface that occur in droplet environments right after a virus-containing-droplet impacts and attaches to a solid surface are the key to the mechanism how the virus contaminates the surface. The intermolecular forces of spike protein in droplet environments play a central role in the adsorption and adhesion of spike protein on substrate surfaces. To ensure the accuracy of force measurements, force mapping was performed on bare surfaces in an area of $5 \times 5\ \mu m^2$ using the protein-functionalized AFM probe to acquire a two-dimensional array of force-separation profiles at 10×10 points (100 consecutive force-separation measurements). Force mapping was performed in at least three different regions of the substrate surface and at least two independently prepared samples of the same batch. The interaction forces measured between the protein-functionalized AFM tip and selected surfaces that are ubiquitous in daily life, including glass, gold, SS, and PS, during the approach−separation cycle under the typical simulated respiratory droplet condition (10 mM NaCl solution at pH 5.6 and 23 °C) are shown in Figure 4 (left). For spike protein interacting with glass, the measured force−distance profile (orange open symbols) shows a purely

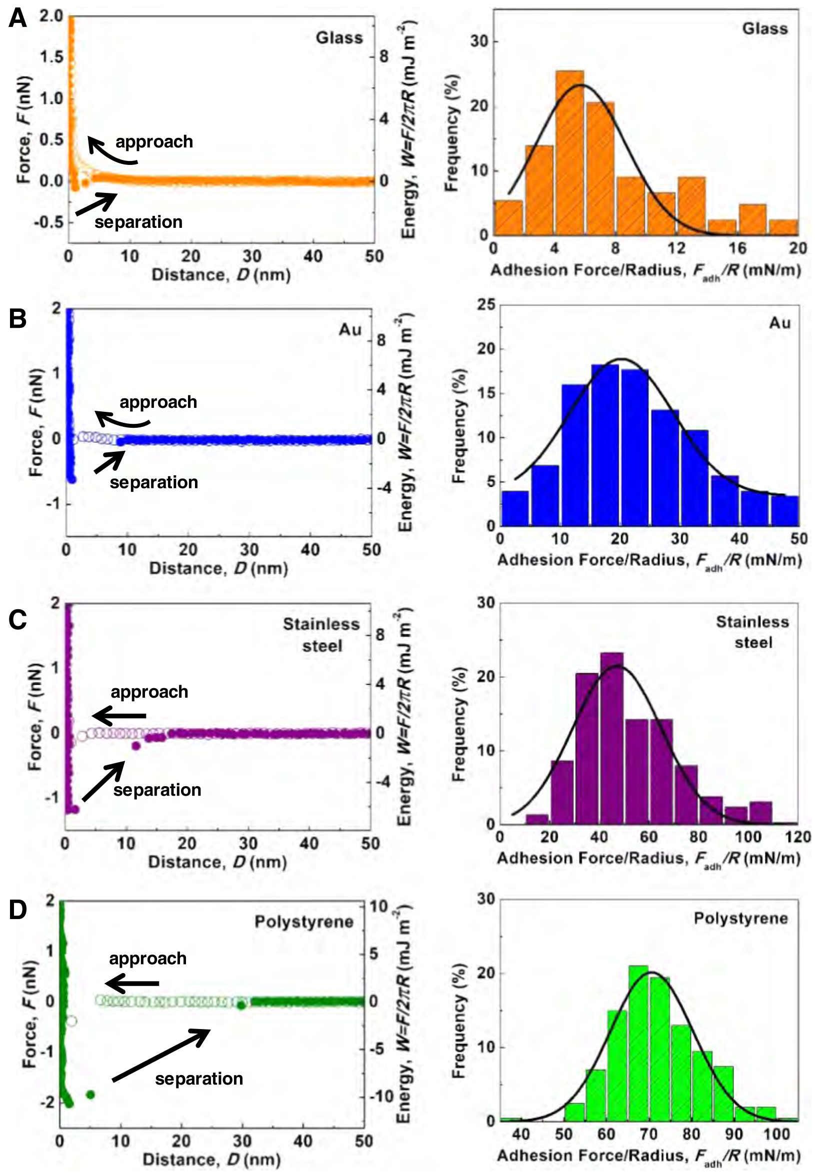

Figure 4. Force−distance profiles between the spike protein-functionalized AFM tip and different solid substrates in 10 mM NaCl solution at pH 5.6 and 23 °C (approach data: open symbols and separation data: solid symbols) and the histogram of normalized adhesion force F_{adh}/R with the fitted Gaussian distribution: (A) glass, (B) gold, (C) SS, and (D) PS.

repulsive force during approach. Zeta potential measurements (Table S1) show that the isoelectric point of spike protein is below pH 5.6, while glass always carries the negative charges under the testing condition;[35] therefore, the measured repulsion is attributed to the repulsive electrical double layer (EDL) force. Upon separation (orange solid symbols), an interfacial adhesion is occasionally detected, probably contributed by the short-range hydrogen bonding between the side chains of amino acids (e.g., lysine, asparagine, and tyrosine) in the spike protein and glass surface. For gold (blue symbols) and SS (purple symbols), in addition to the long-range EDL repulsion, an attractive force starting from a separation distance of 3−4 nm is measured during approach because of the relatively strong van der Waals (VDW) force for metal-involved systems.[36] The adhesion force for gold and SS during separation is mainly induced by the strong coordination interaction between metal atoms and specific sites of spike protein (e.g., carboxyl group and aromatic ring of amino acids),[37] which is evidently stronger than the adhesion force measured for glass. The spike protein−PS interaction (green symbols) exhibits a strong attraction during approach that induces a "jump-in" phenomenon at ∼7 nm. Evidently, the attraction measured is stronger and has a longer range than VDW contribution and considered as the hydrophobic interaction between hydrophobic PS and hydrophobic moieties of spike protein (e.g., hydrophobic side chains of tyrosine). Such strong hydrophobic interaction enables intimate contact between the spike protein and PS, which correspondingly triggers a considerable adhesion during separation.

Based on the adhesion forces measured during separation (300−500 events), the histograms of normalized adhesion force, F_{adh}/R, are established and fitted by the Gaussian distribution (solid curve) as shown in Figure 4 (right). The magnitude of average normalized adhesion force follows the trend: glass (5.71 ± 0.36 mN/m) < gold (20.23 ± 0.66 mN/

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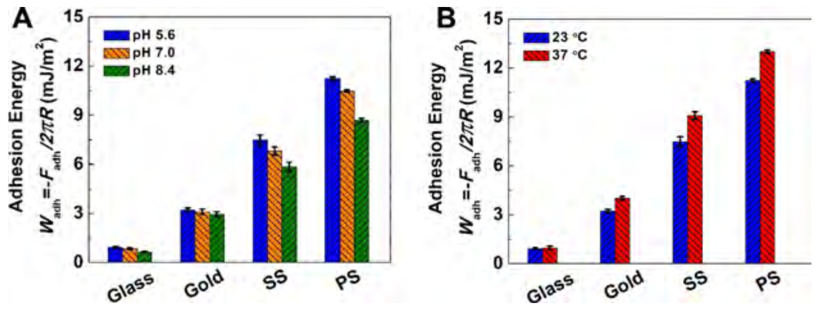

Figure 5. Average adhesion energy $W_{adh} = -F_{adh}/2\pi R$ between the spike protein-functionalized AFM tip and solid surfaces, including glass, gold, SS, and PS, in 10 mM NaCl solution (A) at 23 °C under the effect of pH: 5.6, 7.0, and 8.4 and (B) at pH 5.6 under the effect of temperature: 23 and 37 °C.

m) < SS (47.02 ± 1.89 mN/m) < PS (70.58 ± 0.63 mN/m). Based on the Derjaguin−Muller−Toporov model $W_{adh} = -F_{adh}/2\pi R$ that correlates the normalized adhesion force (F_{adh}/R) of a sphere on a plane with the adhesion energy per unit area (W_{adh}) of two flat surfaces of the same materials,[36,38−40] the average adhesion energy is obtained as ∼0.91 mJ/m^2 for glass, ∼3.22 mJ/m^2 for gold, ∼7.48 mJ/m^2 for SS, and ∼11.23 mJ/m^2 for PS, respectively. The adhesion energy between the spike protein and these substrates could be contributed by surface interactions involving hydrogen bonding, hydrophobic interaction, and coordination interaction.

Glass can form hydrogen bonding with the side chains of amino acids in spike protein. Considering the theoretically simulated hydrogen bond energy for protein in solution (2.09−6.28 kJ/mol)[41] and the measured adhesion energy (0.91 mJ/m^2 for protein−glass), there only exists one effective hydrogen bond between spike protein and glass within an area of over 2.76 nm × 2.76 nm. The possible reason for such a low bonding efficiency is that the entropic (or steric) effect restricts the optimization of spike protein toward the preferential formation of hydrogen bonds.[42] As compared to the spike protein−glass interaction, the adhesion energy mainly arising from hydrophobic interaction of PS with spike protein is even 10 times stronger, revealing the dominant role of hydrophobic interaction in modulating the adhesion of spike protein (or stickiness of new coronavirus), particularly under the nano-confined regime. The hydrophobic interaction energy is expressed as $W_{HB} = 2\gamma\exp(-D/D_0)$ for the symmetric cases (e.g., PS−PS interaction in water), where γ is the interfacial energy, D_0 is the decay length of hydrophobic interaction, and D is the separation distance.[36,43] From the thermodynamic perspective, $W_{HB} \approx 2\gamma = 79$ mJ/m^2 for PS−PS interaction as D approaches zero.[36,43] It is noted that the adhesion energy of ∼11.23 mJ/m^2 for the spike protein−PS interaction is approximately one seventh of the adhesion energy of PS−PS interaction, which indicates that the hydrophobic moiety of spike protein that contributes to the hydrophobic interaction with PS only accounts for a small portion of the entire protein molecule. Metals interacting with spike protein display the adhesion energies that are evidently stronger than those for glass but relatively weaker than those for PS. It is known that metals could form a coordination complex with specific binding sites of protein, and the magnitude of metal−protein binding energy is dependent on the binding capability of the metal and the number of binding sites on the protein. Thus, metals with relatively weaker binding capability (e.g., gold as compared to SS) exhibit smaller adhesion energy, while the relatively weaker adhesion energies for gold and SS, as compared with that for PS, are likely due to the limited metal−protein binding sites.

2.3. Effect of Environmental Factors on Adhesion. The respiratory droplet normally displays a pH value ranging from 5.6 to 8.4, and the environmental temperature is also varied for different seasons and regions, which could affect the intermolecular interactions of spike protein and thus alter its adsorption behavior and the stickiness of the new coronavirus on substrates. To further unravel the impact of environmental conditions on the interaction mechanism of spike protein, the adhesion energy of spike protein with solid surfaces was measured in 10 mM NaCl solution at different pH values (Figure 5A) and temperatures (Figure 5B). As shown in Figure 5A (with the histogram shown in Figure S3), with pH increasing from 5.6 to 7.0 and 8.4, the adhesion energy slightly drops from ∼0.91 mJ/m^2 to ∼0.84 and ∼0.65 mJ/m^2 for glass as well as from ∼3.22 mJ/m^2 to ∼3.09 and ∼2.93 mJ/m^2 for gold. In contrast, the adhesion energy for the SS and PS cases is more pH-dependent. In particular, the adhesion energy for SS is dramatically reduced from ∼7.48 mJ/m^2 at pH 5.6 to ∼6.80 mJ/m^2 at pH 7.0 and ∼5.84 mJ/m^2 at pH 8.4, while the adhesion energy for PS also significantly decreases from ∼11.23 mJ/m^2 at pH 5.6 to ∼10.47 mJ/m^2 at pH 7.0 and ∼8.69 mJ/m^2 at pH 8.4. Because spike protein, glass, gold, SS, and PS all carry negative charges over the pH range investigated,[35,44,45] it is reasonable that the electrostatic repulsion is strengthened with the increase of pH, which ultimately weakens the adhesion energy and triggers the pH-mediated adhesion.

The role of temperature in altering the adhesion energy is shown in Figure 5B (with the histogram shown in Figure S4). As the temperature increases from 23 to 37 °C, the adhesion energy for glass almost remains unchanged (0.91−0.95 mJ/m^2), while the adhesion energy dramatically increases from ∼3.22 to ∼4.01 mJ/m^2 for gold and from ∼7.48 to ∼9.08 mJ/m^2 for SS. It is known that enhanced temperature could improve the binding activity of metal−protein interaction, thereby increasing the adhesion energy. It is known that the entropy-driven hydrophobic interaction is also temperature-dependent.[46] The possible conformational rearrangement in spike protein and PS upon heating results in increased entropy, which is the main reason the adhesion for spike protein−PS interaction increases from ∼11.23 mJ/m^2 at 23 °C to ∼13.00 mJ/m^2 at 37 °C. Although the overall trend of average adhesion energy "glass < gold < SS < PS" remains the same regardless of pH and temperature, the environmental factors to a certain degree could contribute to the alternation of protein adhesion, suggesting that the new coronavirus is more readily to stick to solid materials in an acidic environment and at a high temperature.

2.4. Adhesion of Spike Protein with Different Materials. In addition to glass, gold, SS, and PS, we also select a variety of other inorganic, metallic, and polymeric materials for probing their intermolecular forces with spike protein in droplet environments. Figure 6 summarizes the normalized adhesion force and average adhesion energy between the spike protein-functionalized AFM tip and a variety of solid materials in 10 mM NaCl solution at pH 5.6 and 23 °C (with the histogram shown in Figure S5). The hydrophilic inorganic surfaces, such as glass and silica, exhibit the lowest adhesion energy (0−1 mJ/m^2), revealing the negligible role of hydrogen bonding in the adhesion of spike protein. On the other hand, hydrophobic polymeric materials, including PS, polyethylene plastic, and even low-surface-energy polytetrafluoroethylene (PTFE), can achieve very high adhesion energy (6−11 mJ/m^2), which indicates the significance of hydrophobic interaction in the adhesion of spike protein. Because the proteins binding to the substrate surfaces rely on their hydrophilicity, the adhesion results demonstrate that the spike protein preferentially binds to hydrophobic surfaces as compared to hydrophilic cases. It is noted that the interaction mechanism between the spike protein and hydrophobic surfaces in aqueous solution is different from that in air. The adsorption of particles or droplets onto hydrophobic commercial masks in air could be mainly due to electrostatic attraction, while the major contribution of the interaction mechanism between the spike protein and hydrophobic surfaces in aqueous solution is considered as hydrophobic interaction. Because both the spike protein and hydrophobic surfaces carry the overall negative charges, the overall electrostatic interaction between spike protein and hydrophobic surfaces in aqueous solution is repulsive. However, spike protein could display positively charged sites and negatively charged sites. The contribution of electrostatic attraction between the positively charged sites of spike protein and polymer surfaces could not be ruled out. For the metals, the adhesion energy with spike protein lies in a wide range from 2 to 9 mJ/m^2, which relies on the binding capability of metals with spike protein. In the metallic materials investigated, copper exhibits the strongest adhesion with spike protein followed by SS, gold, and alumina foil.

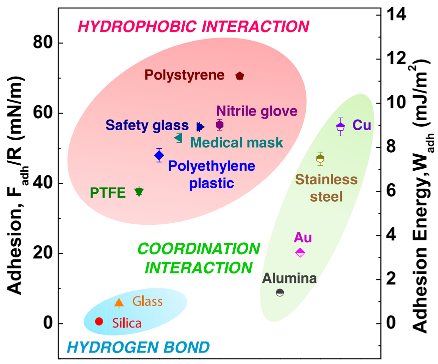

Figure 6. Normalized adhesion force F_{adh}/R and average adhesion energy $W_{adh} = -F_{adh}/2\pi R$ between the spike protein-functionalized AFM tip and a variety of solid materials in 10 mM NaCl solution at pH 5.6 and 23 °C.

It is worth mentioning that the oriented spike protein could be a perfect molecular model for the experimental design; meanwhile, the surrounding temperature, pH, saline concentration, and/or shrinkage because of dehydration could all affect the virion shape and size, as well as the orientation of spike protein on surfaces. In this work, despite the random orientation of the S1 subunits on AFM tips (the exposed subunits of spike protein), over 600 force measurement events have been collected for each S1-surface pair, and the statistical plots can reflect the trend of virion adhesion on various surfaces. It is noted that the real contact region for the force measurements between an AFM tip (a radius of 25−35 nm) and a substrate surface is only at the nanoscopic level, and thus, the influence of surface roughness on the adhesion energy has been dramatically reduced. The uniform distribution of adhesion forces, which can also be reflected from the histogram of adhesion forces (Figures S3−S5), ensures the accuracy of force measurements. It is also noted that the rough alumina foil and copper foil lie in a similar regime of adhesion energy with smooth SS and gold coating (metals), while the rough nitrile glove, safety glass, medical mask (polypropylene), and polyethylene plastic lie in a similar region with smooth PS and PTFE surfaces (hydrophobic polymers).

It is known that the interfacial adhesion of solid materials can be mediated by tuning their surface properties.[47−51] Because the surface hydrophilicity of materials plays an important role in their interactions with the spike protein, it is reasonable to conclude that glass-based materials (e.g., windows, mirrors, glass doors, and glass screens) exhibit relatively low stickiness for the new coronavirus compared to the plastics and fabrics. Nevertheless, the stickiness of the new coronavirus on glass can become strong once the glass is contaminated by organics. It is worth noting that the commonly used personal protective equipment (PPE), including medical masks (polypropylene), safety glass, and nitrile gloves, also displays very high adhesion energy (6−11 mJ/m^2), which could be altered by applying the superhydrophilic or superhydrophobic coatings. In addition, the addition of alcohol (e.g., methanol, ethanol, and isopropyl alcohol) into aqueous media is known to suppress the hydrophobic interaction,[52−54] and thus, the new coronavirus stuck on plastic, fabric, and PPE could be washed off by the alcohol even if the alcohol is insufficiently concentrated to kill the virus. Similarly, the surfactant-containing aqueous solution is also an efficient approach to eliminate the hydrophobic interaction and remove the new coronavirus.

The adhesion of spike protein with solid materials could be an important contributor to the substance-dependent persistence of SARS-CoV-2 virions. There were few reports on the persistence of SARS-CoV-2 on typical substrates under a water-based environment,[9,10] which limit the data availability at this time. The persistence of SARS-CoV-2 was reported to be 4 h for copper, 2 days for SS, and 3 days for plastic.[9] Based on our studies, the adhesion energy of spike protein interacting with copper, SS, and plastic is 8.93, 7.48, and 7.64 mJ/m^2, respectively. It has been reported that the adhesion could lead to the compression of virus, which disrupts the 3D structure of proteins and ultimately inactivates the virus.[55,56] Thus, the higher adhesion for copper could be one contributor to the shorter persistence of coronavirus on copper. Although the adhesion for SS and plastic is similar, other factors such as the complex metal antiviral mechanism could play a critical role in the persistence of coronavirus.

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3. CONCLUSIONS

In this work, we systematically quantified the intermolecular interactions between spike protein (the corona-like component of the SARS-CoV-2 virion) and a series of inanimate surfaces (e.g., glass, plastics, metals, and fabrics) under a simulated respiratory droplet environment at the nanoscale. The environmental factors, including pH and temperature, were observed to affect the spike protein binding. According to the quantitative AFM force measurements, the adhesion of spike protein was (i) very weak on hydrophilic inorganics (e.g., glass) because of the lack of substantial hydrogen bonding formation, (ii) relatively high on metal surfaces because of the strong coordination interaction, and (iii) very strong on hydrophobic polymers (e.g., PS, PTFE, plastics, and PPE), attributed to the hydrophobic interaction. The alternation of surface hydrophilicity of materials or addition of chemical additives could effectively modulate the hydrophobic interaction and even tune the interaction mechanism between hydrogen bonding and hydrophobic interaction, which would be a promising strategy to mediate the adhesion of spike protein and stickiness of new coronavirus. Additionally, the adhesion of spike protein with solid materials could be an important contributor to the substance-dependent persistence of SARS-CoV-2 virions. The developed protein−surface model database for SARS-CoV-2 with respect to their intermolecular and surface interactions will provide scientific guidance for developing effective preventive strategies to prohibit virus transmission via surface contaminations.

4. EXPERIMENTAL METHODS

4.1. Materials. Sodium chloride (NaCl, ACS reagent grade), hydrochloric acid (HCl, ACS reagent grade), and sodium hydroxide (NaOH, ACS reagent grade) were purchased from Fisher Scientific. 11-Mercaptoundecanoic acid ($HS(CH_2)_{10}COOH$, 98%), N-hydroxysuccinimide (NHS, $C_4H_5NO_3$, and 98%), N-(3-Dimethylaminopropyl)-N′-ethylcarbodiimide hydrochloride (EDC, $C_8H_{17}N_3{\cdot}HCl$, 98%), and phosphate buffered saline (pH 7.4) were purchased from MilliporeSigma. COVID-19 spike S1 coronavirus active protein (purity >90% by sodium dodecyl sulfate polyacrylamide gel electrophoresis and molecular weight of 120 kDa) was purchased from MyBioSource, Inc. All the chemicals were used as received without further purification, and all aqueous solutions were prepared using Milli-Q water (Millipore deionized, 18.2 MΩ·cm resistivity).

4.2. Preparation of the Spike Protein-Functionalized AFM Probe and Solid Substrates. Spike protein solution was prepared by dissolving 0.1 mg COVID-19 spike S1 coronavirus active protein in 2 mL PbS buffer (pH 7.4), and the prepared spike protein solution was stored at −20 °C. The gold-coated AFM probes were cleaned by UV/ozone treatment for 30 min and then immersed in 10 mM 11-mercaptoundecanoic acid in ethanol overnight. After the self-assembly via the Au−S bonding, the COOH-functionalized AFM probes were washed with ethanol to remove the physisorbed thiol, dried with high-purity nitrogen, and then immersed in an aqueous solution containing 20 mM NHS and 40 mM EDC to activate the COOH functional groups on AFM probes. After 1 h, the NHS/EDC-activated AFM probes were immersed in 0.05 mg/mL spike protein in PbS buffer for 2 h to prepare the protein-functionalized AFM probes. Thereafter, the protein-functionalized AFM probes were washed with Milli-Q water, dried with high-purity nitrogen, and immediately used for characterization and force measurements.

A glass sheet and a silicon wafer (with an oxidation layer) were washed with ethanol and water three times, dried with high-purity nitrogen, and then cleaned by UV/ozone treatment for 10 min. Gold-coated silicon wafers were cleaned with a typical RCA procedure with slight modifications.[57,58] The gold wafer shards were first sonicated in methanol for 5 min, dried with high-purity nitrogen, and immersed in RCA1 solution (Milli-Q water:30% NH_4OH:30% H_2O_2 = 6:1:1 volume ratio) and RCA2 solution (Milli-Q water:37.5% HCl:30% H_2O_2 = 6:1:1 volume ratio) for 5 min at 80 °C. The gold wafer shards were dried and went through argon plasma to further remove residues. Alumina and copper were obtained directly from the aluminum foil and copper foil, which were cleaned with ethanol and water three times. A QSX 304 SS sensor (SS2343, Biolin Scientific) was cleaned by immersing the sensor in 1% Hellmanex II for 30 min, rinsed with Milli-Q water, and dried with high-purity nitrogen. The PS surface was prepared by spin coating PS solution (0.5 wt % in toluene) on silicon wafer at 2000 rpm, and the spin-coated surface was dried under vacuum overnight to completely remove the residual solvent. The plastic bottle of Nestlé pure life natural spring water and a Uline medical mask, which are ubiquitous in daily life and have drawn much attention, were selected as the representative samples of the polyethylene surface and polypropylene surface, respectively. PTFE, polyethylene plastic, medical mask (polypropylene), safety glass, and nitrile glove were cleaned with ethanol and water three times. All the samples were immediately used for the force measurements after the cleaning procedure.

4.3. Characterization. Several selected solid surfaces before and after spike protein adsorption were characterized by AFM topography imaging. The COOH-functionalized and protein-functionalized AFM probes were subjected to AFM imaging, contact angle measurements, HIM, and AES. The imaging of the solid surfaces and the cantilever base of AFM probes was performed using the tapping mode of a Dimension Icon AFM (Bruker, Santa Barbara, CA, USA). Typically, the functionalized gold-coated AFM probe was glued onto the AFM scanning stage by double-sided tape, and then a silicon AFM probe was used to perform the imaging on the cantilever base of the AFM probe. The water contact angle on the cantilever base of AFM probes was measured using the sessile drop method with a contact angle goniometer (ramé-hart instrument Co., NJ, USA). The average water contact angle was reported based on the measurements of few microliter water droplets on at least three independently prepared AFM probes. It is noted that AFM imaging and contact angle measurements were difficult to conduct directly on the AFM cantilever and AFM tip because of their small size, and thus, these two tests were conducted on the AFM cantilever base of the AFM probe with the same material composition as the AFM cantilever and tip. HIM of AFM tips was conducted using a Zeiss Orion NanoFab (Carl Zeiss AG, Oberkochen, Germany) equipped with the He beam, while AES of AFM tips was performed using a JAMP-9500F Field Emission Auger Microprobe (JEOL, MA, USA) equipped with a Shottky field emitter, which produces an electron probe diameter of 3−8 nm.

4.4. Helium Ion Microscopy. HIM was performed using the Zeiss Orion NanoFab (Zeiss Peabody, MA, USA) tool at ProVIS−Centre for Chemical Microscopy at the Helmholtz−Centre for Environmental Research, Leipzig, Germany. For imaging, the landing energy of the ions was set to 25 keV, and a 10 μm aperture was used. By variation of the spot-control parameter (values between 4 and 6), the ion-beam current was adjusted to about 1.0 pA measured at the blanker of the tool. For image acquisition, secondary electrons were detected using an Everhard−Thornley detector. Typically dwell time and line-averaging were set to 0.2 μs and 64, respectively. All micrographs were acquired at a pixel resolution of 2048 × 2048. To achieve a more 3D impression of the images, the stage was tilted by 45°. During imaging, the flood-gun was switched on and used in line-flooding mode such that charging effects could be avoided. Prior to imaging, the resolution of the tool was checked to be better than 3 nm using edge contrast on an empty sample holder.

4.5. AFM Force Measurements. The interaction forces between the protein-functionalized AFM tips and a variety of solid materials were measured under simulated respiratory droplet conditions using an MFP-3D AFM (Asylum Research, Santa Barbara, CA, USA). Typically, the AFM tip was positioned over solid substrates, following which the AFM tip was driven at a loading rate of 0.1 μN/s to approach the substrates until a maximum force load of 5 nN was achieved. After 1 s contact, the AFM tip was retracted from the substrates at a loading rate of 0.1 μN/s. The approach−retraction force measurements were conducted for 300−500 cycles on several different samples for the same material and several different locations for the same sample, based on which the distribution of adhesion forces was reported.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsami.0c16800.

AFM topography images (2×2 μm^2), high-resolution HIM, histogram of normalized adhesion force, and zeta potential of spike protein subunit S1 (PDF)

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Notes

The authors declare no competing financial interest.

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HEALTH AND SCIENCE

Virus that causes Covid-19 can survive for 28 days on common surfaces, research says

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KEY POINTS

The findings from Australia's national science agency, the CSIRO, appeared to show that SARS-CoV-2 can survive on surfaces for significantly longer than many had anticipated.

The study, which was peer reviewed, also found the virus responsible for the Covid-19 disease was "extremely robust" at lower temperatures, remaining infectious for a longer period when compared to higher temperatures.

The WHO recommends cleaning hands thoroughly and often, and avoiding touching your eyes, mouth and nose.

A worker cleans the seats in a cinema hall as part of preparations for a possible reopening after the government eased the lockdown restrictions previously imposed due to the Covid-19 coronavirus, in Chennai on October 8, 2020.

Australian researchers said Monday, reinforcing the importance of effective cleaning and handwashing to curb the spread of Covid-19.

The findings from Australia's national science agency, CSIRO, appeared to show that SARS-CoV-2 can survive on surfaces for significantly longer than many had anticipated.

The study, which was peer reviewed, also found the virus was "extremely robust" at lower temperatures, remaining infectious for a longer period when compared with higher temperatures.

The researchers tested the survival rates of the virus, dried in an artificial mucous solution, at three temperatures on six common surface areas. All the experiments were carried out in the dark, however, since UV light has already been shown to kill the virus.

VIDEO 04:46

Covid-19 virus we're seeing is not the same one we saw in March: Holy Name Medical Center CEO

The coronavirus is mostly spread from person to person via small droplets from the nose or mouth, which are expelled when an infected person coughs, sneezes or speaks.

However, the World Health Organization has also said it is possible to become infected when these droplets land on objects and surfaces that are touched by people who may then touch their eyes, nose or mouth.

To protect yourself, the United Nations health agency recommends that people keep a distance of at least 1 meter from others, and disinfect frequently touched surfaces. It also recommends cleaning hands thoroughly and often, and avoid touching your eyes, mouth and nose.

More than 37.4 million people worldwide have contracted the coronavirus, killing 1.07 million people, according to data

CSIRO researchers tested SARS-CoV-2 on several surfaces at 20 degrees Celsius, 30 degrees Celsius, and 40 degrees Celsius, with the relative humidity kept at 50%. The surfaces used in the study were stainless steel, glass, vinyl, paper and polymer banknotes, and cotton cloth.

A droplet of fluid containing the virus at concentrations similar to levels observed in infected patients was dried on multiple small test surfaces and left for up to 28 days, the researchers said.

The study, published in Virology Journal, found the virus survived on smooth surfaces, such as stainless steel, glass, vinyl, and paper polymer banknotes, for 28 days when kept at 20 degrees Celsius (68 F), which is roughly room temperature, and in the dark.

The virus stopped being infectious within 24 hours on some surfaces when tested at 40 degrees Celsius (104 F). At 30 degrees Celsius (80 F), the virus' viability fell to three days on cotton and vinyl, and seven days on glass, steel and polymer banknotes.

A worker cleans the classes to prepare the school before face-to-face teaching at certain classes on October 10, at Taybe Schools in Khan Yunis, Gaza on October 04, 2020.
Mustafa Hassona | Anadolu Agency via Getty Images

"These findings demonstrate SARS-CoV-2 can remain infectious for significantly longer time periods than generally considered possible," the study authors said, noting further research on the number of virus particles that can cause infection was still necessary.

The researchers said that whether virus particles on a surface could infect someone was dependent on several conditions and the time it takes for viruses to naturally inactivate was also dependent on many factors.

remains viable. Environmental conditions such as temperature, exposure to sunlight and humidity also play a part," they said.

CSIRO confirmed to CNBC that what was found was a live viable virus, rather than SARS-CoV-2 RNA or virus fragments.

One previous laboratory test published in The Lancet medical journal found that SARS-CoV-2 could survive for three days on banknotes and glass, and up to six days on plastic and stainless steel.

By comparison, the influenza A virus has been found to survive on surfaces for 17 days.

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Virology Journal

RESEARCH
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The effect of temperature on persistence of SARS-CoV-2 on common surfaces

Shane Riddell*, Sarah Goldie, Andrew Hill, Debbie Eagles and Trevor W. Drew

Abstract

Background: The rate at which COVID-19 has spread throughout the globe has been alarming. While the role of fomite transmission is not yet fully understood, precise data on the environmental stability of SARS-CoV-2 is required to determine the risks of fomite transmission from contaminated surfaces.

Methods: This study measured the survival rates of infectious SARS-CoV-2, suspended in a standard ASTM E2197 matrix, on several common surface types. All experiments were carried out in the dark, to negate any effects of UV light. Inoculated surfaces were incubated at 20 °C, 30 °C and 40 °C and sampled at various time points.

Results: Survival rates of SARS-CoV-2 were determined at different temperatures and D-values, Z-values and half-life were calculated. We obtained half lives of between 1.7 and 2.7 days at 20 °C, reducing to a few hours when temperature was elevated to 40 °C. With initial viral loads broadly equivalent to the highest titres excreted by infectious patients, viable virus was isolated for up to 28 days at 20 °C from common surfaces such as glass, stainless steel and both paper and polymer banknotes. Conversely, infectious virus survived less than 24 h at 40 °C on some surfaces.

Conclusion: These findings demonstrate SARS-CoV-2 can remain infectious for significantly longer time periods than generally considered possible. These results could be used to inform improved risk mitigation procedures to prevent the fomite spread of COVID-19.

Keywords: Environmental stability, SARS-CoV-2, COVID-19, Survivability

Background

The World Health Organization (WHO) declared SARS-CoV-2 a pandemic on 11th March 2020 and as at the 7th August 2020, there have been over 18.8 million confirmed cases with more than 708,000 reported deaths from SARS-CoV-2 [1].

The transmission of SARS-CoV-2 appears to be primarily via aerosols [2–4] and recent studies have shown that SARS-CoV-2 is able to remain infectious in airborne particles for greater than 3 h [5, 6]. The role of fomites in the current pandemic is yet to be fully determined, although they have been suggested as a potential mode of transmission [7] also reflected by the strong focus on hand-washing by WHO and national control schemes. Broadly, viruses have been shown to be readily transferred between contaminated skin and a fomite surface [8], with high contact surfaces such as touchscreens on mobile phones, bank ATMs, airport check-in kiosks and supermarket self-serve kiosks all acting as fomites for the transmission of viruses [9]. Fomite transmission has previously been shown to be a highly efficient procedure, with transmission efficiencies of 33% for both fomite to hand and fingertip to mouth transfer for bacteria and phages [10]. With the high efficiency of fomite transfer, the persistence of SARS-CoV-2 on environmental surfaces is therefore a critical factor when considering the potential for fomite transmission for this virus. Currently, there are conflicting reports on the survivability of SARS-CoV-2, with data ranging from 3 to 14 days at room temperature for a single surface type, stainless steel

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[5, 11]. This study aims to provide environmental stability data for SARS-CoV-2 under controlled temperature and humidity conditions for a range of common surfaces.

Methods

Virus isolate

The SARS-CoV-2 isolate (*Betacoronavirus/Australia/SA01/2020*) used in this study was kindly supplied by the Peter Doherty Institute (Victoria, Australia) on behalf of South Australian Health (South Australia). The virus was passaged four times through Vero E6 cells (ATCC CRL-1586) in Dulbecco's Modified Eagle Medium (DMEM) supplemented with Penicillin, Streptomycin, Fungizone and 10% fetal calf serum and pelleted via ultracentrifugation at 100,000 $\times g$ for 90 min. The virus was resuspended in phosphate buffered saline (PBS) with 1% bovine serum albumin (BSA) and stored at −80 °C. The virus stock was titrated on Vero E6 cells and the $TCID_{50}$ was determined to be 4.97×10^7/mL by the Spearman–Karber method [12, 13].

All work with infectious SARS-CoV-2 was conducted in the high containment laboratory (Biosafety level 4) at the Australian Centre for Disease Preparedness.

Surfaces

Australian polymer bank notes, de-monetised paper bank notes and common surfaces including brushed stainless steel, glass, vinyl and cotton cloth were used as substrates in this study. Both polymer and paper banknotes were included in the study to gather information on the possible roles of note based currency in general for the potential for fomite transmission. Stainless steel is used in kitchen areas and public facilities and is the substrate used in some disinfectant testing standards [14, 15]. Glass was chosen due to its prevalence in public areas, including hospital waiting rooms, public transport windows and shopping centres, and high contact surfaces such as mobile phone screens, ATMs and self-serve check-out machines. Vinyl is a common substrate used in social settings, tables, flooring, grab handles on public transport, as well as mobile phone screen protector material. Cotton was chosen as a porous substrate, often found in clothing, bedding and household fabrics.

All surfaces were prepared by cutting into approx. 1–1.5 cm^2 coupons, non-porous surfaces were disinfected prior to use by washing in a mild detergent (Beckman 555), rinsing in distilled water and then immersing in 80% v/v ethanol. Paper bank notes (in very good condition) were heated in a dry oven to 75 °C for 1 h to reduce bacterial/viral contamination. The 100% cotton cloth was steam sterilised prior to use.

Following preparation, all surfaces were placed into a petri dish and allowed to dry in a class II biological safety cabinet (BSCII) at room temperature and humidity prior to inoculation.

Surface inoculation and sampling

Stock virus was diluted in a defined organic matrix, consisting of bovine serum albumin (BSA), mucin and tryptone, following international standard ASTM E2197 [15], designed to mimic the composition of body secretions. Briefly, 360 µL of virus stock was added to 160 µL of a solution consisting of 2.5 mg/mL BSA, 3.5 mg/mL tryptone and 0.8 mg/mL mucin. Ten microlitres of the resulting suspension (final concentration of 3.38×10^5/10 µL) was inoculated onto the centre of the coupon and allowed to dry in a BSCII for 1 h. Once dry, the coupons were placed into a humidified climate chamber (Memmert HPP110) for specified time points. Samples were incubated in the dark to limit any effect light might have on viral decay. A single humidity set point (50% relative humidity) was maintained for each of three separate temperature experiments (20 °C, 30 °C, 40 °C). For the 20 °C and 30 °C temperature experiments, three replicates of each surface type were inoculated and sampled at the following time points; 1 h, 1 day, 3 days, 7 days, 14 days, 21 days and 28 days post inoculation. For the 40 °C experiment, triplicate samples were inoculated for the following time points; 1 h, 1 day, 2 days, 3 days, 4 days, and 7 days.

For non-porous surfaces, for each replicate, virus was eluted in 2 × 115 µL volumes of DMEM with repeated pipetting then titrated individually, in quadruplicate wells on a 96-well plate. For recovery from cotton cloth, inoculated swatches of the cloth were individually submersed in 500 µL DMEM and pipetted repeatedly for at least 1 min before 230 µL of the recovered eluent from each swatch was titrated separately, in quadruplicate. Suspensions of Vero E6 cells (3×10^5/mL) were added to the wells and the plates were incubated for 3 days at 37 °C with 5% CO_2. Wells were scored for the presence of cytopathic effect and titres calculated using the Spearman–Karber method.

Statistical analysis

Data analysis (regression analysis) and graphical representations were performed using GraphPad Prism (version 5). Decimal reduction time (D value—time at which there was a one log/90% reduction in titre) was calculated using

$$D = \frac{t}{\left(\log N_0 - \log N_f\right)}$$

Z-values (temperature change required to achieve a tenfold (i.e. 1 $\log_{10}$) change in the D value) was calculated by plotting log D values against temperature. Calculated using:

$$Z = (t_2 - t_1)/(\log D_1 - \log D_2)$$

The half-life of each surface was calculated using;

$$t_{1/2} = \frac{log_{10}2}{k}$$

Results

At 20 °C, infectious SARS-CoV-2 virus was still detectable after 28 days post inoculation, for all non-porous surfaces tested (glass, polymer note, stainless steel, vinyl and paper notes). The recovery of SARS-CoV-2 on porous material (cotton cloth) was reduced compared with most non-porous surfaces, with no infectious virus recovered past day 14 post inoculation. The majority of virus reduction on cotton occurred very soon after application of virus, suggesting an immediate adsorption effect. The calculated D values for surfaces at 20 °C ranged from 5.5 days for cotton to 9.1 days for paper notes and are shown in Table 1.

At 30 °C, infectious virus was recoverable for 7 days from stainless steel, polymer notes and glass, and 3 days for vinyl and cotton cloth. For paper notes, infectious virus was detected for 21 days, although there was less than 1 log of virus recovered for both 14 day and 21 day time points. The D values for surfaces at 30 °C ranged from 1.4 days for vinyl to 4.9 days for paper notes (Table 1).

At 40 °C, virus recovery was significantly reduced compared to both 20 °C and 30 °C experiments. Infectious SARS-CoV-2 was not recovered past 24 h for cotton cloth and 48 h for all remaining surfaces tested. Greater than 4-log reduction (99.99% reduction from starting titre) was observed in less than 24 h at 40 °C on all surfaces. The D values for surfaces at 40 °C have been converted to hours as they were all less than 1 day, values ranged from 5 h for polymer notes to 10.5 h for vinyl (Table 1).

For each temperature and substrate material, the mean titre from three replicates of recovered virus was plotted against time, with standard deviations included. Linear regression was used to calculate a line of best fit. Plots showing virus survival on each substrate at the three temperatures investigated are shown in Fig. 1. Plots presenting this data grouping all substrates at each of the three temperatures are given in Fig. 2. Calculated D-value, Half Life and Z-value are presented in Table 1.

An additional table containing average titre and standard deviation for all substrates, time points and temperatures is available (See Additional file 1).

Table 1 Calculated D values (time taken to achieve a 90% reduction in titre) and half-life (time taken to achieve a 50% reduction in titre—in parentheses) for all surfaces at 20 °C, 30 °C and 40 °C

	D values (half-life)			Z value
	20 °C—days	30 °C—days	40 °C – hours	(°C)
Stainless steel	5.96 (1.80)	1.74 (12.6 h)	4.86 (1.5 h)	13.62
Polymer note	6.85 (2.06)	2.04 (14.7 h)	4.78 (1.4 h)	13.02
Paper note	9.13 (2.74)	4.32 (32.7 h)	5.39 (1.6 h)	12.43
Glass	6.32 (1.90)	1.45 (10.5 h)	6.55 (2.0 h)	14.65
Cotton	5.57 (1.68)	1.65 (11.0 h)	–	18.91
Vinyl	6.34 (1.91)	1.40 (10.1 h)	9.90 (3.0 h)	16.86

Calculated Z values (temperature shift required to alter D value by 1 log). No infectious virus was recovered for cotton cloth at 40 °C at 24 h, D values were not able to be calculated

Discussion

While the primary spread of SARS-CoV-2 appears to be via aerosols and respiratory droplets, fomites may also be an important contributor in transmission of the virus. Fomite transmission has been demonstrated as an important factor in the spread other coronaviruses such as porcine epidemic diarrhea virus [16], as well as being suspected for Middle East Respiratory Syndrome coronavirus [17], human coronavirus 229E and OC43 [18] and SARS-CoV-2 [7].

This study utilised a virus concentration of 4.97×10^7/mL diluted into a standard solution which mimics body fluid composition (final concentration of 3.38×10^5/10 µL inoculum), which equates to a cycle threshold (CT) value of 14.2, 14.0 and 14.8 for N gene, E gene and RdRp gene real time RT-PCR, respectively (unpublished data). Previous studies have shown some patients with high viral loads have recorded CT values of between 13 and 15 [19–21]. van Doremalen et al. [5] described their test material (10^5 $TCID_{50}$/mL) as having a CT of 20–22, which compared similarly to CTs reported from clinical patients [5, 22]. While the titre of virus utilised in this study is high it represents a plausible amount of virus that may be deposited on a surface.

The present study has demonstrated that in controlled conditions, SARS-CoV-2 at a starting viral load and in a fluid matrix equivalent to that typically excreted by infected patients, remains viable for at least 28 days when dried onto non-porous surfaces at 20 °C and 50% relative humidity. Research on the original SARS virus also showed recovery of infectious virus when dried on plastic for up to 28 days at room temperature and 40–50% RH [23]. Recent data published on SARS-CoV-2 survivability on hospital PPE observed viable virus up to 21 days post inoculation on both plastic and N95 mask material when

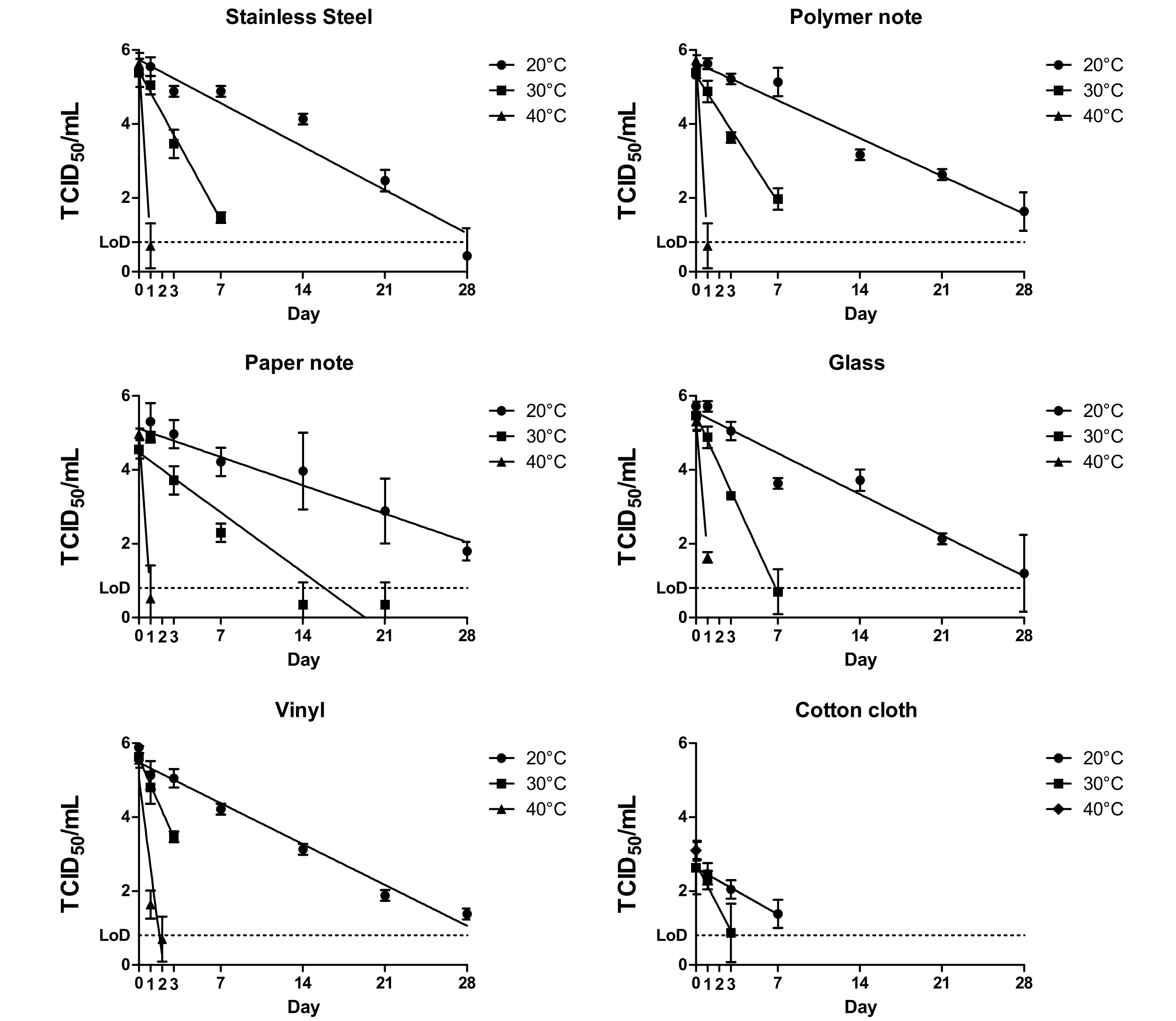

Fig. 1 Recovery of infectious SARS-CoV-2 for all surfaces and temperatures over time, $TCID_{50}$ data is plotted in $\log_{10}$ intervals. No infectious virus was recovered at 24 h at 40 °C for cotton cloth. LoD (limit of detection) is recorded as 0.8 Log_{10} $TCID_{50}$

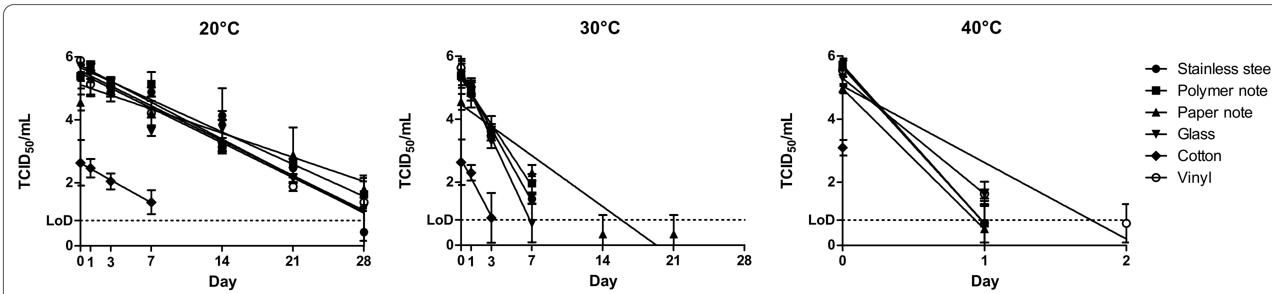

Fig. 2 Grouping of each surface for individual temperatures. Trend lines for 20 °C show similar slopes, including for cotton cloth (although a reduced recovery was observed). A single well of virus was observed for paper banknotes in one out of three replicates for both 14 days and 21 days.

held at room temperature [11], correlating with the data presented in this study. The persistence of SARS-CoV-2 on surfaces presented here and from Kasloff et al. [11] demonstrate significantly longer time points than previously published data for SARS-CoV-2 [5, 24]. These earlier studies reported recovery of infectious SARS-CoV-2 up to 3 days post inoculation and 4 days on non-porous surfaces, respectively. The titre of virus used in this study is at least 2 logs higher than used in the paper by van Doremalen et al. [5], which may account for the longer survivability. Work by Lai et al. has shown that stability of SARS virus was enhanced with higher concentrations [25]. Temperature and humidity are both critical factors in viral survivability with an increase in either being detrimental to virus survival [23, 26, 27]. Survivability on stainless steel coupons for transmissible gastroenteritis virus and murine hepatitis virus (both coronaviruses) was reduced with higher humidity's and temperature [28] and survivability of Middle East Respiratory Syndrome coronavirus also followed a similar pattern [29]. The higher humidity of ~ 65% RH used by Chin et al. [24] may explain the shorter persistence of virus when compared to the data presented here.

SARS-CoV-2 has been shown to be rapidly inactivated under simulated sunlight [30, 31]. To remove any potential decay by light sources, inoculated coupons were held in the dark for the duration of the experiment.

Decimal reduction (D value; the timetaken to reduce the titre by 1 log) for SARS-CoV-2 at 20 °C and 50%RH ranged from 5.57 to 9.13 days (average 6.82) for all surfaces tested. This data is significantly longer than modelling predications performed by Guillier et al. [32]. The data presented here was performed under controlled conditions with fixed temperatures, relative humidity, suspension matrix and in the absence of light, which may explain the enhanced survivability observed in this study. The generation of Z values at different temperatures also allows for extrapolation of D values for each surface at other temperatures. The Z value represents the temperature change required to alter the D value by 1 log. For stainless steel, the D value was determined to be 6.48 days at 20 °C, and the Z value of 13.62 °C, therefore if the temperature was to drop by 13.62 °C from 20 °C (i.e. to 6.38 °C), then the D value would increase from 6.48 days to over 64 days. This data could therefore provide a reasonable explanation for the outbreaks of COVID-19 surrounding meat processing and cold storage facilities. The data also supports the findings of a recent publication on survival of SARS-CoV-2 on fresh and frozen food [33].

Stainless steel is a common surface for study of viral stability, and has been used to study the persistence on a number of viruses such as Ebola virus, hepatitis virus, Influenza A and Coronaviruses [28, 34–37]. This study demonstrates that SARS-CoV-2 is extremely stable on stainless steel surfaces at room temperature (> 28 days at 20 °C/50%RH) however, is less stable at elevated temperatures (7 days at 30 °C and < 48 h at 40 °C). Recovery of infectious virus on stainless steel has been observed for murine hepatitis virus and transmissible gastroenteritis virus for up to 28 days albeit at a lower humidity 20%RH [28]. Interestingly, the same study showed survivability at 20 °C and 50%RH was significantly less (4–5 days), further suggesting the humidity may play a significant role in virus survival.

The persistence of virus on both paper and polymer currency is of particular significance, considering the frequency of circulation and the potential for transfer of viable virus both between individuals and geographic locations. While other studies have shown that paper notes harbour more pathogens than polymer notes [38], this data demonstrates that SARS-CoV-2 persists on both paper notes and polymer notes to at least 28 days at 20 °C, albeit with a faster rate of inactivation on polymer notes. Data presented in this study for banknotes is significantly longer than reported for other respiratory viruses such as Influenza A (H3N2) which demonstrated survival up to 17 days at room temperature [39]. It is also noted that prior to SARS-Cov-2 being declared a pandemic, China had commenced decontamination of its paper based currency, suggesting concerns over transmission via paper banknotes existed at the time [40, 41]. The United States and South Korea have also quarantined bank notes as a result of the pandemic [42, 43]. It is important to note that after 28 days, infectious SARS-CoV-2 was also recovered from stainless steel, vinyl and glass, suggesting survivability on paper or polymer banknotes was not very different from the other non-porous surfaces studied.

The persistence on glass is an important finding, given that touchscreen devices such as mobile phones, bank ATMs, supermarket self-serve checkouts and airport check-in kiosks are high touch surfaces which may not be regularly cleaned and therefore pose a transmission risk of SARS-CoV-2. It has been demonstrated that mobile phones can harbour pathogens responsible for nosocomial transmission [44], and unlike hands, are not regularly cleaned [45]. The data presented in this study correlates well with previously published data for Influenza A (H1N1) which recovered infectious virus up to 22 days at 22 °C and 7 days at 35 °C [37]. The persistence of SARS-COV-2 on glass and vinyl (both common screen and screen protector materials, suggest that touchscreen devices may provide a potential source of transmission, and should regularly be disinfected especially in multi-user environments.

The persistence of both SARS and SARS-CoV-2 on cotton has been demonstrated to be significantly shorter than on non-porous surfaces [11, 25]. The data presented here also shows a significant decrease in titre of recovered virus after just 1 h drying at room temperature (20 °C) the amount of virus recovered from cotton swatches was approximately 99% less than for comparable virus recovery time points for non-porous material. To verify the reduced recovery on cotton, virus was eluted 5 min after depositing on the cotton, as well as 1 h, the titre of recovered virus after 5 min was similar to that of non-porous surfaces (data not shown) suggesting the process of drying down was a significant factor for cotton material but not from the non-porous surfaces. Recovery of virus from porous substrates is also likely to be reduced compared to non-porous substrates due to adherence of the virus to the fabric fibres. When the rate of viral inactivation is considered over time rather than the gross reduction from the initial inoculum there is a more subtle difference from the non-porous surfaces. The D values for cotton at 20 °C, when compared other materials, are not significantly different from other substrates (eg. 5.6 days for cotton vs. 6.3 days for vinyl), and the slopes of the line which suggests the decay rate of virus is similar across substrates. This study also demonstrates significantly longer survival times on cotton (7 days) than previous reported [11, 25]. This difference could be due to differences in the types of cotton material used, the current study used 100% cotton cloth, while previous studies used either a cotton gown or cotton t-shirt.

Conclusions

The data presented in this study demonstrates that infectious SARS-CoV-2 can be recovered from non-porous surfaces for at least 28 days at ambient temperature and humidity (20 °C and 50% RH). Increasing the temperature while maintaining humidity drastically reduced the survivability of the virus to as little as 24 h at 40 °C. The persistence of SARS-CoV-2 demonstrated in this study is pertinent to the public health and transport sectors. This data should be considered in strategies designed to mitigate the risk of fomite transmission during the current pandemic response.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12985-020-01418-7.

Additional file 1. Table of average titre and standard deviation for recovery of infectious SARS-CoV-2 for all substrates, time points and temperatures.

Abbreviations

ASTM: American Society for Testing and Materials; ATM: Automatic teller machine; BSCII: Biological Safety Cabinet, Class 2; BSA: Bovine serum albumin; CO_2: Carbon dioxide; CT: Cycle threshold; DMEM: Dulbecco's Modified Eagle Medium; E gene: Envelope gene of SARS-CoV-2; N gene: Nucleocapsid gene of SARS-CoV-2; N95: Non-oil 95 mask; PBS: Phosphate buffered saline; RH: Relative humidity; RT-PCR: Reverse transcription polymerase chain reaction; RdRp: Ribonucleic acid dependant ribonucleic acid polymerase; SARS: Severe Acute Respiratory Syndrome; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2; $TCID_{50}$: Tissue Culture Infectious Dose—Fifty; U/V: Ultraviolet; WHO: World Health Organisation; V/V: Volume per volume.

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Authors' contributions

SR—Conceptualisation, Data curation, Formal analysis, investigation, methodology, writing—original draft. SG—Conceptualisation, Data curation, Formal analysis, investigation, methodology, writing—review and editing. AH—Conceptualisation, Data curation, Formal analysis, writing—review and editing, supervision. DE—Conceptualisation, writing—review and editing, funding acquisition. TD—Conceptualisation, analysis methodology, writing—review and editing. All authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analysed during the study is included in the Additional file 1.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Publisher's Note

Indoor Air and Coronavirus (COVID-19)

Spread of COVID-19 occurs via airborne particles and droplets. People who are infected with COVID can release particles and droplets of respiratory fluids that contain the SARS CoV-2 virus into the air when they exhale (e.g., quiet breathing, speaking, singing, exercise, coughing, sneezing). The droplets or aerosol particles vary across a wide range of sizes – from visible to microscopic. Once infectious droplets and particles are exhaled, they move outward from the person (the source). These droplets carry the virus and transmit infection. Indoors, the very fine droplets and particles will continue to spread through the air in the room or space and can accumulate.

Frequent Questions

- Read Frequent Questions about Indoor Air and Coronavirus (COVID-19) <https://epa.gov/coronavirus/frequent-questions-about-indoor-air-and-coronavirus-covid-19>.
- Explore all EPA Frequent Questions related to Coronavirus (COVID-19) <https://epa.gov/coronavirus/frequent-questions-related-coronavirus-covid-19>.

Since COVID-19 is transmitted through contact with respiratory fluids carrying the infectious SARS-CoV-2 virus, a person can be exposed by an infected person coughing or speaking near them. They can also be exposed by inhaling aerosol particles that are spreading away from the infected person. Transmission of COVID-19 from inhalation of virus in the air can occur at distances greater than six feet. Particles from an infected person can move throughout an entire room or indoor space. The particles can also linger in the air after a person has left the room – they can remain airborne for hours in some cases. Someone can also be exposed via splashes and sprays of respiratory fluids directly onto their mucous membranes. Spread may also sometimes occur through contact with contaminated surfaces, though this route is now considered less likely. See Science and Technical Resources related to Indoor Air and Coronavirus (COVID-19) <https://epa.gov/coronavirus/science-and-technical-resources-related-indoor-air-and-coronavirus-covid-19> or Indoor Air and COVID-19 Key References and Publications <https://epa.gov/coronavirus/indoor-air-and-covid-19-key-references-and-publications> for technical information.

Though the risk of infection by breathing in particles carrying the virus generally decreases with distance from infected people and with time, some circumstances increase the risk of infection:

- Being indoors rather than outdoors, particularly in indoor environments where ventilation with outside air is inadequate
- Activities that increase emission of respiratory fluids, such as speaking loudly, singing, or exercising
- Prolonged time of exposure (e.g. longer than a few minutes)
- Crowded spaces, particularly if face coverings are inconsistently or improperly worn

Indoor Air and COVID-19 & Information in Other Languages

- Español <https://espanol.epa.gov/cai/el-aire-en-espacios-cerrados-y-el-coronavirus-covid-19>
- عربى <https://epa.gov/node/258587>
- 中文:简体版 <https://epa.gov/node/258835>

There are straightforward steps that can be taken to reduce the potential for airborne transmission of COVID-19 and the focus of this material is on those measures. The layout and design of a building, as well as occupancy and type of heating, ventilation, and air conditioning (HVAC) system, can all impact potential airborne spread of the virus. Although improvements to ventilation and air cleaning cannot on their own eliminate the risk of airborne transmission of the SARS-CoV-2 virus, EPA recommends increasing ventilation with outdoor air and air filtration as important components of a larger strategy that may include physical distancing, wearing cloth face coverings or masks, surface cleaning <https://epa.gov/coronavirus>, handwashing, and other precautions. Consult guidance from the Centers for Disease Control and Prevention (CDC <https://www.cdc.gov/coronavirus/2019-ncov/communication/guidance.html>) and local authorities on current guidelines on the use of masks.

Best practices recommended by the CDC can be found at:

- How to Protect Yourself and Others <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html>
- Cleaning and Disinfecting Your Home <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/disinfecting-your-home.html>
- Community, Work and School: Cleaning and Disinfecting <https://www.cdc.gov/coronavirus/2019-ncov/community/clean-disinfect/index.html>
- Masks <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/masks.html>
- How to decrease levels of virus particles during and after a guest visits a home (Interactive Ventilation Tool) <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/interactive-ventilation-tool.html>

- 中文:繁體版 <https://epa.gov/node/258855>
- 한국어 <https://epa.gov/node/258719>
- Kreyòl ayisyen <https://epa.gov/node/258825>
- Português <https://epa.gov/lep/ar-interno-e-coronavirus-covid-19>
- Русский <https://epa.gov/node/258693>
- Tagalog <https://epa.gov/node/258635>
- Tiếng Việt <https://epa.gov/node/258709>

Resources Related to Indoor Air and Coronavirus (COVID-19)

- Healthy Indoor Environments in Schools During the COVID-19 Pandemic and Beyond <https://epa.gov/coronavirus/healthy-indoor-environments-schools-during-covid-19-pandemic-and-beyond>
- Indoor Air in Homes and Coronavirus (COVID-19) <https://epa.gov/node/250623/>
- Ventilation and Coronavirus (COVID-19) <https://epa.gov/node/250615/>
- Air Cleaners, HVAC Filters and Coronavirus (COVID-19) <https://epa.gov/node/250619/>
- Implementing a Layered Approach to Address COVID-19 in Public Indoor Spaces <https://epa.gov/coronavirus/implementing-layered-approach-address-covid-19-public-indoor-spaces>
- COVID-19, Wildfires, and Indoor Air Quality <https://epa.gov/coronavirus/covid-19-wildfires-and-indoor-air-quality>
- Science and Technical Resources related to Indoor Air and Coronavirus (COVID-19) <https://epa.gov/coronavirus/science-and-technical-resources-related-indoor-air-and-coronavirus-covid-19>
    - Indoor Air and COVID-19 Key References and Publications <https://epa.gov/coronavirus/indoor-air-and-covid-19-key-references-and-publications>

Please supplement this information with the latest advice from state, local, Tribal and federal agencies.

Reduce Exposure to COVID-19 Using the Interactive Ventilation Tool

Explore which ventilation practices could help reduce airborne virus particles when guests visit your home with the Centers for Disease Control and Prevention's Interactive Ventilation Tool <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/interactive-ventilation-tool.html>.

To explore more detailed scenarios, see the National Institute of Standards and Technology expanded model: ViPER - Virus Particle Exposure in Residences <https://www.nist.gov/services-resources/software/viper-virus-particle-exposure-residences>.

Coronavirus Home <https://epa.gov/coronavirus>

Disinfectants <https://epa.gov/coronavirus/disinfectant-use-and-coronavirus-covid-19>

Indoor Air

Drinking Water and Wastewater <https://epa.gov/coronavirus/coronavirus-and-drinking-water-and-wastewater>

Frequent Questions <https://epa.gov/coronavirus/frequent-questions-related-coronavirus-covid-19>

Contact Us <https://epa.gov/coronavirus/forms/contact-us-about-coronavirus-covid-19> to ask a question, provide feedback, or report a problem.

LAST UPDATED ON JANUARY 27, 2023

Air Cleaners, HVAC Filters, and Coronavirus (COVID-19)

When used properly, air cleaners and HVAC filters can help reduce airborne contaminants including viruses in a building or small space. By itself, air cleaning or filtration is not enough to protect people from COVID-19. When used along with other best practices recommended by CDC and other public health agencies, including social distancing and mask wearing, filtration can be part of a plan to reduce the potential for airborne transmission of COVID-19 indoors.

Air cleaners and HVAC filters are designed to filter pollutants or contaminants out of the air that passes thru them. Air cleaning and filtration can help reduce airborne contaminants, including particles containing viruses.

In order for an air cleaner to be effective in removing viruses from the air, it must be able to remove small airborne particles (in the size range of 0.1-1 um). Manufacturers report this capability in several ways. In some cases, they may indicate particle removal efficiency for specific particle sizes (e.g. "removes 99.9% of particles as small as 0.3 um"). Many manufacturers use the Clean Air Delivery Rate (CADR) rating system to rate air cleaner performance. Others indicate they use High Efficiency Particulate Air (HEPA) filters. In order to select an air cleaner that effectively filters viruses from the air, choose: 1) a unit that is the right size for the space you will be using it in (this is typically indicated by the manufacturer in square feet), 2) a unit that has a high CADR for smoke (vs. pollen or dust), is designated a HEPA unit, or specifically indicates that it filters particles in the 0.1-1 um size range.

Air Cleaners

Portable air cleaners (also known as air purifiers) may be particularly helpful when additional ventilation with outdoor air is not possible without compromising indoor comfort (temperature or humidity), or when outdoor air pollution is high.

Caution: The use of air cleaners alone cannot ensure adequate indoor air quality, particularly where significant pollutant sources are present and ventilation is insufficient. Read EPA's "Guide to air cleaners in the home" (PDF). <https://epa.gov/sites/production/files/2018-07/documents/guide_to_air_cleaners_in_the_home_2nd_edition.pdf>

Air cleaners and HVAC filters in Homes

Where to place a portable air cleaner in your home

Choosing where in your home to place a portable air cleaner to help protect from airborne infections depends on the situation. Put the air cleaner in the room where most people spend most of their time (e.g., a living room or bedroom) unless:

How to select a portable air cleaner for a residence that can effectively remove

1. Someone in a household is especially vulnerable to the risks from infection, then, place the air cleaner where they spend most of their time or
2. If someone is isolating because of an active infection, then, place the air cleaner where they are isolating. See CDC guidance for creating isolation spaces - COVID-19 Quarantine and Isolation <https://www.cdc.gov/coronavirus/2019-ncov/your-health/quarantine-isolation.html>.

- Read EPA's "Guide to air cleaners in the home" for more information on HVAC filters and placing and operating a portable air cleaner. <https://epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home>
- Learn how to decrease levels of virus particles during and after a guest visits a home. (Centers for Disease Control and Prevention's Interactive Ventilation Tool) <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/interactive-ventilation-tool.html>

viruses

Choose a portable air cleaner that is intended for the room size in which it will be used and be sure it meets at least one of the following criteria:

1. it is designated as High-Efficiency Particulate Air (HEPA),
2. it is CADR rated for smoke, or
3. the manufacturer states that the device will remove most particles in the size range below 1 um.

Most manufacturers provide this information on the air cleaner packaging, label or website description.

Do not use air cleaners that intentionally generate ozone in occupied spaces or that do not meet state regulations or industry standards for ozone generation.

Air cleaners and HVAC filters in Offices, Schools, and Commercial Buildings

The HVAC systems of large buildings typically filter air before it is distributed throughout a building, so consider upgrading HVAC filters as appropriate for your specific building and HVAC system (consult an HVAC professional). The variety and complexity of HVAC systems in large buildings requires professional interpretation of technical guidelines, such as those provided by ASHRAE <https://www.ashrae.org/technical-resources/resources> and CDC <https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html>. EPA, ASHRAE and CDC recommend upgrading air filters to the highest efficiency possible that is compatible with the system and checking the filter fit to minimize filter air bypass.

Consider using portable air cleaners to supplement increased HVAC system ventilation and filtration, especially in areas where adequate ventilation is difficult to achieve. Directing the airflow so that it does not blow directly from one person to another reduces the potential spread of droplets that may contain infectious viruses.

Air cleaning may be useful when used along with source control and ventilation, but it is not a substitute for either method. Source control involves removing or decreasing pollutants such as smoke, formaldehyde, or particles with viruses. The use of air cleaners alone cannot ensure adequate air quality, particularly where significant pollutant sources are present and ventilation is insufficient. See ASHRAE and CDC for more information on air cleaning and filtration and other important engineering controls.

- See CDC's Interactive School Ventilation Tool <https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/interactive-ventilation-tool.html> to learn how to improve ventilation.

Air Cleaning Devices that use Bipolar Ionization, including Portable Air Cleaners and In-duct Air Cleaners used in HVAC Systems

Bipolar ionization (also called needlepoint bipolar ionization) is a technology that can be used in HVAC systems or portable air cleaners to generate positively and negatively charged particles. Provided manufacturers have data to demonstrate efficacy, manufacturers of these types of devices may market this technology to help remove viruses, including SARS-2-CoV, the virus that causes COVID-19, from the air, or to facilitate surface disinfection of surfaces within a treated area. This is an emerging technology, and little research is available that evaluates it outside of lab conditions. As typical of newer technologies, the evidence for safety and effectiveness is less documented than for more established ones, such as filtration. Bipolar ionization has the potential to generate ozone and other potentially harmful by-products indoors, unless specific precautions are taken in the product design and maintenance. If you decide to use a device that incorporates bipolar ionization technology, EPA recommends using a device that meets UL 2998 standard certification (Environmental Claim Validation Procedure (ECVP) for Zero Ozone Emissions from Air Cleaners).

Please note that there are many air cleaning devices that do not use bipolar ionization – the device packaging or marketing materials will typically indicate if bipolar ionization technology is being used.

Do not use ozone generators in occupied spaces.

Some products sold as air cleaners intentionally generate ozone. These products are not safe to use when people are present because ozone can irritate the airways. **Do not use ozone generators in occupied spaces**. When used at concentrations that do not exceed public health standards, ozone applied to indoor air does not effectively remove viruses, bacteria, mold, or other biological pollutants.

DIY Air Cleaners

Do-it-yourself (DIY) air cleaners are indoor air cleaners that can be assembled from box fans and square HVAC (or furnace) filters. They are sometimes used during wildfire events when air quality is poor and other filtration options are unavailable. There have been questions about whether DIY air filters can be effective in reducing virus particles in indoor environments. DIY air cleaners may provide some benefits for reducing concentrations of viruses and other indoor air pollutants, but research is limited and there are several important considerations explained below.

EPA does not recommend the routine use of DIY air cleaners as a permanent alternative to products of known performance (such as commercially available portable air cleaners). The performance of different DIY air cleaners will vary and cannot be reliably assessed without specialized instruments. Commercial devices have been tested for performance and can be chosen to match the size of a room.

EPA and Underwriter Laboratories evaluated the use of DIY air cleaners and the risk of fire. Fans that were built since 2012 and met UL standard 507 did not pose a fire hazard under the conditions tested in the study. (See Research on DIY Air Cleaners to Reduce Wildfire Smoke Indoors <https://epa.gov/air-research/research-diy-air-cleaners-reduce-wildfire-smoke-indoors> for more information.)

Tips - If You Choose to Use a DIY Air Cleaner

- **Use government, state, tribal, university or other expert instructions for building the device.** There is limited evidence on the effectiveness of DIY air cleaners. There are many possible DIY designs and variations of those designs, and few tests have been done to see how well they work.

- **Cost and Design Considerations:**
  - Initial costs for single filter designs can be lower than designs that use multiple filters.
  - Designs that use more than one filter can be harder to put together, bulkier, and more difficult to move than single filter designs.
  - Designs with more than one filter may also be harder to disassemble in order to replace the filters.
- Some example designs are:
  - How to build a low-cost air filter (pdf) (from the University of Washington, School of Public Health) <https://deohs.washington.edu/sites/default/files/airfilterinfographic_final.pdf>
    - Spanish version (pdf) <https://deohs.washington.edu/sites/default/files/airfilterinfographic_bj_lh_spanish_tb.pdf>
  - One filter flat against the fan (from the Washington Dept of Ecology)
  - Two filters taped with cardboard to form a triangle against the fan (from the Confederated Tribes of the Colville Reservation)
  - Four filters used to create an air filtration box, also known as the Corsi-Rosenthal box (pdf) (from the University of California, San Diego) <https://blink.ucsd.edu/_files/safety-tab/covid-filter-system-poster.pdf>
- **Use a newer box fan (made since 2012) with a UL (Underwriters Laboratory) or ETL (Intertek) logo because they have verified safety features** to reduce the risk of the fan overheating. EPA does not recommend using DIY air cleaners built with older model box fans (built before 2012), but if they are used, they should not be used unattended or while sleeping.
- **Consider running DIY air cleaners the entire time a space is occupied.** The longer they run, the more particles they will likely remove.
- **When assembling a DIY air cleaner, choose a high-efficiency filter, rated MERV 13 or higher, for better filtration.** Align the arrows on the filter to be in the same direction of the air flow through the fan. Create a good seal between the fan and the filter.
- **Change the filters periodically.** Longer run times, higher fans speeds, and higher levels of air pollution will mean that the filter will be removing more particles from the air, but the filter will also get dirty more quickly. Change the filter when it appears dirty.
- **When changing the filter(s), wear gloves, an N-95 respirator or similar, and goggles (without holes) for personal protection.** Remove the filters gently - outdoors if possible. Avoid shaking or banging the filters to minimize the release of accumulated dust. Dispose of the filters in garbage bags.

Features that can improve DIY air cleaner performance:

- **Cover the outside corners of the front of the box fan**, so that air flows only through the center part of the fan where the blades are visible. You can use cardboard, duct tape, or wood to make the cover – some DIY fan designers call these “shrouds”.
- **Use a thick HVAC filter** that is 2” or 4” thick instead of a 1” filter. Generally, thicker filters are more expensive than thinner filters, but need to be changed less often.
- **Increase the number of filters** in the design. Some designs can have 2, 3, 4 or 5 filters.
- **Improve the seal** where the filters are attached to the fan or each other. Seal the edges using duct tape, for example, instead of ties or clamps.

Additional Information

- See EPA Air Cleaners and Air Filters in the Home for more information. <https://epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home>

- Read ASHRAE guidance <https://www.ashrae.org/technical-resources/resources>.
    - Schools and universities (pdf) <https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools-and-universities-c19-guidance.pdf> (1.93 MB)
    - Commercial buildings (pdf) <https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-commercial-c19-guidance.pdf> (1.32 MB)
    - Multifamily owners/managers (pdf) <https://www.ashrae.org/file%20library/technical%20resources/covid-19/covid-19-guidance-for-multifamily-building-owners-and-managers.pdf> (1.19 MB)
    - Core Recommendations for Reducing Airborne Infectious Aerosol Exposure (pdf) <https://www.ashrae.org/file%20library/technical%20resources/covid-19/core-recommendations-for-reducing-airborne-infectious-aerosol-exposure.pdf> (152.72 KB)
- CDC websites for more information:
    - Improving Ventilation in Your Home <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/improving-ventilation-home.html>
    - CDC Interactive Ventilation Tool (for Homes) <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/interactive-ventilation-tool.html>

Return to Indoor Air and Coronavirus (COVID-19). <https://epa.gov/node/250495>

Coronavirus Home <https://epa.gov/coronavirus>

Disinfectants <https://epa.gov/coronavirus/disinfectant-use-and-coronavirus-covid-19>

Indoor Air <https://epa.gov/coronavirus/indoor-air-and-coronavirus-covid-19>

Drinking Water and Wastewater <https://epa.gov/coronavirus/coronavirus-and-drinking-water-and-wastewater>

Frequent Questions <https://epa.gov/coronavirus/frequent-questions-related-coronavirus-covid-19>

Contact Us <https://epa.gov/coronavirus/forms/contact-us-about-coronavirus-covid-19> to ask a question, provide feedback, or report a problem.

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HEALTH

Where Has All the Lysol Gone?

Disinfectant sprays, along with other cleaning supplies, are hard to find. Here's why – and what to do about it

Many cleaning supplies and all disinfecting wipes were sold out at a Lucky supermarket in Danville, California, amid shortages of many products during the pandemic.

SMITH COLLECTION/GADO/GETTY IMAGES

By: Rachel Nania, AARP

EN ESPAÑOL | August 05, 2020

Months into the coronavirus pandemic, shelves once stocked with everyday household cleaning products remain picked over — or worse, bare — in retail stores across the country.

Antibacterial wipes and disinfectant sprays are a rare sighting, and multipurpose powders, tablets and foams can be just as difficult to track down. The Environmental Protection Agency's (EPA) July 6 announcement that two Lysol sprays were proven effective in lab testing to kill the novel coronavirus on surfaces hasn't helped matters. AARP has heard from many members nationwide indicating that the two Lysol sprays are all but impossible to find online or at local retailers. (The EPA later announced on July 30 that 13 more products have received the same stamp of approval for their ability to eliminate the virus in lab testing.) All the while, the Centers for Disease Control and Prevention (CDC) recommends cleaning and disinfecting frequently touched surfaces as a way to protect against a coronavirus infection. So what's a person to do?

Focus less on disinfecting, more on handwashing

If you can't get your hands on cleaning products, switch your prevention strategy and, instead, focus on your hands. After all, frequent handwashing is “the most effective way to break the chain” of virus transmission from contaminated surfaces, says Joseph Allen, an assistant professor of exposure assessment science and director of the Healthy Buildings Program at Harvard's T.H. Chan School of Public Health.

When it comes to cleaning and disinfecting — especially high-touch surfaces such as doorknobs and light switches in schools and offices — “it's really difficult to clean and disinfect enough,” Allen says. “To really eliminate the hazard, you'd have to clean and disinfect every single time someone touched something. Well, that's not practical; it's not feasible. And it's also not the right strategy. The better strategy is when people come into the building, they wash their hands and use hand sanitizer,” and they continue to do so throughout the day.

Also: Don't forget about additional prevention measures, such as keeping at least 6 feet from others and wearing a face covering in public. It may be possible to catch the virus by touching a surface or object that has the virus on it and then touching your mouth, nose or eyes, the CDC says. But experts think you're more likely to catch it from respiratory droplets exchanged during close contact with an infected individual.

How to Clean Your Face Mask

Hundreds of cleaners work against the coronavirus

Lysol Disinfectant Spray and Lysol Disinfectant Max Cover Mist were the first disinfectant products to receive EPA approval for their proven effectiveness in killing the new coronavirus (SARS-CoV-2) on surfaces in lab testing. Thirteen additional products, including Lysol Disinfecting Wipes and 12 products from manufacturer Lonza, have since received the same EPA approval, bringing the total number of approved products to 15. But there are other cleaners out there that are presumably just as good of a match against the virus that have yet to undergo lab testing. In fact, the EPA has a list of more than 460 products that meet its criteria for use against SARS-CoV-2, and the agency expects more of them will receive its official approval in the near future, once lab testing results are submitted and reviewed.

If you're faced with only one type of surface cleaner or disinfectant at the store, "I would bring that choice home," says Diane Leichter, director of Infection Prevention and Control at the Hospital of the University of Pennsylvania. "Any disinfecting wipe will probably remove most of [the virus] from a surface and kill most of it on a surface" — especially if you clean first with soap and water, which is also what the CDC recommends.

"Remember that cleaning and disinfecting are separate steps," and that cleaning a surface with soap and water "goes a long way toward removing most germs," Leichter adds.

If you still can't get your hands on one of these products, the CDC says a simple bleach-and-water solution (4 teaspoons of bleach per quart of room temperature water) will do the trick. Alcohol solutions with at least 70 percent alcohol may also be used. Just remember: When cleaning, always follow the instructions on the label to ensure your personal safety and the effectiveness of the cleaner. Some products, for example, have a longer drying time than others, and wiping a surface down with a towel before that time is up could make the cleaner less powerful.

Many Americans have dangerously misused household cleaning products during the pandemic, CDC data show. This has led to an uptick in calls to poison centers across the country. To avoid health hazards, wear skin protection and make sure you use cleaning products in well-ventilated areas. Finally, always store and use chemicals out of the reach of children and pets, the CDC advises.

What's behind the disinfectant shortages?

There are a number of reasons why the U.S. is experiencing a shortage of cleaning supplies, says Tom Derry, chief executive officer at the Institute of Supply Chain Management. "Probably the biggest is we're seeing this incredible surge in demand for these kinds of products," he adds.

Sales of aerosol disinfectants were up 148.3 percent during the week ending March 28, compared with the same week last year — that's right around the time stay-at-home orders went into effect in several states. Multipurpose cleaner sales spiked 84.6 percent during that same timeframe, according to data from Nielsen.

"And companies in the short term and on short notice don't physically have the ability to reconfigure their manufacturing lines or to create new manufacturing lines to add capacity to meet the higher level of demand," says Derry, who also points to shipping and production delays overseas where many raw materials are sourced.

The "stock up" mentality brought on by the pandemic has also contributed to ongoing supply shortages, says Saurabh Bansal, associate professor of supply chain management at Penn State University. The advice from public health experts has been to limit public outings as much as possible and to keep essential items on hand, especially if you are at increased risk for severe illness from COVID-19.

However, when customers start shopping every two weeks instead of weekly, for example, their purchases essentially double, Bansal points out. "If companies don't take that into account, if they keep on replenishing the same amount of stuff week after week, then essentially what is happening is that the same stuff is now going to only half of the customers because they have increased their basket size, which means that the first half of the customers end up buying the product, and the second half of the customers don't see the product on the shelf," he says.

Figuring out this new purchasing pattern takes time for stores, Bansal explains, and not all retailers have done a good job with it.

When will stores be restocked?

Major brands, including Lysol, have acknowledged the "unprecedented and accelerated demand" for their products, and have said in statements that they are working to resolve them. Reckitt Benckiser, the maker of Lysol products, did not respond to AARP's requests for comment about the supply shortages. The Clorox Company, the maker of disinfecting wipes and other cleaning products, declined to comment for this story, but in an early August earnings call told analysts that the company likely won't be able to meet the demand for its cleaning and disinfecting products until 2021.

Even so, it may still be a little while before you see a steady stock of common cleaning supplies in stores. Martin Dresner, a professor of supply chain management at the University of Maryland, says it will likely take "a change in circumstances" to bring demand back down to a point where stores don't sell out of disinfectants right away. He expects that time will come when fears of future lockdowns ease and COVID-19 case counts start to decline.

In the meantime, the shortages for products made by big companies have created an opportunity for smaller businesses to break into the market, Derry says. So be on the lookout for new brands that may be just as effective when it comes to fighting the spread of the coronavirus, including hand sanitizers made by local distilleries and craft brewers.

Another thing consumers can do in the wake of ongoing shortages is preorder groceries and household supplies online for curbside pickup at their local store. This essentially gives the store an advance order and removes an element of uncertainty in the supply chain, Bansal says.

"And when that happens, it benefits everybody. It benefits the stores because they know how much they need to stock without incurring the holding cost, and it benefits the customer because the customer is more likely to get the product that they want."

Editor's Note: This story, originally published July 22, has been updated to reflect new information.

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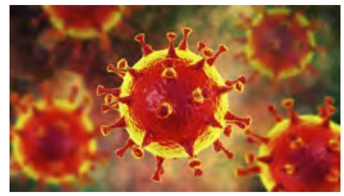
Cases fall after omicron's record-breaking surge



As COVID-19 Cases Skyrocket, Let's Stay Diligent

It's more important than ever to protect ourselves and our loved ones from the coronavirus

List of Coronavirus-Related Restrictions in Every State

Most states have dropped COVID-related restrictions

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COVID-19

Safety Precautions When Using Electrostatic Sprayers, Foggers, Misters, or Vaporizers for Surface Disinfection During the COVID-19 Pandemic

Updated Feb. 27, 2023

Carefully select cleaners and disinfectants and application methods for use in facilities, businesses, and public indoor spaces to ensure that you can clean and disinfect safely and effectively.

In most situations, cleaning surfaces (using soap or detergent) is enough to reduce SAR-CoV-2, the virus that causes COVID-19. Clean surfaces before disinfecting.

Disinfection (using a product or process designed to inactivate SARS-CoV-2) is recommended in indoor community settings where there has been a suspected or confirmed case of COVID-19 within the last 24 hours; when the presence of infectious virus is more likely. When disinfecting, choose the safest method that is also effective. For most situations, using traditional disinfectant methods, such as liquids, wipes, or disinfectant spray bottles, is sufficient to reduce virus exposure. Be sure to use products safely and according to label instructions, and use products that are on EPA's List N: Disinfectants for Coronavirus (COVID-19) .

> **Electrostatic sprayer:** A device that works by applying a small electrical charge to aerosols when passing through the nozzle. These charged droplets adhere easier and stick to environmental surfaces.
>
> **Fogger (also known as mister):** A device that uses a fan and a liquid solution to create a fog (aerosol with small droplets) or mist.
>
> **Vaporizer:** A device used with hydrogen peroxide disinfectant solutions. Doors and ventilation systems must be sealed while in use. Should be used only in healthcare or laboratory settings.

Choosing to use an electrostatic sprayer, fogger, mister, or vaporizer:

If trained professionals are available to apply them, people may decide to use newer technologies that either spray disinfectant electrostatically, or disperse it through fog, mist, or vapor. Cases where these technologies could be more practical include situations where there might be a confirmed case of COVID-19, use of the space is needed quickly, and some surfaces could be very hard to reach to disinfect by hand. These are sometimes used in healthcare settings after a patient is no longer using a room.

These devices aerosolize chemicals, or suspend them in the air, and they can stay in the air for long periods of time, especially if the area is not well ventilated. Aerosolizing any disinfectant can irritate the skin, eyes, or airways and can cause other health issues for people who breathe it in.

CDC does not either recommend, or not recommend, use of these devices for disinfecting community spaces for COVID-19. If they are used, they should be used with extreme caution. A disinfectant product's safety and effectiveness might change based on how you use it. If electrostatic sprayers or foggers are used, they should be used:

- Only by trained professionals
- With disinfectants approved for this method of application
- According to manufacturer instructions for safety, use, and contact time
- With appropriate personal protective equipment (PPE) and other safety measures to ensure safety for the operator, others nearby, and for people who might use the room afterward
- When rooms are not occupied

- With extreme caution if using around food preparation or areas where children play

For information about the application of Environmental Protection Agency (EPA) List N disinfectants with electrostatic sprayers and foggers, refer to the EPA's "Can I use fogging, fumigation, or electrostatic spraying or drones to help control COVID-19?" website . If the product's label does not include disinfection directions for use with fogging, fumigation, wide-area or electrostatic spraying, EPA has not reviewed any data on whether the product is safe and effective when used by those methods.

Understand the risks

Note: Directions for specific devices and chemicals may vary. Always follow safety directions on product labels. If the label is hard to read or missing, do not use the product.

Exposures to chemicals in aerosolized disinfectants can cause skin, eye, or respiratory irritation.

- If you use an electrostatic sprayer or fogger, only the person applying it, wearing appropriate PPE, should be in the room. The person applying should leave the room following application. Stay out of the area for the time indicated in the product label and specified by the application device. Open windows and doors after use, if possible, to air out the space.
- Remove chemical residue, which can pose health risks, before others enter the room. Follow product label directions for wiping or rinsing residue after the appropriate contact time has been achieved.
- Some people, such as children or people with asthma, are more vulnerable to certain chemicals. Follow CDC guidance for People with Moderate to Severe Asthma as any disinfectant can trigger an asthma attack.

In dining and food preparation areas or areas where children spend time, safety risks are greater.

- Use extreme caution if you choose to use an electrostatic sprayer or fogger in dining and food preparation areas. The aerosolized disinfectant could land in areas where the chemical may contaminate food preparation surfaces (e.g., countertops, dishware) or food, or areas where children might touch things (e.g., toys, desktops). Using a liquid, spray bottle, or wiped disinfectant gives you more control over where the disinfectant goes.
- Use only products approved for food contact surfaces in food areas.
- Follow recommendations about how to safely disinfect daycares and schools and restaurants and bars.

Disinfectants have different safety precautions and hazard risks. Anyone handling or using disinfectants with electrostatic sprayers or foggers should understand how to choose the appropriate disinfectant for the device, how to use Safety Data Sheets , and how to protect workers and others.

- Train cleaning and janitorial staff on how to apply disinfectant safely (e.g., use of PPE; how to respond to chemical exposure) and effectively (e.g., application method, concentration, contact time).
- Disinfectant products are approved for certain devices or equipment and are not interchangeable with different products.
- Follow manufacturer's label for application instructions. Beware of new technologies and devices or equipment not specified on manufacturer's label.
- Wash your hands with soap and water after handling disinfectants. Be sure to wash your hands immediately after removing gloves.

Last Updated Feb. 27, 2023

The Atlantic

HEALTH

How Are We Possibly Still Disinfecting Things?

America can't quit hygiene theater.

By Yasmin Tayag

Jens Kalaene / picture alliance / Getty

JULY 7, 2022

Two weeks into the pandemic, a box of Cheerios sent me into an existential tailspin. I'd just returned from an unnerving trip to a New York City supermarket, where bandanna-masked customers with carts full of toilet paper dodged one another like bandits. As I unpacked my groceries, I was gripped by fear. *If I don't Lysol the living daylights out of this cardboard*, I wondered, *will I die?*

I kept up the cleaning for weeks. My garbage bin, like so many in America, turned into a disposable-wipe repository. It took until May 2020 for the CDC to confirm that the coronavirus is rarely transmitted by touching things. My Cheerios boxes became markedly less soggy, but even then, other, more public surfaces—elevator buttons, subway poles, shopping-cart handles—remained in a continuous wash cycle. I knew this because signs everywhere told me they had recently been cleaned.

Today, it's well understood that because the coronavirus spreads through the air, good ventilation and air filtration are far more effective at disrupting transmission than wiping down surfaces. Best practices for avoiding infection during a surge include opening a window when gathering indoors, opting for outdoor dining, and masking. In March, the Biden administration made air quality a pillar of its COVID response (finally). Meanwhile, study after study has found that the risk posed by lingering virus on surfaces is low compared with the threat it poses in the air.

Which raises the question: Why in the world is so much cleaning still happening?

Although most people are no longer disinfecting their groceries, signs flaunting cleanliness are still all over the place. Public bathrooms tout regular spray-downs with disinfectant. Elevators advertise self-cleaning buttons. At my local Marshalls, the cashier sanitizes the credit-card reader after every use—even if I use Apple Pay! A recent issue of United Airlines' in-flight magazine was "treated with an antimicrobial process," according to its cover. Signs lining the queue for a Delta flight in June read, cryptically: CERTIFIED BY LYSOL PRO SOLUTIONS.

It's not just the cleaning, either. Months after mask mandates have lifted and vaccine requirements have eased—meaningful interventions that *do* protect people—you'll still come across QR-code menus, floor stickers placed six feet apart (has anyone ever used these correctly?), temperature screening, and hand-sanitizing stations. In 2020, *The Atlantic*'s Derek Thompson dubbed such measures "hygiene theater": precautions that are far more performative than useful at stopping the spread of the coronavirus. Somehow, in 2022, the show goes on.

Some places hardly bothered with pandemic protections, theatrical or otherwise, in the first place. Among those that did, some of the pushy signs and other small measures you might still find are likely vestiges of a more cautious time—the flimsy plexiglass shield that no employee has bothered to remove, the long-empty dispenser of hand sanitizer. Perhaps in some cases, like the constant wipe-downs at Marshalls, performative cleanliness has simply become part of the employee script, like asking customers to sign up for a credit card.

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But hygiene theater also continues to rear its useless head in much more deliberate ways, lingering in offices, airports, and shops, often proudly touted as a service to patrons. Joseph Allen, an associate professor at the Harvard T. H. Chan School of Public Health, told me that he recently stayed at a hotel where the remote control was sheathed in a disposable wrapper that said it had been sanitized. Just another day in pandemic-era travel.

One simple explanation for hygiene theater's enduring appeal is that some Americans who remain pandemic-cautious (and the businesses that cater to them) still don't understand that this virus primarily spreads through face-to-face airborne transmission. Though the messaging on this point is now abundantly clear, confusion is understandable. At the beginning of the pandemic, studies *did* detect potentially infectious remnants of the coronavirus on surfaces in cruise ships and hospitals, and the health messaging at the time reflected those findings. The idea stuck. "I don't blame the public at all," Allen told me. "The science has changed every day for two years."

A related reason might be that some people who do understand how the virus spreads see no harm in erring overwhelmingly on the side of caution. Though it's irrational, they feel more secure knowing—or better yet, *seeing*—that their surroundings have recently been cleaned or that attempted safety protocols are in place. As customers have come to expect a higher level of visible hygiene, some businesses might feel as though they have no choice but to supply the theatrics. They're left with an inflated standard that they don't dare to burst.

If we're talking about actual safety, it would make more sense to ask both customers and employees to simply wear good masks when infection rates are high. But America has never been especially prudent about effective COVID interventions, and hygiene theater has the perk of shifting the perceived burden of safety onto other people, implying that protection against COVID is a service to be provided rather than a personal act of self-preservation and community good. This seems to add to the pressure on businesses that want to remain pandemic safe, even if they already have good COVID hygiene protocols in place.

At Voance Salon in New York City, standard protocol is for masked and vaccinated staff to sanitize stations and tools between clients, who are required to wear masks when a CDC recommendation or mask mandate is in effect. But the salon also provides additional measures upon request, such as heavy cloth dividers between stations to wall off other guests, Voance's owner, Rasheda Akter, told me. Precautions like these give customers "confidence to get their hair done," she said.

Meanwhile, in Santa Barbara, California, "sanitation captains" roam the dining area of a restaurant called the Lark, cleaning surfaces. The restaurant also employs the R-Zero, an ultraviolet-light-powered disinfection system that looks like a human-size lamp on wheels. There is good evidence that UVC light inactivates the coronavirus, but perhaps the device's bigger draw is that it's noticeable. It's "one of the ways we tried to bring comfort and visible safety," Skyler Gamble, the director of people and culture at Acme Hospitality, the restaurant group that owns the Lark, told me. Gamble added that the company's strict hygiene protocols are as much for guests as they are for staff, many of whom are worried about being unable to work. "We're asking our employees what would help them feel safe and comfortable coming to work," he said. "For us, it's for peace of mind."

Peace of mind can go only so far, however. The Lark is fortunate: It operates in perpetually sunny and warm Southern California, where open windows and outdoor seating can significantly bolster the safety of restaurant dining. But in general, with or without sanitation captains, dining indoors is always going to be a higher-risk pandemic activity. The same is true for traveling on cruise ships, where some of the largest early COVID-19 outbreaks occurred, and where hygiene measures—useful and otherwise—are now especially prevalent. Most major cruise lines require the majority of guests to be vaccinated, but masking policies and COVID-19 protocols vary widely. In a number of cases, cruise ships' measures have been insufficient. In May, for example, an outbreak on a fully vaccinated Carnival Cruise forced many passengers into quarantine and prompted a highly publicized CDC investigation.

No wonder so many ships feel the need for hygiene overkill. Variety Cruises, an international line based in Greece, maintains a vaccine requirement and asks employees to wear masks at all times and guests to do the same when indoors. It also screens guests for body temperature and blood oxygen content, disinfects all luggage before boarding, and steam-sterilizes the ship's upholstery, cushions, and curtains daily, according to Constantine Venetopoulos, Variety's PR and communications manager. Research shows that temperature checks are useless for diagnosing COVID, and some people with COVID do not have altered blood oxygen levels. Furthermore, although pulse oximeters may be more helpful than thermometers for detecting illness in the elderly, they have been found to be unreliable when used on Black, Hispanic, and Asian COVID patients.

A related and more nefarious reason hygiene theater persists is that good ventilation and filtration, great measures at cutting back infection, are invisible. For companies aiming to demonstrate their concern about COVID, these practices can have less payoff because they're harder to flaunt (or at least, they'll seem to have less payoff until the staff has a COVID outbreak and business stalls out). Instead of a wrapped and sanitized remote control in his hotel, Allen told me, "what I would have loved to have seen was a note on my bed that said they've upgraded the filters and increased the ventilation rate. The other stuff is just silly." Maybe so, but plastic-wrapping a remote is a lot easier and cheaper than installing a suite of HEPA filters and convincing people that they're there.

And thus, the theater continues. Jim Dudlicek, the director of communications and external affairs for the National Grocers Association, told me that his organization expects grocery stores' "enhanced sanitation procedures to be permanent, as consumers will continue to look for that assurance when they choose where to shop."

At its best, hygiene theater is benign—albeit time-consuming, wasteful, and expensive. It's never a bad idea to keep places clean or to insist on hand-washing; clean hands and surfaces are a cornerstone of public health. (Hotel-room TV remotes might not give you COVID, but they *are* pretty gross.) Hygiene theater becomes a serious problem, however, when it falsely reassures people that an environment is safe, giving them permission to relax their expectations and behavior. A hotel that sanitizes its common areas with hospital-grade disinfectant isn't safe if guests are unmasked at the bar during a surge. Neither is a restaurant that uses QR-code menus but doesn't filter its air or open its windows. The real dangers posed by hygiene theater are that it perpetuates unscientific thinking about coronavirus transmission and takes time, attention, energy, and resources away from the measures that are effective against COVID.

While visibility is keeping hygiene theater alive, perhaps it will also be its downfall. Those who understand how ridiculous hygiene theater is may get into the habit of using it as a barometer for outdated standards. There are already signs that more people and businesses are updating their beliefs: Trade associations representing the banking, hospital, restaurant, and airline industries told me that they've shifted their recommendations for members toward improving air quality, signaling a change in consumer expectations. Maybe, eventually, plastic barriers and floor stickers will go the way of disinfected cereal boxes—humorously obsolete trash.

1.48

v 4 08/18/2005

Air Space And Air Rights.

SEE UNDERWRITING MANUAL
3.40 Condominiums

1.48.1

v 3 08/18/2005

In General

Every piece of real estate has three separate and distinct physical elements: the subsurface, the surface, and the air space. The owner of the land acquires title to the land in conjunction with title to the underground space and the space above it.

Air rights mean the estate, title, interest and rights in the open space or vertical area above ground level. Any ownership of land includes the ownership of air rights, which are subject to reasonable aircraft interference.

The air itself is not real property; airspace, however, is real property when described in three dimensions with reference to a specific parcel of land. Such air rights are alienable. They can be sold, purchased, mortgaged, leased, or otherwise encumbered, subject to. easements of light and air.

Examples of the possible alienation of air rights are a condominium unit, which involves the ownership of a certain specified layer of air space, and an aviation easement, which is the right granted to aircraft, generally when approaching an airport, to fly at a stipulated altitude over certain specific land.

1.48.2

v 4 08/18/2005

Methods Of Conveying, Transferring, Or Severing Air Rights From The Surface Area

The following are the most common methods:

- A lease of air rights above a fixed plane, together with the air and ground necessary for the foundations of and access to the airspace structure.

- An aerial easement. This method is generally used in the construction of elevated highways.
- By purchase of the fee of ground and air space with reservation of easement by the grantor.
- By purchase of the fee of air space plus easement for support and access.
- By purchase of the fee of air space and purchase of fee of support parcels.
- By purchase of the fee in condominiums.

1.48.3

v 3 08/18/2005

Title Held By The Seller Or Transferor Of Air Space Or Air Rights

- Fee title;
- Leasehold;
- Easement;
- Determinable fee.

1.48.4

v 4 08/18/2005

Special Title Insurance Considerations Regarding Air Space

Insurable legal description

Drafting requires the expertise of an engineer. An air space description is always extremely difficult and complicated to draft. Only local experts should attempt such a task. Any air space description must also encompass the tracts describing the easements of support and access.

- Verify that relevant state law recognizes the property interest in the air space description to be real property.
- Verify that the property interest in the air space, as described, is an estate recordable under applicable recording acts.
- Ascertain and comply with all special recording requirements.
- Determine whether the Model Air Space Act been enacted in the state where the land is located.
- Are there specific means of support?
- Are there specific means of access? Access can be achieved through any of the following property interest:
  - A fee;
  - An easement;
  - A leasehold;

    - A license; or,
    - Any combination thereof.
- Note that any access through a leasehold estate is dependent upon the life and termination date of the leasehold.
- Note that any access through an easement would be dependent on any limitation on the easement.
- Note that any access through a license would be dependent on the conditions of the license.
- Review and list mortgages, easements, restrictions, and other liens and encumbrances affecting the subjacent parcel prior to its division.
- Review leases affecting the subjacent parcel prior to its division.
- List mechanic's liens based upon work done or materials furnished to the subjacent parcel prior to its division.
- Compliance with zoning regulations.
- Compliance with subdivision acts.
- Do statutes contain any provision for separate taxation of an air parcel?
- If the air space is over a railroad, does the railroad own the fee title?
- If the air space is over a street or highway, who owns the fee title?
- If the air space is over a navigable body of water, who owns the fee title?

1.48.5

v 4 08/18/2005

Title Insurance Of Air Space

Insuring title to air space separated from the title to the soil is an extrahazardous risk.

If the air space is part of a condominium unit, please review the section on Condominiums.

In any other case in which the estate to be insured is a space above the surface of the property, specific approval must be obtained from the National Legal Department before issuing any title commitment or title policy.

American Pandemic Preparedness: Transforming Our Capabilities

September 2021

September 2, 2021

The Biden-Harris Administration is currently engaged in a whole-of-government review and update of U.S. national biopreparedness policies, as directed by the President in Executive Order 13987 and National Security Memorandum-1. This work will culminate in the release later this year of the Administration's strategy on biodefense and pandemic readiness.

As the President's American Jobs Plan stated, the United States has the opportunity and need to fundamentally transform our capabilities to protect the Nation. To ensure that the United States and the world are properly prepared, the work to develop those capabilities needs to begin now.

As a core element of the Administration's strategy on biodefense and pandemic readiness and informed by lessons from the COVID-19 pandemic, this document describes the critical work needed to transform U.S. capabilities to respond rapidly and effectively to any future pandemic or high consequence biological threat.

The work is organized across five pillars: (1) Transforming our Medical Defenses, (2) Ensuring Situational Awareness, (3) Strengthening Public Health Systems, (4) Building Core Capabilities, and (5) Managing the Mission.

Achieving these capabilities will require a systematic effort and shared vision for biological preparedness across our government that is akin to the nation's Apollo mission. The mission will require program management with the seriousness, commitment, and accountability of the Apollo Program, overseen by a dedicated program office.

Eric S. Lander
Assistant to the President for
Science and Technology

Jacob J. Sullivan
Assistant to the President for
National Security Affairs

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I. Introduction

Introduction

Protecting the United States from threats is a core responsibility of the Federal government. We have robust national defense capabilities that provide us with broad and deep protection against human threats, including missiles, terrorism, and cyberattacks. In the 21st century, we also need robust national biodefense capabilities that will provide us with broad and deep protection against biological threats, ranging from the ongoing and increasing risk of pandemic disease, to the possibility of laboratory accidents and the deliberate use of bioweapons.

The current pandemic has illustrated the seriousness of biological threats. As of mid-August 2021, COVID-19 has killed over 4.3 million globally, with excess-mortality estimates suggesting a death toll exceeding 10 million. In the United States, the number of deaths directly attributed to COVID-19 has surpassed 623,000, with many recovered patients living with long-term effects. The economic damage to the U.S. has been estimated at $16 trillion dollars in lost economic output, direct spending, mortality and morbidity[1]. And, the societal impact has been borne disproportionately by front-line and vulnerable populations, especially people of color.

As devastating as the COVID-19 pandemic is, there is a reasonable likelihood that another serious pandemic that may be worse than COVID-19 will occur soon — possibly within the next decade. Unless we make transformative investments in pandemic preparedness[2] now, we will not be meaningfully prepared.

1. Future biological threats could be far worse, and we are not adequately prepared

As staggering as the toll has been, future pandemics could be far worse.

• SARS-CoV-2, the virus responsible for COVID-19 disease, was favorable in certain respects. It is far less lethal than the 1918 influenza virus. It also belongs to a well-understood family: coronaviruses. It was possible to design vaccines within days of knowing the virus's genetic code because nearly 20 years of Federally-funded fundamental scientific research, spurred by the emergence of SARS and MERS, had provided detailed knowledge about coronaviruses, including revealing which protein to target and how to stabilize it. And while the current virus spins off variants, its mutation rate is slower than many viruses that have been studied. Unfortunately, most of the 26 families of viruses that infect humans are less well understood or harder to control than coronaviruses. While there are important lessons to be learned from COVID-19, we must not fall into the trap of preparing for yesterday's war.

The next pandemic will likely be substantially different from COVID-19. We must be prepared to deal with any viral threat.

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[1] *JAMA 2020; 324:1495–1496.*

[2] Pandemic "preparedness" and "readiness" are used synonymously.

• The development of mRNA vaccine technology and other 'programmable platforms'[3] — thanks to more than a decade of foresighted investment by the public and private sector — have been game-changing. mRNA vaccines shortened the time needed to design and test vaccines to a record-setting 314 days — far less than previous vaccines, which had taken several years. They have also been surprisingly effective against COVID-19. Still, there's so much we don't know about this vaccine platform, as well as other new platforms — including how they will perform against other types of viruses and how to optimize them.

Even with knowledge and tools that dramatically improved our ability to respond, COVID-19 has still been a catastrophe for the nation and the globe.

Conclusion: Before the next pandemic or other biological threat, we need to be able to respond to any possibility and to respond even faster and even better.

2. Serious biological threats will occur at an increasing frequency

Biological threats are increasing, whether naturally occurring, accidental, or deliberate, and the likelihood of a catastrophic biological event is similarly increasing.

Serious viral outbreaks have occurred frequently over the past century. Since the early 1900s, there have been at least 11 serious viral outbreaks, caused by pandemic pathogens which span five virus families (Table 1). Of those serious outbreaks, five have had lethality rates greater than or equal to COVID-19. In addition, many other new viruses have been emerging in recent decades.

Table 1. Serious Viral Outbreaks Over Past 100 Years

	Name	Virus Type	Year Began	Global Deaths	US. Deaths
1	**Spanish Flu**	Orthomyxovirus	1918	50,000,000	**675,000**
2	**Asian Flu (H2N2)**	Orthomyxovirus	1957	1,100,000	**116,000**
3	**Hong Kong Flu (H3N2)**	Orthomyxovirus	1968	1,000,000	**100,000**
4	**HIV**	Retrovirus	1981	32,700,000	**700,000**
5	**SARS-CoV-1**	Coronavirus	2002	774	
6	**Influenza (H1N1)**	Orthomyxovirus	2009	284,000	**12,469**
7	**MERS**	Coronavirus	2012	875	
8	**Ebola**	Filovirus	2014	11,310	**1**
9	**Zika**	Flavivirus	2015	N/A	
10	**Ebola**	Filovirus	2018	2,300	
11	**SARS-CoV-2**	Coronavirus	2019	4,100,000+	**621,000+**

There are compelling reasons to expect that the frequency will increase further in the years ahead:

[3] 'Programmable platforms' refer to technologies that can be easily adapted by inserting new genetic instructions.

• New infectious diseases have been emerging at a quickening pace due to increased zoonotic transmission from animals, driven by population growth, climate change, habitat loss, and human behavior, and these diseases are spreading faster with increased global travel.
• The number of laboratories around the world handling dangerous pathogens is growing in part as a response to increasing pandemic risk, boosting the likelihood that a contagious pathogen could be released accidentally.[4]
• As the technologies of modern biology become more powerful, affordable, and accessible, there is also the disturbing possibility that a malign actor could develop and use a biological weapon, including one that is highly contagious, in violation of the Biological Weapons Convention and UN Security Council Resolution 1540.

Conclusion: There will be an increasing frequency of natural — and possibly human-made — biological threats in the years ahead.

3. Pandemic Preparedness: Planning and Resources

For the first time in our history, we have the opportunity—due to advances in science and technology—not just to refill our stockpiles, but also to transform our capabilities. However, we need to start preparing now.

The United States must fundamentally transform its ability to prevent, detect, and rapidly respond to pandemics and high consequence biological threats. This would include investments in critical scientific goal areas—vaccines, therapeutics, diagnostics, and early warning—as well as associated investments in strengthening disease surveillance, health systems, surge capacity, personal protective equipment (PPE) innovation, biosafety and biosecurity, regulatory capacity, and global pandemic preparedness.

This document describes goals under five pillars:

I. **Transforming our Medical Defenses**, including dramatically improving vaccines, therapeutics, and diagnostics.
II. **Ensuring Situational Awareness** about infectious-disease threats, for both early warning and real-time monitoring.
III. **Strengthening Public Health Systems**, both in the U.S. and internationally to be able to respond to emergencies, with a particular focus on protecting the most vulnerable communities.
IV. **Building Core Capabilities**, including personal protective equipment, stockpiles and supply chains, biosafety and biosecurity, and regulatory improvement.
V. **Managing the Mission**, with the seriousness of purpose, commitment, and accountability of the Apollo Program.

The next section describes the goals and sub-goals. A separate Appendix provides scientific elaboration concerning the first pillar (‘Transforming our Medical Defenses’).

All of these efforts must, from the outset, include a strong emphasis on reducing inequities and increasing access by all Americans to the resulting advances.

[4] The 1977 H1N1 influenza pandemic killed ~700,000 people. Genomic evidence suggests it may have been caused by either a laboratory accident or botched vaccine trial (Rozo M and Gronvall G. mBio. 2015 6(4): e01013-15).

While the plan is focused on pandemic preparedness, the capabilities generated will also be extremely valuable for dealing with infectious disease in general — including improvements in vaccines, therapeutics, diagnostics, disease surveillance, public health, and regulation. Moreover, like previous ambitious scientific endeavors, the advances produced by this work will lead to broader benefits to human health.

Importantly, the COVID-19 pandemic has exposed fundamental issues with the Nation's public heath that go far beyond pandemic preparedness. These issues include the need to increase overall public health funding, strengthen the public health workforce, eliminate barriers to access, improve data systems, address disparities, improve communication, and improve coordination across Federal, state, local and Tribal authorities. This plan addresses needs directly related to pandemic preparedness, but the broader public health issues will need to be addressed separately in a concerted fashion.

This plan, aimed at transforming our capabilities, is a core element of the broader biodefense and pandemic preparedness strategy being developed by the Biden-Harris Administration, which will include updates to additional elements, policies, and practices.

Conclusion: We have the opportunity to transform our pandemic preparedness, and doing so will have major benefits for medical care and public health in ordinary times.

4. Pandemic Preparedness: Managing the Mission

The mission of transforming U.S. pandemic preparedness and biodefense capabilities should be managed with the seriousness of purpose, commitment, and accountability of an Apollo Program.

There should be a centralized 'Mission Control', acting as a single, unified program management unit, that draws on expertise from multiple HHS agencies, including NIH, CDC, BARDA, FDA, and CMS, as well as other departments such as DoD, DoE, and VA. (As an example, the Countermeasures Acceleration Group (formerly 'Operation Warp Speed') is led by a single joint program management unit.)

Mission Control should have the responsibility and authority to (i) develop and update plans with objective and transparent milestones; (ii) regularly assess and publicly report on mission progress; (iii) shift funding to ensure that goals are achieved; (iv) coordinate linkages across performers in government, academia, philanthropy, and industry; and (v) conduct periodic exercises to evaluate national pandemic preparedness by deploying national capabilities, including by rapid product development.

Mission Control should seek the input of outside experts on critical issues and consider establishing working group(s) that focus on scientific and technical assessments, improving public health and ensuring that the capabilities serve all communities, especially the most vulnerable.

5. Pandemic Preparedness: Cost and Economic Case

An effective program to ensure that the United States is prepared for future pandemics and other major biological threats will require significant annual investment over a sustained period.

However, the required investment is modest relative to other efforts to create the capabilities needed to protect the Nation against important threats: the annualized cost would be much smaller than what the U.S. spends on missile defense ($20 billion/year) and on preventing terrorism ($170 billion/year).

In addition to protecting American lives, the annual investment is strongly justified from an economic standpoint: If major pandemics similar to COVID-19, costing the U.S. roughly $16 trillion, occur at a frequency of every 20 years, the *annualized* economic impact on the U.S. would be $800 billion per year. **Even for somewhat milder pandemics, the *annualized* cost would likely exceed $500 billion.**

Conclusion:

Investing a modest amount annually to avert or mitigate the huge toll of future pandemics and other biological threats is an economic and moral imperative.

It's hard to imagine a higher economic — or human — return on national investment.

In any realistic accounting of costs and benefits, modest investments in pandemic preparedness should not be viewed as a cost, but instead as providing a large return on investment.

II. Goals

Goals

To be ready for the next pandemic, the United States will need to pursue goals in the five areas described below.

I. Transforming our Medical Defenses[5]

1. Vaccines

Goal: Have the ability to rapidly make effective vaccines against any virus family.

(1.1) Vaccine design, testing, and authorization. Enable design, testing, and review of a safe and effective vaccine against any human virus within 100 days after the recognition of a potential emerging pandemic threat.

(1.2) Vaccine production. Enable production of enough vaccine for the entire United States population within 130 days and for the global population within 200 days after its recognition as a potential emerging pandemic threat.

(1.3) Vaccine distribution. Enable delivery of vaccines rapidly and easily to anywhere in the world, by eliminating challenging requirements for transportation and storage, and enable distributed manufacturing.

(1.4) Vaccine administration. Enable rapid, large-scale vaccination campaigns, by simplifying vaccine administration — for example, replacing the need for sterile injection with skin patches and nasal sprays and the need for multiple doses with time-released formulation.

(1.5) Vaccine adaptation. Develop ways to rapidly adapt, test, and review modified vaccines to keep pace with changes in the virus.

2. Therapeutics

Goal: Have a range of therapeutics suitable for any virus family, available before a pandemic or readily created during a pandemic.

(2.1) Inhibiting key viral functions. Develop inhibitors that target essential viral functions, such as cell entry and replication, for any human viruses within a family or subfamily. (Effective inhibitors of this type have been developed for HIV and Hepatitis C.) Viral inhibitors would be valuable for treatment and prevention in both pandemic response and ordinary times (for example, to treat shingles or virally-caused meningitis). Promising approaches to develop anti-viral therapeutics include: (i) broadly-acting, small-molecule therapeutics against key viral functions, in advance of a pandemic and (ii) programmable RNA-based therapeutics targeted against specific viruses, for use during a pandemic.

[5] Acheiving the goals for 'Transforming Our Medical Defenses' will require extensive scientific and technological efforts, as outlined in the Scientific Appendix.

(2.2) Producing neutralizing antibodies against a virus. Develop, to deploy when a pandemic threat emerges, the ability to rapidly identify neutralizing antibodies in recovered patients and manufacture monoclonal antibodies for administration to infected individuals. While this approach is known to yield effective therapies for protecting infected individuals, we have lacked to ability to produce such antibodies at rapid-enough speed and large-enough scale for wide spread use.

(2.3) Controlling counterproductive patient responses to infection. Develop and characterize new therapeutics that limit damage from infectious diseases caused by over-or under-active responses of the human body to infection.

3. Diagnostics

Goal: Have simple, inexpensive, high-performance diagnostic tests available at large scale within weeks after the recognition of an emerging pandemic threat.

(3.1) Diagnostic test development. Develop diagnostic platforms for rapid, highly accurate tests that can be readily modified to respond to new and multiple pathogens and that can be deployed in a range of settings and use cases, including home, point of care, and central labs. Technologies should be inexpensive and accessible enough to meet national needs for frequent diagnostic testing, screening, and surveillance during sustained periods of high demand — including, if required, enabling daily home testing by an entire population to limit spread and direct medical care.

(3.2) Employ these diagnostics in public health. To ensure availability of diagnostic platforms in pandemic response, promote large-scale use of inexpensive, accessible, and reconfigurable testing platforms in medical care and public health in ordinary times, to enable routine testing for circulating viruses, including in home settings.

II. Ensuring Situational Awareness

4. Early-Warning Systems

Goal: Have the ability to detect viruses that pose a pandemic threat soon after they emerge in humans and produce and publicly share the full genome sequence.

(4.1) Viral threat detection in clinical settings. Incorporate into clinical care routine genome sequencing of samples from patients with unexplained fever or respiratory disease in the United States and abroad, in order to detect novel viral pathogens soon after they emerge. Expand capacity for genomic sequencing in clinical settings and data sharing, both domestically and internationally.

(4.2) Viral threat detection through environmental monitoring. Expand environmental sequencing, such as through wastewater sampling, in order to detect viruses closely related to known human pathogens circulating in communities, as a complement to viral threat detection in clinical settings.

(4.3) Aggregation of public health information. Create systems that connect real-time information about symptoms with genomic and other relevant public health information.

(4.4) Global early warning network. Support the establishment of a reliable global system for early warning of emerging pandemic threats. Enhance the effectiveness, interoperability, and connectivity of early threat detection at national and international levels with international partners.

5. Real-time Monitoring

Goal: When an emerging pandemic threat has been detected, have the ability to monitor the spread and evolution of the virus.

(5.1) Viral-infection monitoring. Enable effective monitoring, through various means, of virus spread in communities and large populations in order to inform public health response (by the integration of diagnostic, epidemiological, sequencing, environmental monitoring data).

(5.2) Tracking viral variants. As a virus spreads in communities, track changes in the genetic code of the virus and the potential impact of such changes on human health and effectiveness of vaccines, therapeutics, and diagnostics.

(5.3) Epidemic analysis and forecasting. Strengthen real-time analytics and develop accurate models to improve situational awareness and forecast the course of an outbreak, in order to inform communities and decision-makers about where to direct public health resources, bolster healthcare systems, deploy countermeasures, and communicate to the public. In support of this goal, examine and improve the quality of public health data streams.

III. Strengthening Public Health Systems

6. Strengthen the U.S. Public Health System by Expanding Capabilities to Respond to Public Health Emergencies

Goal: Modernize public health infrastructure, domestically and internationally, to effectively prevent, respond to, and contain biological threats.

(6.1) Strengthen the public health work force. Recruit and sustain a diverse cadre of public health experts at the local, state, and federal levels dedicated to preparing for and responding to public health emergencies, including teams that can be rapidly deployed internationally.

(6.2) Invest in public health laboratories and public health digital infrastructure. Ensure that public health labs have the capacity and infrastructure to detect, characterize, and report data (such as genome sequence and functional characterization) on pathogens safely and securely. In support of this, deploy a public health digital infrastructure, based on consistent data standards, which enables real-time data sharing and access across stakeholders involved in pandemic response as well as the public.

(6.3) Prioritize vulnerable communities. Develop strategies to mitigate the health inequities exacerbated during a public health emergency, including prioritizing allocation of public health emergency response resources – from public health workers assigned to communities to connectivity of clinical, data, and laboratory systems – to vulnerable and under-served communities.

(6.4) Support evidence-based public health communication. Support community engagement strategies, based in social science research, and involving community health workers, faith-based organizations, local leaders, and other community voices, to establish trusted communications channels for conveying critical public health information in preparation for and response to public health emergencies, including pandemics, and to bolster broader public health efforts.

7. Global Health Security Capacity to Support Pandemic Preparedness

Goal: Establish the international infrastructure and financing needed for pandemic preparedness.

(7.1) Local Capacity and International Systems. Create local capacity and international systems to optimally coordinate on R&D, clinical evaluation, product approval, and distribution of vaccines, therapeutics, diagnostics, and supplies.

(7.2) Sustainable financing. Catalyze sustainable international financing for health security capabilities for future pandemics and high consequence biological threats, including sustainable support for a global health security financing mechanism, such as a Financial Intermediary Fund, to support metrics-driven approaches to country capacity for countering biological threats.

IV. Building Core Capabilities

8. Personal Protective Equipment

Goal: Have effective, comfortable, and affordable Personal Protective Equipment (PPE).

(8.1) PPE Innovation. Develop solutions that increase the effectiveness, comfort, reusability, affordability, and manufacturability, including warm or surge capability, of PPE, to provide protection against pathogens with a range of properties.

(8.2) Pathogen protection within the built environment: Develop and deploy new technologies to improve indoor air quality, surface materials, and related aspects of transportation, buildings, and other infrastructure to suppress pathogen transmission among people. Invest in retrofitting high-risk infrastructure and incentivize private sector adoption of built environment pathogen suppression technologies for public protection.

9. Stockpiles and Supply Chains

Goal: Restore and expand the ability of the United States to produce the vital supplies to stop the next pandemic in its tracks.

(9.1) Refill stockpiles. Refill stockpiles that have been depleted by the current pandemic, to avoid near-term shortages while building longer-term onshore and near-shore manufacturing capacity for essential medical supplies.

(9.2) Build resilient supply chains. Ensure a stable and secure supply chain for key active ingredients for making vaccines, therapeutics, and diagnostics and for personal protective equipment.

10. Biosafety, Biosecurity, and Prevention of Catastrophic Biological Events

Goal: Prevent laboratory accidents and deter bioweapons development.

(10.1) Accelerate biosafety and biosecurity innovation. Expand capabilities to identify and minimize safety and security risks in the design and development in biotechnology, and share these tools globally.

(10.2) Ensure safe and secure R&D. Ensure R&D involving potentially dangerous biological agents is conducted safely and securely, by fostering a global research environment that adopts and enforces high standards.

(10.3) Deter and detect bioweapons development. Strengthen global norms against the development of pathogens as weapons, including by promoting international norms, transparency, and responsible scientific conduct. Strengthen oversight by developing better approaches to detect violations.

11. Regulatory Improvement

Goal: Improve regulatory capacity to support the development of safe and effective vaccines, therapeutics, and diagnostics.

(11.1) Regulatory approval for platforms. Improve regulatory systems, which typically focus on individual products, to be able to efficiently approve programmable platform technologies for vaccines, therapeutics, and diagnostics, in order to streamline the review of individual products that use these platforms.

(11.2) Clinical trial networks. Promote the development and operation of efficient, large-scale clinical trials networks in inter-pandemic times, with the ability to rapidly pivot to pandemic response. Design master protocols, ensure nationwide geographic coverage, train study coordinators to stand up sites quickly, include rural and community hospitals, and develop guidance for data collection and sharing.

(11.3) Regulatory capacity. Increase regulatory capacity and expand regulatory approaches at the FDA, in order to keep up with expanding needs in the years ahead.

V. Managing the Mission

12. Program Management

Goal: Manage this crucial national endeavor with the seriousness of purpose, commitment, and accountability of an Apollo Program and coordinate work with the international scientific community.

(12.1) U.S. Mission Control. Establish a strong, unified Mission Control to manage, integrate, and ensure accountability for all aspects of the U.S. pandemic preparedness program. Mission Control should have responsibility and authority to develop, update, and execute plans with objective and transparent milestones; regularly assess and report on mission progress, including by drawing on independent scientific panels; and conduct periodic exercises to evaluate national pandemic preparedness by deploying national capabilities, including by rapid product development.

(12.2) International Coordination. Galvanize global support and investment in international capabilities to contain pandemic threats wherever they emerge. Support the establishment of an international science and technology expert group to support and review progress toward global pandemic preparedness goals, including the 100 Day Mission.

III. Summary of Goals

Summary of Goals

This list provides a brief summary of the goals above.

I. Transform our Medical Defenses

1. Vaccines: Rapidly make effective vaccines against *any* human virus family

- Design, test, and review by 100 days after pandemic threat appears (for COVID-19 = May 2020)
- Produce enough vaccine for the U.S. by 130 days and entire world by 200 days
- Simplify vaccine distribution (e.g., eliminate need for cold storage)
- Simplify vaccine administration (e.g., replace sterile injection, with skin patches and nasal sprays)

2. Therapeutics: Life-saving medicines suitable for *any* virus family

- Develop medicines to block key virus functions (as done for HIV)
- Enable rapid production of neutralizing antibodies (currently too slow)
- Develop medicines to prevent severe immune over-reactions (useful in public health)

3. Diagnostics: Simple, inexpensive, accurate tests for *any* virus available within weeks

- Develop technologies to meet sustained demand, including daily home testing for all, if required
- Use new diagnostics in routine care, to serve public health, drive down costs, and expand capacity

II. Ensure Situational Awareness

4. Early-Warning Systems: Rapidly detect new viral outbreaks with pandemic potential

- Detect new threats by genome sequencing of patients with unexplained fevers in U.S. and abroad
- Detect new viral threats by wastewater sampling
- Create early-warning networks to aggregate and analyze global data

5. Real-time Monitoring: Follow existing viral outbreaks for spread and evolution

- Improve tracking by combining diagnostic, epidemiological, sequencing, and environmental data
- Improve analysis and forecasting

III. Strengthen Public Health Systems

6. U.S. Public Health. Modernize infrastructure to prevent and contain biological threats

- Strengthen the public health work force
- Invest in public health laboratories and public health digital infrastructure
- Prioritize vulnerable communities

7. Global Health. Establish international infrastructure and financing for pandemic preparedness

- Create local capacity and international systems
- Catalyze sustainable international financing

IV. Build Core Capabilities

8. Personal Protective Equipment. Increase effectiveness, comfort, affordability, and manufacturability

9. Stockpiles and Supply Chains. Ensure U.S. ability to produce vital supplies

10. Prevent Catastrophic Biological Events. Accelerate biosafety, biosecurity, and deterrence

11. Regulatory Improvement. Ensure regulatory capacity for vaccines, therapeutics, and diagnostics

V. Manage the Mission

12. Mission Control. Manage this national responsibility with the seriousness of purpose, commitment, and accountability of an Apollo Program and coordinate work with international scientific community

IV. Funding

Funding

The table below describes the total funding, above baseline, required to achieve the goals laid out in American Pandemic Preparedness: Transforming Our Capabilities. The total cost of the plan is $65.3 billion, to be invested over 7 to 10 years. (A portion of these funds are requested under the current budget reconciliation.)

It is critical that funds be appropriated to a single, unified "Mission Control" office at the Department of Health Human Services, responsible for overseeing the funds — in order to ensure the overall program management, execution, and accountability necessary to achieve the goals, as well as to enable close oversight by the White House and Congress.

Category	Funds ($B)
1. Vaccines	**$24.2**
1.1 Vaccine design, testing, and authorization, including testing of a range of candidate vaccines for all viral families and Phase III clinical trials for vaccines against active viral diseases	
1.2 Enable rapid, large-scale manufacturing capacity based on programmable platforms	
1.3 Simplify vaccine distribution, including by eliminating cold- chain transportation requirements	
1.4 Develop and test novel routes to simplify vaccine delivery and administration	
1.5 Adapt vaccines to keep pace with vaccine-defying variants	
2. Therapeutics	**$11.8**
2.1 Develop antivirals that inhibit key proteins for viral families, and evaluate in clinical trials against relevant diseases	
2.2 Ensure large-scale, programmable manufacturing capacity for monoclonal antibodies	
2.3 Develop host-specific therapeutics and immunomodulators, and evaluate in clinical trials	
3. Diagnostics	**$5.0**
3.1 Develop affordable and accessible diagnostics that can be deployed quickly at scale	
3.2 Expand diagnostic manufacturing capacity, by deploying new diagnostics in public health	
4. Early Warning	**$3.1**
4.1 Establish reliable clinical surveillance system for early detection of emerging pathogens	
4.2 Expand sequencing of pathogens circulating in communities, including in wastewater	
4.3 Aggregation and accessibility of relevant public health information, including clinical, epidemiological, and genome sequencing data	
4.4 Support establishment of a reliable, international early warning network	

5. Real-time Monitoring	**$2.3**
5.1 Enable effective monitoring of virus spread in communities, during a pandemic	
5.2 Enable effective tracking of virus evolution and its impacts on human health and vaccine efficacy	
5.3 Develop accurate models to forecast the course of an outbreak	
6. Strengthen the U.S. Public Health System by Expanding Capabilities to Respond to Public Health Emergencies	**$6.5**
6.1 Recruit and sustain a strong public health workforce dedicated to preparing for and responding to public health emergencies	
6.2 Strengthen public health lab infrastructure and capacity for pathogen detection, characterization, and reporting	
6.3 Reduce health inequities exacerbated by public health emergencies	
6.4 Support evidence-based public health communication	
7. Global Health Security Capacity to Support Pandemic Preparedness	**$2.8**
7.1 Strengthen local capacity and international systems for R&D, product approval, and rapid distribution of vaccines, therapeutics, diagnostics, and supplies	
7.2 Catalyze sustainable financing for health security capabilities for future pandemics and high consequence biological threats	
8. Personal Protective Equipment	**$3.1**
8.1 Promote next-generation PPE innovation	
8.2 Enhance pathogen protection in the built environment	
9. U.S. Capacity to Produce Vital Supplies	**$2.1**
9.1 Refill depleted pandemic stockpiles	
9.2 Build resilient supply chains, including for active pharmaceutical ingredients	
10. Strengthen Biosafety and Biosecurity, and Reduce Catastrophic Biological Threats	**$2.0**
10.1 Accelerate biosafety and biosecurity innovation	
10.2 Ensure safe and secure R&D	
10.3 Deter and detect biological weapons development and use	
11. Improve the Regulatory Environment	**$1.6**
11.1 Enable efficient regulatory approvals for platform technologies	
11.2 Create large, agile, and flexible clinical trials networks that can be rapidly ramped up for urgent needs	
11.3 Ensure regulatory capacity keeps pace with new technological developments	
12. Manage the Mission	**$0.8**
12.1 Establish Mission Control for pandemic preparedness	
12.2 Investment in international capabilities to contain pandemic threats where they emerge	
TOTAL AMOUNT NEEDED FOR MISSION (ABOVE BASELINE)	**$65.3**

[1] These estimates are preliminary and subject to change, depending on evolving agency assessments and ongoing agency consultations as part of the President's Budget process.

V. Scientific Appendix for Transforming our Medical Defenses

Scientific Appendix for Transforming our Medical Defenses

Preventing emerging infectious diseases from turning into devastating pandemics will require transforming our capabilities to produce vaccines that can protect against disease and block spread; therapeutics to prevent serious illness or death in infected individuals; and diagnostics to identify infected individuals in order to contain spread and target medical treatment.

With advances in science, we have the opportunity to develop scientific and technological capabilities that will not only help to prevent future pandemics, but will also provide broad public health benefits during inter-pandemic times. Importantly, we must be prepared for any type of virus, because the next potential pandemic may not resemble COVID-19.

This section serves as an appendix to American Pandemic Preparedness: Transforming Our Capabilities, providing scientific background concerning the plan's first pillar, on Transforming Our Medical Defenses.

Goal 1. Vaccines: Have the ability to rapidly make effective vaccines against any virus family.

(1.1) Vaccine design, testing, and approval. Design, test, and approve a safe and effective vaccine against any pathogenic human virus within 100 days following the identification of an emergent viral pandemic. While the 100-day target to produce vaccines for any virus is easy to state, achieving it will require an extensive scientific workplan:

- **Select one or more representative viruses for each virus family to characterize intensively ('prototype pathogens').** Success in quickly creating COVID-19 vaccines was possible only because of two decades of intense coronaviruses research that followed the 2002 SARS-CoV-1 outbreak in Asia. Since the next pandemic may not be caused by a coronavirus, we need to generate comparable information for all of the 26 families of viruses known to infect humans.
- **Leverage "programmable" platforms for rapid vaccine development.** New platforms for vaccine development, such as nucleic acid and recombinant viral vector technologies, are dramatically accelerating vaccine design by avoiding specialized, costly, and time-consuming steps of classical approaches. These platforms are at early stages: we should work to enhance these platforms and develop further new platforms.
- **Identify effective potential targets for design of vaccine candidates.** For each prototype pathogen, we will need to characterize viral protein structures, isolate antiviral antibodies, and identify the best viral targets for optimal vaccine design. In addition, we will need to define the extent of genetic variation and create virus family-specific tools and animal models that can be used for pre-clinical and clinical testing of vaccine candidates in animal models and humans.
- **Test the efficacy of dozens of candidate vaccines in animal models.** In animal studies, we will need to answer key questions for each virus family: Which viral proteins and specific sequences code for immunogens that generate the strongest immune responses? How well do vaccines perform against various targets? How much does vaccine safety and efficacy depend on how it is formulated?
- **Identify correlates/surrogates of protection in animal models.** Identifying correlates or surrogates of protection (such as the quantity and quality of neutralizing and other functional antibodies, as well as cellular responses), the tissues in which they are found, and the kinetics of

their appearance and persistence will aid in assessing the likely efficacy of human vaccine candidates.

- **Conduct small human clinical trials for many vaccine candidates to assess safety, likely efficacy based on correlates/surrogates of protection, and the impact of dose and schedule on immungenicity.** Small human research studies ("Phase 0") can show whether a vaccine candidate can elicit immune responses expected to mediate protection, although they won't directly test immune protection. (In the case of a highly transmissible and lethal threat from a pandemic or biological weapon, it is possible that biomarkers might need to serve as a substitute for direct protection.)
- **Test the effectiveness of vaccines developed against multiple targets and multiple genetic variants.** It will be important to assess the effectiveness of vaccines that target multiple viral proteins and/or genetic variants simultaneously. Such approaches might improve vaccine design in general, and might provide new ways to combat resilient and highly mutable viruses, like HIV and influenza, by encoding multiple targets in a single vaccine to generate broadly neutralizing antibodies and T-cell responses capable of broad-based protection.
- **Test the ability to develop 'universal vaccines' against all viruses in a family or subfamily.** A holy grail of vaccine research is creating vaccines that can protect against entire virus families, such as all coronaviruses or all influenza viruses, that mutate frequently and/or circulate seasonally. Programmable vaccine platforms will enable testing of multiple approaches to assess whether universal vaccines may be possible, with the potential to address entire families of viruses.
- **To enable the R&D work above, support the creation of biological foundries and pilot manufacturing plants to enable the design and production of many candidate vaccine design for clinical testing.** Access to excellent and efficient facilities for creating candidate vacines, using various programmable platforms, will streamline research and development. This includes foundries for cGMP synthesis of nucleic acids and proteins to serve as vaccine components and pilot-scale production lines to create cGMP vaccines for clinical testing.
- **Create infrastructure to enable rapid, large-scale clinical testing.** Vaccine trials involve administering vaccine or placebo to participants and waiting until a sufficient number of infections have occurred to determine if the vaccinated individuals show greater protection. Vaccine testing can be accelerating by increasing the size of the trial and by enrolling them rapidly. We will need robust, agile, and large-scale national and global clinical trials networks that can enroll many participants when needed. This should be a cooperative effort, involving public and private sponsors of clinical trial networks, standard-setting organizations such as the International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use, and global health leaders, such as the World Health Organization, to create interoperable clinical trial networks and sites that can be seamlessly pivoted towards pandemic response.
- **Develop effective clinical trial resources.** COVID-19 vaccine trials illustrated the importance of centralized, coordinated resources to support large-scale clinical trials. There needs to be a coordinated effort, established in advance, to proactively establish resources important to the conduct, review, and monitoring of clinical trials. This includes advance development of diverse and inclusive participant registries, master protocols, creation of centralized Institutional Review Boards and Data Safety Monitoring Boards, negotiated Reliance Agreements and Data Sharing/Use Agreements, development of data standards and standardized consent forms, and agreements on data repositories and intellectual property issues.

- **Apply technologies and standards to enable widely-distributed clinical trials.** Vaccine trials can be accelerated through decentralized clinical trial platforms that provide digital screening, remote enrollment, and remote patient monitoring (e.g., at-home sample collection, continuous physiological monitoring). Such approaches will improve quantitative outcome measures for trials for both efficacy and safety and will allow underserved populations to more readily participate.
- **Expanded regulatory capacity, vaccine safety monitoring, and post-market safety surveillance.** Vaccine trials that involves 100,000 participants may nonetheless not detect side effects that occur in only a tiny proportion of the population. As with any medical treatment, the only way to observe extremely rare risks is to continue to gather data once the vaccine is in use in the population. We must create and strengthen international safety monitoring networks to look for adverse events, including in low- and middle-income countries.

(1.2) Vaccine production. Enable production of enough vaccine for the entire U. S. population within 130 days and for the global population within 200 days after the recognition of a potential emerging pandemic threat.

- **To ensure that large-scale vaccine manufacturing capacity based on programmable platforms is available when pandemics emerge, ensure that such capacity is in active use for other purposes to serve regular medical and public health needs during inter-pandemic times.** It is not feasible to maintain idle factories that are be taken out of mothballs when pandemics strike. Rather, it is will be important to have "hot" manufacturing capacity in continuous use during inter-pandemic times (producing vaccines against infectious diseases, as well as possibly other products, such as cancer vaccines) that can be redirected for pandemic response.
- **To ensure that there is sufficient capacity to vaccinate the world, develop and simplify methods that decrease the material required for effective vaccination.** It is critical to have the ability to rapidly produce enough vaccine to supply the world. At present, producing 20 billion doses in Pfizer-BioNtech's five manufacturing facilities would require about three years. However, if the dosage could be reduced by ten-fold, the time could be slashed to under four months. Efforts should be undertaken to define dosage-response relationships in animals (based on protection) and humans (using predictors of protection) and to increase the vaccine potency—for example, via adjuvants, delivery mechanisms and, in the case of mRNA vaccines, approaches such as self-amplifying RNA.

(1.3) Vaccine distribution. Enable delivery of vaccines rapidly and easily to anywhere in the world, by eliminating challenging requirements for transportation and storage.

- **Simplify vaccine distribution and delivery, including by eliminating the need for cold chain.** Vaccine formulations that do not require specialized conditions, such as ultra-cold temperatures, and are long-lived will simplify transportation to both resource-rich and resource-constrained settings around the world.

(1.4) Vaccine administration. Enable rapid, large-scale vaccination campaigns, by simplifying vaccine administration — for example, replacing the need for sterile injection with skin patches and nasal sprays and the need for multiple doses with time-released formulation.

- **Simplify vaccine administration so that vaccines can be safely administered by minimally-trained personnel.** Needle-free vaccine delivery methods, such as nasal sprays or microneedle skin patches, could reduce or eliminate the need for specialized health personnel to administer vaccines. Multi-dose vaccines might be delivered in a single administration by using timed-release formulations.

(1.5) Vaccine adaptation. Develop ways to quickly and easily update vaccines to keep pace with changes in the virus.

- **Develop strategies to address viral variants that evade vaccine-induced immunity.** As virus spreads, they will likely evolve the ability to increase their transmissibility — including in vaccinated individuals. Efforts should be undertaken now to understand the relative effectiveness of various strategies for dealing with vaccine evasion, including using boosters to increase antibody titer and administering 'next-generation' of vaccines matched to variant strains.

Goal 2. Therapeutics: Have a range of therapeutics suitable for any virus family, available before a pandemic or readily created during a pandemic.

(2.1) Inhibiting key viral functions. Develop inhibitors that target essential viral functions, such as cell entry and replication, for any human viruses within a family or subfamily. (Effective inhibitors of this type have been developed for HIV and Hepatitis C.) Viral inhibitors would be valuable for treatment and prevention in both pandemic response and ordinary times (for example, to treat shingles or virally-caused meningitis). Promising approaches to develop anti-viral therapeutics include:

- **Develop broadly-acting small-molecule therapeutics against key viral functions, in advance of a pandemic.** Development of small-molecule therapeutics against viral proteins, such as polymerases or proteases, is a well-established approach — involving high-throughput screening using in vitro or cellular systems to identify molecules, chemical optimization to produce lead molecules, preclinical testing, and clinical testing. Because the approach is too slow to enable creation of new therapeutics in the midst of a pandemic, it is necessary to identify and test broadly-acting therapeutics against viral families in advance of a pandemic. The goal would be to develop therapeutics that are effective across a broad spectrum of viruses within a viral family or across multiple viral families.
- **Develop the ability to rapidly create programmable RNA-based therapeutics targeted against specific viruses, for use during a pandemic response.** Programmable RNA-based therapeutics, in which pathogen sequences are inserted into an existing platform, may enable rapid development of therapeutics against specific viruses — for example, to block viral replication, entry into cells, or other key functions. (These technologies include short interfering RNAs (siRNAs), antisense oligonucleotides, and CRISPR-based approaches. For example, siRNA is currently being developed as a possible treatment for Hepatitis B.) Developing these platforms now to treat existing viral infections would develop the knowledge base and capacity to use programmable RNA therapeutics to rapidly respond to a novel pathogen.

(2.2) Producing neutralizing antibodies against a virus. Develop, to deploy when a pandemic threat emerges, the ability to rapidly identify neutralizing antibodies in recovered patients and manufacture monoclonal antibodies for administration to infected individuals. While this approach is known to yield effective therapies for protecting infected individuals, we have lacked to ability to produce such antibodies at rapid-enough speed and large-enough scale for wide spread use.

- **Ensure large-scale programmable manufacturing capacity for monoclonal antibodies.** Continued efforts are needed to optimize the process for identifying and selecting neutralizing antibodies, and to design manufacturing processes for large-scale antibody production.

Opportunities exist to expand the use of monoclonal antibodies in clinical care for chikungunya and other known viruses during inter-pandemic periods to offer the first targeted. As with vaccine production, it is will be important to have “hot” manufacturing capacity in continuous use during inter-pandemic times (producing antibodies against infectious diseases, as well as possibly other products) that can be redirected for pandemic response.

(2.3) Controlling counterproductive patient responses to infection. Develop and characterize new therapeutics that limit damage from infectious diseases caused by over-or under-active responses of the human body to infection.

- **Develop therapeutics to modulate responses by the immune, circulatory, and other organ systems to viral infection.** Modulators of the immune system—such as dexamethasone and tocilizumab, which act through distinct mechanisms—were found to reduce mortality among the sickest COVID-19 patients. Therapeutics targeting the respiratory system or the circulatory system would be useful for treatment of pneumonia or blood clotting symptoms in both ordinary times and during pandemic response.

Goal 3. Diagnostics: Have simple, inexpensive high-performance diagnostic tests available at large scale within weeks after the recognition of an emerging pandemic threat.

(3.1) Diagnostic test development. Develop diagnostic platforms for rapid, highly accurate tests that can be readily modified to respond to new and multiple pathogens and that can be deployed in a range of settings and use cases, including home, point of care, and central labs. Technologies should be affordable and accessible enough to meet national needs for frequent diagnostic testing, screening, and surveillance during sustained periods of high demand — including, if needed, enabling daily home use by an entire population, to limit spread and direct medical care.

- **Develop viral-specific, rapid-turnaround tests that can be self-administered in any environment.** We promote innovation in diagnostic testing, by supporting the design, development, and deployment of programmable platforms with the potential to be highly accurate, extremely inexpensive, easy to use, readily accessible, and rapidly manufactured. In addition, manufacturing capacity needs to be maintained in inter-pandemic times, and raw materials need to be available immediately at the onset of a pandemic. There are opportunities with respect to the analyte detected (nucleic acids, proteins), sampling strategies (nasal swabs, saliva or exhaled breath), analytical chemistries, and integration with mobile devices. We also need to ensure that tests can be reconfigured within two weeks of the detection of a potential pandemic threat.

(3.2) Employ these diagnostics in public health. Develop and produce innovative test platforms for routine diagnosis, screening, and surveillance of existing infectious and chronic diseases in patients today, while ensuring the ability to rapidly reconfigure them to detect new pathogens and threats in future pandemics.

- **Integrate rapid diagnostics into current point-of-care treatment.** Diagnostic tests that cost pennies and yield results in minutes could speed patient triage in emergency rooms, extend diagnostics into primary care settings, and be used for home testing together with telehealth. These diagnostic tests would have immediate benefit for diagnosing and treating influenza, human respiratory syncytial virus, antibiotic-resistant bacterial infections, and many other infectious diseases.

Corps of Engineers Converts NYC's Javits Center Into Hospital

April 1, 2020 | By C. Todd Lopez , DOD News

The New York District of the Army Corps of Engineers has completed its conversion of the 1,800,000-square-foot Jacob K. Javits Convention Center in New York City into an alternate care facility for more than 2,000 non-COVID-19 patients.

More than 165 New York District personnel provided design, engineering and construction support to facilitate the conversion in response to a Federal Emergency Management Agency request, said Michael Embrich, a Corps of Engineers spokesman.

The Corps of Engineers got the call from FEMA about two weeks ago to outfit the convention center into an alternate care facility, Embrich said. Work began about a week later, and was complete just a week after that. The speed at which the Corps was able to get the project completed is unusual, he said, but the circumstances warranted the extra effort.

"It was much quicker than we usually design, engineer and construct a project," he said. "We worked 24 hours a day, seven days a week with our vertical team to spec out the sites [and] award contracts, and then began work immediately after the contracts were awarded."

Patients were able to move into the converted facility March 30, Embrich said.

The alternate care facility will not be used for COVID-19 patients. It will be used for non-COVID-19 patients, allowing area hospitals more room to treat patients infected by the coronavirus.

Contracts were recently awarded to convert additional locations in New York into alternate care facilities. Included among those are the Westchester County Community Center in White Plains, New York, and at the State University of New York's campuses at Stony Brook and Old Westbury on Long Island. Work should begin on those projects soon, Embrich said.

It wasn't the Corps of Engineers alone that made the effort at the convention center possible, Embrich said.

This effort wouldn't be possible without the "phenomenal teammates" the Corps of Engineers has at the state of New York, the city of New York, the New York National Guard, FEMA, the Department of Health and Human Services, the Centers for Disease Control and Prevention, the General Services Administration, as well as the Defense Department and the armed forces, he said.

"There are so many people from the health care professionals to the staff at the Javits Center who are still working throughout New York and New Jersey," he added. "Truthfully, there are too many to name."

Embrich said that during emergencies, the Corps of Engineers serves as the federal government's lead public works and engineering support agency.

"The New York District works 365 days a year in New York and in the surrounding communities," he said. "Currently, the Corps has numerous studies that will help bring more constructed projects to New York City that will increase resiliency and reduce risk to persons, property and infrastructure in the city."

GOVERNMENT RESOURCES

www.coronavirus.gov

www.cdc.gov/coronavirus

www.usa.gov/coronavirus

'I Still Can't Believe What I'm Seeing.' What It’s Like to Live Across the Street From a Temporary Morgue During the Coronavirus Outbreak

A covered body is seen in the back of a temporary morgue erected outside Wyckoff Heights Medical Center in Brooklyn, New York, on March 29, 2020. Benjamin Norman for TIME

BY **SIMON SHUSTER**

MARCH 31, 2020 2:11 PM EDT

From the living room window of her Brooklyn apartment, Alix Monteleone watched the team of workers assemble the morgue in stages over the

A-344

weekend. First, they parked the refrigerated trailer along the curb, a white box about the size of a large shipping container. Then, they built a wooden ramp to allow hospital staff to wheel the bodies inside. Finally, on Monday, the workers erected a wall of panels, thin and white, to stop passersby from staring or getting too close to the dead.

After that, the gawkers mostly went away. But Monteleone, a 28-year-old event planner from Long Island, kept up her vigil from the third-floor window.

"I spend my entire day like this," she says, propping her elbows onto the back of her couch and looking out toward the Wyckoff Heights Medical Center, the hospital across the street. "I still can't believe what I'm seeing."

The deployment of temporary morgues across the city—known to emergency planners as Body Collection Points, or BCPs—marks a new phase of the COVID-19 pandemic for New Yorkers, whose city has rapidly become the global center of the crisis. By late Monday, the state's death toll had surpassed 1,200, with more than 66,000 confirmed infections. More than 900 of the deaths were in New York City.

Until now, it had been largely possible for residents to shut out the worst of this calamity, retreat into their homes and only go out for short trips around the neighborhood, all without confronting anything more grim than empty streets and people wearing face masks.

The arrival of the morgues and makeshift hospitals—which have been installed in public spaces—has thrust the pandemic into full view as it envelops the nation's largest city, making this escapism difficult. Anyone strolling through Central Park could observe a field hospital erected on the lawns to alleviate the patient load at hospitals like Wyckoff Heights. Another pop-up hospital has been set up at the Jacob K. Javits Convention Center in Manhattan, and on Monday, the Navy ship Comfort docked in New York to take on more patients.

The largest temporary morgue in New York City occupies a tent set up over the weekend outside Bellevue Hospital in Manhattan. “We have them at public and private hospitals throughout the boroughs,” says Aja Worthy-Davis, a spokesperson for the office of the chief medical examiner, the city agency responsible for caring for the dead. At least four had been set up as of Monday, she said: two in Brooklyn, one in Queens, and one in Manhattan. “We expect to start utilizing the large tent in Bellevue soon.”

***Keep up to date with our daily coronavirus newsletter by clicking** here.*

Ramon Rodriguez, the President and CEO of the Wyckoff Heights hospital, says it was not his decision to deploy the refrigerated truck, but he is thankful that the office of the medical examiner was able to provide it to his facility, whose morgue can only house nine bodies at a time. “Over the last three weeks we have filled that morgue many times over,” he says of the hospital’s usual morgue space.

The bodies in the refrigerated truck are being picked up by funeral homes for burial as quickly as possible, adds Rodriguez. Given the distress this process was likely to cause local residents, placing the truck on a public street was not an easy decision, he says. But the hospital had no other viable place to put the trailer, which is 53 feet long.

“We want to be respectful and kind both to the people who have left this earth and those who live across the street,” says Rodriguez. And the need for extra privacy is why the hospital put an enclosure around the wooden ramp leading to the trailer.

Under the New York City medical examiner’s protocols for a pandemic, the deployment of temporary morgues becomes necessary when the death toll tops 200 per day, overwhelming the capacity of hospitals to store bodies safely. New York City passed that threshold last week, triggering a new “mobilization level” in the city—the third level on a scale of six—according to a copy of the chief medical examiner’s pandemic “surge plan” for handling the dead, which Worthy-Davis shared with TIME.

Drafted in 2008 to prepare for a devastating flu pandemic, the plan envisions far more dramatic measures of “mass fatality management” if the virus continues to spread. Officials at Rikers Island, the city’s main jail, could put inmates to work burying some of the dead in the city-run public cemetery on Hart Island, the plan states. Under the current level of mobilization, the city must also draw up contracts with cemeteries that can accommodate temporary mass graves, which the plan describes in jarring detail: "Ten bodies in caskets are placed lengthwise in a long narrow section in the ground."

By comparison, the installation of temporary morgues would seem like a measure New Yorkers could stomach. But it has been enough to unsettle the neighbors of the Wyckoff Heights hospital. Before the refrigerated trailer arrived on Friday, Monteleone and her fiance, Marc Kozlow, had gotten used to the routines of confinement and boredom that come with social distancing. They took turns walking their dog Hank around the neighborhood. She had tried doing needlepoint to pass the time. He had started baking sourdough in the kitchen.

But by Saturday, when they saw the first bodies taken on gurneys from the hospital and carried into the trailer, their hopes for riding out the pandemic at home began to dim. "If a nuclear reactor is exploding near you, you don't stay near the hot zone," says Kozlow, 33. "You get out."

Although they understood from news reports that the hospital across the street was quickly filling with COVID-19 patients last week, the reality only sank in after they began to see the bodies, some of them zipped into bags, others wrapped in what appeared to be white bed sheets. They counted more than a dozen over the weekend.

Monteleone keeps insisting they stay. "This is my home," she says in the living room of their one-bedroom apartment. "The only semblance of control I have in my life right now is staying in my home. So we just need to adjust. We need to close the blinds."

But within a few minutes she was back at the window. "I want to know," she says. "I want to know the body count."

CONTACT US AT LETTERS@TIME.COM.

CALIFORNIA

Spiraling COVID-19 deaths leave morgues overflowing and funeral homes turning away grieving families

Family and friends console one another as they gather at a service Dec. 20 for Julio Aguilar at the Continental Funeral Home in East Los Angeles. The 74-year-old died Nov. 28 from complications of COVID-19. (Brian van der Brug / Los Angeles Times)

BY MATTHEW ORMSETH, RONG-GONG LIN II, LUKE MONEY, SOUMYA KARLAMANGLA

JAN. 1, 2021 5 AM PT

A months-long surge of coronavirus cases in Los Angeles County is reaching its grim if inevitable zenith as deaths reach once-unthinkable levels, medical infrastructure is buckling under a flood of patients and officials fear the mortality numbers will only worsen in the coming weeks.

The county recorded an average of 151 people dying from COVID-19 each day in the past week — a figure that's almost as high as the average number of people dying daily from every other cause, about 170 a day. But more recently, those numbers have spiked considerably.

Single-day COVID-19 death records have been broken every day for the last three days of the year, with 242 deaths reported Tuesday, 262 on Wednesday and 291 on New Year's Eve.

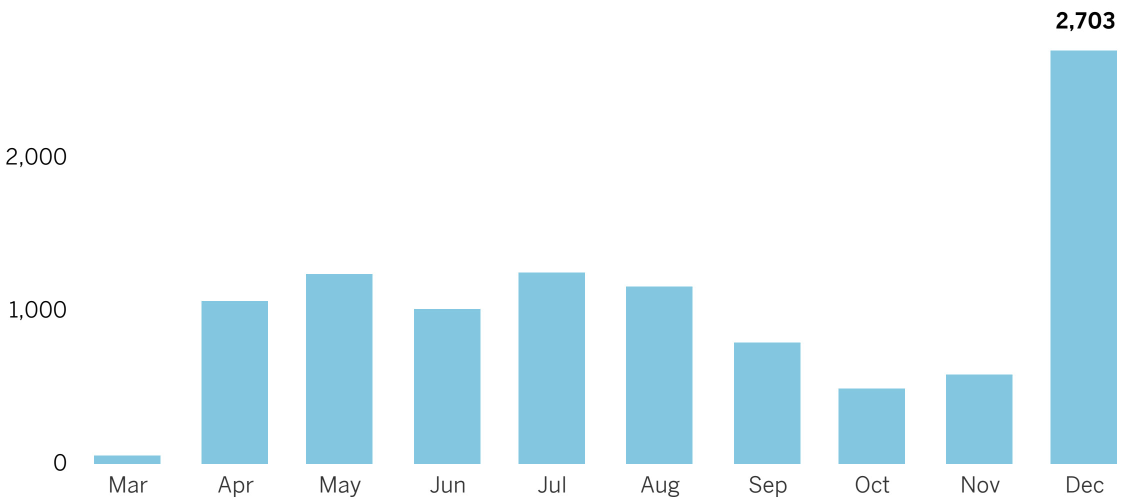
The sheer number of fatalities is causing more challenges to already overwhelmed hospitals and other institutions. Many hospital morgues are now filled with bodies, and officials are trying to move them for temporary storage at the county medical examiner-coroner's office.

Mortuary and funeral home operators say they are having to turn away bereaved families because they don't have the capacity to handle more bodies.

L.A. County monthly COVID-19 deaths

December was Los Angeles County's deadliest month of the pandemic.

Monthly COVID-19 deaths



Source: Times county-by-county tally

Los Angeles Times

Turning away families from mortuaries

Jennifer Bagues, the general manager of Felipe Bagues Mortuary in Boyle Heights, started turning away families this week. Her family's small mortuary on 1st Street, which was founded by her great-grandfather, can accommodate no more than 20 bodies.

Bagues estimates that 75% of the calls she's fielded in the last two weeks have been from families whose relatives have died of COVID-19. Lately, she's realized some families are returning to bury a second loved one. Bagues scheduled a service this weekend for a husband and wife who both died from COVID-19, the fifth one she's arranged since the pandemic began, she said.

Telling grieving families she can't take their loved ones is heartbreaking, Bagues said. "I think my dad would be turning over in his grave if he heard me saying that."

Rob Karlin, the owner and funeral director of Los Angeles Funeral Service in Culver City, attributed his capacity issues both to the rising caseload and to a slowdown in the process of burying the dead. Obtaining death certificates, retrieving bodies from the coroner, embalming them — “everything is taking longer,” he said.

Embalmers, he added, are treating every body as if it had been infected with COVID-19.

“They’re taking extra precautions and using a lot of bleach,” he said. “There’s an uncertainty about how long it’s dangerous on a dead body. I don’t know. There’s so much unknown.”

Karlin founded a casket company in 1996 and the funeral service in 2005. “I’ve never been in a position where I had to say, ‘I’m sorry. I can’t help you,’” he said.

‘Our morgue has been full all the time’

At St. Francis Medical Center in Lynwood, morticians from funeral homes can’t come fast enough to remove bodies from the hospital morgue, said Scott Byington, a nurse at the hospital. Morticians visit the hospital multiple times a day to pick up as many bodies as they can, but limited space at the funeral homes has created a backlog.

Any open spots are quickly filled with more deceased patients, Byington said.

At the beginning of a recent shift, Byington was told there were enough gurneys for nine more people in the hospital morgue. Six hours later, several patients had died and the morgue was at capacity, he said.

“We were calling the mortuary to come and take what you can,” he said. “Our morgue has been full all the time.”

Based off of previous patterns, the spike in COVID-19 deaths related to Thanksgiving may last through early to mid-January. Hospitalizations related to the expected surge in virus transmission over Christmas and New Year's are expected to worsen around the middle and later weeks of January.

'We're running out of ambulances'

In L.A. County, in the days before Christmas, overloaded hospitals were already adding in a net additional 234 more COVID-19 patients in hospitals every day over a weekly period, a record.

The pace has settled somewhat since then; for the seven-day period ending on Wednesday, a net additional 129 new COVID-19 patients were added to hospitals daily. But there hasn't been as much relief for the ICUs. In mid-December, the already full ICUs were adding a net average of 44 new ICU patients a day; by the end of the month, there were still a net average of 36 new ICU patients a day.

Lengthy wait times to offload patients at the county's critically overcrowded hospitals are increasingly keeping ambulances from being able to respond to other emergency calls, officials said Thursday — the latest repercussion of the rampant and widespread coronavirus surge that's walloping the region's healthcare system.

Sometimes as many as 10 ambulances are queued up waiting to drop off patients, and "we've had patients waiting in ambulance bays outside of [emergency departments] for seven hours, eight hours," said Cathy Chidester, director of the L.A. County Emergency Medical Services Agency.

"We're running out of ambulances, and our responses to 911 calls are getting longer and longer," she said during a briefing Thursday.

Running low on oxygen

In the Antelope Valley, "response times are getting longer," forcing officials to begin relying on ambulance companies that are not traditionally used to respond to 911 calls, Chidester said.

Hospitals are scrambling to find staff. Sometimes emergency medical technicians are asked to work in hospitals. Older hospitals are being reconfigured to house far more patients than they ever anticipated holding. The demand for oxygen for patients suffocating from their inflamed lungs is causing some hospitals to lose adequate air pressure in their pipes.

"Running low of oxygen and oxygen tanks is an issue," Chidester said. The shortage of oxygen tanks is a problem for hospitals trying to discharge recovering COVID-19 patients as fast as possible, as they often need to be sent home with oxygen tanks.

Unlike other disasters, where the impact can be easily seen from a dramatic fire or earthquake, the pandemic for some people appears to be hidden, with the illness and deaths "all happening behind the doors of households and hospitals, so … the general public is not really seeing what is going on," Chidester said.

The number of deaths reported in California each day on Tuesday, Wednesday and Thursday was more than on any other previous day throughout the course of the entire pandemic — a back-to-back battering that has propelled the state's total death toll past 25,000.

California is the third state to reach that morbid mark, joining Texas and New York.

Over the last four days, the deaths of about 1,700 people in California from COVID-19 have been reported, including a record-high of 442 Tuesday and the next-highest total, 424, a day later. The single-day record was broken again on New Year's Eve, with 573 additional deaths.

Those numbers represent roughly the equivalent of one Californian dying from the disease every three and a half minutes.

In Los Angeles County, officials say one person is dying every 10 minutes.

Starting at midnight Thursday, county officials began posting new messages on Twitter at that interval, describing someone who may have just lost his or her battle with COVID-19: the principal who stayed late to watch every school play, an ER nurse who pulled double shifts for months on end, the activist who labored to uplift a community, a cherished co-worker or friend, a beloved family member.

Each message was punctuated with the same plea: "Slow the spread. Save a life."

Times staff writers Maloy Moore and Thomas Suh Lauder contributed to this report.

Matthew Ormseth

Matthew Ormseth is a reporter for the Los Angeles Times. Before joining The Times in 2018, he covered city news and state politics at the Hartford Courant.

Rong-Gong Lin II

Rong-Gong Lin II is a Metro reporter based in San Francisco who specializes in covering statewide earthquake safety issues and the COVID-19 pandemic. The Bay Area native is a graduate of UC Berkeley and started at the Los Angeles Times in 2004.

Luke Money

Luke Money is a Metro reporter covering breaking news at the Los Angeles Times. He previously was a reporter and assistant city editor for the Daily Pilot, a Times Community News publication in Orange County, and before that wrote for the Santa Clarita Valley Signal. He earned his bachelor's degree in journalism from the University of Arizona.

Soumya Karlamangla

Soumya Karlamangla previously covered healthcare in California for the Los Angeles Times. She was part of the team of reporters awarded the Pulitzer Prize for its coverage of the 2015 San Bernardino terrorist attack. Before joining The Times in 2013, she worked for the Oregonian, San Francisco Chronicle, Nation magazine in

D.C. and Thomson Reuters in London. She was raised in Thousand Oaks and graduated from UC Berkeley with degrees in biology and English literature.

THOSE WE'VE LOST

Herman Cain, Former C.E.O. and Presidential Candidate, Dies at 74

Mr. Cain sought the 2012 Republican nomination and became an early supporter of Donald Trump's 2016 bid. He had been hospitalized with the coronavirus.

By Aimee Ortiz and Katharine Q. Seelye

Published July 30, 2020 Updated Aug. 3, 2020

Herman Cain, who rose from poverty in the segregated South to become chief executive of a successful pizza chain and then thrust himself into the national spotlight by seeking the 2012 Republican presidential nomination, has died. He was 74.

His death was announced on Thursday on his website and on social media accounts. It did not say precisely when or where he died. Dan Calabrese, the website's editor, attributed the death to the coronavirus, which President Trump, in a White House briefing, later referred to as the "China virus" and a "horrible plague" in affirming it as the cause.

Mr. Cain had been hospitalized in the Atlanta area this month after testing positive for the virus on June 29.

Mr. Cain in 1971, the year he earned a master's degree in computer science at Purdue University. Cain family, via Zumapress

"We knew when he was first hospitalized with Covid-19 that this was going to be a rough fight," Mr. Calabrese said in the announcement, adding, "Although he was basically pretty healthy in recent years, he was still in a high-risk group because of his history with cancer." Mr. Cain had overcome colon and liver cancer in the mid-2000s.

Mr. Cain had attended President Trump's indoor rally in Tulsa, Okla., on June 20 and had done "a lot of traveling" recently, Mr. Calabrese said.

"I don't think there's any way to trace this to the one specific contact that caused him to be infected," he said at the time. "We'll never know."

In a video posted to his website after the Tulsa rally, Mr. Cain said he had worn a mask while he was in groups of people. But he also posted photographs of himself on social media that showed him without a mask and surrounded by people in the arena. Later, after Mr. Trump had scheduled an event at Mount Rushmore in South Dakota, Mr. Cain wrote approvingly on Twitter that masks would not be mandatory. "PEOPLE ARE FED UP!" he wrote.

On the stump, Mr. Cain called himself an ABC candidate — American Black Conservative. He brought an irreverent style to the 2011 campaign as he touted his by-the-bootstraps story in an appeal to Tea Party conservatives.

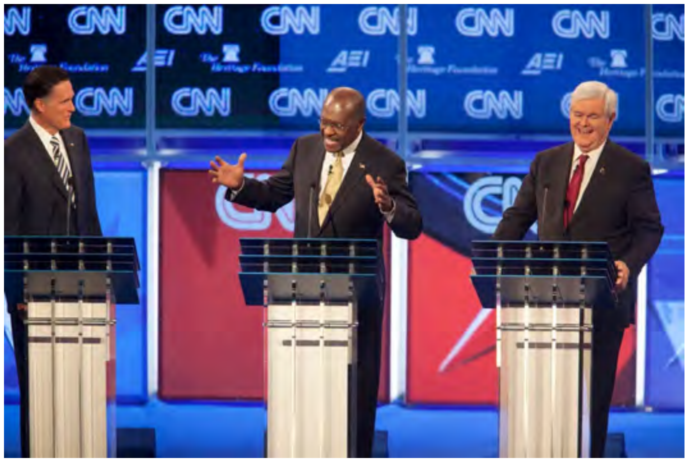
Mr. Cain in McClellan, Ala., in October 2011, early in his campaign for the Republican presidential nomination. Rich Addicks for The New York Times

He dropped out of the race after he was accused of sexual misconduct, allegations he denied. But his celebrity in conservative circles endured, and he became an ardent ally of Mr. Trump.

Mr. Cain said he had become a Republican after a Black man at a restaurant yelled out: "Black Republicans? There's no such thing."

"When I got back to Omaha," where he was living at he time, "I registered as a Republican," he told The New York Times Magazine in 2011. "It haunted me for three days that someone would dare tell me what party affiliation I should have."

Mr. Cain's 2011 presidential campaign was not his first foray into politics, but it catapulted him onto the national stage. His platform was best known for his 9-9-9 tax plan: a flat 9 percent individual income tax rate, a 9 percent corporate tax rate and a 9 percent national sales tax.



Mr. Cain at a Republican presidential debate in November 2011 with Mitt Romney, left, and Newt Gingrich. The cornerstone of his campaign was a tax plan he called "9-9-9." Philip Scott Andrews/The New York Times

After his campaign ended, he continued to appear at political conferences and in the conservative news media. Once Mr. Trump took office, Mr. Cain's name was floated periodically as a potential addition to the administration. President Trump considered naming him to a seat on the Federal Reserve Board last year, but several Republican senators indicated that they would vote against his confirmation, partly because of the sexual harassment accusations against him. He withdrew his name.

After the announcement of his death, Kayleigh McEnany, the White House press secretary, wrote on Twitter that Mr. Cain had "embodied the American dream and represented the very best of the American spirit."

Herman Cain was born on Dec. 13, 1945, in Memphis, to Lenora (Davis) and Luther Cain. His mother was a cleaning woman and domestic worker; his father, who grew up on a farm, worked as a janitor and a barber and as a chauffeur for Robert W. Woodruff, president of the Coca-Cola Company, which is based in Atlanta, where Herman was raised.

Herman graduated from historically Black Morehouse College in Atlanta in 1967 with a bachelor's degree in mathematics. He worked as a civilian ballistics analyst for the Navy and earned his master's degree in computer science at Purdue University in 1971.

He married Gloria Etchison in 1968. She survives him, as do their children, Melanie and Vincent, and four grandchildren. Mr. Cain's younger brother, Thurman L. Cain, died in 1999.

After finishing his education, Mr. Cain worked for Coca-Cola as a computer systems analyst. He then moved to Minneapolis to work for Pillsbury, and in 1978 he became an executive in the company's restaurant and foods group.

Mr. Cain after speaking at the Pennsylvania Leadership Conference in Harrisburg in 2012. Monica Lopossay for The New York Times

At Pillsbury, Mr. Cain joined a training program at Burger King, a company subsidiary, in which potential executives were trained from the grill up, working as "Whopper floppers" and cleaning bathrooms. He rose to oversee 400 Burger King franchises in the Philadelphia area, and his success in improving their bottom line led Pillsbury to appoint him to run its Godfather's Pizza chain.

He served as chairman and chief executive of the chain from 1986 to 1996 and lived in Omaha, where the company was headquartered.

Mr. Cain first gained wide attention in 1994, when he had the chance to spar with President Bill Clinton during a nationally televised town hall-style meeting on health care. Mr. Cain insisted that a broad Clinton health care plan would cost jobs. "If I'm forced to do this," he asked, "what will I tell those people whose jobs I'm forced to eliminate?"

Their polite, if pointed, back and forth — Mr. Clinton pushed back with calculations that Mr. Cain declared "incorrect" — made the pizza executive a minor celebrity, particularly among conservatives.

One was Jack Kemp, a leading Republican member of Congress, who shared Mr. Cain's free-market views. In 1996, when Bob Dole, the Republican nominee for president, chose Mr. Kemp as his running mate, Mr. Cain became an adviser to their campaign.

He left the pizza company in 1996 and became president of the National Restaurant Association, a once-sleepy trade group that he transformed into a lobbying powerhouse.

At the time, anti-drunken-driving groups were trying to lower the legal blood-alcohol limit to 0.08 percent from 0.10 percent, a change that restaurant owners feared would hurt liquor sales. Mr. Cain called instead for stiffer penalties for drunken driving. That argument drew a pointed rebuke from Diane Riibe, a board member of Mothers Against Drunk Driving.

“Mr. Cain and those he represents are in the business of selling alcohol,” Ms. Riibe wrote, “not saving lives.”

The restaurant association gave Mr. Cain an intimate view of the way Washington worked. And it helped him lay the groundwork for his first entry into electoral politics, a short-lived bid for the White House in 2000.

After that, he became co-chairman of the businessman Steve Forbes’s unsuccessful presidential campaign. And that same year, he moved back to Georgia to concentrate on his motivational speaking business and to write books espousing his business and political philosophies.

They included “Speak as a Leader: Develop the Better Speaker in You” (1999), “CEO of Self: You’re in Charge” (2001) and “They Think You’re Stupid: Why Democrats Lost Your Vote and What Republicans Must Do to Keep It” (2005).

He sought the Republican nomination for the Senate from Georgia in 2004 but lost badly in the primary to Johnny Isakson, who went on to win the general election.

Less than two years later, Mr. Cain received a diagnosis of late-stage colon cancer, which had spread to his liver. He recovered, and he later said he believed that his survival had shown that God had other plans for him. He credited God with persuading him to run for president after Barack Obama, a Democrat, took office in early 2009.

Mr. Cain published a memoir, “This Is Herman Cain!,” in 2011, just as he was saddling up again for a presidential run. Some critics said he was running for president to sell his book, and his travel schedule, which rarely took him to the early voting states of Iowa and New Hampshire, resembled a book tour more than a serious campaign.

Still, he grabbed attention with his novel “9-9-9” plan. Thanks to the strength of his debate performances and a surprise victory in a Florida straw poll in September, Mr. Cain did well in early polling. He was essentially tied with Mitt Romney, the former Massachusetts governor who had consistently led most polls and who eventually became the Republican nominee.

Mr. Cain campaigning in Birmingham, Ala., in 2011. He did well in early polling but dropped out after allegations of sexual misconduct surfaced. Rich Addicks for The New York Times

Mr. Cain’s political downfall came as swiftly as his ascent, after Politico reported that the National Restaurant Association had paid settlements to two former employees who claimed Mr. Cain had sexually harassed them.

Other complaints piled up. He called them smears dreamed up by his opponents and categorically denied them.

Then came a complaint by a woman named Ginger White, who contended that she had had a 13-year extramarital affair with Mr. Cain that ended shortly before he announced his presidential bid. Ms. White produced phone records to prove that they had called or texted each other frequently, and Mr. Cain acknowledged giving her financial support. He said his wife of 43 years had been unaware of what he insisted was only a friendship.

With Ms. White’s revelation, some of Mr. Cain’s supporters and defenders began backing away, and he eventually dropped out.

The flurry of attention he received in his presidential run helped him land a job as a radio host in 2013. He also wrote columns for Newsmax and appeared as a commentator on Fox News.

During the 2016 election season, Mr. Trump, running as a businessman and a brash political outsider, drew early comparisons to Mr. Cain. At a time when many Republicans were skittish about Mr. Trump, Mr. Cain came to his defense, pushing back against accusations that Mr. Trump was a racist.

After Mr. Cain’s death was announced, Mr. Romney, now a senator from Utah, took to Twitter to write: “Saddened that Herman Cain — a formidable champion of business, politics and policy — has lost his battle with Covid. St. Peter will soon hear ‘999!’ Keep up the fight, my friend.”

The Washington Post
Democracy Dies in Darkness

HEALTH

Almost one-third of black Americans know someone who died of covid-19, survey shows

By Amy Goldstein and Emily Guskin
June 26, 2020 at 6:30 a.m. EDT

Nearly 1 in 3 black Americans know someone personally who has died of covid-19, far exceeding their white counterparts, according to a Washington Post-Ipsos poll that underscores the coronavirus pandemic's profoundly disparate impact.

The nationwide survey finds that 31 percent of black adults say they know someone firsthand who has been killed by the virus, compared with 17 percent of adults who are Hispanic and 9 percent who are white.

Adding in those who know someone with symptoms consistent with covid-19, slightly more than half of black Americans say they know at least one person who has gotten sick or died of the disease caused by the novel coronavirus. Fewer than 4 in 10 white or Hispanic Americans say they do.

Taken together, the poll's findings attest to sharp racial differences in the sense that the virus is close at hand, after nearly a half-year in which it has sparked the nation's worst public health calamity in more than a century.

According to authorities on health disparities, those differences arise from the nation's deep-seated socioeconomic inequality and help explain the recent spasm of unrest across much of the country in a drive for racial justice.

"This pandemic has really unearthed — shone a real bright light on — the ways these disparities should not be accepted and are not tolerable," said Joseph Betancourt, vice president and chief equity and inclusion officer at Massachusetts General Hospital in Boston.

The differing close-up exposure to the virus's ravaging effects is accompanied by divergent attitudes about the best way for the country to recover. Asked whether it is more important to try to control the spread of the coronavirus or to try to restart the economy, even if one hurts the other, 83 percent of black Americans say trying to control the virus is a higher priority.

By contrast, when the same question was asked in a Washington Post-ABC News poll last month, just about half of white Americans said trying to control the virus is more important.

The differences in proximity to coronavirus sickness and death align, too, with political attitudes, the survey shows. More than 8 in 10 black Americans say that, in deciding which presidential candidate to vote for in the November election, the coronavirus outbreak will be one of the most important factors or very important. Nearly as many Americans who are Hispanic say they hold that view — but fewer than 6 in 10 who are white say the same.

The survey "tells us a lot about how the life experiences of individuals in the United States are different by race," said Georges C. Benjamin, executive director of the American Public Health Association. "Life experiences drive a lot about how you view the world, how you make decisions and what you do."

The poll's central findings — the frequency of knowing someone killed by the virus — hold a mirror to the well-established pattern that the coronavirus has made its deepest inroads in the United States among black Americans. The virus has been more likely to infect black Americans and more likely to have a devastating effect on their bodies if they contract it.

"A lot of people have lost folks, and who knows who will be next?" said Lois R. Travillion, 82, a retired Chicago math teacher and school administrator who has had two friends die of covid-19.

In early April, Travillion got a call that a former co-worker in the Chicago school system — a man whom she still saw now and then and still played in his own band — had died of the virus.

Travillion said the other was a man, sharp and mobile in his mid-80s, who always sat two seats away from her at the monthly seniors breakfast, followed by Bible study that she attends at St. Stephen AME Church. Next thing she knew, he was infected, in the hospital, on a ventilator. On one of the last days of April, he died.

She found out just last Sunday that a member of her own church, Kelly Woodlawn United Methodist, had tested positive and is quarantining at home. And another man she knows, Travillion said, "was on a ventilator for a long time — and we thought he wasn't going to make it, but by the grace of God, he pulled through."

When she was a young woman still living in Mississippi, she took part in a 1963 Woolworth lunch counter sit-in to protest segregated seating. When she was new to Chicago in the late 1960s, she took part in the Black Manifesto, a set of demands to improve education at a high school where she taught.

The past months, she has shut herself in against the virus, relying on a former student to bring her groceries, wearing a mask when she walks down the hall to empty trash in the incinerator in the complex where she lives near Lake Michigan.

"People's lives are more important" than focusing on restoring the economy, Travillion said. "There are so many people who have died. You won't even need the economy because there won't be anybody around."

Lester Danner, 28, who lives in northwest Mississippi, has the same view. "It's important to control the virus because we have a walking-dead society with the virus in the air," he said. "A lot of people have died."

Early on, a cousin got infected working in a nursing home laundry, Danner said. But she did not develop symptoms.

Then, an aunt called to tell him a family friend's brother had died. He got sick in March, held on for a month in a hospital, then succumbed. The man and Danner's father were born on the same day 66 years ago.

And now, just across the Tennessee line in Shelby County, cases are spiking — 400 new cases one day this week, more than twice as many as any day in March, April or May. Last week, the city council in Memphis, the county seat, voted to require residents to wear masks in public.

"People, they were so excited to be out of quarantine, they probably thought it would be okay, but now we are getting another wake-up call," said Danner, who does branding and marketing work. "You can't take anything for granted."

According to the poll, there is not much difference among racial and ethnic groups in the proportion of people saying they know someone who has had possible symptoms of covid-19 but do not know anyone who died. Among white Americans, 28 percent say they know someone with symptoms. That is slightly higher than among black and Hispanic Americans, both at 21 percent.

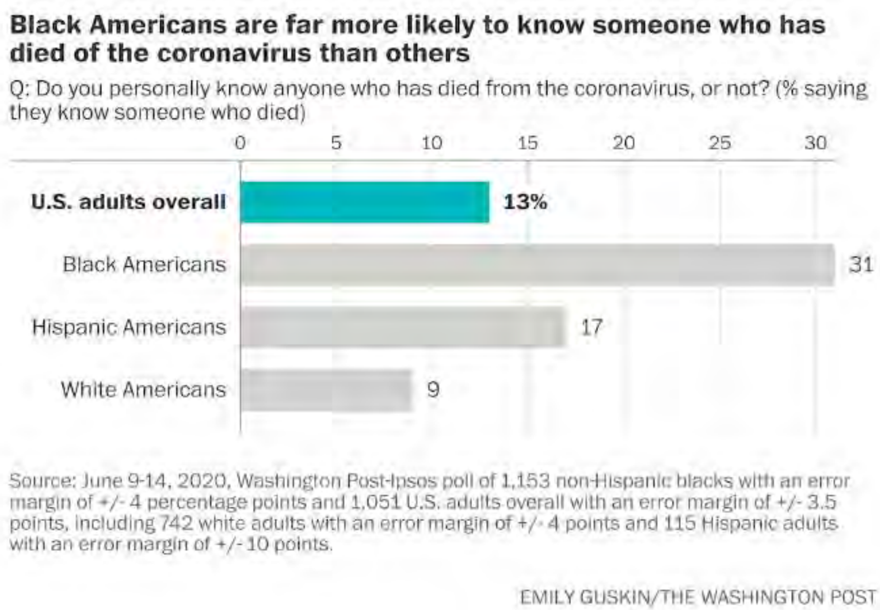
It is the proximity to death that is stark. Among black Americans, the percentage knowing someone who died increases steadily with age. Nearly 1 in 4 adults younger than 35 say they know someone, compared with more than 4 in 10 people 65 and older.

The findings are "a true indication of reality," said Betancourt, of Massachusetts General Hospital.

He said people of color in the United States tend to live with “a series of preconditions” that put them at greater risk of becoming infected with the virus and of then faring poorly. They include higher rates of poverty and the varied effects of structural racism, Betancourt said. The downstream effects, he said, include crowded housing, more frequent asthma, diabetes and other chronic diseases, and a greater likelihood of being in jobs that do not allow them to work from the greater safety of home.

The Post-Ipsos poll was conducted June 9-14 through Ipsos’s KnowledgePanel, a large online survey panel recruited through random sampling of U.S. households. Results among the sample of 1,153 non-Hispanic black adults have a margin of sampling error of plus or minus four percentage points; the error margin is 3.5 points among the parallel sample of 1,051 U.S. adults overall, four points among the sample of 742 white adults and 10 points among the sample of 115 Hispanic adults.

Scott Clement contributed to this report.



COUCH'S "PHYSICAL ALTERATION" FALLACY: ITS ORIGINS AND CONSEQUENCES

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I. INTRODUCTION

Look at virtually any Covid-19 case favoring an insurer, and you will find a citation to Section 148:46 of *Couch on Insurance*.[1] It is virtually ubiquitous: courts siding with insurers cite *Couch* as restating a "widely held rule" on

1. 10A Steven Plitt, et al., Couch on Insurance 3d § 148:46. As shown below, some courts quote *Couch* itself, while others cite cases citing *Couch* and merely intone the "distinct, demonstrable, physical alteration" language without citing *Couch* itself. *Couch 1st* and *Couch 2d* were published in hardback books (with pocket parts), in 1929 and 1959 respectively. As explained below (*infra* n.5), *Couch 3d*, a looseleaf, was first published in 1995.

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the meaning of "physical loss or damage"—words typically in the trigger for property-insurance coverage, including business-income coverage. It has been cited, ad nauseam, as evidence of a general consensus that all property-insurance claims require some "distinct, demonstrable, *physical alteration* of the property."[2] Indeed, some pro-insurer decisions substitute a citation to this section for an actual analysis of the specific language before the court.

Couch is generally recognized as a significant insurance treatise, and courts have cited it for almost a century.[3] That respect began with the first edition written by George Couch and subsequent editions written by his successors.

This particular section, however, as formulated in the third edition of *Couch*, contains an unfortunate, and serious, error. *Couch*'s apparent conclusion—that "direct physical loss" requires a "distinct, demonstrable, physical alteration"—is wrong. It was wrong when *Couch* first made it in the 1990s, and it is wrong today. As another well-respected treatise puts it, "when an insurance policy refers to *physical loss of or damage* to property, the 'loss of property' requirement can be satisfied by any 'detriment,' and a 'detriment' can be present *without there having been a physical alteration of the object*."[4]

A review of the three editions of *Couch* shows that this statement first appeared in the third edition.[5] As originally published, it supported its assertion by citing to five cases for support and two cases holding to the contrary, presenting the former as the "widely held" majority rule.[6]

But none of these cases used the "distinct, demonstrable, physical alteration" test that *Couch 3d* presents, and it was far from the majority rule. As of March 2020, there were at least *thirty-five* cases adopting a broader rule (including many binding appellate decisions and several rulings by state high courts), and significantly fewer following the *Couch* test. The "physical

2. *Id.* (emphasis added); Oral Surgeons, P.C. v. Cincinnati Ins. Co., 2 F.4th 1141, 1144 (8th Cir. 2021).

3. Girard Fire & Marine Ins. Co. v. Winfrey, 26 S.W.2d 701, 705 (Tex. Ct. App. 1930) (citing 4 George J. Couch, Cyclopedia of Insurance Law § 915).

4. 3 Allan D. Windt, Insurance Claims & Disputes § 11:41 (6th ed. 2013) (emphasis added).

5. The authors conducted searches in an effort to identify when this phrase first appeared in *Couch*. The authors ran searches on the first edition through HeinOnline and reviewed the hard copy of *Couch 2d* to see if those editions used this language. We found no language in either of the first two editions that was similar to that in section 148:46 of *Couch 3d* ("distinct, demonstrable, physical alteration"). *Couch 3d*, unlike *Couch 1st* and *Couch 2d*, was published in loose-leaf format. Without saving all versions of superseded pages in the updates published over the years, it is not possible at this point in time for us to say with certainty when language first appeared. We were able to verify that the first time that a court cited the "distinct, demonstrable" phrase in *Couch 3d* was in 1999. Columbiaknit, Inc. v. Affiliated FM Ins. Co., 1999 WL 619100, at *7–8 (D. Or. Aug. 4, 1999).

6. 10A Couch on Insurance 3d § 148:46. Couch added four cases to supplement this position following the original publication date.

alteration" test gained traction only because courts relied on *Couch*'s initial mischaracterization—inferred from a single district court opinion that was disapproved three years later by the governing court of appeals, rather than from the thirteen extant cases then holding to the contrary.

We may never know why *Couch* got the law so profoundly backwards on this key issue. But one thing is clear: courts need to stop citing it as the *sine qua non* of what "physical loss or damage" means. It is not. If the courts, and particularly the federal courts,[7] continue down this path without addressing *Couch*'s fallacy, there will be serious practical consequences. They risk overruling decades of insurance law and drastically narrowing the scope of property insurance that forms the backbone of risk protection for homeowners, businesses, and the banks that lend to them. All of those policies rest on the same terms *Couch* misconstrued. More immediately, courts will deprive American businesses of billions of dollars in coverage they paid for and need to survive the worst public health crisis in a century. Until *Couch* reckons with this error, busy trial and appellate judges cannot, and should not, trust it to give them the straight answer on this foundational question.

II. THE LAW OF "DIRECT PHYSICAL LOSS"

Modern property-insurance policies are triggered by some "direct physical loss or damage" to the property (or some variant of that term).[8] After this standard-form language was adopted, courts were quickly called upon to determine what it meant. Plainly it included injuries by fire, lightning, or tornado. But the breadth of the words—layered on the broad "all risk"[9] template—generated questions about whether a loss of use or function was sufficient to trigger these policies.

7. There is a stark disparity between the way state and federal courts are treating these claims in the Covid-19 context. *Trial Court Rulings on the Merits in Business Interruption Cases*, *Covid Coverage Litigation Tracker*, U. Pa. L. Sch., https://cclt.law.upenn.edu/judicial-rulings (last viewed Oct. 9, 2021). As of this writing, state courts have heard fewer than 130 insurer motions to dismiss and have denied 32 of them. Federal courts have heard 484 motions, yet they have denied even fewer (25), with the balance finding, as a matter of law, that there is no claim. *Id.* Since federal courts are constitutionally bound to follow state insurance law under the *Erie* doctrine, this massive disparity simply should not exist. That it does may require corrective action from the U.S. Supreme Court. *See* Brief of *Amicus Curiae* United Policyholders, Mama Jo's, Inc. v. Sparta Ins. Co., No. 20-998 (U.S. Feb. 25, 2021) (raising similar concerns, though in a non-Covid case and without the benefit of current case data), *cert. denied*, 141 S. Ct. 1737 (Mar. 29, 2021).

8. 5 New Appleman on Insurance Law, Libr. Ed. § 42.02[3].

9. There are two general types of property insurance. The first is "all risk" insurance. As its name suggests, it is the broadest of all insurance products because it "creates a type of coverage not ordinarily present under other types of insurance, and recovery is allowed for all fortuitous losses unless the loss is excluded by a specific policy provision." 10A Couch on Insurance 3d § 148:50. The second is "named perils" insurance, which insures only for specified causes of loss.

From 1950 to 1990, courts uniformly found that such losses qualified. Over the insurance industry's objections at the point of claim, courts asked only whether the property was unsafe or unusable for its intended purpose. If the answer to either question was "yes," then there was "direct physical loss or damage" to the property. The contrary view—requiring "distinct, demonstrable, physical alteration"—emerged in the 1990s but was in the distinct minority. Despite this backdrop, *Couch* wrongly portrayed "physical alteration" as the "widely held" majority rule.

A. *The Original Meaning of "Physical Loss": 1950 to 1995*

Until the 1990s, courts uniformly gave "direct physical loss" and its variants their broad, ordinary meaning. That phrase included cases where property became unsafe or unusable for its intended purpose. Standard-form policies were triggered in such circumstances in the 1950s,[10] the 1960s,[11] the 1970s,[12] the 1980s,[13] and the 1990s.[14]

In 1995, the Third Edition of *Couch on Insurance* added a new section, titled "*Generally; 'Physical' loss or damage*."[15] The first case to cite this section

10. Am. Alliance Ins. Co. v. Keleket X-Ray Corp., 248 F.2d 920, 925 (6th Cir. 1957) (finding coverage when a release of radon dust and gas made the policyholders' building unsafe to work in and unusable for its purpose, which was calibrating medical instruments); Marshall Produce Co. v. St. Paul Fire & Marine Ins. Co., 98 N.W.2d 280, 295, 300 (Minn. 1959) (finding that egg powder, which had been exposed to smoke, was physically damaged because it suffered a loss of market value even without actual injury).

11. Hughes v. Potomac Ins. Co., 18 Cal. Rptr. 650, 655 (Ct. App. 1962) (finding "physical loss" because policyholder's home was unsafe for occupancy after a landslide deprived it of support); W. Fire Ins. Co. v. First Presbyterian Church, 437 P.2d 52, 54 (Colo. 1968) (en banc) (finding a "direct physical loss" where gasoline vapors made "use of the building highly dangerous").

12. Cyclops Corp. v. Home Ins. Co., 352 F. Supp. 931, 937 (W.D. Pa. 1973) (finding business-income coverage where vibration of motor, without apparent damage, caused it to be shut down).

13. Hampton Foods, Inc. v. Aetna Cas. & Sur. Co., 787 F.2d 349, 352 (8th Cir. 1986) (finding Business Income coverage where danger of collapse required abandonment of grocery store); Intermetal Mexicana, S.A. v. Ins. Co. of N. Am., 866 F.2d 71, 76 (3d Cir. 1989) (theft of property, depriving policyholder of possession and control, qualified as "direct physical loss"); Blaine Richards & Co. v. Marine Indem. Ins. Co., 635 F.2d 1051, 1055–56 (2d Cir. 1980) (finding policyholder could recover lost value of beans exposed to chemical not accepted in the United States but not actually harmed).

14. In chronological order: Hetrick v. Valley Mut. Ins Co., 1992 WL 524309, at *3 (Pa. Comm. Pl. May 28, 1992) (finding coverage for loss of use of a house if an outside oil spill made the house uninhabitable); Largent v. State Farm Fire & Cas. Co., 842 P.2d 445, 446 (Or. Ct. App. 1992) (noting insurance company conceded meth fumes could cause "direct physical loss"); Farmers Ins. Co. v. Trutanich, 858 P.2d 1332, 1335 (Or. Ct. App. 1993) (finding costs of meth odor covered as direct physical loss or damage); Azalea, Ltd. v. Am. States Ins. Co., 656 So. 2d 600, 602 (Fla. Ct. App. 1995) (chemicals that destroyed a bacteria colony necessary for sewage treatment plant to operate caused "direct damage to the structure").

15. 10A Couch on Insurance 2d § 148:46.

was decided in 1999.[16] The fourth paragraph in that section (as reprinted without relevant change in the June 2021 update) reads:

> The requirement that the loss be "physical," given the ordinary definition of that term, is widely held to exclude alleged losses that are intangible or incorporeal and, thereby, to preclude any claim against the property insurer when the insured merely suffers a detrimental economic impact unaccompanied by a *distinct*, *demonstrable*, *physical alteration of the property*.[17]

The origin of this matter-of-fact statement is puzzling. At the time this section first appeared, only one reported case had adopted this test in the circumstances relevant here—*Great Northern Ins. Co. v. Benjamin Franklin Federal Savings & Loan Ass'n*, decided by a federal district court in Oregon, in 1990.[18]

Benjamin Franklin involved the sudden discovery of non-friable (or intact) asbestos in a building.[19] The property insurer refused to pay for its removal, arguing there was no "direct physical loss."[20] The district court agreed, citing a 1978 Oregon Supreme Court case (*Wyoming Sawmills v. Transportation Ins. Co.*) finding that a lumber manufacturer's third-party liability-insurance policy did not cover a lawsuit seeking labor expenses for removing defective 2 × 4 studs from a building.[21] Despite the many cases actually addressing "direct physical loss" language in this context—and universally coming out the other way—the *Benjamin Franklin* court found this liability-insurance case "most helpful."[22] The court held that property insurance, like liability insurance, does not "include consequential or intangible damages such as depreciation in value, within the terms property damage."[23] Ignoring the distinction between first-party and third-party coverage, the court held that, since the building was "physically intact and undamaged," there was no "*physical* loss, direct or otherwise."[24]

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16. Columbiaknit, Inc. v. Affiliated FM Ins. Co., 1999 WL 619100, at *7–8 (D. Or. Aug. 4, 1999) (finding that policyholder could bear its burden to demonstrate that clothes contaminated with mold or mildew suffered "direct physical loss or damage" if it established "at trial a class of garments which has increased microbial counts and that will, as a result, develop either an odor or mold or mildew").

17. 10A Couch on Insurance 3d § 148:46 (emphasis added).

18. Great N. Ins. Co. v. Benjamin Franklin Fed. Sav. & Loan Ass'n, 793 F. Supp. 259, 263 (D. Or. 1990). There were other cases favoring insurers, but they involved (for example) claims that a title impairment was a "physical loss," which it obviously is not. Those cases are discussed in more detail below. *Benjamin Franklin* was the first to apply this rule in the context of physical effects on property.

19. *Id.* at 261.

20. *Id.* at 263.

21. *Id.* (citing Wyoming Sawmills v. Transp. Ins. Co., 578 P.2d 1253, 1256 (Or. 1978)).

22. *Id.*

23. *Id.* (quoting *Wyoming Sawmills*, 578 P.2d at 1256).

24. *Id.* (emphasis in original). Third-party and first-party insurance serve significantly different functions. Third-party insurance is essentially fault-based; it provides compensation for loss suffered by "third parties" that is caused by the policyholder's wrongful acts.

The "physically intact and undamaged" gloss was brand new in *Benjamin Franklin*. At that time, the major decisions predating it—*Hughes* and *First Presbyterian*—had rejected that precise logic. *Hughes* was particularly forceful:

> To accept [the insurer's] interpretation of its policy would be to conclude that a building which has been overturned or which has been placed in such a position as to overhang a steep cliff has not been "damaged" so long as its paint *remains intact and its walls still adhere to one another*. Despite the fact that a "dwelling building" might be rendered completely useless to its owners, [the insurer] *would deny that any loss or damage had occurred unless some tangible injury to the physical structure itself could be detected*. Common sense requires that a policy should not be so interpreted in the absence of a provision specifically limiting coverage in this manner.[25]

Similarly, *First Presbyterian* found that a church rendered too dangerous for occupancy because it was permeated with gasoline fumes had suffered a "loss of use" that triggered the policy.[26]

Perhaps because the "intact and undamaged" rule was invented by a single district judge, it did not stick. Three years after *Benjamin Franklin*, the Oregon Court of Appeals refused to follow it in *Farmers Ins. Co. v. Trutanich*, a case involving methamphetamine contamination.[27] *Trutanich* distinguished *Wyoming Sawmills* (the liability-insurance case *Benjamin Franklin* found "most helpful") and instead followed *First Presbyterian*.[28]

When *Couch 3d* cited *Benjamin Franklin* as evincing a "distinct, demonstrable, physical alteration" rule,[29] it ignored that *Trutanich* had rendered the "intact and undamaged" rule a dead letter three years earlier.[30] It also added the modifiers "distinct" and "demonstrable" out of thin air—we have found no pre-*Couch 3d* case where a court frames the test using those adjectives. In spite of this, *Couch 3d* crafted its own rule out of whole cloth, and

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First-party insurance, in contrast, provides coverage for loss regardless of fault. This distinction is important in understanding *Wyoming Sawmills*. Most commercial third-party policies have "business risk" exclusions—in *Wyoming Sawmills*, it was an exclusion for liability arising from damage to "your product" or "your work" (i.e., the defective 2 × 4s). The aim of such exclusions is to enforce the general third-party rule that coverage exists only for damage to *someone else*'s property, and so that liability insurance is not equated with a builder's "performance bond." Thus, *Wyoming Sawmills* is not properly read to require a "physical alteration" rule, even in the third-party context. Loss of use to a third party's property is indisputably "property damage" under standard-form general liability insurance.

25. Hughes v. Potomac Ins. Co., 18 Cal. Rptr. 650, 655 (Ct. App. 1962) (emphasis added).
26. W. Fire Ins. Co. v. First Presbyterian Church, 437 P.2d 52, 54 (Colo. 1968) (en banc).
27. Farmers Ins. Co. v. Trutanich, 858 P.2d 1332, 1335 (Or. Ct. App. 1993).
28. *Id.* at 1335–36.
29. 10A Couch on Insurance 3d § 148:46 (emphasis added).
30. *Trutanich*, 858 P.2d at 1335 n.4 (limiting *Benjamin Franklin* to asbestos that was "intact" and nonfriable).

then then included a paragraph, written in the passive voice, suggesting that there was only some case law to the contrary:

> The opposite result has been reached, allowing coverage based on physical damage despite the lack of physical alteration of the property, on the theory that the uninhabitability of the property was due to the fact that gasoline vapors from adjacent property had infiltrated and saturated the insured building, and the theory that the threatened physical damage to the insured building from a covered peril essentially triggers the insured's obligation to mitigate the impending loss by undertaking some hardship and expense to safeguard the insured premises.[31]

This lukewarm counterpoint cited only *First Presbyterian* and *Hampton Foods*—two of at least *thirteen* cases that had adopted the broader rule when the section was first drafted.[32]

B. *The One-Sided Portrayal Grows: 1995–2019*

Like any treatise updated regularly, *Couch 3d* over the years generally added citations as the law developed. However, a problem appeared on this issue as *Couch 3d* began discussing it—the third edition only added cases favorable to its made-up "majority" position.[33] Every one of these decisions cited *Couch 3d*'s "physical alteration" doctrine.[34] For example, under facts identical to *Benjamin Franklin*, the Third Circuit denied coverage by declaring (citing *Couch* and nothing else) that this was the "widely accepted definition."[35]

Yet this rule was neither "widely accepted" nor correct. *Couch 3d* did not address many of the significant decisions adopting the contrary and earlier generally accepted position. In fact, the only case supporting *Couch 3d*'s

31. 10A Couch on Insurance 3d § 148:46.

32. The others are similar. *See* Marshall Produce Co. v. St. Paul Fire & Marine Ins. Co., 98 N.W.2d 280, 295, 300 (Minn. 1959) (unsalable goods); Hughes v. Potomac Ins. Co., 18 Cal. Rptr. 650, 655 (Ct. App. 1962) (erosion); Am. All. Ins. Co. v. Keleket X-Ray Corp., 248 F.2d 920, 925 (6th Cir. 1957) (radon contamination); Intermetal Mexicana, S.A. v. Ins. Co. of N. Am., 866 F.2d 71, 76 (3d Cir. 1989) (theft); Blaine Richards & Co. v. Marine Indem. Ins. Co., 635 F.2d 1051, 1055–56 (2d Cir. 1980) (unsalable goods); Cyclops Corp. v. Home Ins. Co., 352 F. Supp. 931, 937 (W.D. Pa. 1973) (inoperable motor); Hetrick v. Valley Mut. Ins Co., 1992 WL 524309, *3 (Pa. Comm. Pl. May 28, 1992) (oil spill); Largent v. State Farm Fire & Cas. Co., 842 P.2d 445, 446 (Or. Ct. App. 1992) (meth contamination); Farmers Ins. Co. v. Trutanich, 858 P.2d 1332, 1335 (Or. Ct. App. 1993) (same); Azalea, Ltd. v. Am. States Ins. Co., 656 So. 2d 600, 602 (Fla. Ct. App. 1995) (chemical contamination).

33. 10A Couch on Insurance 3d § 148:46 (adding Port Auth. of N.Y. & N.J. v. Affiliated FM Ins. Co., 311 F.3d 226, 236 (3d Cir. 2002); Universal Image Prods., Inc. v. Fed. Ins. Co., 475 F. App'x 569, 573 (6th Cir. 2012); Newman Myers Kreines Gross Harris, P.C. v. Great N. Ins. Co., 17 F. Supp. 3d 323, 331 (S.D.N.Y. 2014); MRI Healthcare Ctr. of Glendale, Inc. v. State Farm Gen. Ins. Co., 115 Cal. Rptr. 3d 27, 38 (Ct. App. 2010)).

34. *Port Authority*, 311 F.3d at 235; *Universal Image*, 475 F. App'x at 573–74; *Newman Meyers*, 17 F. Supp. 3d at 331; *MRI Healthcare*, 115 Cal. Rptr. at 778–79.

35. *Port Authority*, 311 F.3d at 235.

assertion was at the trial level, was not binding, and had been disapproved by the governing state's court of appeals. Beyond that, more and more cases began to recognize that the *Hughes* rule—and not the *Couch 3d* theory—was correct. There were five such cases (including two from state courts of last resort) before the turn of the twenty-first century.[36] *Couch 3d* to date has ignored all of them.

The law continued to snowball in policyholders' favor after that. In 2000,[37] 2001,[38] 2002,[39] 2003,[40] 2005,[41] courts rendered eleven decisions for policyholders on this issue without requiring "physical alteration." *Couch 3d*

36. Arbeiter v. Cambridge Mut. Fire Ins. Co., 1996 WL 1250616, at *2 (Mass. Super. Ct. Mar. 15, 1996) (finding oil fumes present in house after discovery of oil leak constituted physical damage to the house); Sentinel Mgmt. Co. v. N.H. Ins. Co., 563 N.W.2d 296, 300 (Minn. Ct. App. 1997) (asbestos); Dundee Mut. Ins. Co. v. Marifjeren, 587 N.W.2d 191 (N.D. 1998) (power outage causing potatoes to freeze); Murray v. State Farm Fire & Cas. Co., 509 S.E.2d 1, 16–17 (W. Va. 1998) (concluding that a home rendered dangerously unlivable by the presence of falling rocks had suffered a "direct physical loss to the property"); Matzner v. Seaco Ins. Co., 9 Mass. L. Rptr. 41, 1998 WL 566658, at *4 (Mass. Super. Ct., Aug. 12, 1998) (concluding that the phrase "direct physical loss or damage" was ambiguous and could mean either "only tangible damage to the structure of insured property" or "more than tangible damage to the structure of insured property," and that "carbon monoxide contamination constitutes 'direct physical loss of or damage to' property"); Bd. of Educ. v. Int'l Ins. Co., 720 N.E.2d 622, 625–26 (Ill. Ct. App. 1999) (citing liability insurance coverage cases finding that incorporation of asbestos into buildings caused "property damage," defined under liability policies to be "physical injury to or destruction of tangible property," and finding that policyholder had established that the asbestos fiber contamination constituted physical damage).

37. Sentinel Mgmt. Co. v. Aetna Cas. & Sur. Co., 615 N.W.2d 819, 825–26 (Minn. 2000) ("A principal function of any living space [is] to provide a safe environment for the occupants," and "[i]f rental property is contaminated by asbestos fibers and presents a health hazard to the tenants, its function is seriously impaired.").

38. Gen. Mills, Inc. v. Gold Medal Ins. Co., 622 N.W.2d 147, 152 (Minn. Ct. App. 2001) (oats rendered unsalable by FDA regulation suffered "direct physical loss").

39. Prudential Prop. & Cas. Ins. Co. v. Lillard-Roberts, 2002 WL 31495830, at *8–9 (D. Or. June 18, 2002) (concluding that mold damage to house could constitute "distinct and demonstrable" damage and that inability to inhabit a building may constitute "direct, physical loss"); Cooper v. Travelers Indem. Co. of Ill., 2002 WL 32775680, at *1 (N.D. Cal. Nov. 4, 2002) (coliform bacteria and E.coli); Graff v. Allstate Ins. Co., 54 P.3d 1266, 1269 (Wash. Ct. App. 2002) (methamphetamine vapors); Yale Univ. v. CIGNA Ins. Co., 224 F. Supp. 2d 402, 413 (D. Conn. 2002) (finding while the presence of asbestos and lead in buildings did not constitute "physical loss of or damage to property," contamination by such materials could, citing "the substantial body of case law" "in which a variety of contaminating conditions have been held to constitute 'physical loss or damage to property'").

40. S. Wallace Edwards & Sons, Inc. v. Cincinnati Ins. Co., 353 F.3d 367, 374–75 (4th Cir. 2003) (affirming finding that meat exposed to ammonia and thus less valuable even though not actually affected had suffered property damage).

41. Motorists Mut. Ins. Co. v. Hardinger, 131 F. App'x 823, 824, 826–27, 824–26 (3d Cir. 2005) (E. coli contamination); De Laurentis v. United Servs. Auto. Ass'n, 162 S.W.3d 714, 722–23 (Tex. Ct. App. 2005) (finding mold damage constituted "physical loss to property"); Pepsico, Inc. v. Winterthur Int'l Ins. Co., 24 A.D.3d 743, 744 (N.Y. App. Div., 2d Dep't 2005) (unmerchantable product); Schlamm Stone & Dolan LLP. v. Seneca Ins. Co., 800 N.Y.S.2d 356 (Sup. Ct. 2005) (finding that "the presence of noxious particles, both in the air and on surfaces of the plaintiff's premises, would constitute property damage under the terms of the policy").

took no notice. In 2007,[42] 2009,[43] and 2010,[44] courts decided eight more. Again, *Couch 3d* ignored them. Five more cases came in 2011,[45] 2013,[46] 2014,[47] 2015,[48] and 2016,[49] including from another state supreme court. None of these decisions were featured in *Couch 3d*, and even its June 2021 update failed to grapple with (or even cite) any of them.

Couch 3d may not have recognized these cases, but insurers did—when it served their purposes. In late 2019, Factory Mutual Insurance Company ("FM"), one of the largest and most sophisticated property insurers in the world, sued another insurer seeking to shift some of its liability for mold

42. Cook v. Allstate Ins. Co., 2007 Ind. Super. LEXIS 32, at *6–10 (Madison Cnty. Nov. 30, 2007) (finding that infestation of house with brown recluse spiders constituted "direct physical loss" to the house: "Case law demonstrates that a physical condition that renders property unsuitable for its intended use constitutes a 'direct physical loss' even where some utility remains and, in the case of a building, structural integrity remains"); Stack Metallurgical Servs., Inc. v. Travelers Indem. Co., 2007 WL 464715, at *8 (D. Or. Feb. 7, 2007) (finding "physical loss or damage" where the policyholder's heat treater for medical implants was contaminated by lead and could no longer be used); Fed. Ins. Co. v. Hartford Steam Boiler Inspection & Ins. Co., 2007 WL 1007787, at *12 (E.D. Mich. Mar. 31, 2007) (finding that food in cardboard containers exposed to ammonia was physically injured, despite the fact the food was judged fit to eat).

43. Essex v. BloomSouth Flooring Corp., 562 F.3d 399, 406 (1st Cir. 2009) (unpleasant odor in home); Wakefern Food Corp. v. Liberty Mut. Fire Ins. Co., 968 A.2d 724, 734 (N.J. Super. App. Div. 2009) ("In the context of this case, the electrical grid was 'physically damaged' because, due to a physical incident or series of incidents, the grid and its component generators and transmission lines were physically incapable of performing their essential function of providing electricity."); Manpower Inc. v. Ins. Co. of the State of Pa., 2009 WL 3738099, at *1 (E.D. Wis. Nov. 3, 2009) (finding "direct physical loss . . . or damage to" a building adjacent to a building which collapsed despite the fact that the collapse did not cause any noticeable damage to the policyholder's occupied space).

44. Travco Ins. Co. v. Ward, 715 F. Supp. 2d 699, 707–08 (E.D. Va. 2010) (finding that drywall emitting toxic gases, causing the policyholder to move out, caused a direct physical loss, despite the fact that it was "physically intact, functional and ha[d] no visible damage," noting the majority of cases nationwide find that "physical damage to the property is not necessary"); *In re* Chinese Mfr'd Drywall Prods. Liab. Litig., 759 F. Supp. 2d 822, 831 (E.D. La. 2010) (finding that "the presence of Chinese-manufactured drywall in a home constitutes a physical loss" because it "renders the [policyholders'] homes useless and/or uninhabitable").

45. Widder v. La. Citizens Prop. Ins. Corp., 82 So.3d 294 (La. Ct. App. 2011) (lead).

46. Ass'n of Apartment Owners of Imperial Plaza v. Fireman's Fund Ins. Co., 939 F. Supp. 2d 1059, 1068 (D. Haw. 2013) (finding that intrusion of arsenic into roof caused "direct physical loss or damage" to the roof).

47. Gregory Packaging, Inc. v. Travelers Prop. Cas. Co., 2014 WL 6675934, at *5–6 (D.N.J. Nov. 25, 2014) (concluding that "property can sustain physical loss or damage without experiencing structural alteration," that "the heightened ammonia levels rendered the facility unfit for occupancy until the ammonia could be dissipated," and therefore that the ammonia discharge caused direct physical loss).

48. Mellin v. N. Sec. Ins. Co., 115 A.3d 799, 806 (N.H. 2015) (rejecting "tangible alteration" rule and holding that pervasive odor of cat urine was "physical loss" to condominium).

49. Oregon Shakespeare Festival Ass'n v. Great Am. Ins. Co., 2016 WL 3267247, at *5–6 (D. Or. June 7, 2016), *vacated by joint stipulation*, 2017 WL 1034203 (Mar. 6, 2017) (smoke from wildfires, making operations hazardous to human health, caused a "direct physical loss").

and mold spore contamination at a biopharmaceuticals lab.[50] In the case, it brought a motion *in limine* contending that "physical loss or damage" to property exists when a physical substance renders property unfit for its intended use, despite that there was *no* physical alteration.[51] Citing cases like *First Presbyterian*, *Gregory Packaging*, and *Trutanich*, FM argued to the Court:

> Numerous courts have concluded that loss of functionality or reliability under similar circumstances constitutes physical loss or damage. *See*, *e.g.*, *Western Fire Insurance Co. v. First Presbyterian Church*, 437 P.2d 52 (Colo. 1968) (church building sustained physical loss or damage when it was rendered uninhabitable and dangerous due to gasoline under the building); *Gregory Packaging*, *Inc. v. Travelers Property and Casualty Company of America*, Civ. No. 2:12-cv-04418, 2014 U.S. Dist. LEXIS 165232, 2014 WL 6675934 (D. N.J. 2014) (unsafe levels of ammonia in the air inflicted "direct physical loss of or damage to" the juice packing facility "because the ammonia physically rendered the facility unusable for a period of time."); *Port Authority of N.Y. and N.J. v. Affiliated FM Ins. Co.*, 311 F.3d 226, 236 (3d Cir. 2002) (asbestos fibers); *Essex v. BloomSouth Flooring Corp.*, 562 F.3d 399, 406 (1st Cir. 2009) (unpleasant odor in home); *TRAVCO Ins. Co. v. Ward*, 715 F. Supp. 2d 699, 709 (E.D. Va. 2010), *aff'd*, 504 F. App'x 251 (4th Cir. 2013) ("toxic gases" released by defective drywall).[52]

Moreover, FM argued that, *at worst*, it had put forward a reasonable interpretation of the undefined phrase "physical loss or damage"—and even if Federal could propose a reasonable reading, this merely rendered the subject policy ambiguous and required the court to construe it in favor of coverage.[53]

The oddity and error in *Couch 3d*'s statement is further shown by other major insurance-coverage treatises. Allan Windt's *Insurance Claims & Disputes* (6th ed. 2013) is most explicit: "[W]hen an insurance policy refers to physical loss of or damage to property, the 'loss of property' requirement can be satisfied by *any* 'detriment,' and a 'detriment' can be present *without there having been a physical alteration of the object*."[54] Windt then proceeds to discuss the major cases that *Couch 3d* ignores, including *Murray*, *Sentinel*, and *Hardinger*.[55]

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50. Factory Mut. Ins. Co. v. Fed. Ins. Co., 1:17-cv-00760-GJF-LF, 2019 U.S. Dist. LEXIS 191769 (D.N.M. Nov. 5, 2019).

51. Motion *in Limine* No. 5 re Physical Loss or Damage at 3, *Factory Mut. Ins. Co.*, filed Nov. 19, 2019, ECF#127, https://3inbm04c0p4j2h1w132uyb5e-wpengine.netdna-ssl.com/wp-content/uploads/2021/02/fm_v._federal.pdf.

52. *Id.* at 3–4 (emphasis added).

53. *See id.* at 3 n.1.

54. 3 Allan D. Windt, Insurance Claims & Disputes § 11:41 (6th ed. 2013) (emphasis added).

55. *Id.*

Appleman's *Insurance Law and Practice*, often cited side-by-side with *Couch*, contains a similar statement of the standard in its section on "all risk" insurance.[56] After discussing *First Presbyterian*, it concluded that "[t]he courts have construed the scope of what constitutes 'physical loss or damage' liberally," while still recognizing that some losses (such as a withdrawn warranty) were not "physical."[57] At the time it was discontinued, in favor of the *New Appleman* series, the "Old" *Appleman* recognized all, or nearly all, of the seminal decisions on "physical loss" that *Couch* omitted. Those cases include dispossession of property (*Intermetal Mexicana*), "unusable or uninhabitable" property (*Murray*), and contamination (*Board of Education*).[58]

The 1999 update to another treatise by Peter J. Kalis reaches the same conclusion.[59] Explaining that "direct" and "physical" loss or damage is the coverage trigger for property insurance, the authors correctly summarized the law at the time by saying that disputes over these words "generally have

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56. 5 John Alan Appleman & Jean Appleman, Insurance Law & Practice 2d § 3092 (1970 & 2012 Supp.), *reprinted in* 5f-142f Appleman on Insurance Law & Practice Archive § 3092 (LEXIS 2011). *Appleman*, like *Couch*, is a venerable treatise, used for decades by coverage practitioners including authors of this article. The "Original" *Appleman*, first published in 1929, was updated for years after the death in 1936 of the original author, John Alan Appleman. The hard copy volume of the "original" *Appleman* containing § 3092 was last copyrighted in 1970 and thereafter was updated through pocket parts. From the authors' knowledge and research on provenance of this section, the last "cumulative supplement" for this volume (volume 5) of "Old" *Appleman* was copyrighted in 2012. The "original" *Appleman* was joined by a successor, *New Appleman*, in the last two decades, which overlapped with original *Appleman* and was called first *Holmes Appleman on Insurance* and later *Appleman on Insurance 2d*. The publisher also published *New Appleman on Insurance Law*, *Law Library Edition* (Jeffrey E. Thomas & Francis J. Mootz, III, eds., Lexis-Nexis 2009 & Dec. 2020 Supp.); and most recently, *New Appleman Insurance Law Practice Guide* (Leo P. Martinez, Marc S. Mayerson & Douglas R. Richmond eds., Lexis-Nexis 2020). *Appleman on Insurance 2d*, for example, while focusing on many issues of import in insurance law, includes little analysis of the relevant policy language in consideration in this article.

57. *Id.*

58. *Id.* The *New Appleman* successor to this work, rather than carrying forward the existing research, borrowed heavily from *Couch 3d*'s misstatement of the rule—down to the cases *Couch 3d* cited and some of the descriptive words *Couch 3d* used. 5 New Appleman on Insurance Law, Libr. Ed., § 46.03[2] (offering the "generally prevailing" rule as one that "preclude[s] coverage for losses that are solely intangible or incorporeal; for example, an economic loss unaccompanied by a distinct physical alteration to property"). To the *New Appleman* authors' credit, their statements are more restrained, and (unlike *Couch 3d*) they do follow this introduction with treatments of important cases like *Trutanich*, *Sentinel*, *Hardinger*, *Pepsico*, *General Mills*, and *Wakefern*, discussed throughout this article. *Id.* § 46.03[3] ("Contamination by Vapor, Bacteria, or other Foreign Substance," "Intact Property Rendered Unfit for Intended Purpose," "Destruction or Corruption of Electronic Data," and "Deprivation of Access by Government Authorities"). Although *New Appleman*'s decision to borrow its summary from *Couch 3d* was ill-advised, the balance of the section—and the nuance it explains—illustrates the severity of *Couch 3d*'s error.

59. I Peter J. Kalis, Thomas M. Reiter & James R. Segerdahl, Policyholder's Guide to the Law of Insurance Coverage § 13.04 (Aspen L. & Bus., Supp. 1999). As the name of this treatise suggests, its authors generally represented policyholders. But unlike this section of *Couch*, the discussion is balanced and accurately represents the case law.

been resolved in favor of coverage."[60] It then proceeds to discuss *Hampton Foods*, *First Presbyterian*, *Hughes*, and *Intermetal Mexicana*, among other cases, as representing the majority rule.[61] It acknowledged *Benjamin Franklin* but noted that it was an outlier.[62] It concluded that while insurers may argue for a more stringent version of "physical loss," "[t]hese arguments have generally been unsuccessful if the loss arises out of some external event or condition changing and devaluing the property."[63] In 2013, the principal author of *Couch 3d*, Steven Plitt, published an article in an insurance industry magazine entitled "Direct Physical Loss in All-Risk Policies: The Modern Trend Does Not Require Specific Physical Damage, Alteration."[64] He discussed recent case law and concluded that the "modern trend" is that "courts are not looking for physical alteration, but for loss of use." It is unclear why the current 2021 update of *Couch 3d* does not match its principal author's stated understanding of the law.

For whatever reason, this robust body of scholarship—all contrary to *Couch 3d*—has not caught the courts' attention. That is unfortunate. Windt, Appelman, and Kalis present a far superior resource for courts interested in understanding the full scope of the law, rather than *Couch 3d*'s truncated, one-sided version.

C. Couch 3d*'s 2021 Update Has Not Remedied This Significant Error*

In 2021, *Couch 3d* updated this section. The current edition repeats the error of the previous ones.

For the proposition that its "physical alteration" rule is "widely held," *Couch 3d* currently cites seven cases—none of which were decided in 1995, when it appears that *Couch 3d* first made this statement. Moreover, nearly all of these cases *themselves cite Couch 3d* (or cases citing *Couch 3d*) for this proposition.[65] This is a remarkable feat: state *ipse dixit* you wish was true, convince courts to cite it, and then cite *those* cases as establishing that the rule is "widely held."

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60. *Id.*

61. *Id.* at 13-15 to 13-18.

62. *Id.* at 13-18 to 13-19.

63. *Id.* at 13-19.

64. Steven Plitt, *Direct Physical Loss in All-Risk Policies: The Modern Trend Does Not Require Specific Physical Damage, Alteration*, Claims J. (Apr. 15, 2013) (https://amp.claimsjournal.com/magazines/idea-exchange/2013/04/15/226666.htm) (discussing *Murray* and *Trutanich*, among other cases).

65. Port Auth. of N.Y. & N.J. v. Affiliated FM Ins. Co., 311 F.3d 226, 236 (3d Cir. 2002); Universal Image Prods., Inc. v. Fed. Ins. Co., 475 F. App'x 569, 573 (6th Cir. 2012); Newman Myers Kreines Gross Harris, P.C. v. Great N. Ins. Co., 17 F. Supp. 3d 323, 331 (S.D.N.Y. 2014); *In re* Chinese Mfd. Drywall Prods. Liab. Litig., 759 F. Supp. 2d 822, 831 (E.D. La. 2010); MRI Healthcare Ctr. of Glendale, Inc. v. State Farm Gen. Ins. Co., 115 Cal. Rptr. 3d 27, 38 (Ct. App. 2010); Welton Enters., Inc. v. Cincinnati Ins. Co., 131 F. Supp. 3d 827 (W.D. Wis. 2015); Shirley v. Allstate Ins. Co., 392 F. Supp. 3d 1185 (S.D. Cal. 2019).

For its claim that there must be a "distinct, demonstrable, physical alteration of the property," *Couch 3d* now cites five cases extant in 1995 (*Benjamin Franklin* and four others).[66] None of these pre-1995 cases cure *Couch 3d*'s original error. Nor do they offer support for the way courts are citing this section in Covid-19 cases.

For example, in the oldest case (*Cleland Simpson*) the Pennsylvania Supreme Court summarily affirmed the lower court's decision.[67] That case, however, involved a *named perils* policy for "all direct loss by fire [and] lightning."[68] The court held that an order of civil authority was not covered in the absence of fire or lightning damage.[69] In the context of a named-perils property-insurance policy, that made perfect sense: without a loss caused by an insured peril, there is no coverage. But the use of "physical loss" in an *all* risk policy is entirely different, because *all* (nonexcluded) perils are insured. *Cleland Simpson* fails to support *Couch*'s proposition at all.

In the next two cases (*Sponholz* and *HRG*) the courts held that a defect in the title to property was not a "physical loss."[70] That too, makes sense, but fails to support a "physical alteration" requirement. Title defects are *legal* injuries, not physical ones, and these cases are perfectly reconcilable with the loss-of-safe-use rule from *Hughes* and *First Presbyterian*, neither of which required "physical alteration."

The final case from this group of pre-1995 cases (*Covert*) involved products that were discarded because the manufacturer had rescinded its warranty.[71] The policyholder would not sell them without the warranty. This case comes the closest to supporting *Couch 3d*'s argument, but it still fails. As in the title-defect cases, the defect was legal or contractual (i.e., the manufacturer would not indemnify the seller from potential product defects). However, that can still be squared with the prevailing loss-of-safe-use and loss-of-function rules.[72] These cases did not support the rule *Couch 3d* derived from them.

In sum, *Couch 3d* seized on a single trial-level case with no support in the appellate law, asserted in the first instance that such a rule was "widely

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66. Great N. Ins. Co. v. Benjamin Franklin Fed. Sav. & Loan Ass'n, 793 F. Supp. 259, 263 (D. Or. 1990) (asbestos), *disapproved by* Farmers Ins. Co. v. Trutanich, 858 P.2d 1332 (Or. Ct. App. 1993); Comm. Union Ins. Co. v. Sponholz, 866 F.2d 1162, 1162 (9th Cir. 1989) (title defect); HRG Dev. Co. v. Graphic Arts Mut. Ins. Co., 527 N.E.2d 1179, 1181 (Mass. Ct. App. 1988) (title defect); Cleland Simpson Co. v. Fireman's Ins. Co. of Newark, 140 A.2d 41, 44 (Pa. 1958) (named-perils coverage); Glens Falls Ins. Co. v. Covert, 526 S.W.2d 222, 223 (Tex. Ct. App. 1975) (products lacking manufacturer's warranty).

67. *Cleland Simpson*, 140 A.2d at 44.

68. Cleland Simpson Co. v. Fireman's Ins. Co., 1957 Pa. Dist. & Cnty. LEXIS 202, at *5 (Lackawanna Cnty. Jan. 11, 1957).

69. *Id.* at *8.

70. *Sponholz*, 866 F.2d at 1162; *HRG*, 527 N.E.2d at 1181.

71. *Covert*, 526 S.W.2d at 223.

72. *See supra* notes 10–13 and accompanying text.

held," did not confess error when that case was disapproved, convinced courts to cite it as authoritative, and then cited *those* cases as showing that its scantly supported test was correct. That circular process does not create sound jurisprudence, it is not persuasive, and it should not be followed any further.

D. *The Current Majority of Covid-19 Cases Adopt and Perpetuate* Couch 3d*'s Error*

To any objective observer, *Couch 3d*'s treatment of this issue is incorrect and unnerving. Despite this, a large number of courts are relying upon it to dismiss claims that the presence of SARS-CoV-2, the Covid-19 pandemic, and/or the associated orders of Civil Authority cause "physical loss or damage" to property. The result of these decisions is that many businesses—entitled to business-income coverage under the *actual* majority rule—are not receiving it.

At least twenty-eight of the early pandemic decisions ruling for insurers expressly rely on this section.[73] Another fifteen cases applied *Couch 3d*'s

73. E.g., Brunswick Panini's LLC v. Zurich Am. Ins. Co., 2021 WL 663675, at *8 (N.D. Ohio Feb. 19, 2021) (Ohio law); Kahn v. Pa. Nat'l Mut. Cas. Ins. Co., 2021 WL 422607, at *5 (M.D. Pa. Feb. 8, 2021) (Pennsylvania law); Wellness Eatery La Jolla LLC v. Hanover Ins. Grp., 2021 WL 389215, at *5 (S.D. Cal. Feb. 3, 2021) (California law); Frank Van's Auto. Tag, LLC v. Selective Ins. Co., 2021 WL 289547, at *5 (E.D. Pa. Jan. 28, 2021) (Pennsylvania law); Graspa Consulting, Inc. v. United Nat'l Ins. Co., 2021 WL 199980, at *5 (S.D. Fla. Jan. 20, 2021) (Florida law); 1 S.A.N.T., Inc. v. Berkshire Hathaway, Inc., 2021 WL 147139, at *6 (W.D. Pa. Jan. 15, 2021) (Pennsylvania law); Zagafen Bala, LLC v. Twin City Fire Ins. Co., 2021 WL 131657, at *4 (E.D. Pa. Jan. 14, 2021) (Pennsylvania law); TAQ Willow Grove, LLC v. Twin City Fire Ins., 2021 WL 131555, at *4 (E.D. Pa. Jan. 14, 2021) (Pennsylvania law); Ultimate Hearing Sols. II, LLC v. Twin City Fire Ins. Co., 2021 WL 131556, at *5 (E.D. Pa. Jan. 14, 2021) (Pennsylvania law); Moody v. Hartford Fin. Grp., Inc., 2021 WL 135897, at *4 (E.D. Pa. Jan. 14, 2021) (Pennsylvania law); ATCM Optical, Inc. v. Twin City Ins. Co., 2021 WL 131282, at *4 (E.D. Pa. Jan. 14, 2021) (Pennsylvania law); Indep. Rest. Grp. v. Certain Underwriters at Lloyd's, London, 2021 WL 131339, at *5 (E.D. Pa. Jan. 14, 2021) (Pennsylvania law); Santo's Italian Café LLC v. Acuity Ins. Co., 508 F. Supp. 3d 186, 197–98 (N.D. Ohio 2020) (Ohio law); Newchops Rest. Comcast LLC v. Admiral Indem. Co., 507 F. Supp. 3d 616, 623–24 (E.D. Pa. 2020) (Pennsylvania law); Terry Black's Barbecue, LLC v. State Auto. Mut. Ins. Co., 2020 WL 7351246, at *5 (W.D. Tex. Dec. 14, 2020) (Texas law); Richard Kirsch, DDS v. Aspen Am. Ins. Co., 507 F. Supp. 3d 835, 839 (E.D. Mich. 2020) (Michigan law); SA Palm Beach LLC v. Certain Underwriters at Lloyd's, London, 506 F. Supp. 3d 1248, 1253 (S.D. Fla. 2020) (Florida law); El Novillo Rest. v. Certain Underwriters at Lloyd's, London, 505 F. Supp. 3d 1343, 1349 (S.D. Fla. 2020) (Florida law); Hajer v. Ohio Sec. Ins. Co., 505 F. Supp. 3d 646, 650 (E.D. Tex. 2020) (Texas law); Promotional Headwear Int'l v. Cincinnati Ins. Co., 504 F. Supp. 3d 1191, 1198 n.38 (D. Kan. 2020); S. Fla. Ent. Assocs., Inc. v. Hartford Fire Ins. Co., 2020 WL 6864560, at *6 (S.D. Fla. Nov. 13, 2020) (Florida law); Dab Dental PLLC v. Main St. Am. Prot. Ins. Co., 2020 WL 7137138, at *5 (Fla. Cir. Ct. Hillsborough Cnty. Nov. 10, 2020); Hillcrest Optical, Inc. v. Cont'l Cas. Co., 497 F. Supp. 3d 1203, 1211 & n.4 (S.D. Ala. 2020) (Alabama law); Plan Check Downtown III, LLC v. AmGuard Ins. Co., 485 F. Supp. 3d 1225, 1229 (C.D. Cal. 2020) (California law); Malaube, LLC v. Greenwich Ins. Co., 2020 WL 5051581, at *5 (S.D. Fla. Aug. 26, 2020) (Florida law); Diesel Barbershop, LLC v. State Farm Lloyds, 479 F. Supp. 3d 353, 360 (W.D. Tex. 2020) (Texas law); Visconti Bus. Serv., LLC v. Utica Nat'l Ins. Grp., 71 Misc. 3d 516, 528 (N.Y. Super. Ct. 2021).

"distinct, demonstrable, physical alteration" rule without citing it directly.[74] And the first three published appellate decisions on this issue cite the section as authoritative.[75]

III. THINKING CRITICALLY ABOUT *COUCH* AND PROPERTY INSURANCE LAW

Whatever the ultimate outcome of the Covid-19 business-income-coverage litigation, the courts' treatment of this section in *Couch 3d* will have profound impacts on property-insurance coverage. The error originating from that section is poised to reshape insurance law without the rigorous intellectual analysis of a state appellate court charged with determining the law in its jurisdiction. If courts continue to blindly follow *Couch 3d* on this point, they will effectively overrule decades of property-insurance law without grappling with *stare decisis* or the usual stabilizing principles attached to precedent. Courts must dismantle *Couch 3d*'s fallacy, and the cases it has spawned, before it is too late—and, above all, stop citing *Couch 3d* on this point until the authors address the problem. We offer three general reasons for this position.

First, this section of *Couch 3d* never provides a precedent-driven or intellectual justification for its test (for it is, in reality, a test *Couch 3d* invented). Generally, when staking a position that rests at the core of a body of law, a treatise will either (a) rely on the reasoned decisions of then-extant judicial decisions to justify the rule, or (b) develop its own, independent reason that the rule is correct. *Couch 3d* does neither. This oversight is having

74. Café La Troya LLC v. Aspen Spec. Ins. Co., 2021 WL 602585, at *7 (S.D. Fla. Feb. 16, 2021) (Florida law); Vandalay Hosp. Grp. LP v. Cincinnati Ins. Co., 2021 WL 462105, at *1 (N.D. Tex. Feb. 9, 2021) (Texas law); Protégé Rest. Partners LLC v. Sentinel Ins. Co., 2021 WL 428653, at *4 (N.D. Cal. Feb. 8, 2021) (California law); Colgan v. Sentinel Ins. Co., 2021 WL 472961, at *3 (N.D. Cal. Jan. 26, 2021) (California law); Ba Lax, LLC v. Hartford Fire Ins. Co., 2021 WL 144248, at *3 (C.D. Cal. Jan. 12, 2021) (California law); O'Brien Sales & Mktg, Inc. v. Transp. Ins. Co., 2021 WL 105772, at *3–4 (N.D. Cal. Jan. 12, 2021) (California law); Humans & Resources, LLC v. Firstline Nat'l Ins. Co., 2021 WL 75775, at *5 (E.D. Pa. Jan. 8, 2021) (Pennsylvania law); Karen Trinh, DDS, Inc. v. State Farm Gen. Ins. Co., 2020 WL 7696080, at *4 (N.D. Cal. Dec. 28, 2020) (California law); Mortar & Pestle Corp. v. Atain Spec. Ins. Co., 2020 WL 7495180, at *3 (N.D. Cal. Dec. 21, 2020) (California law); Kessler Dental Assocs., P.C. v. Dentists Ins. Co., 505 F. Supp. 3d 474, 480 (E.D. Pa. 2020) (Pennsylvania law); Long Affair Carpet & Rug, Inc. v. Liberty Mut. Ins. Co., 500 F. Supp. 3d 1075, 1078 (C.D. Cal. 2020) (California law); Brian Handel D.M.D., P.C. v. Allstate Ins. Co., 499 F. Supp. 3d 95, 99 (E.D. Pa. 2020) (Pennsylvania law); Uncork & Create LLC v. Cincinnati Ins. Co., 498 F. Supp. 3d 878, 883 (S.D. W. Va. 2020) (West Virginia law); Mudpie, Inc. v. Travelers Cas. Ins. Co., 487 F. Supp. 3d 834, 839 (N.D. Cal. 2020) (California law); Pappy's Barber Shops, Inc. v. Farmers Group, Inc., 487 F. Supp. 3d 937, 944 (S.D. Cal. 2020) (California law); 10e, LLC v. Travelers Indem. Co., 483 F. Supp. 3d 828, 836 (C.D. Cal. 2020) (California law).

75. Oral Surgeons, P.C. v. Cincinnati Ins. Co., 2 F.4th 1141 (8th Cir. 2021); Mudpie, Inc. v. Travelers Cas. Ins. Co. of Am., __ F.4th __, 2021 WL 4486509 (9th Cir. Oct. 1, 2021); Santo's Italian Cafe, LLC v. Acuity Ins. Co., __ F.4th __, 2021 WL 4304607 (6th Cir. Sept. 22, 2021).

devastating consequences for businesses struggling to survive the Covid-19 pandemic, and it will have even greater consequences for the homeowners and lenders who purchase property insurance on a daily basis.

The *Couch 3d* test is largely circular. It does not flow from any substantial body of insurance law that existed (or that currently exists) outside of *Couch 3d*'s own sphere of influence. Nor is it compelling on its own. Property policies generally cover "direct physical loss or damage," which does not unmistakably communicate *Couch 3d*'s rule to an ordinary person. Perhaps insurers view "physical" as a term of art that means a "distinct, demonstrable, physical alteration." But they have not *communicated* that intent in the policy by actually defining "physical loss or damage," as courts have "begged" them to do for decades.[76]

Basic textual analysis shows why the opposite rule is correct. When property is stolen, unusable, unsafe, or nonfunctional, the policyholder has suffered a "physical loss." This comports with the distinction between "loss"[77] and "damage,"[78] two words with different meanings in the English language. If "physical" required some "distinct, demonstrable, physical alteration," then "physical loss" would be rendered meaningless.

The word "physical" simply restricts coverage to losses that are "of or relating to natural or material things, as opposed to things mental, moral, spiritual, or imaginary."[79] This draws the same line as pre-1995 decisions favoring policyholders (involving physically unsafe, physically unusable, or physically contaminated property) and pre-1995 cases favoring insurers (involving title insurance and voided warranties). An impaired title or an invalid warranty is a *legal* loss. It injures a legal right appurtenant to the

76. Cherokee Nation v. Lexington Ins. Co., 2021 WL 506271, at *3–6 (Okla. Dist., Cherokee Cnty. Jan. 28, 2021).

77. "[T]he act or fact of losing : failure to keep possession : deprivation." *Loss*, Webster's Third New Int'l Dictionary 1338 (Unabridged ed. 1966) [hereinafter Webster's]; *Loss*, I The Compact Edition of the Oxford English Dictionary 1666 (2d ed. 1986) [hereinafter Oxford's] ("**2.a.** The being deprived of, or the failure to keep (a possession, appurtenance, right . . . or the like). . . . **5.** Diminution of one's possessions or advantages; detriment or disadvantage involved in being deprived of something."); *Loss*, Merriam-Webster Online Dictionary, www.merriam-webster.com/dictionary/loss (last visited Sept. 1, 2021) ("2.a(2) the partial or complete deterioration or absence of a physical capability or function"); *Loss*, Dictionary.com, www.dictionary.com/browse/loss (last visited Sept. 1, 2021) ("1. detriment, disadvantage, or deprivation from failure to keep, have, or get").

78. "[L]oss due to injury : injury or harm to person, property, or reputation : hurt, harm." *Damage*, Webster's, *supra* note 77, at 571; *Damage*, I Oxford's, *supra* note 77, at 641 ("**2.** Injury, harm ; *esp.* physical injury to a thing."); *Damage*, Merriam-Webster Online Dictionary, *supra* note 77 ("[L]oss or harm resulting from injury to person, property, or reputation."); *Damage*, Dictionary.com, *supra* note 77 ("injury or harm that reduces value or usefulness").

79. *Physical*, Webster's, *supra* note 77, at 1706; *see Physical*, The American Heritage Dictionary of the English Language 1331 (5th ed. 2011) (same); II Oxford's, *supra* note 77, at 2161 ("Of or pertaining to material nature . . . as opposed to *psychical*, *mental*, *spiritual*"); *Physical*, Merriam-Webster Online Dictionary, *supra* note 77 ("of or relating to material things"); *Physical*, Dictionary.com, *supra* note 77 ("of or relating to that which is material").

property, and does not impair the property itself. Thus, *Couch 3d* is correct in observing that the term "physical loss" excludes losses "that are intangible or incorporeal," such as a defect in title.[80] But that statement, true as it is, does not support *Couch 3d*'s blanket "physical alteration" test. It simply illustrates one kind of "loss" that property insurance does not cover.

As the title-insurance litigation shows, the word "physical" exists in the policy for a good reason. English speakers often use the word "loss" in the mental, moral, spiritual, or imaginary sense. We speak of a "loss of reputation," a "loss of affection," or even (as John Milton wrote) a world in a state of "utter loss" and in need of divine intervention.[81] Or, in another direction, the unwitting purchaser of a house "widely reputed to be possessed by poltergeists" might have made a claim on his property insurer for a "loss," had the New York Appellate Division not excused him from the purchase by holding the seller "is estopped to deny their existence and, as a matter of law, the house is haunted."[82] In contrast to property overrun by chemicals[83] or spiders,[84] a house possessed by ghosts would seem to be the prototypical example of an "incorporeal," and thus a "nonphysical," loss.

However, this discussion of ghosts, titles, and damnation simply shows that the traditional analysis—supported by the decades of case law predating this section of *Couch 3d*—is not outlandish at all. A property perched on a cliff, inundated with gasoline, unusable due to odors or bacteria, or in danger of a rockfall is at risk due to the laws of the physical realm, not of perils legal or paranormal. *Couch 3d*'s rule erases this important distinction.

Second, the pre-*Couch* rule has a firm basis in the risk-based nature of insurance, in basic principles of insurance law, and in insurance-industry intent. Actuaries can predict the likelihood of physical phenomena that might affect property, even if those perils do not alter or structurally injure property, and even if the peril strikes the entire risk pool at the same time.[85] They can set appropriate premiums. But more difficult (or impossible) to predict, in advance, is the risk that décor will go out of style, that a house will be deemed haunted as a matter of law, or that a market meltdown will impair property values.

80. 10A Couch on Insurance 3d § 148:46.

81. *Loss*, I Oxford's, *supra* note 77, at 1666.

82. Stambovsky v. Ackley, 169 A.D.2d 254, 255–56 (N.Y. App. Div., 1st Dep't 1991).

83. Gregory Packaging, Inc. v. Travelers Prop. Cas. Co., 2014 WL 6675934, at *5–6 (D.N.J. Nov. 25, 2014).

84. Cook v. Allstate Ins. Co., 2007 Ind. Super. LEXIS 32, at *6–10 (Madison Cnty. Nov. 30, 2007).

85. Erik S. Knutsen & Jeffrey W. Stempel, *Infected Judgment: Problematic Rush to Conventional Wisdom and Insurance Coverage Denial in a Pandemic*, 27 Conn. Ins. L.J. 185, 194–95 (2020) (explaining that pandemic losses are "insurable in theory because the timing of the pandemic itself is a fortuitous event," because "not all industries will be affected at the same time and to the same degree," and because some portions of the risk pool "may profit from the pandemic in their specific industries and may have no loss at all").

Thus, the traditional distinction between physical and nonphysical losses matches up neatly with risks that insurers can price, predict, and guard against. *Couch 3d*'s test draws the line much further upstream, leaving homeowners, businesses, and lenders exposed to large swaths of perfectly insurable risks. That fact provides ample reason to doubt *Couch 3d*'s argument that insurers drew the line there.

The more likely explanation is that "physical loss" is what the *Restatement (Second) of Contracts* calls a "deliberately obscure" term.[86] It is broad enough to let insurers charge "all risk" premiums, but ambiguous enough so the insurer can "decide at a later date what meaning to assert,"[87] i.e., a narrower, "physical alteration" rule.[88] This is illustrated by the industry's acts of playing both sides of the "physical loss" question—restrictive when it faces the policyholder, and expansive when it faces another insurer to whom it might shift liability.[89] As the *Restatement of the Law, Liability Insurance* points out, this is the definition of ambiguity: when "there is more than one meaning to which the language of the term is reasonably susceptible when applied to the facts of the claim."[90] If the insurance industry interprets the language both ways, surely both readings must be reasonable. But it is in these situations that both *Restatements* and every jurisdiction in the country calls for words to be construed against the drafter.[91]

Third, property insurance is one of the least negotiable types of insurance. Millions of homeowners are required, by their lenders, to maintain insurance on mortgaged property. Homeowners lack the kind of leverage that a multinational company would have to negotiate manuscript commercial-property coverage. They must have it, and due to insurers' antitrust immunity, they have no power to negotiate the terms of the policy. Yet they (and the banks that hold their mortgages) would be among the ones who suffer the most if *Couch 3d*'s rule actually becomes "widely held."

Homeowners' policies, like commercial property policies, are written on "physical loss" forms. If property insurance is construed as *Couch 3d* (incorrectly) suggests, the courts will unwittingly shift an enormous body of risks

86. Restatement (Second) of Contracts § 206, cmt. a (Am. L. Inst. 1981).

87. *Id.*

88. This is far from speculation. One writer recounts the story of an "experienced policy underwriter justifying an ambiguous draft policy as follows: 'We draft them this way so we can say later that the policy means whatever we want it to mean.'" George M. Plews & Donna C. Marron, *Survey: Environmental Law Developments: Hope and Ambiguity in Achieving the Optimum Environment*, 37 Ind. L. Rev. 1055, 1058–59 (2004).

89. *See supra* notes 50–53 and accompanying text.

90. Restatement of the Law, Liability Insurance § 4(1) (Am. L. Inst. 2019).

91. Restatement (Second) of Contracts, *supra* note 86, § 206, cmt. a. The *Restatement of the Law, Liability Insurance* provides for the same outcome, for the same reasons. Restatement of the Law, Liability Insurance, *supra* note 90, § 4(2), *see id.* §§ 3(3), (4), cmt. d ("The *contra proferentem* rule gives the supplier of the terms the incentive to take all reasonable steps to eliminate ambiguity in the drafting of terms.").

back on consumers and financial institutions. Homes condemned due to contamination, health hazards, or nearby natural perils could suddenly lack coverage. And if there are outstanding mortgages on those homes, the loss would be borne by the homeowner (saddled with five-or-six-figure debt or an additional mortgage payment) or the lender (unable to sell foreclosed property for anywhere near its mortgaged value). Given the long-term nature of these arrangements, blindly following *Couch* threatens to upend the law mid-stream and throw these reliance interests into disarray.

IV. CONCLUSION

The current Covid-19 coverage litigation is important in its own right. However, it is also a test of the courts' ability to be curious, thorough, and prudent in the way they resolve disputes. There is no substitute for a court's thorough review and analysis of the actual language before it and the actual law governing that language. Consulting a treatise is helpful. But they are only aids in legal analysis and can, as we have shown, be grievously wrong.

This particular section of *Couch 3d* does not aid courts whatsoever in their efforts to faithfully apply the law. Not only does it get the law wrong, but it invites courts to set dangerous precedent that could unravel decades of settled property-insurance law, on which ordinary businesses, banks, and families rely. If courts accept *Couch 3d*'s "physical alteration" fallacy, the results could be catastrophic. The ensuing legal regime could well deny policyholders the benefit of the all-risk coverage they purchased and, under the pressure of the greatest health and economic dislocation in a century, send droves of policyholders into bankruptcy. That is both bad law and bad policy.

2021

Infected Judgment: Problematic Rush to Conventional Wisdom and Insurance Coverage Denial in a Pandemic

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INFECTED JUDGMENT: PROBLEMATIC RUSH TO CONVENTIONAL WISDOM AND INSURANCE COVERAGE DENIAL IN A PANDEMIC

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Abstract

The COVID-19 pandemic created not only a public health crisis but also an insurance coverage imbroglio, prompting near-immediate business interruption claims by policyholders impacted by government restrictions ordered in response to the pandemic. ***Insurers and their representatives "presponded" to the looming*** *coverage claims by quickly moving to denigrate arguments for coverage, engaging in a pre-emptive strike that has largely worked to date, inducing too many courts to rush to judgment by declaring—as a matter of law—**that policy terms such as** "direct physical loss or damage" **do** not even arguably encompass the business shutdowns resulting from COVID-19. Our closer examination of the term and of other key coverage questions suggests that policyholders have a much stronger case than suggested by the initial—and often superficial and conclusory—conventional wisdom flowing from the first wave of judicial decisions. Only a few courts have analyzed the COVID coverage debate with the type of reflective care, judicial humility, and respect for the trial process one would hope to see.* ***The "early returns" in these coverage wars*** *have been analytically disappointing, creating risk of an unfortunate path dependency or cascade of cases excessively narrowing the* ***meaning of key terms such as "loss" and "damage,"*** *and diminishing the quality of future coverage decisions.*

[*] Respectively, Professor of Law, Queens University-Canada and Doris S. & Theodore B. Lee Professor of Law, William S. Boyd School of Law, University of Nevada Las Vegas. Thanks to Bill Boyd, Jay Feinman, Chris French, Dan Hamilton, Yong Han, Helmut Heiss, the late Doris Lee, Ted Lee, Randy Maniloff, David McClure, Ann McGinley, our colleagues in the American College of Coverage Counsel and the Project Group for the Principles of Reinsurance Law (PRICL), and the ALI Restatement of the Law of Liability Insurance process. The opinions expressed in this article are of course our own and should not be attributed to any of those we cite or thank.

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I. INTRODUCTION

A. COVID-19 AND COVERAGE CONTROVERSY

As the world now knows, a variant of the SARS coronavirus emerged in Asia in late 2019[1] creating a severe concentration of infections in Wuhan, China that spread rapidly throughout the world reaching the United States perhaps as early as December 2019.[2] By February 2020, the new virus named COVID-19[3] was a

[1] "SARS" (Severe Acute Respiratory Syndrome) is the name given to a class of particularly dangerous virus that causes respiratory problems but often adversely affect other organs. Julia Ries, ***Here's How COVID**-19 Compares to Past Outbreaks*, HEALTHLINE (Mar. 12, 2020), https://www.healthline.com/health-news/how-deadly-is-the-coronavirus-compared-to-past-outbreaks. SARS viruses are common in animals and only occasionally cross over to humans—with dangerous results. *Id.* The SARS-1 virus, which spread rapidly between 2002 and 2004, infected many and caused an estimated 774 deaths worldwide (though none in the United States). *Id. See generally* Center for Disease Control and Prevention, CDC.GOV, https://www.cdc.gov (providing range of information regarding the SARS virus and COVID-19 in particular).

[2] *See* CDC.GOV, *supra* note 1 (noting that as of January 1, 2021, COVID-19 surpassed twenty million cases and 341,199 deaths in the United States). *Accord*, Johns Hopkins Coronavirus Resource Center, https://www.coronavirus.jhu.edu.

[3] COVID-19 is "a mild to severe respiratory illness that is caused by a coronavirus (*Severe acute respiratory syndrome coronavirus 2 of the genus Betacoronavirus*)" transmitted chiefly by contact with infectious material (such as respiratory droplets) or with objects or surfaces contaminated by the causative virus, and is characterized especially be fever cough, and shortness of breath and may progress to pneumonia and respiratory failure." *See COVID-19*, MERRIAM-WEBSTER DICTIONARY (2020), https://www.merriam-webster.com/dictionary/COVID-19.

The term coronavirus derived from the crown-like spikes of the virus that appear when it is viewed by microscope. Kathy Katella, *Our New COVID-19 Vocabulary—What Does it All Mean?*, YALE MEDICINE (Apr. 7, 2020), https://www.yalemedicine.org/stories/covid-19-

widely acknowledged serious problem[4] that was deemed a "pandemic" by March 11, 2020.[5] Beginning in March 2020, state and local governments began issuing

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glossary/. It is a relative of the SARS-CoV (often referred to as "SARS" or Severe Acute Respiratory Syndrome) that caused substantial injury and death in a 2002-2003 worldwide outbreak. *Id.* Coronaviruses of various types can cause common colds as well as SARS and Middle East respiratory syndrome (MERS). *Id.* The variant emerging in 2019 "is believed to have started in animals and spread to humans. *Id.* Animal-to-person spread was suspected after the initial outbreak in December among people who had a link to a large seafood and live animal market in Wuahn, China." *Id.*

COVID-19 is thus the name for the disease resulting from infection by the virus with the letters COVI standing for coronavirus, the D for disease, and the number 19 in the name resulting because this particular strain of the virus emerged in Wuhan in November 2019 Because the name is derived from initials, it is frequently abbreviated as "COVID-19" in capital letters.

[4] *See* Christopher C. French, *COVID-19 Business Interruption Insurance Losses: The Cases for and Against Coverage*, 27 CONN. INS. L.J. 1 (2020) (acknowledging that COVID-19 infections were presenting serious problem). As is not common knowledge, governments exhibited a range of reactions to the COVID-19 problem. Some (*e.g.*, Canada, New Zealand, Hawaii), ordered substantial comprehensive "lockdowns" as a means of retarding the spread of the disease. *See, e.g.*, Lauren Vogel, *COVID-19: A Timeline of Canada's First-wave Response*, CAN. MED. ASS'N J. NEWS (June 12, 2020), https://cmajnews.com/2020/06/12/coronavirus-1095847; Alexis Robert, *Lessons from New Zealand's COVID-19 Outbreak Response*, THE LANCET (November 1, 2020), https://www.thelancet.com/journals/lanpub/article/PIIS2468-2667(20)30237-1/fulltext; Alejandro de la Garza, *Hawaii Is Riding Out the COVID-19 Storm. But Geographic Isolation Isn't the Blessing it May Seem,* TIME (Nov. 25, 2020 10:07 AM), https://time.com/5915084/hawaii-covid-coronavirus/. Others, such as Sweden, adopted a system of modified restrictions that varied among states. Mariam Claeson & Stefan Hanson, *COVID-19 and the Swedish Enigma*, THE LANCET (January 23, 2021), https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)32750-1/fulltext.

[5] The World Health Organization declared COVID-19 a pandemic on March 11, 2020. *See WHO Characterizes COVID-19 as a Pandemic*, WHO (Mar. 11, 2020), https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen (providing a timeline of COVID-19 developments and quoting WHO Director-General that the organization has "made the assessment that COVID-19 can be characterized as a pandemic" and is "the first pandemic caused by a coronavirus. And we have never before seen a pandemic that can be controlled, at the same time."). *See also* Natasha Frost, *Coronavirus, QAnon, Trump: Your Monday Briefing*, N.Y. TIMES (Oct. 11, 2020), https://www.nytimes.com/2020/10/11/briefing/coronavirus-qanon-trump-your-monday-briefing.html ("More than six months since the start of the pandemic, European countries such as France, Spain and Britain are reporting daily infection numbers comparable to—and sometimes far beyond—those of their first peaks.").

closure orders barring access to and operation of many facilities deemed insufficiently essential.[6]

The governmental orders varied, of course. Some demanded a stronger or more comprehensive shutdown than others. But many, if not most, precluded normal operation of "nonessential" business functions, perhaps most prominently indoor dining and entertainment, under pain of punishment for violation.[7] Within days of government recognition (now widely seen as belated) that COVID was highly contagious and dangerous,[8] insurance claims for business interruption were widely anticipated with additional anticipated coverage controversy involving other insurance products. The insurance coverage community was abuzz about the topic throughout Spring 2020, attention that continues only slightly abated today.[9] Lawsuits followed relatively quickly, numbering more than 1,000 by Fall 2020.[10]

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[6] *See* French, *supra* note 4; Terry Spencer & Teresa Crawford, *US Moves Nearer to Shutdown Amid Coronavirus Fears*, AP (Mar. 16, 2020), apnews.com/article/1510caddee80ea2d73363fab76d55967 ("Officials across the country curtailed many elements of American life to fight the coronavirus outbreak. . . Governors and mayors closed restaurants, bars, and schools as the nation sank deeper into chaos.").

[7] *See infra* Part I(B) and Part II.

[8] *See Death Rates from Coronavirus (COVID-19) in the United States as of December 22, 2020, by State*, STATISTA (Dec. 22, 2020), https://www.statista.com/statistics/1109011/coronavisure-covid19-death-rates-by-state (noting that, as of December 22, 2020, more than 319,000 American deaths were attributed to COVID-19 from a total of more than 20 million infections). Visible case studies of COVID-19 dangers were chronicled in often heart-wrenching news reports, *see, e.g.*, *Those We've Lost*, N.Y. TIMES (Nov. 3, 2020), https://www.nytimes.com/interactive/2020/obituaries/people-died-coronavirus-obituaries.html (discussing as a regular feature in the Times since the onset of the pandemic), as well as being demonstrated rather dramatically and contemporaneously when President Donald Trump, three US Senators, White House employees, and Secret Service agents were afflicted during late September and early October 2020. The President was treated by a large team of physicians utilizing an array of antibiotics, steroids, and supplemental oxygen during the President's 3-day hospitalization, with continuing treatment after discharge. *See* Katie Thomas & Denise Grady, *Trump Returns Home After Downplaying Disease, but Doctor Says He Isn't 'Out of the Woods,'* N.Y. TIMES (Oct. 7, 2020, 1:38 AM), https://www.nytimes.com/live/2020/10/05/world/covid-trump; Maggie Haberman & Annie Karni, *Trump's Return Leaves White House in Disarray as Infections Jolt West Wing*, N.Y. TIMES (Oct. 6, 2020), https://www.nytimes.com/2020/10/06/us/politics/white-house-coronavirus.html.

[9] *See infra* Part II.

[10] *See* Tom Baker, *COVID Coverage Litigation Tracker*, cclt.law.upenn.edu/author/tombaker/ (last visited December 31, 2020).

In the early spring days of the pandemic, the insurance industry began a remarkable media campaign to make known its position on the issue of coverage for virus-related losses: there is no coverage. In insurance industry publications, in lawyers' news media, and even in the news media consumed by the general public, the message of "no coverage for pandemic losses" was repeated again and again. This lies in stark contrast to the treatment of coverage for COVID-related losses in other jurisdictions such as Western Europe. But in America, however, the insurance industry repeated the mantra.

Policyholders only had to open a newspaper to see how the industry was advancing their views that claims would be denied, imposing motions to dismiss, at least before presumably favorable tribuinals. And insurers began to win. Those wins were reported and highlighted in the media. This anti-coverage public relations media blitz forms a curious backdrop to what actually occurred in courts across the United States deciding COVID-related claims. In short, as this article discusses below, courts often fell short in their analyses in these coverage cases, ignoring time-tested principles of insurance policy interpretation and even of basic civil litigation rules. The spectre of the anti-coverage media blitz may well have primed the judiciary for the results to come.

By January 2021, roughly seventy-five of these cases had some sort of substantive court decision, most commonly the grant or denial of a motion to dismiss for failure to state a claim, particularly the latter, pro-insurer result.[11] Insurers prevailed in sixty-seven of the seventy-five cases, with courts granting Rule 12(b)(6) (or its state equivalent) dismissal on the basis of a lack of sufficiently triggering damage, a virus exclusion that ousts coverage, or both.[12] The speed of these decisions and the success of insurers should be regarded—at least on the triggering damage question—as surprising and erroneous.[13] Although insurers have a significant array of arguments against coverage, we find them considerably less powerful than suggested by insurers and accepted by many judges to date.[14]

[11] *Id.* In what might be termed the "first wave" of COVID-19 property insurance and business interruption cases, the majority have been brought by policyholders as plaintiffs rather than by insurers seeking a declaratory judgment of no coverage. For clarity, this article will generally use the term "policyholders" to include both named insureds and all other insureds under a policy unless insured status is important to determination of a coverage issue.

[12] *See* Baker, *supra* note 10.

[13] *See infra* Part IV.

[14] *See infra* Part III. This is not to say that insurers deserve none of these early victories. Where policies contain a sufficiently broad virus exclusion, the facts of many cases will likely make the exclusion applicable and support a finding of no coverage. As Professor Baker has noted:

In our view, each insurance coverage case needs to be decided based upon not only its particular factual context but also according to the specific policy at issue. Some policies contain a virus exclusion (which of course makes a stronger, perhaps even irrefutable, case for no coverage)[15] while many others lack any such limitation on coverage—a factor strongly favoring policyholders.[16] But the "early returns" point toward excessively impulsive and overbroad (in our view) embrace

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> Of the seven cases in which a merits-based motion to dismiss has been denied, four involve insurance policies without any virus exclusion, one involves the Hartford's Endorsement for Limited Fungi, Bacteria, or Virus Coverage (which contains a virus exclusion that could be read to apply only to losses involving defective materials), and two have virus exclusions that apply to sickness or disease.
>
> By contrast, of the eighteen cases in which a court has granted a merits-based motion to dismiss, only two don't have virus exclusions.
>
> This matters, among other reasons because the presence of a virus exclusion inhibits policyholders from pleading their cases in ways that would help them meet the requirement that their business income losses result from "physical loss of or damage to" the premises in question.
>
> Bottom line [as of Oct. 7, 2020]: insurers are winning, overwhelmingly, when their polices have virus exclusions. But they are losing, at least at the motion to dismiss stage, when their policies do not have virus exclusions.

Baker, *supra* note 10. We are, as discussed in Part IV, nonetheless disturbed by many of these early insurer victory cases because of their superficial and weak reasoning taking an excessively narrow view of what constitutes "physical loss or damage," which may have negative implications for future coverage disputes.

[15] *See infra* Part V.

[16] If nothing else, the presence of an exclusion implies, sometimes strongly in light of the language of the insuring agreement, that in the absence of an exclusion, a claim or loss is covered. As discussed in Part IV, the virus exclusion was developed to avoid potential coverage pursuant to standard issue policies. If the insuring agreement or other exclusions in those policies had sufficiently precluded coverage, there logically would have been no need for a specific virus exclusion. We appreciate that insurers may want a "belt and suspenders" approach to policy drafting and that exclusions in some cases may be added simply to solidify widely accepted understandings and to foreclose unrepresentative judicial construction of policies. But courts should also appreciate that just as often (or perhaps more frequently), exclusions are added to policies because the policies provide coverage in the absence of such exclusions.

of an insurer-sponsored conventional wisdom that COVID claims are simply not insured.[17]

In particular, we are unimpressed with insurer arguments that COVID and attendant government closure orders do not—as a matter of law—constitute "direct physical loss or damage" to covered property. To date, the majority of judges hearing COVID cases disagree. Although their views are positive law and ours are not, we remain disappointed in the quality of analysis applied in many of the COVID coverage cases, which has often been reductionist, simplistic, crabbed, and overconfident regarding textual analysis, as well as insufficiently sensitive to the value of trial proceedings for resolving these disputes.[18]

Judges granting dismissal motions without any opportunity for discovery, and denying any possibility of coverage at the metaphorical starting gate, have undermined the traditional American commitment to jury trials as well as widely accepted legal principles of insurance policy construction such as interpreting ambiguous terms against the drafter and considering policyholder reasonable expectations.[19] Where the issue is solely whether sufficient "loss" or "damage" has taken place, standard property insurance policy language is simply not as conclusive as purported by these courts. Although other defenses such as a virus exclusion may carry the day for some insurers, insurers have to date gotten much more mileage out of very weak "no-loss/no-damage" arguments than should be the case if trial judges were consistently doing a thorough job.

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[17] Consistent with discussion in Part II of this article regarding the (in our view) successful public relations efforts of insurers to paint COVID-19 business interruption claims as (to use a favorite phrase of the former President Trump) losers, the legal and insurance trade press has tended to under-report policyholder victories while giving significant attention to insurer victories, emphasizing judicial statements labeling policyholder coverage arguments as meritless. Having followed the legal and trade press thoroughly the pandemic, we were surprised upon reading Professor Baker's COVID Coverage Litigation Tracker to find that policyholders had "prevailed" on as many dismissal motions as they have (which is still a tiny fraction of the total number of motions). Baker, *supra* note 10. We put the term "prevailed" in scare quotes to emphasize that that surviving a motion to dismiss is not the equivalent of obtaining coverage—and certainly does not reflect payments that small business policyholders state they desperately need to survive. By contrast, when an insurer obtains a Rule 12 dismissal, it really has won something. In all eighteen cases where insurers have to date prevailed on dismissal motions, the court has dismissed the entire case with prejudice, leaving the policyholder with the unattractive options of appeal or accepting defeat.

[18] *See infra* Part IV.

[19] *See infra id.*

Potentially aiding and abetting this judicial failure has been substandard briefing and advocacy by policyholder counsel, many of whom are not insurance specialists but tort lawyers prosecuting coverage cases with perhaps relatively little experience or expertise about the nuances of insurance coverage law.[20] In many of the cases with outcomes we criticize, insurers have been served by better advocacy, an important factor in cases where judges also lack insurance expertise. In some other cases, a judge's background formerly representing insurers may also foreshadow pro-insurer rulings.[21] But we also posit that the bench was probably affected by widespread insurer efforts to "poison the well" against COVID-19 coverage claims through an early onslaught of pro-insurer, anti-coverage commentary in the legal press, the insurance trade press, and in mass circulation media.[22]

A more extensive and nuanced analysis of COVID coverage issues suggests to us that policyholders should be winning most of these dismissal motion cases—at least on the loss and damage issues—and proceeding further in the adjudication process. Notwithstanding some shining exceptions,[23] the first wave of decisions in these cases has been largely disappointing and reflects poorly on the legal and hyper-textual analysis of the bench. If this trend continues, the insurance industry will have

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[20] Insurers have taken the rare step of filing memoranda opposing amicus participation in Covid coverage cases, presumably because they wish the court not to have the benefit of analysis by more seasoned coverage counsel. *See, e.g.,* Defendant's Opposition to United Policyholders, National Independent Venue Association, and Washington Hospitality Association's Motion for Leave to Appear as Amici Curiae, Vita Coffee, LLC v. Fireman's Fund Ins. Co., No. 2:20-cv-01079-JCC-DWC (W.D. Wash. 2020) (noted insurer side law firm opposes, *inter alia*, submission of United Policyholders amicus brief authored by Covington & Burling partner David Goodwin, a prominent policyholder coverage attorney).

[21] *See, e.g.*, Franklin EWC, Inc. v. Hartford Fin. Servs. Grp., No. 20-cv-04434 JSC, 2020 U.S. Dist. LEXIS 174010 (S.D. Cal. Sept. 22, 2020) (granting of an insurer's dismissal motion by Magistrate Judge Jacqueline Scott Corley, formerly at DLA Piper, a firm known for representing insurers that has been involved in COVID coverage litigation, sufficiently aggressively that it has opposed judicial consideration of a proffered amicus brief by United Policyholders. *See also infra* Part II.

[22] By legal press, we refer to media directed primarily at lawyers, such as *US Law Week*, *Law 360* and the like. By insurance trade press, we refer to periodicals such as *Insurance Journal*, *Business Insurance*, *National Underwriter*, ***Best's Review*** and electronic newsletters, bulletins, and blogs (*e.g.*, Randy Maniloff's *Coverage Opinions* or the Hunton & Williams newsletters). General circulation media is aimed primarily at laypersons and runs the gamut from individual blogs or websites to major newspapers of record.

[23] *See infra* Part IV(A) (discussing well-reasoned cases finding sufficient allegations of physical loss or damage for coverage claim to proceed).

obtained an undeserved victory that is inconsistent with the extent of coverage it promised to policyholders, particularly small businesses.

The remainder of this part of the article examines the risk management and insurability issues presented by pandemic claims and identifies the principal types of first-party property insurance that could be implicated. Part II recaps the remarkable public relations campaign of insurers designed to influence both judicial and lay perception of insurance coverage for COVID-related losses. Part III examines the crucial coverage issues of whether there has been direct physical loss or damage sufficient to create coverage, acknowledging that coverage may be taken away by certain virus exclusions or other aspects of the policy or situation. Part IV briefly raises the virus exclusion contained in many policies and some challenges with it.

We conclude with concerns regarding the success of a tightly packaged, insidiously executed, and albeit factually and legally incorrect adversarial position put forth in insurance media may well have affected the initial outcomes of COVID-related coverage litigation. While we of course hope that to be untrue, when one begins to stack together some of the bizarre and frankly un-judicial goings on in these early COVID coverage cases, one has to wonder whether and to what degree concerted insurer-directed media infected the judicial outcomes. If true, that lays a haunting precedent over future coverage litigation for insurance matters both about pandemic-related losses and beyond.

B. CONSIDERING COVID COVERAGE DISPUTES IN THE BROADER CONTEXT OF THE INSURABILITY OF PANDEMIC-RELATED LOSSES

A pandemic is a "clash event,"[24] like a war or nuclear accident. Losses flowing from this event are large, uniformly repeated amongst many policyholders, and simultaneously cut across multiple insurance product lines. Insurance is built as a risk-based product, designed to buffer chance happenings of loss-related events by pooling collective risk in a pool while knowing that not all policyholders in that risk pool will experience a loss at exactly the same time.

With a pandemic, "chance" may be frustrated in that the precise manner in which risks become losses may not be fully expected (or rather modelled) by insurers. This makes it difficult for the insurer to spread risk amongst the risk pool or even amongst various lines of insurance products. While some industries in a

[24] Michelle E. Boardman, *Known Unknowns: The Illusion of Terrorism Insurance,* 93 GEO. L.J. 783, 784 (2004) (dubbing "clash events" those large-scale losses like earthquakes and nuclear disasters that affect many policyholders at once and cut across multiple insurance lines).

pandemic can be severely affected (like the travel and hospitality industries in the current COVID-19 pandemic), and most at least significantly affected (such as retailers and services), there will be some industries that actually thrive in a pandemic (such as online retailers and delivery services). It may be fair to argue that it is the job of insurers to predict and price their insurance products accordingly, as part of building a solvent insurance framework. A failure to incorrectly build and price insurance in the wake of a clash event can leave only two outcomes: financial decimation for either the policyholder or the insurer. The stakes are high.

In a pandemic situation like that with COVID-19, a downturn in commercial activity is also often related to a resulting downturn in the financial markets. This challenges an insurer's ability to capitalize on investment returns for its retained insurance premium funds. The differential between premiums obtained and losses paid out—the spread—becomes tougher to profitably manage, because the financial markets unexpected reacted as a result of the very factor causing the losses insured.

But losses realized in a pandemic are not, by nature, impossible to insure. The difficulty is with estimating the correct pricing of the insurance products that tracks the realistic risks of payouts while still maintaining a profitable baseline for the insurer.

Anything that is fortuitous can be insured, in principle. The pandemic is an unexpected event. Whether insurers choose to insure pandemic-related losses as a matter of commercial choice is, of course, itself another matter.

Pandemic-relating losses are insurable in theory because the timing of the pandemic itself is a fortuitous event. We do not know when—or if—one will strike. But even in the wake of a full-blown pandemic, there are still fortuitous aspects making insurance a potentially profitable financial product to sell. Because, as noted above, not all industries will be affected at the same time and to the same degree, insurers may still be able to structure and price insurance profitably, even during a full-blown pandemic. This is because the degree and extent of loss experienced amongst individual policyholders is fortuitous. In fact, some policyholders may profit from the pandemic in their specific industries and may have no loss at all.

An insurer's ability to properly price an insurance product that appropriately accounts for pandemic-related losses based on the underwriting risk involves three factors:

a) can the insurer properly rate the risk?
b) is the premium for the risk affordable to policyholders?
c) will the premium (along with investment income) exceed the loss?

As has probably occurred with COVID, insurance products were likely priced with the foresight of only a slight possibility of a pandemic. The insurer model may not have accounted for the various kinds of losses amongst policyholders (i.e. largely business interruption losses from governmental orders either closing businesses or telling customers to shelter at home to quell the spread of the virus).

Insurers cannot claim that the pandemic was completely unforeseen as an event. The world has seen its share of rising health epidemics in the recent decades, from Ebola to SARS to H1N1, swine flu, Zika, MERS, and HIV/AIDS. In fact, the insurance industry had a virus and bacteria exclusion approved by regulators for inclusion in property insurance policies in 2006, in direct response to the SARS virus (though this exclusion is not featured in all property policies).[25] The insurance industry also marketed specific insurance for pandemic-related losses, a product still available at the start of the COVID-19 pandemic in March 2020.[26]

However, most insurers began the COVID-19 pandemic with blanket coverage denials for policyholders' COVID-related claims. And insurers did this not on the basis of the virus exclusion most logically relevant to the issue, but instead on the argument that the policyholder has suffered no physical loss or damage.

The insurance denials prompted some governments to propose legislation to mandate either government reinsurance for pandemic-related losses,[27] or insist that insurers cover such losses, even despite actual policy coverage wording.[28] In

[25] INSURANCE SERVICE OFFICE, ISO FORM CP 01 40 07 06 - EXCLUSION OF LOSS DUE TO VIRUS OR BACTERIA (July 6, 2006) [hereinafter ISO VIRUS EXCLUSION], https://www.propertyinsurancecoveragelaw.com/files/2020/03/ISO-Circular-LI-CF-2006-175-Virus.pdf (mentioning specifically SARS, avian flu, and influenza, as well as anthrax).

[26] *See, e.g.*, *PathogenRX, An Innovative Solution for Pandemic and Epidemic Risks*, MARSH, https://www.marsh.com/us/campaigns/pathogenrx.html (last visited Jan. 24, 2021) (which had almost no take-up prior to COVID-19); Stuart Collins, *Insurers Wary of Meeting Growing Demand for Specialist Pandemic Cover,* COM. RISK ONLINE (Apr. 9, 2020), https://www.commercialriskonline.com/insurers-wary-meeting-growing-demand-specialist-pandemic-cover/; *see also* Robert Hartwig, Greg Niehaus & Joseph Qiu, *Insurance for Economic Losses Caused by Pandemics,* 45 GENEVA RISK & INS. REV. 134, 138 (2020) (discussing the failed PathogenRX market).

[27] *See, e.g.*, Pandemic Risk Insurance Act of 2020, H.R. 6983, 116th Cong. (2020).

[28] Various state governments in New Jersey, New York, Pennsylvania, Louisiana, Ohio, Massachusetts, and South Carolina all proposed bills mandating that insurers cover COVID-19 pandemic-related losses. *See, e.g.,* The Gen. Assemb. of Pa., H.B. 2372, 2020 Sess. (Pa. 2020) ("Business Interruption Insurance Act"); State of N.Y. Assemb., A. 10226-B, 2020 Assemb. (N.Y. 2020) ("An Act in relation to requiring certain perils be covered under business interruption insurance during the coronavirus disease 2019 (COVID-19) pandemic"); State of N.Y. Senate, S. 8178, 2020 S. (N.Y. 2020) ("An Act in relation to

response, the National Association of Insurance Commissioners (NAIC) warned in correspondence to the U.S. House Committee on Small Business that such legislation requiring insurers to cover COVID-19 related losses would financially decimate the insurance industry.[29] The Insurance Commissioners argued that most insurance products were not designed or priced to provide coverage for pandemic-related losses. They also contended that "virtually every policyholder suffers significant losses at the same time." But pandemic-related losses themselves are not uninsurable in principle. Insurers may just not have properly estimated how the particular losses of this pandemic have played out and may not have priced their products accordingly. Or, perhaps, the insurance products were not designed to cover pandemic-related losses at all.

C. INSURANCE IMPLICATED IN A PANDEMIC

A pandemic such as the COVID crisis can result in insurance claims across a variety of insurance product lines, including:

a) property insurance, especially for contamination losses and business interruption losses, as well as losses arising from civil authority 'stay at home' orders or forced business closure orders;
b) liability insurance, in the event an employee or customer takes legal action against the policyholder for injury suffered as a result of failure to take reasonable health precautions;
c) workers compensation and employment insurance, for the sickness or quarantining or isolation of employees;
d) directors and officers insurance, for any liability visited by corporate decisions as a result of the pandemic; and
e) event cancellation insurance, triggered if a major event is cancelled (such as a sporting event or concert or film production).

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requiring certain perils be covered under business interruption insurance during the coronavirus disease 2019 (COVID-19) pandemic"). These bills are currently winding their way through the legislative processes.

[29] Letter from Nat'l Ass'n of Ins. Comm'rs and the Cntr for Ins. Pol'y & Rsch to The Honorable Nydia M. Veláquez, Chairwoman, U.S. House Committee on Small Business (May 20, 2020), https://naic.org/documents/government_relations_200521.pdf.

1. Business Interruption Coverage

The most active area for insurance coverage issues at this stage of the COVID-19 pandemic has been litigation arising from business losses by commercial entities, as a result of policyholder claims for losses under business interruption and civil authority insurance provisions. This has triggered interpretive debates in the courts over the meaning of business interruption and civil authority coverage contained in commercial property policies. These types of insurance products are additional coverages to the standard all-risk commercial property insurance policy.[30]

The standard commercial property policy provides coverage for losses arising from all risks to the policyholder's commercial property, save and except those risks that are specifically excluded in the policy. As a separate add-on, usually as an endorsement and for additional premiums, the policyholder can augment its property policy with various types of insurance coverage for other potential business-related losses.[31]

One such potential business-related loss is the interruption of a business' potential to generate income. This type of coverage is designed to protect the earning stream of the business in the event the business' capacity to earn income is interrupted as a result of a covered cause of loss. The coverage indemnifies the policyholder for income lost while the building restores its operations.[32]

The coverage clause in the standard property policy typically covers "direct physical loss of or damage to" insured property.[33] The business interruption coverage clause typically dictates that the insurer will pay for the loss of business income "due to the necessary suspension or delay of operations caused by direct physical loss of or damage to property." To determine insurance coverage, the policyholder must prove it suffered some "direct physical loss of or damage to property." The archetypal scenario for triggering business interruption insurance is the fire at a commercial establishment. The fire damages the storefront and the

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[30] *See* French, *supra* note 4, at 17–20; MARK S. DORFMAN & DAVID A. CATHER, INTRODUCTION TO RISK MANAGEMENT AND INSURANCE 346–47 (10th ed. 2013); EMMETT J. VAUGHAN & THERESE M. VAUGHAN, FUNDAMENTALS OF RISK AND INSURANCE 563–65 (11th ed. 2013).

[31] *See* French, *supra* note 4, at 21–30; DORFMAN & CATHER, *supra* note 30, at 346–47; VAUGHAN & VAUGHAN, *supra* note 30, at 563–65.

[32] *See* French, *supra* note 4, at 21–30; DORFMAN & CATHER, *supra* note 30, at 346–47; VAUGHAN & VAUGHAN, *supra* note 30, at 563–65.

[33] *See* JEFFREY W. STEMPEL & ERIK S. KNUTSEN, STEMPEL & KNUTSEN ON INSURANCE COVERAGE §15.01[D] (4th ed. 2015 & Supp. 2020).

business is unable to earn income until such time as the business can repair the fire-damaged storefront.

In a pandemic situation like COVID, however, the place of business is not physically destroyed but contaminated by virus, making use of the business property unsafe. Alternatively, access to the business' property may be curtailed due to governmental orders designed to curb the spread of the disease. For example, many restaurants have been ordered closed to dine-in customers and could only operate via take-out or delivery for a period of time. The question becomes whether the policyholder has suffered a "direct physical loss of or damage to" its commercial property by either contamination by virus or by a governmental order restricting property access or use.

Insurers will likely stress that commercial property policies are designed to cover physical damage to tangible property—like fire damage. One way of looking at the issue is that any loss of business income should be tied to the necessary interruption of a business' income stream as a result of something that harms the property in a way that would interfere with a policyholder using its property as a place to earn income. If the property itself is not damaged, the coverage should not be triggered.[34]

Policyholders, however, likely believe that they purchased business interruption insurance as an add-on to their property coverage in order to insure a capital asset—the income-earning power of their business (hence the name "business interruption insurance"). If that income stream is interrupted due to an interference with their use of their property—whether by virus contamination or by orders of government—their reasonable expectation would be that the business interruption portion of their policy would cover such losses. The property policy is, after all, "all-risk" property insurance, and the business interruption coverage is tied to that "all-risk" concept. Policyholders who purchased business interruption insurance would expect coverage for an inability to use their property to earn business income.[35]

2. Civil Authority Coverage

A common extension to the business interruption coverage in a commercial property policy is civil authority coverage. Under this coverage, a policyholder can insure its lost business income stream if access to its property is impaired or prohibited due to the order of some civil authority (i.e. a government). Some wordings of this coverage specifically require that the civil authority's order is due

[34] *See* French, *supra* note 4, at 51.
[35] *See* French, *supra* note 4, at 68–71.

to the direct physical loss of or damage to property adjacent to the policyholder's insured property as a result of a covered cause. A common coverage clause for civil authority insurance states: " . . . if an order of civil or military authority limits, restricts or prohibits partial or total access . . . provided such order is the direct result of physical damage of the type insured."[36] The classic example is the burned warehouse that sits next to the policyholder's place of business. To keep people in the adjacent properties safe, a civil authority could ban access to a policyholder's property simply because it is close to another property exhibiting unsafe characteristics (like the unstable structure after a fire).

Business interruption insurance claims due to COVID have arisen under the civil authority coverage provisions, resulting from losses due to state or municipal "shelter in place" orders or the closure of non-essential businesses or the modification of the use of businesses, such as eliminating indoor dining at restaurants. The risk of COVID with its airborne and highly contagious quality prompted many civil authorities to issue various orders in an attempt to contain the disease.

Courts examining civil authority coverage tend to look to causation arguments: was the order the result of directly physical loss of or damage to property? If so, is such a covered cause of loss? Policyholders have argued that they suffered loss of use or loss of functionality of their property due to the civil authority orders, and that constitutes a direct physical loss of property. However, insurers have argued that the language of most coverage grants demands that policyholders must also prove that alleged property damage to some property adjacent to the policyholder's place of business actually led to the civil authority making the order.

3. Contingent Business Interruption Coverage

Contingent business interruption coverage is similar to business interruption coverage except that the policyholder's income stream is affected by loss or damage to a related business' property, and not the property of the policyholder. This coverage is commonly implicated in a manufacturer setting, where a supplier suffers a loss and the manufacturer cannot obtain a needed component in a timely fashion and suffers a business interruption.[37]

For example, if a tire manufacturer suffers a fire at the tire plant and is unable to ship its tires to auto makers because of fire damage to the plant, the auto makers will likely have a business interruption loss due to the inability to get tires

[36] *See* STEMPEL & KNUTSEN, *supra* note 33, at §28.04.

[37] *See* French, *supra* note 4, at 21–30; Dorfman & Cather, *supra* note 30, at 346–47; Vaughan & Vaughan, *supra* note 30, at 563–65.

in a timely manner from their supplier. The auto maker can then make a contingent business interruption claim in that, although it did not suffer the loss itself on its own property, its supplier did, and that loss to the supplier affected the policyholder's own business income stream. The key to coverage for contingent business interruption insurance is that, like business interruption insurance, the supplier must have suffered some "direct physical loss of or damage to" property as a result of a cause covered by the policyholder's all-risk insurance.

4. Ingress/Egress Coverage

Ingress/egress coverage is also sub-coverage that may be included in business interruption coverage. It provides coverage for losses arising if access to a policyholder's property is impeded through some reason other than by a civil authority order (i.e. blocked due to construction debris). To date, this coverage has not yet been implicated in any court decisions deciding COVID pandemic-related coverage issues. This makes sense as it was civil authority orders that largely affected property access for policyholders.

II. INSURER PUBLIC RELATIONS BLITZ: INSURERS PUSH THEIR ANTI-COVERAGE MESSAGE

As previously noted, COVID-19 became recognized as a major public health issue likely to adversely impact commerce in early March 2020. It was fairly clear at the outset, particularly when citizens began to stockpile supplies and stay indoors and when governments issued closure orders, that COVID would have a serious negative impact on many businesses, particularly entertainment, dining, and tourism.[38]

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[38] *See* French, *supra* note 4, at 1–3; *Why Are Markets Collapsing? How Bad Will COVID-19 Really Be?*, KNOWLEDGE@WHARTON (Mar. 16, 2020), https://knowledge.wharton.upenn.edu/article/why-are-the-markets-collapsing-how-bad-will-covid-19-really-be ("markets are acting as if we are going to encounter the worst-case scenario") (italics removed). The actual downturn in these areas of commerce has perhaps been even worse than anticipated due to the difficulty in containing COVID, resulting in a quilted cycle of closures and declining customer patronage that has perhaps lasted even longer than predicted. *See* Zoe Wood, *How the Cineworld Closures Could Turn Leisure Parks into a Disaster Movie*, THE GUARDIAN (Oct. 10, 2020 03:00 EDT), https://www.theguardian.com/business/2020/oct/10/how-the-cineworld-closures-could-turn-leisure-parks-into-a-disaster-movie (describing massive movie theatre closures and layoffs and ripple effect on bars, restaurants, and shops that benefitted from entertainment traffic). *Accord* Julian Kozlowski, Laura Veldkamp, & Venky Venkateswaran,

In response to the COVID-19 pandemic, insurers quickly took control of the insurance coverage message in the media: there will be no coverage for COVID-19 related losses.[39] Typical of the industry line were statements by insurance executives that "[p]andemics are not insurable because they are too widespread, severe, and unpredictable to underwrite" and that "[c]ommercial-property insurance policies that include business-interruption coverage generally are not intended to cover disease- or pandemic-related losses."[40]

Another prominent insurer executive claimed to "see very minimal loss exposure from this" due to the addition of coverage-restricting language in policies

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Scarring Body and Mind: The Long-Term Belief-Scarring Effects of COVID-19 (Nat'l Bureau of Econ. Rsch., Working Paper No. 27439, June 2020), https://www.nber.org/system/files/working_papers/w27439/w27439.pdf (finding that "long-run costs for the U.S. economy" from adverse psychological impact of pandemic will be "many times higher than the estimates of the short-run losses in output. This suggests that, even if a vaccine cures everyone in a year, the COVID-19 crisis will leave its mark on the US economic for many years to come.").

[39] *See, e.g.*, Caroline Glen, ***Insurers Are Telling Businesses Their Policies Don't*** *Cover Coronavirus Shutdown.* ***John Morgan Attorneys Say They're Wrong***, ORLANDO SENTINEL (May 4, 2020), https://www.orlandosentinel.com/coronavirus/jobs-economy/os-bz-coronavirus-insurance-denials-morgan-lawsuits-20200504-pbrpq6z7ofbevau67cpgq4nzqi-story.html; Ellen Ioanes, *Does My Business-Interruption Insurance Cover Closing Because of COVID-19?*, BARRON'S (June 17, 2020 5:30 AM), https://www.barrons.com/articles/does-my-business-interruption-insurance-cover-closing-because-of-covid-19-51592386201; Leslie Scism, *Companies Hit by COVID-19 Want Insurance Payouts. Insurers Say No.*, WALL ST. J. (June 30, 2020 10:24 AM), https://www.wsj.com/articles/companies-hit-by-covid-19-want-insurance-payouts-insurers-say-no-11593527047. *See also* INS. INFO. INST., *Insurance Industry Provides Interactive* ***'Explainer'*** *to Help Navigate Business Interruption Insurance*, III (Oct. 16, 2020), https://www.iii.org/pres-release/insurance-industry-porovides-interactive-explainer-to-help-navigate-business-interruption-insurance-101620. The navigation tends to leave policyholders on the shoals of no coverage as the III Explainer consistently takes a narrow view of the scope of coverage and, in particular, contends that most all COVID-related coverage is not covered. *Accord Business Interruption Insurance: An Interactive Explainer Outlining the Case for a Federal Solution to Pandemic Relief*, FUTURE OF AM. INS. & REINSURANCE, https://fairinsure.org/business-interruption-insurance/?utm_source=Board+of+Directors&utm_campaign=5ca10385b4-EMAIL_CAMPAIGN_2018_08_15_11_45_COPY_01&utm_medium=email&utm_term=0_0934a86008-5ca10385b4-122588685.

[40] *See* Ioanes, *supra* note 39 (quoting David Sampson, president and CEO of the American Property Casualty Insurance Association (APCIA)).

because of "past pandemics and/or partial pandemics."[41] Swinging into attack mode, this industry leader also took the by-now almost obligatory insurer swipe at plaintiff counsel and made it clear that seeking coverage would not be for the faint of heart: "Lawyers and the trial bar will attempt to torture the language on standard industry forms and try to prove something exists that actually doesn't exist . . . ." "The industry will fight this tooth and nail. We will pay what we owe."[42]

Whether this evolved to be the message over a short period of time, or whether it was a concerted industry effort (likely the latter), we believe it made an impact on the subsequent insurance coverage court decisions about COVID-related claims. It provides an interesting example of insurers seizing the messaging opportunity to potentially affect legal decisions. Making use of extra-legal media messaging to impact the legal sphere is a useful tactic for prospective litigants and insurers seem to be good at it.

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[41] *See* Leslie Scism, *U.S. Businesses Gear Up for Legal Disputes with Insurers Over Coronavirus Claims*, WALL ST. J. (Mar. 6, 2020 10:00 AM), https://www.wsj.com/articles/u-s-businesses-gear-up-for-legal-disputes-with-insurers-over-coronavirus-claims-11583465668 (quoting Chubb Ltd. CEO Evan Greenberg, however "Chubb declined to comment further" on the issue when asked by the Journal reporter). *See also* Maria Sassian, *Triple-I CEO Tells U.S. House—Global Pandemics are Uninsurable,* INS. INFO. INST. (May 21, 2020), https://www.iii.org/insuranceindustryblog/triple-i-ceo-tells-u-s-house-global-pandemics-are-uninsurable/ ("'An event like a global pandemic is uninsurable [said the executive.] Unlike a typical covered catastrophe, which is limited in terms of geography and time, pandemics have the potential to impact everywhere, all at once . . . . As such, this type of magnitude requires government resources to step in and provide support.").

[42] *See* Scism, supra note 39 (quoting Chubb Ltd. CEO Evan Greenberg).

Media targets included both the legal press,[43] the insurance trade press[44] as well as the business press,[45] and even the mainstream lay press read by the average public[46]

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[43] *See, e.g.*, Larry P. Schiffer, *Does the Novel Coronavirus Cause Direct Physical Loss of or Damage to Property?*, NAT'L L. REV. (July 13, 2020), https://www.natllawreview.com/article (concluding that "[b]ased on the case law and the nature of the novel coronavirus, it appears unlikely that courts will conclude that viral contamination causes 'direct physical loss.'"); *Insurers' COVID-19 Notepad: What You Need to Know Now*, CROWELL MORING (June 9, 2020), https://www.crowell.com/NewsEvents/AlertsNewsletters/all/Insurers-COVID-19-Notepad-What-You-Need-to-Know-Now-Week-of-June-8 (suggesting that coverage unlikely for COVID-related claims); Lauraann Wood, ***Insurer Says Policy Isn't Triggered*** *in COVID-19 Coverage Suit*, LAW360 (July 14, 2020 3:56 PM), https://www.law360.com/articles/1291736/insurer-says-policy-isn-t-triggered-in-covid-19-coverage-suit.

> Even if the virus had been present on the covered businesses' properties, it wouldn't constitute direct physical loss or damage because it doesn't cause 'a tangible change to the physical characteristics of property,' [the insurer argued]. COVID-19 isn't incorporated into their properties' physical structure, doesn't require a building's physical alteration for removal 'and does not render the building unfit for use,' it said.
>
> 'Rather, the coronavirus can be removed from surfaces with soap and water and rendered inert with various common household disinfectants, including bleach,' [said the insurer.] '[The insureds'] alleged losses are at most economic losses, not a direct physical loss or damage.'
>
> The businesses also aren't entitled to coverage under the civil authority provision for additional coverage under their policies, which 'has a very specific set of terms and conditions that must be met,' [the insurer represented to the court.]

Wood, *supra*.

[44] *See, e.g.*, Jeff Dunsavage, *COVID-19 Wrap-up: BI Coverage Continues to Make Headlines,* TRIPLE-I BLOG (May 21, 2020), https://www.iii.org/insuranceindustryblog/covid-19-wrap-upbi-coverage-continues-to-make-headlines ("The *Post* interviewed Triple-I CEO Sean Kevelighan and Triple-I non-resident scholar Michael Menapace, who explained why the suits are unreasonable and threaten the insurance industry's solvency. 'The insurance business works by spreading risk around so the industry isn't hit all at once with claims,' Kevelighan says. 'A pandemic disrupts business far and wide, with no end date in sight.'"); *Focus on Facts, Not Media Misinformation: Berkley*, CARRIER MGMT (June 7, 2020), https://www.carriermanagement.com/news/2020/06/07/207575.htm?print ("Arguing that the media has been fed misinformation by

the plaintiffs bar, the chief executive officer of a property/casualty insurer said facts will win out on debates over business interruption coverage disputes related to COVID-19 shutdowns.") (referring to W. Robert Berkley, Jr., president and CEO of WR Berkley); Stephan Kahl, *Munich Re to Stop Selling Pandemic Business Coverage*, INS. J. (Sept. 11, 2020), https://www.insurancejournal.com/news/international/2020/09/11/582141.htm; *Beazley Hikes Estimate for COVID-19 Related Claims Amid Resurgence in Virus*, SHARES MAG. (Sept. 22, 2020 07:30), https://www.sharesmagazine.co.uk/news/market/7092096/Beazley-hikes-estimate-for-Covid-19-related-claims-amid-resurgence-in-virus (estimating range of exposure from $170 to $350 million net of reinsurance).

[45] *See, e.g.*, Leslie Scism, *U.S. Businesses Gear Up for Legal Disputes with Insurers Over Coronavirus Claims*, WALL ST. J. (Mar. 6, 2020 10:00 AM), https://www.wsj.com/articles/u-s-businesses-gear-up-for-legal-disputes-with-insurers-over-coronavirus-claims-11583465668; Ioanes, *supra* note 39; Katherine Chiglinsky, *Virus Fight Insurers Thought They'd Dodged Is Looming Anyway*, WASH. POST (Mar. 24, 2020 11:20 AM), https://www.washingtonpost https://www.washingtonpost.com/business/on-small-business/virus-fight-insurers-thought-theyd-dodged-is-looming-anyway/2020/03/24/aef84e06-6de1-11ea-a156-0048b62cdb51_story.html; Kate Rogers & Betsy Spring, *On Main Street, Business Owners Push for Greater Protection from Coronavirus-related Lawsuits*, CNBC (June 15, 2020 1:37 PM), https://www.cnbc.com/2020/06/12/on-main-street-a-push-for-protection-from-coronavirus-related-lawsuits.html ("'It turns out that business interruption insurance is not what it sounds like,' [Robert Cresanti, president and CEO of the International Franchise Association] said. 'Most of the insurance companies are telling our people that business interruption insurance is actually business destruction insurance. So if your business is burned down or destroyed by a flood, you're covered. But you're not [covered] in a crisis like this where your business is truly interrupted.'"); Karen Epper Hoffman, *Business Interruption: Insurers Balk at Paying Claims*, CFO.COM (Sept. 10, 2020), https://www.cfo.com/risk-management/2020/09/pandemic-losses-out-in-the-cold ("Robert Gordon, senior vice president for policy, research, and international for the American Property Casualty Insurance Association (APCIA), says that because government emergency orders closed businesses to limit human transmission of COVID-19 and not because there had been direct property loss or damage, business interruption policies are not relevant.").

[46] *See, e.g.*, Ron Hurtibise, *Sorry, That's Not Covered: Insurers Fight Businesses Over COVID-19 Shutdowns*, S. FLA. SUN SENTINEL (Sept. 12, 2020 8:55 AM), https://www.sun-sentinel.com/business/fl-bz-owners-losing-covid-related-business-interruption-suits-20200912-46jlyxsftjenvlyrxg4tfbqyam-story.html ("the industry has reinforced its message by boasting about nearly every court ruling that has gone its way. 'Another court agrees: Business Interruption Insurance Does Not Cover Pandemic-Related Losses,' said the subject line of an email release by the Insurance Information Institute, a trade group created by the industry to educate consumers about insurance-related issues."); Judith Bachman, *Judges Are Deciding Whether Business Interruption Policies Cover Pandemic-Related Losses*,

as well as scholarly journals.[47] When insurers prevailed in litigation, victory was quickly trumpeted.[48]

A similar public relations campaign by small business policyholders was harder to mount given the disparate number and dispersion of random policyholders with potential claims.[49] Although plaintiff law firms fulfilled some of this function in banging the drum for coverage, their efforts were (in our view) problematic in that many of these lawyers were not insurance coverage specialists from experienced policyholder-side coverage firms. In addition, early pro-coverage efforts were (in our view) too grandiose and not well-targeted.

For example, plaintiff firms sought mass consolidation of claims, including a request for consolidation by the federal Judicial Panel on Multi-District Litigation

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ROCKLAND CNTY. BUS. J. (Oct. 8, 2020), https://rcbizjournal.com/2020/10/08/judges-are-deciding-whether-business-interruption-policies-cover-pandemic-related-losses.

47 *See, e.g.*, Robert Hartwig, Greg Niehaus & Joseph Qiu, *Insurance for Economic Losses Caused by Pandemics*, 45 GENEVA RISK & INS. REV. 134, 134 (2020) ("Private insurance coverage for economic losses caused by pandemics is limited [due in large part] to the high levels of capital that would be required to credibly insure pandemic economic losses with cross-sectional pooling mechanisms.").

48 Leslie Scism, *Insurance Firms Gain Early Lead in Coronavirus Legal Fight With Businesses*, WALL ST. J. (Sept. 1, 2020 9:00 AM), https://www.wsj.com/articles/insurers-gain-early-lead-in-covid-19-legal-fight-with-businesses-11598965200 ("Insurers say the policies are intended to help policyholders as they recover from events, such as fires, that lead to repairs and rebuilding, and were never intended to cover virus-related claims."); Alison Frankel, *Latest COVID-19 Insurance Coverage Loss Shows Narrowing Path for Policyholders*, REUTERS (Sept. 15, 2020 6:54 PM), https://www.reuters.com/article/legal-us-otc-insurance-idUSKBN2663HC; Andrew G. Simpson, *Judges Nix Consolidating COVID Business Interruption Suits Against Big Insurers*, INS. J. (Oct. 4, 2020), https://www.insurancejournal.com/news/national/2020/10/04/585092.htm.

49 This is not to say that the business community did not on occasion make itself heard on the issue. *See, e.g.*, Stephen Gandel, *Companies Say Insurance Companies Are Stiffing Them Over Coronavirus Losses*, CBS NEWS (Sept. 21, 2020 11:16 AM), https://www.cbsnews.com/news/covid-insurance-business-continuity-interruption-declined-coverage; Kate Rogers & Betsy Spring, *On Main Street, Business Owners Push for Greater Protection from Coronavirus-related Lawsuits*, CNBC (June 12, 2020), https://www.cnbc.com/2020/06/12/on-main-street-a-push-for-protection-from-coronavirus-related-lawsuits.html. *See also,* Tim Carman, *Restaurants Are Suing Insurance Companies Over Unpaid Claims—And Both Sides Say Their Survival Is at Stake*, WASH. POST (May 19, 2020 1:37 PM), https://www.washingtonpost.com/news/voraciously/wp/2020/05/19/restaurants-are-suing-insurance-companies-over-unpaid-claims-and-both-sides-say-their-survival-is-at-stake (reporting both insurers and small businesses taking positions that adverse coverage decisions will be financially ruinous).

(MDL), which almost everyone (including the judges on the Panel) viewed as inapt unless confined to the same policy forms of a single insurer in light of the varying facts and policies of different cases.[50] More extremely, lawyers and legislators sympathetic to business sought to legislatively require coverage by insurers regardless of the policies at issue—a seemingly rather clear attempt to violate the Contract Clause of the U.S. Constitution that gave insurers a rather effortless public relations victory.[51]

As discussed below, we find the insurers' industry-wide disparagement of coverage as legally misplaced as it may have been rhetorically brilliant. While we cannot help but admire the manner in which insurers moved quickly and uniformly to spin public opinion against coverage, we are dismayed that the tactic seems to have worked on judges. There are real arguments to be made about whether and how policyholders may have coverage for COVID-related losses. In fact, we think the insurance industry's main contention about coverage—the "physical loss or damage" requirement—can be refuted in most cases. But this requires a more searching analysis of the question and less reflexive recoil than has been displayed in the bulk of court decisions to date.

In several states, legislation was introduced to require insurers to pay for lost policyholder revenue. There was also congressional inquiry pushing for such coverage without regard to the actual insurance policy terms at issue in a particular case. Predictably—and correctly in our view—insurers opposed any such legislative mandates or compulsion as violative of the Contract Clause of the U.S. Constitution.[52] In doing so, they took the doctrinaire position—with which we

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[50] *See* Andrew G. Simpson, *Judges Nix Consolidating COVID Business Interruption Suits Against Big Insurers*, INS. J. (Oct. 4, 2020), https://www.insurancejournal.com/news/national/2020/10/04/585092.htm. However, more limited consolidated treatment has been approved for particularized groupings of policies with the same operative language. *See* Jacob Rund, *Ski Pass Insurance Row Highlights Complex Route for Virus Suits*, BLOOMBERG L. (Oct. 20, 2020, 6:31 AM), https://news.bloomberglaw.com/insurance/ski-pass-insurance-row-highlights-complex-route-for-virus-suits (approving consolidation of 30 actions by policyholders against Society Insurance "for denying business interruption claims of restaurants and other hard-hit shops" as well as skiers' lawsuits against Arch Insurance Co. and United Specialty Ins. Co. for denials of cancellation insurance purchased in connection with season-long ski passes). Regarding MDL proceedings generally, see DAVID F. HERR, MULTIDISTRICT LITIGATION MANUAL: PRACTICE BEFORE THE JUDICIAL PANEL ON MULTIDISTRICT LITIGATION (2020 ed.).

[51] *See infra* text accompanying notes 51–53.

[52] *See* Letter from Nat'l Ass'n of Ins. Comm'rs & Ctr. for Ins. Pol'y and Rsch. to Members of Cong. (May 20, 2020) (supporting insurer arguments against legislation forcing

disagree—that business interruption insurance was never intended (apparently under any circumstances) to provide coverage for any losses related to infectious disease like COVID.[53]

coverage). *See also* H.B. 589, 133d Gen. Assemb., 2019-2020 Sess. (Ohio 2019) introduced by Representatives Crossman and Rogers. The bill would "require insurers offering business interruption insurance to cover losses attributable to viruses and pandemics and to declare an emergency" that presumably would support further orders providing for government-mandated closure of non-essential businesses. *See also* Elizabeth Blosfield, *Despite Insurance Industry Concerns, More States Introduce COVID-19 BI Bills*, INS. J. (Apr. 15, 2020), https://www.insurancejournal.com/news/east/2020/04/15/564920.htm ("'It's just not constitutional,' Don Hayden, co-founder and partner of Mark Migdal & Hayden, added. 'I mean, what you're essentially doing is creating insurance where there is nothing. You're essentially throwing out the underwriting and the risk evaluation that insurance companies have done before writing a policy and saying, "You have to cover this. Even though you had expressly said that you would not cover it in your exclusion and in your insurance agreement."'"). *But see* Mark A. Packman, *Constitutionality Under the Contracts Clause of Proposed Legislation Enabling Policyholders to Obtain Insurance Coverage for Coronavirus Claims*, 55 TORT TRIAL & INS. PRAC. L.J. 509 (2020) (concluding that such legislation is constitutional due to emergency nature of pandemic and economic harm to particular businesses).

[53] Erin Ayers, ***Insurers Decline Congress'*** *Request To Pay All COVID-19 Business Interruption Claims*, ADVISEN FRONT PAGE NEWS (Mar. 23, 2020), https://www.advisen.com/tools/fpnproc/fpns/articles_new_1/P/363166470.html?rid=363166470&list_id=1 (responding to congressional inquiry re insurer coverage of COVID business loss claims, insurer interest groups state that "[b]usiness interruption policies do not, and were not designed to, provide coverage against communicable diseases such as COVID-19") (statement from leadership of American Property Casualty Insurance Association, National Association of Mutual Insurance Companies, Council of Insurance Agents and Brokers, and Independent Insurance Agents & Brokers of America) (also taking position that the members of these insurance industry organizations "include many small businesses and employers grappling with the same issues as many businesses."). *See also id.* (acknowledging that COVID coverage claims will be brought concerning other types of insurance policies); Jeff Sistrunk, *4 Coronavirus Developments Insurance Lawyers Should Know*, LAW360 (Mar. 20, 2020, 5:31 PM), https://www.law360.com/articles/1255415/4-coronavirus-developments-insurance-lawyers-should-know (listing the four important topics with subheadings as follows: "Insurers Spurn Call to Expand Business Interruption Coverage"; "NJ Lawmakers Mull Business Interruption Coverage Bill"; "House Lawmakers Press Travel Insurers on Claim Denials"; and "Calif. Regulator Seeks 'Grace Period' on Policy Cancellations").

Insurers also consistently maintained that they would go broke and the insurance industry would be destroyed if carriers were forced to provide COVID coverage.[54] Risk managers and brokers, who are normally viewed as representing policyholder interests, tended to align with insurers, presumably because they feared disruption of the industry more than denial of coverage to policyholder employers or clients, many of which were likely to fail in the absence of prompt payment of insurance coverage.[55] Regulators also sided with insurers,[56] in our view, without sufficient reflection and consciousness of their mission as public servants.[57] These entities also seemed to overlook the likely perception of policyholders who expected (perhaps with sufficient objective reasonableness to obtain coverage) that the premiums they had paid for years for something deemed "business interruption" coverage would provide at least some assistance in the face of the largest business interruption of this type in a century.[58]

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[54] *See, e.g.*, Kate Smith, *Pandemic Partnerships*, BEST'S REV. (Aug. 2020), news.ambest.com/articlecontent.aspx?refnum=299433&altsrc=43 ("Even with pandemic excluded from most business interruption policies, COVID-19 is expected to cost the insurance industry more than $200 billion."). *But see* Kate Smith, *The COVID Catastrophe*, BEST'S REV. (June 2020), http://news.ambest.com/ArticleContent.aspx?pc=1009&altsrc=158&refnum=297254 (stating that "The COVID-19 outbreak could dwarf other catastrophe losses insurers have seen. . . ." but also noting that "[e]ven with the economic downturn, the insurance industry, on the whole, is in a strong capital position"). Carman, *supra* note 49. *Accord*, Andrew G. Simpson, *P/C Insurers Put a Price Tag on Uncovered Coronavirus Business Interruption Losses*, INS. J., (Mar. 30, 2020), https://www.insurancejournal.com/news/nationa/2020/03/30/562738.htm.

> "Pandemics are an extraordinary catastrophe that can impact nearly every economy in the world, so it is hard to predict and manage the risk," Sean Kevelighan, CEO of the Insurance Information Institute, stated. "Pandemic-caused losses are excluded from standard business interruption polices because they impact all business, all at the same time."
>
> Moreover, he said, the exclusion for pandemic-caused losses have been incorporated into standard business interruption policies for years.

Simpson, *supra*. *See also* Elizabeth Pineau & Maya Nikolaeva, *Insurer AXA Must Pay Restaurant's COVID-19 Losses*, French Court Rules, REUTERS (May 22, 2020, 2:08 PM) https://uk.reuters.com/article/us-health-coronavirus-insurance-axa/french-court-orders-insurer-axa-to-pay-restaurants-covid-19-losses-idUKKBN22Y2LR. ("AXA reacts to decision by stating that it would appeal."); Elizabeth Blosfield, *Despite Insurance Industry*

Concerns, More States Introduce COVID-19 BI Bills, INS. J. (Apr. 15, 2020), https://www.insurancejournal.com/news/east/2020/04/15/564920.htm.

> "I think in layman's terms, [legislation forcing payment of covid claims] would implode the industry," Doug Jones, managing director of JAG Insurance Group, told *Insurance Journal* in a March webinar on business interruption and the coronavirus. "At the end of the day, the ripple effect of what that would cause down the road, and I'm talking short-term, not long-term; I'm talking about months from now, not years from now. It would be difficult for anybody to buy any type of insurance."
>
> Additional concerns among the insurance industry about this type of legislation surround The Contracts Clause in the U.S. Constitution, which places limitations on states' ability to interfere with private contracts.
>
> "It's just not constitutional," Don Hayden, co-founder and partner of Mark Migdal & Hayden, added. "I mean, what you're essentially doing is creating insurance where there is nothing. You're essentially throwing out the underwriting and the risk evaluation that insurance companies have done before writing a policy and saying, 'You have to cover this. Even though you had expressly said that you would not cover it in your exclusion and in your insurance agreement.'"

Blosfield, *supra*.

[55] The tone of reporting appears to suggest that this element of the risk management and insurance community tacitly accepted widespread lack of coverage and economic danger to the insurance industry. As reported in one publication geared toward risk managers and brokers only 14 percent of surveyed risk managers and corporate insurance buyers planning to add new pandemic coverage. Andy Toh, *2020 Property Insurance Survey*, BUS. INS. 31 (June 2020). But 27 percent state that their current policies provide coverage related to diseases and epidemics while 49 percent deny having such coverage. *Id.* 41 percent of policyholders are expecting to make a pandemic claim, with 28 percent not planning such claims. *Id*

> 67% of risk professional expect direct business interruption losses due to COVID-19. 77% expect the losses to be over $1 million, of which 36% estimate losses to be more than $25 million. 91% support a federal backstop for pandemic risk insurance similar to the Terrorism Risk Insurance Act. 65% of risk professionals would be willing to pay up to 5% more in premium for pandemic risk insurance coverage.

Claire Wilkinson, *Pressure Builds for Pandemic Backstop*, BUS. INS. 4 (May 2020). A draft Pandemic Risk Insurance Act of 2020 then circulating "would establish a federal backstop for business interruption losses resulting from a future pandemic and would be triggered when insurance industry losses exceed a $250 million threshold and capped at $500 billion . . . ." *Id.* "The growing momentum among insurance buyers and others for a government backstop to cover pandemic risks comes as insurers continue to maintain that most commercial property policies do not provide coverage for business interruption losses arising form the COVID-19 pandemic." *Id.*

> The question of whether a potential Pandemic Risk Insurance Act should be retroactive to the to the COVID-19 pandemic is an issue RIMS is still exploring, she [Mary Roth, RIMS CEO] said
>
> . . . .
>
> RIMS doesn't want to 'get into the business of' altering contractual agreements that were 'legally and freely entered into,' said Whitney Craig, RIMS government relations director.
>
> 'We would be very wary of supporting legislation that has that. We don't want to bankrupt an industry that we as risk managers rely on,' Ms. Craig said.

Id.

[56] *See* Leslie Scism, *Companies Hit by Covid-19 Want Insurance Payouts—Insurers Say No*, WALL ST. J. (June 30, 2020, 10:24 AM), https://www.wsj.com/articles/companies-hit-by-covid-19-want-insurance-payouts-insurers-say-no-11593527047. ("Insurers have some conceptual backing for their stance that business-interruption coverage isn't meant for pandemics. The National Association of Insurance Commissioners, a standards-setting group for state regulators, says pandemics violate a cardinal principle of insurance, which is that large numbers of policyholders pool their risk to fund a few losses at any one time. In a pandemic, almost all policyholders suffer losses, and simultaneously.").

[57] We appreciate NAIC's concern that large coverage obligations could imperil the insurance system generally. But we remain more than a little puzzled that a regulatory group charged with protecting the public seems uninterested in supporting policyholders, particularly small business policyholders, in cases where there is arguable coverage. Insurers are in the business of risk transfer and insurance is one of the largest, most profitable industries in the world. Although it may be regrettable if an insurance company (or several or dozens) should fail, we consider it at least equally regrettable if policyholders who paid for coverage fail after wrongfully being denied coverage due to fears of bankrupting the insurance industry. Past insurer claims that their financial sky was falling proved to be exaggerated, something regulators should know and appreciate. *See* Jeffrey W. Stempel, *Assessing the Coverage Carnage: Asbestos Liability and Insurance After Three Decades of Dispute*, 12 CONN INS. L. J. 349, 353 (2006) (citing asbestos mass torts, despite the massive costs, estimated to have been only a three percent drag on insurer earnings).

In addition, we note that there is more than a little disconnect between NAIC as an entity tending to back the insurer mantra that "everyone knows pandemics are not insured" while

As noted, insurers or their counsel campaigned in earnest to label COVID an uncovered loss in both the general media and what might be termed the insurance trade media.[59] Part of the insurer effort to disparage coverage claims was the continued assertion that nearly all property insurance with business interruption coverage also contained clear virus exclusions precluding coverage.[60] This claim may be overstated. In the COVID coverage decisions to date, more than twenty percent of the policies at issue lacked a virus exclusion.[61] Thus, even if the insurer contention that "most" property policies have such an exclusion, there appear to be

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some individual state commissioners have gone in the opposite direction and attempted to force coverage irrespective of the language, intent, and purpose of particular policies. Our preferred position is between these two extremes.

[58] Matthew Lerner, *Policy Wordings Tested by Interruption Losses*, BUS. INS. 27 (May 2020).

> Business interruption claims have fast become one of the principal legal battlefronts between commercial policyholders and insurers since the outbreak of the coronavirus pandemic.
>
> Dozens of businesses, including numerous restaurants, have filed state and federal lawsuits against their insurers seeking declaratory rulings that income lost due to the government-mandated lockdowns is covered by insurance.
>
> Insurers argue that many of the policies include exclusions for virus related losses and most of those that don't still won't cover lost income because physical damage to an insured property must occur to trigger claims payments.

Id.

[59] *See* CARRIER MGMT, supra note 44. *See, e.g.*, *Larry* P. Schiffer, *Does the Novel Coronavirus Cause Direct Physical Loss of or Damage to Property?*, X NAT'L L. REV. 114 (Apr. 13, 2020), https://www.natlawreview.com/article/does-novel-coronavirus-cause-direct-physical-loss-or-damage-to-property (concluding that "[b]ased on the case law and the nature of the novel coronavirus, it appears unlikely that courts will conclude that viral contamination causes 'direct physical loss.'").

[60] Erin Ayers, ***Insurers Decline Congress' Request to Pay All COVID**-19 Business Interruption Losses*, ADVISEN FRONT PAGE NEWS (Mar. 23, 2020), https://www.advisen.com/tools/fpnproc/fpns/articles_new_1/P/363166470.html?rid=363166470&list_id=1 ("The vast majority of commercial property insurance policies contain not only direct physical damage, but also contain exclusions for viral/bacterial contamination due to the unpredictability of the risk.").

[61] *See* Baker, *supra*, note 10 (visited Oct. 21, 2020).

a large number of cases where policyholders have a substantially better chance of success than suggested by the insurance industry shibboleth of no coverage.

As part of its aggressive "no coverage" strategy, insurers did more than rest on the virus exclusion (which we agree can be a strong defense to coverage where the policy actually contains such a limitation) even when policies at issue contained the exclusion. Rather, insurers dug in on a remarkable first line of defense: that COVID did not and could not cause *any* direct physical loss or damage to property, which is a prerequisite to most commercial property and business interruption coverage.

> [T]he mere **threat** of COVID-19 at the property or the **preemptive closure** of businesses due to the threat of COVID-19 should not be considered "direct physical loss or damage" to property. Additionally, neither **government-ordered closure** of businesses nor a **government's official statement** regarding COVID-19 damage at properties generally should be sufficient for a court to find "direct physical loss or damage" to a particular property. However, those insured that can prove the actual presence of the virus on the surfaces of or otherwise in covered property may be able to establish "direct physical loss or damage" to property.[62]

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[62] Edward M. Koch & Elizabeth C. Dolce, *"Direct Physical Loss or Damage": The Gatekeeper to Property Insurance Coverage and COVID-19*, WHITE & WILLAIMS (Mar. 24, 2020), https://www.whiteandwilliams.com/resources-alerts-Direct-Physical-Loss-or-Damage-The-Gatekeeper-to-Property-Insurance-Coverage-and-COVID-19.html (emphasis in original). *Accord*, Randy Maniloff, *First Coronavirus Coverage Suit Filed for Business Interruption*, COVERAGE OPS. (Mar. 17, 2020), https://www.coverageopinions.info/Vol9Issue2/FirstCOVIDcase.html.

> In general, and putting aside any precise policy language that may apply, one critical requirement, for the potential availability of business interruption insurance, is that there has been physical damage to property. This is either to the insured's own covered premises, or, for purposes of losses on account of the actions of civil authority, another's premises.
>
> Either way, it will be necessary [for policyholders] to prove that the presence of the coronavirus causes physical loss to the affected premises. Thus, we can expect to see arguments, like the one being made [in the first filed case], that there has been physical loss to a premises because the virus stays on the surface of objects or materials—'fomites'—for some amount of time.

> [A]ny legislative action to compel insurers to pay business interruption claims arising out of the coronavirus [would be] breathtaking. To achieve their result, lawmakers would not only obviate the "virus" exclusion, but, in addition, the fundamental 'physical damage' requirement of business interruption coverage.

Maniloff, *supra*. *See* Randy J. Maniloff & Margo Meta, *New DJ Takes Different Tack on Business Interruption Coverage for COVID-19*, WHITE & WILLAIMS (Mar. 27, 2020) https://www.whiteandwilliams.com/resources-alerts-New-DJ-Takes-Different-Tack-on-Business-Interruption-Coverage-for-COVID-19.html (describing French Laundry Partners, LP v. Hartford Fire Ins. Co. case seeking declaration of coverage and noting that loss of business use was caused primarily by government ordered suspension rather than tangible property destruction. Maniloff & Meta are skeptical of the claim and argue that "in general, to implicate 'Civil Authority' coverage, there must be physical damage to property other than the covered premises. But businesses have been closed principally to foster social distancing and not on account of the presence of the virus inside a premises." Maniloff & Meta also note that French Laundry is represented by the same attorney as policyholder Oceana Grill, a New Orleans restaurant, that filed the nation's first COVID coverage case).

> Policyholders will sometimes be asserting that insurers, that issued immediate denials for [COVID]-19 claims, did so in bad faith on account of an alleged failure to investigate the claim under applicable law[.]
>
> One business interruption coverage theory in particular is getting attention from policyholders [what the author dubs the "public space" theory that the ubiquitous COVID-19 virus has filled the air and attached to tangible property, making it physically damaged—which in turn means that the injury trigger of the typical policy is satisfied].
>
> Another business interruption coverage issue has not received a lot of attention. The biggest push for coverage has been for businesses that have been shut down by order of a civil authority. However, even if owed, such coverage is likely quite limited. Civil authority-based business interruption coverage, per policy language, is usually available for only up to four weeks.
>
> The restaurant industry is beating the loudest drum in the pursuit of business interruption coverage.

Randy Maniloff, *Covid-19 And Coverage: Four Weeks and Four Takeaways*, COVERAGE OPS. (Apr. 5, 2020), https://www.coverageopinions.info/COVID19ISSUE/COVIDandCoverage.html. These comments are but from one law firm, albeit a particularly large and prestigious insurer-side firm. Many other lawyers representing insurers wrote in the same vein in various publications and on law firm and other websites.

> The New Jersey legislature has premised its actions on the need to take out the "virus" exclusion from business interruption policies. But that's a tonsillectomy compared to what it is really doing—removing the heart of the policy.[63]

Although there were of course stories highlighting the difficulties faced by businesses and other policyholders due to the COVID pandemic,[64] insurers succeeded in simultaneously pooh-poohing the merits of business interruption claims and painting a scenario of risk management ruin if they were required (either by legislatures or courts) to provide coverage they purportedly never agreed to provide.[65]

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[63] Randy Maniloff & Edward Koch, *COVID-19: The Real Operation of New Jersey's Proposed Insurance Legislation*, COVERAGE OPS. (Mar. 19, 2020), https://www.coverageopinions.info/Vol9Issue2/COVIDOperation.html.

[64] *See, e.g.,* Suzanne Barlyn, *U.S. University Insured Chinese Student Tuition Against Virus. Then COVID-19 Hit*, REUTERS: BUS. NEWS (Aug. 17, 2020, 6:25 AM), https://in.reuters.com/article/us-health-coronavirus-university-insuran-idINKCN25D15P (reporting that despite paying annual premium of $424,000 for coverage, University of Illinois found harder market emerging in early 2020, with only limited coverage and premiums increasing to nearly $2 million).

[65] *See, e.g.*, Lucca De Paoli & Franz Wild, *Don't Be Tricky With Virus Clams, Watchdog Warns U.K. Insurers*, BLOOMBERG (Mar. 19, 2020, 10:49 AM), https://www.bloomberg.com/news/articles/2020-03-19/u-k-fca-requests-coronavirus-contingency-plans-from-insurers (noting that the U.K. Financial Conduct Authority [FCA] has stated that "insurers must also [like policyholders] be adaptable" in lieu of the problems posed by COVID and must take care to communicate clearly and nondeceptively with policyholder claimants).

> The industry has worked to reduce its exposure to pandemics since the 2003 outbreak of SARS in Asia. Over the years, they've tightened up their policies, inserting communicable-disease exclusions to prevent potential losses. That means consumers and companies will bear the brunt of the cost for disruptions related to the virus—which has infected more than 217,000 people worldwide and left at least 9,000 dead.

Id. Laura Foggan & Michael A. Sabino, *Feeling the Effect*, BEST'S REV. (May 2020), http://news.ambest.com/articlecontent.aspx?pc=1009&AltSrc=108&refnum=296290 (predicting claims across various lines of insurance, particularly property insurance with business interruption coverage, and stating that "[i]t is essential that legislators—and the courts—recognize the limits of insurance in accordance with policy terms and exclusions."); Cheri Trites-Versluis, *Renewal Language Scrutiny: COVID-19 Litigation is Generating a*

Policyholder counsel noted and criticized the perceived insurer public relations campaign.[66] And some in the industry had reservations about the industry's aggressive and rather blanket opposition to coverage.[67] Some observers also

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Resurrection of Arguments Asserted at the Height of Asbestos and Silica Coverage Litigation, NAT'L UNDERWRITER 1, 42–43 (Sep. 2020), https://www.sapiens.com/wp-content/uploads/2020/09/NUP_0920-dl.pdf (citing Above It All Roofing & Construction, Inc. v. Security Nat'l Insurance Co. and RLI Insurance v. Gonzalez, which found asbestos to be a "pollutant" within policy's pollution exclusion, and Garamendi v. Golden Eagle Ins. Co., which found silica dust to be a pollutant, implying similar approach apt for COVID cases). Mr. Trites-Versluis is identified in the article as "the director of policy analysis for RiskGenius," the same company whose CEO is extensively quoted in the media disparaging policyholder claims for business interruption coverage. *Id.*

[66] *See, e.g.*, Andrew G. Simpson, *P/C Insurers Put a Price Tag on Uncovered Coronavirus Business Interruption Losses*, INS. J., (Mar. 30, 2020), https://www.insurancejournal.com/news/nationa/2020/03/30/562738.htm (quoting policyholder attorney John Houghtaling II) ("'To avoid payments for a civil authority shut down the insurance industry is pushing out deceptive propaganda that the virus does not cause a dangerous condition to property.' [] 'This is a lie, it's untrue factually and legally.'").

[67] *See, e.g.*, Kate Smith, *Pandemic Partnerships*, BEST'S REV. (Aug. 2020), http://news.ambest.com/articlecontent.aspx?refnum=299433&altsrc=43.

> Stephen Catlin's mobile buzzed nonstop. It was early April, and he had just written a thought leadership piece on the need for a swift and coherent insurance industry response to pandemic. Frustrated by the falling reputation of the industry and the "clumsy" comments and defensive posture of some insurers, the Convex CEO called on the insurance community to be proactive in finding a long-term solution to pandemic. His message struck a chord.

Id. Mr. Catlin is a 50-year veteran of the insurance industry and founder of an insurer and consulting group as well as a member of the International Insurance Society Insurance Hall of Fame, he elaborated on his views in an Op-Ed piece.

> [First,] insurers and brokers should do a much better job when communicating with the public and with governments, especially regarding the true value that insurance provides. Secondly, it's in the nature of our business to focus on the past, and therefore we often neglect giving adequate thought about the future. Finally, I regret that—when an event occurs that causes extreme human suffering—the insurance industry often views the event primarily in terms of dollars and cents.

wondered whether the more receptive negotiable attitude of some European insurers might be more productive.[68] But in the main, American insurers were on the

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> Over the years, we have identified a list of potential 'Big Ones,' events that could cause severe financial stress for insurers and reinsurers. These events range from a Category 5 hurricane that strikes at the heart of Miami to a powerful earthquake devastating Los Angeles or Tokyo. Over the past two decades, an extreme act of terrorism was added to the list.
>
> However, until recently, relatively few insurers would have guessed that a pandemic could be the costliest event the industry could face. I believe that neither governments nor insurers had truly contemplated the economic consequences of a pandemic, in part because the financial impact of such an event is extremely difficult to model.
>
> Unfortunately, the coronavirus has amplified some of the things that I believe the industry often does poorly.
>
> It is not my place to comment on whether individual policies provide coverage for potential claims arising from COVID-19. However, I can say that I was dismayed at the defensive nature of some insurers' statements as the crisis began to expand. There always has been widespread public distrust—if not distain—for the insurance industry, and the comments uttered by some insurers did not help our relationships with governments and our customers.
>
> As I often have said, it's not what you say, but how you say it.
>
> Now that it appears that COVID-19 may be the costliest event in the industry's history, we must begin to think ahead. Will society face pandemics of a similar magnitude in years to come? While I hope we will not, I suspect that we will. If so, what should be the role of the insurance industry? Should we simply adopt policy wording that make it crystal clear that insurance coverage will be of little benefit to policyholders for future losses arising from a pandemic? Or should we think about how insurers can play a meaningful role in economic recovery while still protecting the industry's capital base?

Stephen Catlin, *Setting the Right Tone: Insrers Must Clarify the Role Insurances Can Play in Recovering from Future Pandemics*, BEST'S REV. (Aug. 2020), http://news.ambest.com/articlecontent.aspx?refnum=299423&altsrc=43.

[68] *See, e.g.*, Sergio F. Oehninger & Daniel Hentschel, ***Will European Insurers' Positive*** *Response to COVID-19 Claims Influence US Insurers?*, HUNTON INS. RECOVERY BLOG (July 13, 2020), https://www.huntoninsurancerecoveryblog.com/2020/07/articles/business-interruption/will-european-insurers-positive-response-to-covid-19-claims-influence-us-insurers/.

> The positive response in Europe is in stark contrast with the insurance industry's preliminary positions in the United States. The headlines on this side of the hemisphere demonstrate certain insurers' attempts to avoid liability for COVID-19 related losses, despite accepting billions in premiums form policyholders in exchange for broad coverage promises.
>
> In addition, the regulatory structure abroad may make for more collaborative attack on coverage problems. Describing the role of the Financial Conduct Authority [FCA] in England regarding COVID coverage, one article noted:
>
> Business interruption insurance generally only covers losses where a company is forced to close temporarily form property damage, like a fire. The FCA said those types of policies did not offer protection from pandemics, but it was interested in the minority that have so-called nondamage extensions.
>
> Those extensions can protect against the closure of a property either from the outbreak of an infectious disease or by the denial of access by a public authority.
>
> The FCA said it had examined more than 500 policies from 40 insurers and narrowed down its selection to just 17 policy wordings it felt were both the most contentious and representative.

Id. Martin Croucher, *FCA Picks 8 Insurers for Pandemic Coverage Test Case*, LAW360 (June 1, 2020), https://www.law360.com/articles/127811 ("Colin Edelman QC of Devereuz Chambers, Leigh-Ann Mulcahy QC and Richard Coleman QC of Fountain Court Chambers will represent the FCA in the case, instructed by Herbert Smith Freehills LLP."). For additional background on the Financial Conduct Authority, *see* Daniel Schwarcz, *Redesigning Consumer Dispute Resolution: A Case Study of the British and American Approaches to Insurance Claims Conflict,* 83 TUL. L. REV. 735 (2009).

In the test case litigation in the U.K., policyholders largely prevailed, but upon somewhat different issues and policy language than has to date been litigated in the United States. *See* The Fin. Conduct Auth. v. Arch In. (UK) [2020] EWHC 2448 (Comm) (UK).

In addition, continental insurers may have been nudged toward a less confrontational style due to judicial decisions supporting policyholders. *See, e.g.*, Oehninger, *supra* (noting that after initially stating it would appeal trial court ruling requiring it to provide business interruption coverage to policyholder with lost revenue due to COVID-19, AXA has relented and agreed to provide coverage; "AXA reportedly has already agreed to pay over 200 COVID-19 related claims."). *See also id.* ("Despite initially denying liability, Swiss insurance company, Helvetia Insurance, announced that most of its policyholders in the hospitality industry have accepted settlements following coverage disputes for COVID-19 related business interruption losses. The settlements reportedly included policyholders form Switzerland, Austria, and Germany.").

defensive. COVID business interruption claims were to be strongly resisted, even where policies lacked a virus exclusion, on the ground that these claims failed to satisfy the "physical loss or damage" trigger for coverage. And, to perhaps state the obvious, insurers were denying COVID claims.[69] Unsurprisingly, this produced litigation by upset policyholders on the brink of financial ruin.[70]

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[69] For an example of rather brusque insurer denial of coverage, *see* Letter from Susan Sabouni, Property Claims Supervisor, Philadelphia Indemnity Insurance Company, to Steve Powell, Chief Officer of Policyholder, The Goddard School (May 7, 2020) (on file with author). The Letter repeats portions of the policy verbatim for nine pages and then simply states that the insurer "considers the issues outlined above to be dispositive of coverage" and that the insurer's "Policy does not provide coverage to the Goddard School for the Claim" and thus "respectfully [?] declines coverage for the Claim" in connection with the school's forced closure due to government order because of the COVID pandemic, even though the policy also contained a "Communicable Disease Endorsement." *See id.* at 10. The insurer stated that the policyholder's loss was "not 'due to an outbreak of a 'communicable disease' . . . that caused[d] an actual illness" at the School. The insurer did, however, agreed to "reimburse the Goddard School for the cost of disinfecting the insured premises due to reported symptoms of COVID-19 within the premises." *Id.* at 10.

[70] *See* Randy Ellis, *Coronavirus in Oklahoma: Tribes Sue Insurance Companies Over Business Interruption Coverage*, THE OKLAHOMAN (Mar. 25, 2020 1:22 AM), https://oklahoman.com/article/5658477/coronavirus-in-oklahoma (describing Chickasaw and Choctaw nations suits involving various insurers); *Coronavirus Coverage Issues Loom: Policy Details Crucial to Determine Success of Commercial Claims*, BUS. INS. 4 (April 2020) (surveying possible COVID-related claims implicating Property Business Interruption insurance, Directors and Officers Liability insurance, Cyber Risk insurance, Medical Malpractice insurance, and Workers Compensation insurance); Joseph P. Monteleone, *COVID-19's Management Liability Concerns,* INS. EXCH. AGENCY (Sept. 14, 2020), https://www.ieagency.com/post/covid-19s-management-liability-insurance-concerns (noting that COVID-related losses will prompt substantial coverage claims involving D&O Insurance, Transactional Risk, and EPL insurance as well as Property Insurance); Patricia Vowinkel, *An Insurance Journey: Significant Coronavirus-Related Losses and Legal Battles Over Coverage May Force Some Insurers to Rethink Their Strategic Game Plans*, BEST'S REV., 1 (May 2020); Bob Reville, *Making Waves: COVID-19 Reveals a Possible Future Upswell of Liabilities for Insurers*, BEST'S REV., 16 (Aug. 2020); Celeste Bott, *Coronavirus Litigation: The Week in Review*, LAW360 (Oct. 8, 2020 7:15 PM), https://www.law360.com/articles/1318126/coronavirus-litigation-the-week-in-review (summarizing recent legal developments, including several insurer wins; also noting that the "Judicial Panel on Multidistrict Litigation has centralized in Illinois over 30 lawsuits accusing Society Insurance Co. of wrongfully denying coverage for business losses during the COVID-19 pandemic, but declined to create MDLs to group similar cases against The Hartford, Travelers, Cincinnati Insurance Co., and Lloyd's of London underwriters."); Lauren Berg, *In-N-Out Sues Zurich To Cover COVID-19 Shutdown*, LAW360 (May 29, 2020

To be sure, policyholder counsel were not silent during the time of insurer pleas of poverty and assertion of absolute defenses to coverage. But they seemed to have reduced prominence in both insurance trade and lay media.[71]

10:56 PM), https://www.law360.com/articles/1278397.; *See also* Hannah Smith, *A Closer Look: Coronavirus Insurance Lawsuit Trends*, PROPERTY CASUALTY 360 (Sept. 4, 2020 12:00 AM), https://www.propertycasualty360.com/2020/09/04/a-closer-look-coronavirus-insurance-lawsuit-trends/?slreturn=20210107191656 ("The main issue that courts must decide in addressing these claims is whether businesses whose operations were shut down during the crisis can demonstrate 'direct physical loss or damage.'") (describing several lawsuits where insurers had prevailed in motions to dismiss, including *French Laundry Partners, LP v. Hartford Fire Ins. Co.*, *In-N-Out Burgers v. Zurich American Ins. Co.*, and several claims where insurers had prevailed in motions to dismiss including *Plastic Surgeons of Lexington, PLLC v. Liberty Mut. Ins. and Ohio Sec. Ins. Co.* and noting that in *Gavrilides Management Co. v. Michigan Ins. Co.*, the "plaintiff alleged that the physical requirement of the policy was met because customers could not physically use the dine-in services. The judge denied this allegation, determining that in order to meet the requirement, the insured must show a physical alteration of the premises."). *See also id.* ("So far, courts have ruled in favor of insurers in cases of business interruption coverage vs. COVID-19. But the vast majority of these cases are still yet to be seen."). For additional examples of COVID coverage complaints, *see* Complaint and Demand for Jury Trial, Prime Time Sports Grill, Inc. v. DTW1991 Underwriting Ltd, No. 8:20-cv-00771-CEH-JSS (M.D. Fla. May 4, 2020); *see also,* Motion to Dismiss Pursuant to Rule 12(b)(6), *supra* (contending that plaintiff restaurant was not "ordered to close" by Florida Gov. Ron DeSantis Order of March 17, 2020 but was permitted to continue operating restaurant at fifty percent occupancy).

Insurers of course approve of the *Gavrilides Management* decision and were undoubtedly pleased that the insurance trade press has given prominent display to the case even though it is a "mere" state trial court case, albeit one of the first decisions in the area. *See* Wilson Elser, *Michigan Judge Rules Direct Physical Loss Required to Trigger Business Interruption Coverage,* LEXOLOGY (Jul. 23, 2020), https://www.lexology.com/library/detail.aspx?g=a9de8e82-e549-44f9-83df-7b66cfd10009 (noting that "Judge [Joyce Draganchuk] stated that direct physical loss [of or damage to the property] must be something 'with material existence . . . that alters the physical integrity of the property.'").

[71] *See, e.g.,* Christine Spinella Davis, *Business Interruption Coverage for COVID-19 Losses: You Can Satisfy the "Physical Loss or Damage" Requirement in Your Commercial Property Policy,* BRADLEY (Apr. 24, 2020), https://www.itpaystobecovered.com/2020/04/business-interruption-coverage-for-covid-19-losses-you-can-satisfy-the-physical-loss-or-damage-requirement-in-your-commercial-property-policy ("Temporary loss of use and loss of functionality alone may satisfy the physical loss or damage requirement in a property policy."); Mark Packman & Jason Rubinstein, *COVID-19 Claims May Survive Insurers' Physical Loss Defense*, LAW360 (Sept. 1, 2020), https://www.law360.com/articles/1306134

> Because COVID-19 does not destroy or tangibly alter the structure of property, the insurers have asserted there is no coverage for claims arising from the pandemic. Initial decisions on this issue broke the insurance industry's way. But the litigation of disputes has barely begun. There is significant evidence to suggest there are many legal paths available to plaintiffs as they struggle with losses related to COVID-19. We explore the findings and implications to date.
>
> Policyholder counsel, for example, argued:
>
> In most property insurance policies, business interruption coverage is triggered when the property at issue suffers "direct physical loss or damage." Structural damage to the property, however, is not a requirement for coverage; proof that contamination or other relatively intangible conditions like bacteria, gases, and fumes that "rendered the insured property temporarily or permanently unusable or uninhabitable may support a finding that the loss was a physical loss to the insure property."
>
> Additionally, many insurance policies include civil authority coverage, which covers losses that occur when government authorities restrict access to the area where a business is located or that the business depends on for its operations.
>
> Many property insurance policies also provide contingent business interruption coverage, triggered by damage to or disruption of a business's suppliers, customers, or other key partners. While the policyholder itself need not be physically damaged, it does need to have coverage for the type of damage that affected its suppliers, busines partners, or customers.

Packman & Rubinstein, *supra*. Pamela D. Hans & Marshall Gilinsky, *Insurance Coverage for Losses Stemming from the Coronavirus*, INS. J. (Feb. 26, 2020), https://www.insurancejournal.com/news/national/2020/02/26/559383.htm (citing Mellin v. Northern Sec. Ins. Co., 115 A.3d 799, 805 (N.H. 2015) and also citing Gregory Packaging, Inc. v. Travelers Prop. Cas. Co. of Am., 2014 U.S. Dist. LEXIS 165232, *15-17 (D.N.J. Nov. 25, 2014) "[C]ourts considering non-structural property damage claims have found that buildings rendered uninhabitable by dangerous gases or bacteria suffered direct physical loss or damage.").

> Business owners are submitting claims for business interruption insurance losses, but many insurance companies' knee-jerk reaction is to deny. This has led to a proliferation of lawsuits. While the viability of these suits depends on each business's unique circumstances and policy language, the prospects look very good for many Pennsylvania business owners.

There has also been, in our view, something of a race-to-the-courthouse problem in that a number of the initial policyholder claims appear to be brought by counsel without substantial experience in insurance coverage litigation, something that more seasoned coverage lawyers noted with some dismay (along with voicing concerns that the efforts of some plaintiff counsel to consolidate proceedings was hurtful to the COVID coverage cause).[72]

> Many Pennsylvania businesses bought all-risk commercial property insurance policies that contain business interruption coverage. The coverage provisions are broad . . . .
>
> Many insurance companies will dispute that COVID-19 losses satisfy the direct physical loss or damage requirement. . . . Courts have rejected this view on numerous occasions in numerous contexts.

Patrick Campbell, Charles Casper & Brett Waldron, ***Pa. Insureds' Path to Pandemic Biz*** *Interruption Coverage*, LAW360 (May 19, 2020 5:50 PM), https://www.law360.com/appellate/articles/1274214/pa-insureds-path-to-pandemic-buz-interruption-coverage (also arguing that there should be coverage even if policy has virus exclusion due to rule that exclusions are construed narrowly and government shutdown orders rather than the virus itself are the cause of business interruption).

[72] *See, e.g.*, Chip Merlin, *What is Multidistrict Litigation (MDL) and Will It Impact Virus Business Income Claims?*, PROP. INS. COVERAGE L. BLOG (May 10, 2020), https://www.propertyinsurancecoveragelaw.com/2020/05/articles/commercial-insruance-claims/what-is-multidistrict-litigation-mdl-and-will-it-impact (writing by noted policyholder coverage attorney expresses some doubt about efficacy of consolidation). A large and prominent policyholder firm was less tentative and more critical of consolidation.

> Savvy policyholders and experienced counsel may also find consolidated and class action proceedings ill-suited to the resolution of insurance coverage disputes. That is because claim-specific differences are likely to predominate over common issues in three fundamental respects: (1) the specific facts of any particular insurance claim, and how that claim is best presented and substantiated, often vary greatly from claim to claim, place to place, and industry to industry; (2) the specific language of any given insurance policy is critical, and there can be enormous variation in policy language on the material issues implicated by COVID-19; and (3) insurance coverage is a matter of state law, which varies widely across jurisdictions on issues of importance for many policyholders.
>
> For these reasons, sophisticated insureds should carefully review their own insurance policies, claims, and circumstances before signing on to any

As discussed in the next section, we take issue with the insurance industry's rush to judgment opposing COVID-related coverage across the board. We also are concerned that insurers are exaggerating both their potential financial responsibility if COVID coverage claims succeed and the industry's purported inability to absorb such claims.

First, the estimated costs. Insurers have suggested that if covered, the costs of business interruption claims would range as high as $800 billion per month.[73] But

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> of the current efforts to aggregate coronavirus-related insurance cases into MDL or class action proceedings.

David Goodwin, Allan B. Moore & Rani Gupta, *Policyholders Beware: The Risks of Multi-District and Class Action Treatment of COVID-19 Insurance Claims*, COVINGTON, 1–2 (May 4, 2020), https://www.cov.com/-/media/files/corporate/publications/2020/05/policyholders-beware-the-risks-of-multidistrict-and-class-action-treatment-of-covid-19-insurance-claims.pdf.

> Strong claims should be timely noticed and pursued aggressively by experienced insurance coverage counsel, particularly if insurers do not meet their obligations to pay promptly. Decisions to pursue coverage litigation must take into account the most favorable jurisdictions, procedures, and timing to maximize recovery for policyholders affected by COVID-19. In knowledgeable counsel is able to litigate the strongest claims first, those cases will set appropriate precedents that will establish insureds' rights to recover COVID-19 losses and benefit other policyholders.

Id. at 5.

In addition, despite being defendants, insurers have considerable power to shape early case outcomes by making motions to dismiss when presented with favorable facts, policy language, or courts while simply answering the complaint when faced with unfavorable facts, policy language or tribunals, thereby delaying any legal rulings from these less favorable forums until the industry could accumulated the momentum of early Rule 12 victories.

[73] As reported in one prominent industry periodical:

> It's hard to quantify the full financial impact COVID-19 will have on the industry. But one thing is certain, this pandemic is on track to become the largest event in insurance history.
>
> "It is truly a catastrophic event the proportion of which we have not seen before," Stefan Holzberger, chief rating officer for AM Best, said. "The breadth and depth of the event, how it is affecting multiple

> geographics and multiple segments of the insurance market—this is really something that dwarfs the other major events in recent history."
>
> . . .
>
> And yet, the insurance industry has been prepared to handle this event.
>
> . . .
>
> There is a caveat to this, however. The industry's ability to absorb the impact of COVID-19 hinges on business interruption. As of early May, seven states had introduced legislation requiring insurers to provide retroactive business interruption coverage, in some cases regardless of whether policies included a virus exclusion, as most do.
>
> If forced to pay retroactive BI, the insurance industry could be facing losses of $150 billion to $200 billion per month, according to the Best's Commentary, Legislation to Nullify BI Exclusions Poses Existential Threat to P/C Insurers. The Insurance Information Institute's estimates are even higher. The III [Insurance Information Institute] forecasts costs of up to $380 billion per month, which it said would "break" the insurance industry within months. That scenario, however, is unlikely [because of lack of coverage.]
>
> If you take business interruption out of the equation, the industry as a whole is on solid financial footing.

Kate Smith, *The COVID Catastrophe: The Global Pandemic is on Track to be the Costliest Event in Insurance History. It's also a Defining Moment for the Industry Special Risk Section Sponsored by Lexington Insurance*, BEST'S REV. (Jun. 2020), http://news.ambest.com/articlecontent.aspx?refnum=297254&altsrc=123. *See also* Robert Hartwig, Greg Niehaus & Joseph Qui, *Insurance for Economic Losses Caused by Pandemics*, 45 Geneva Risk and Ins. Rev. 134, 135 (2020) (estimating losses at one trillion dollars per month for business interruption alone).

We like hyperbole as well as the next authors, but we think it is a bit much to suggest that possible business interruption coverage would "dwarf" the financial consequences of major insurance events such as the asbestos mass tort or pollution claims. We are not dismissive of the potential magnitude of COVID claims but remain concerned that the insurance industry has been a bit cavalier in suggesting such large losses and generally wailing gloom and doom in the event of coverage. It may be a good public relations strategy that will gain sympathy from the courts but strikes us as overblown. And, as discussed later in the article, there is something concerning about attempts to convince courts and policymakers that insurers are too vulnerable to be saddled with COVID losses when the alternative is saddling much more vulnerable small businesses with these losses. If that is the fate decreed by contractual agreement, perhaps there is no escape (save for invocation of reasonable expectations, unconscionability, and public policy canons for construing those at this juncture, we have not seen any detailing of this estimate or the methodology behind it. We remain skeptical, particularly so in light of the commonly found sublimits (either temporable or monetary) on coverage for business interruption occasioned by government order that insurers contend is contained in most policies and which appears popular in policy forms. One article provides a flavor of the industry's tone.

> The Insurance Information Institute and American Property Casualty Insurance Association place the estimates much higher: The APCIA forecast losses of up to $668 billion per month, while the III estimated retroactive BI could cost the industry up to $380 billion per month. "That's an industry-breaking event," James Lynch, chief actuary for the II, said. "That would break the industry in two directions. One, the financial load it would place on companies to have to pay claims they had priced the business for, and had specifically excluded, would create financial ruin. Moreover, that intervention into clear policy language would call into question the entire insurance business model."
>
> . . . .
>
> "They're trying to make the case that they're shutting down because of physical loss and damage from the virus," said RiskGenius CEO Chris Cheatham, whose company uses software to help insurers evaluate policy language. "That's not an accident. That's not how people talk."
>
> Bob Hartwig, director of the Risk and Uncertainty Management Center at the University of South Carolina's Darla Moore School of Business, said politicians were fed such language from plaintiffs' attorney groups who are "looking at this as a potentially huge payday."
>
> . . . .
>
> "The State of New York cannot alter the laws of physics to satisfy its trial lawyer masters, "Hartwig said. "That's essentially what happened. They developed this language in an attempt to overruled the virus exclusion."
>
> "All legal scholars agree this will fail a Constitutional test. There's no question about it."

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contracts) from this bothersome result. But, as discussed later, the insurance industry's extreme anti-coverage position is incorrect.

The battle over business interruption will, without doubt, make its way into the courts. And most agree the courts will side with insurance companies.

"The exclusion for viruses is not an ambiguous one," Lynch said. "It's an exclusion of loss due to virus or bacteria. When it was filed, the filing specifically mentioned the potential for a pandemic similar to SARS CoV-1. And the current pandemic is SARS CoV-2. So I don't think there's a lot of ambiguity here about what the exclusion was meant to exclude.

Stefan Holzbeger, chief rating officer of AM Best, agreed.

"Those well-defined, long-instituted, regulator-approved exclusions for pandemics or viruses should hold," Holzberger said. "The business interruption policies that have that exclusion, which is the vast majority in the U.S., should not have to honor claims associated with a loss of revenue related to COVID-19.

[Holzberger further predicted that if legislation negating virus exclusions was enacted and upheld in court] we would see widespread insolvency because the magnitude of lost revenue in relation to the capital surplus is so great. The insurance industry could not bear those losses. Which is why they weren't covered in the first place."[74]

[74] Smith, *supra* note 73. Best's Review loved the inflammatory quote about trial lawyers so much, it was emphasized in a pull-quote from the sidebar in large print, complete with a 20-year-old picture of Professor Hartwig, a former insurer lobbyist before entering academia.

> The property/casualty industry estimates that business interruption losses from the coronavirus just for small businesses in the U.S. could be between $220-$383 billion per month—or a quarter to half of total industry surplus available to pay all P/C claims.
>
> David A. Sampson, president and CEO of the American Property Casualty Insurance Association, said the $200-383 billion per month loss estimate assumes there could be as many as 30 million claims from small business that suffered coronavirus-related losses. According to APCIA, that is 10 times the most claims ever handled by the industry in one year. The industry processed more than three million from the 2005 hurricane season that included Hurricanes Katrina, Rita, Wilma and several other storms, the trade group said.

Second, as to insurer ability to pay: if the insurance industry were a sovereign nation, it would have the third largest economy in the world.[75] Insurers receive hundreds of billions of dollars in premium income alone each year,[76] which in turn has usually been invested for some time before the funds are required to be paid in claims. Insurance is generally a more consistently profitable business than most, advantaged by its ability to amass large sums that can be invested, perhaps for years (or decades in the case of liability insurance) before payment. This "float," as Warren Buffett calls it, enables even insurers with weak underwriting to survive and even thrive. Insurers with sound underwriting and investment do particularly well.[77]

So, what of the effect of the insurance industry's initial media messaging? We are not in a position to pinpoint entirely the impact of the industry's anti-coverage messaging on legal developments to date. We cannot count the claims that

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> Sampson said the combined capital of the top business insurance underwriters represents only a fraction of the amount that might be expected in coronavirus losses form just small businesses.
>
> "Insurance stability is especially important in a time of increased natural catastrophes. Spring flood season is underway, hurricane season is around the corner, and wildfires pose a threat year-round," he said.

Simpson, *supra* note 66.

[75] *See* Richard V. Ericson, Aaron Doyle & Dean Barry, Insurance as Governance, 1, 4 (2003) (noting the degree to which insurance shapes behavior by setting contours of coverage and conduct in order to obtain insurance).

[76] Ranked by 2019 net premiums written, the smallest of the Top 200 (HCI Ins. Group) collects $228,488,000 in annual premiums; 82 insurers have $1 billion or more in annual premium income. *See Top 200 U.S. Property/Casualty Writers*, BEST'S REV. (July 2020), http://www.ambest.com/review/displaychart.aspx?Record_Code=274586&src=43&_ga=2.171650912.1123988532.1612739172-73892297.1612560642. Some household name insurers have astounding volumes of premium income, e.g.: State Farm ($65.1 billion); Berkshire Hathaway ($53.75 billion); Progressive ($37.6 billion); Allstate ($34 billion); Liberty Mutual ($32.3 billion); Travelers ($27.2 billion); USAA ($23 billion); Chubb INA ($18.2 billion); Nationwide ($18 billion); AIG ($14.8 billion); Farmers ($14.5 billion); Harford ($11.9 billion); American Family ($11.8 billion); Auto-Owners ($8.6 billion); Fairfax ($7.6 billion); Erie ($7.5 billion). *Id.* Cincinnati Insurance, a defendant in several prominent COVID coverage actions, received almost $5.4 billion in premiums in 2019. *Id.*

[77] *See* Jeffrey W. Stempel, Erik S. Knutsen & Peter N. Swisher, Principles of Insurance Law § 1.06 (5th ed. 2020) ("A Note on Insurer Operations"); Stempel & Knutsen, *supra* note 33, at § 1.01 (describing insurer operations, using in part description provided by Buffett (who is typically ranked as one of the world's ten richest people) in his annual letter to Berkshire Hathaway shareholders; Berkshire's success, according to Buffett, is due in large part to investment funds generated by its insurance and reinsurance operations).

were not filed because a business or a business' lawyer read in the newspaper that "COVID claims are not covered." Nor can we precisely discern the effect on judges as the majority of COVID-related claims were dismissed in favor of insurers at the pleadings stage (though we find that result quizzical). We have yet to learn the effect of the messaging on lay juries, as these cases have not yet made it far enough in litigation (because most are bounced out on the pleadings alone).

But we are able to say that perhaps it is more influential to get out in front of a story and control the narrative than to be correct. If nearly every insurance trade publication, lawyers' publication and popular news press sees the same message, surely there must be some even subliminal effect on how one approaches the insurance coverage question for COVID cases. Moreover, and most concerning to us, there appear to be absolutely no ramifications if the message proffered in the media is actually incorrect! Are we entering a new phase of insurer public relations tactics that are, at least in part, designed with a motive to affect coverage results in legal cases?

In Part III below, we explain how the main coverage question of "direct physical loss or damage" is counter to the main thrust of the insurance industry's message in the media to date. We conclude with our thoughts as to where the issues will resolve in the end.

III. THE KEY COVERAGE ISSUE: DISCERNING THE (REASONABLE) MEANING(S) OF "DIRECT PHSYICAL LOSS OR DAMAGE"[78]

A. THE INSURER ARGUMENT FOR REQUIRING TANGIBLE DESTRUCTION TO TRIGGER COVERAGE

Insurer efforts to dismiss business interruption claims as strained have resonated with most in the industry, including respected authorities who should in our view be less dismissive of claims of loss or damage. A prominent editor of the Fidelity, Casualty & Surety (FC&S) organization has, for example, approached the question as follows.

> When policies don't define a term, courts generally refer to a standard dictionary. Merriam-Webster defines damage as "loss or harm resulting from injury to person, property or reputation." This

[78] In this article, we focus almost exclusively on coverage issues concerning first-party property insurance and its business interruption component as these policies have been those at issue in the first wave of coverage litigation. We expect significant coverage litigation concerning liability insurance to emerge in the future.

> is not definitive, so we look at the definitions of loss and harm. Loss is defined as "destruction, ruin," and harm is defined as "physical or mental damage."
> The virus does not harm physical property. The virus may be cleaned off like other germs or bacteria. The property does not need to be replaced or repaired, just sanitized as advised by public health authorities.[79]

Continuing in this vein, and seeking a trifecta of sorts of no coverage pursuant to government order provisions plus the prevalent pollution exclusion, she wrote:

> ISO has a mandatory virus and bacteria exclusion, but what about carriers not using ISO forms? What about carriers that have adopted parts of ISO forms, such as the business interruption language, but have not adopted the rest and did not adopt the mandatory endorsement?
> . . . .
> The issue at hand with the virus is business interruption and action of civil authority. Is there coverage when local authorities require bars, restaurants, gyms and other establishments to close because of the chances of spreading the virus? For this, we need to look at an endorsement; for the sake of discussion, we are looking at the Business Income (and Extra Expense) Coverage Form CP 00 30.
> Coverage is provided for the actual loss of business income due to the necessary suspension of business operations during the period of restoration. The period of restoration must be due to direct physical loss of or damage to coverage property. Also covered is loss triggered by a civil authority prohibiting access to the insured property because of damage to other property, but two conditions must apply. That other property must be within one mile of the insured property, and the action of the civil authority is taken in response to dangerous physical conditions resulting form the loss, continuation of the covered cause of loss that caused the damage, or to allow the authority unimpeded access to the property.

[79] Christine G. Barlow, *Does COVID-19 Cause Physical Loss*?, NAT'L UNDERWRITER 1, 10 (May 2020), https://www.property-casualtydigital.com/propertycasualty/202005?pg=12#pg12.

> So herein lies the rub. Coverage is provided only when a property has been physically damaged. COVI-19 does not cause physical damage to property. Even if it is considered physical damage, then you have the pollution exclusion to deal with, and the virus is a pollutant. Pollutants are excluded when they are dispersed, discharged, seep, migrate or otherwise escape. So it comes down to whether an individual can be considered to be dispersing, discharging, or otherwise releasing the virus, action that would trigger the pollution exclusion.
> Recently a physician from San Francisco attended a conference with hundreds of other physicians in New York. Upon returning home, he felt ill and was tested for the virus, which came back with positive results. Those people attending the conference were possibly exposed to the virus. Does this count as dispersing the virus, even though unintentionally? It seems so.
> This is different from closing businesses, because the threat of the threat of exposure or spread of the virus, a threat is not physical damage, and therefore there is no coverage.[80]

B. THE FLAWS OF THE INSURER-ADVANCED CONVENTIONAL WISDOM

1. Dictionary Fetishism: Improperly Collapsing "Loss" and "Damage"

Notwithstanding our respect for this author and the FC&S organization,[81] we are constrained to disagree. Although the "Order of Civil Authority" coverage provided in many policies is limited to four weeks of lost income[82] and the presence of the basic ISO virus exclusion may typically preclude coverage,[83] the FC&S

[80] *Id.* at 10–11.

[81] And Ms. Barlow's dismissiveness toward COVID claims may be mild compared to what is coming from another prominent coverage expert. *See* Bill Wilson, WHY INSURANCE DOESN'T COVER THE COVID-19 PANDEMIC (2020) (e-book format released Oct. 29, 2020). Mr. Wilson is the author of the widely celebrated coverage analysis WHEN WORDS COLLIDE: RESOLVING INSURANCE COVERAGE AND CLAIMS DISPUTES (2018).

[82] *See supra* notes 30–35 and accompanying text discussing order of civil authority coverage.

[83] *See infra* notes 180–202 and accompanying text discussing virus exclusion.

analysis is severely deficient regarding the question of physical loss or damage and utterly absurd regarding application of the pollution exclusion.[84]

Property insurance policies can vary significantly. While many do not include business interruption or "business income" coverage (a plus for insurers in light of the lost business revenue caused by COVID), many also lack a virus exclusion (a plus for policyholders). But almost all make a finding of "direct physical loss or damage" an initial requirement for coverage.[85] As discussed below, in decades of coverage litigation preceding COVID claims, courts have divided over the meaning of these terms. But prior to examining case law, courts might profitably examine the facial clarity of these terms, neither of which is usually defined in the insurance policy despite its separate "Definitions" section that normally contains specifically defined terms.

FC&S's analysis tends not to look to case law but to focus on policy text. This is historically a typical insurer response, as a contextless reading of insurance policy terms most often favors the insurer. This is so because the policyholder litigating the claim probably suffered a loss within the grey areas of coverage (otherwise, why litigate?). The potential pitfalls of the standard insurer textual approach are reflected in its analysis above: seek out the plain meaning of policy terms so as to have the interpretive analysis stop at the plain meaning stage of determining policy coverage—and thus avoid any interpretive ambiguity in the meaning of those terms (otherwise, the policyholder-favoring tools of *contra proferentem* or reasonable expectations are visited upon the entire analysis).

First, the insurer COVID coverage language assessment tends to collapse the terms "loss" and "damage" into one—a rhetorical move that is both unwarranted

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[84] Due to space limitations, we will not present a full examination of the pollution exclusion in the context of COVID-19 in this article. But for reasons we have set forth at length elsewhere, it is absurdist textual literalism to argue that infection of premises by a virus (or bacteria, fungus or the like) is "pollution" as the term is ordinarily understood. It is similarly laughable to suggest that a conference attendee is "dispersing" "pollutants" when sneezing. What, pray-tell, is next, insurers asserting that an attendee's nausea at the office cocktail party is a pollution event? Such broad construction of an exclusion—part of the insurance policy upon which the insurer bears the burden of persuasion must be narrowly and strictly construed against the insurer who—would operate to undermine the basic purpose of property insurance or liability insurance. *See* STEMPEL & KNUTSEN, *supra* note 33, at § 14.11; Jeffrey W. Stempel, *Reason and Pollution: **Construing the "Absolute"** Pollution Exclusion in Context and in Light of its Purpose and Party Expectations*, 34 TORT & INS. L.J. 1 (1998); Jeffrey W. Stempel, *Unreason in Action: A Case Study in the Wrong Approach to Construing the Liability Insurance Pollution Exclusion*, 50 FLA. L. REV. 463 (1998).

[85] *See* French, *supra* note 4, at n. 21–22 and accompanying text.

(we think the two words are distinct) and misleading in its use of "the dictionary." As the fetishism of textualism in American judicial interpretation of insurance policy terms rages on, we think that taking the insurer-led textual charge head-on leads to the opposite result that the insurers advocate. Indeed, this is doubly bizarre because historically, insurers have favored a textualist and literalist approach to policy language—probably because historically they have benefitted from such application. But here, in determining coverage for "direct physical loss or damage," the use of one of the key textualist interpretive tools—the use of dictionary definitions to discern the ordinary lay meaning of policy terms—actually spins counter to insurer interests, when deployed properly.

Regarding the distinction between the words "loss" and "damage", it should be noted that courts typically subscribe to the "surplusage" canon of construction, which posits that each word in a document (statute, contract, regulation) should be given its own meaning and not treated as a mere repetition by synonym.[86] Although it is in some ways a problematic canon,[87] it is nonetheless one of the "rules" of interpretation. And insurers, when it suits their purpose, embrace the surplusage canon.

For example, when litigating the application of the pollution exclusion, insurers routinely argue that each of the seventeen words in the exclusion (e.g., irritant, contaminant, chemical, waste) deserves independent meaning rather than reinforcing a core concept of pollution,[88] with courts frequently agreeing and giving

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[86] The "surplusage" canon of construction posits that "[i]f possible every word and every provision should be given effect (*verba cum effectu sunt accipienda*). None should needlessly be given an interpretation that causes it to duplicate another provision or to have no consequence. 'These words cannot be meaningless, else they would not have been used." ANTONIN SCALIA & BRYAN GARNER, READING LAW: THE INTERPRETATION OF LEGAL TEXTS 174 (2012) (citing U.S. v. Butler, 297 U.S. 1, 65 (1936) (Roberts, J.)).

[87] *See* Laurence Solan & Jeffrey W. Stempel, *Rethinking Redundancy: The False Premises and Practices of the Surplusage Canon* (Jan. 2020) (manuscript on file with author) (describing drawbacks of surplusage and tendence for drafters to use redundancy as a means of attempting to achieve clarity). *Accord*, Ethan J. Leib & James Brudney, *The Belt-and-Suspenders Canon*, 105 IOWA L. REV. 735 (2020) (suggesting that in practice many courts treat drafting repetition as clarifying a particular intent rather than using each word to convey its own concept).

[88] The typical definition of "pollutants" in a standard form general liability, which has been widely used for thirty years or more, includes "any solid, liquid, gaseous or thermal irritant or contaminant, including smoke, vapor, soot, fumes, acids, alkalis, chemicals, and waste" with wasted "include[ing] materials to be recycled, reconditioned or reclaimed." *See, e.g.*, Commercial General Liability Policy Form CG 00 01 01 96, *in* DONALD S. MALECKI & ARTHUR L. FLITNER, COMMERCIAL GENERAL LIABILITY 271 (6th ed. 1998).

the words literal application even though they are contained in an exclusion that is, according to contract construction rules, supposed to be strictly and narrowly construed against the insurer with the insurer bearing the burden of persuasion to demonstrate the applicability of the exclusion.[89] If the insurers are to be consistent in their interpretative arguments, the word "loss" should be viewed as meaning something different than "damage."

Perhaps more important, if one is "making a fortress" out of the dictionary (something cautioned against by the great Second Circuit Judge Learned Hand),[90] that fortress provides quite a lot of protection to policyholders—and this should be conceded by insurer advocates, who have to date disappointingly taken a self-serving view of the terms "loss" and "damage," with too much acquiescence from courts. Even if one is not ready to concede that dictionary definitions favor policyholders more than insurers, it seems to us undeniable that there are many dictionary entries supporting the policyholder perspective. This in turn means that policyholder textual arguments are reasonable. And this further means that the term

[89] *See, e.g.*, *Quadrant Corp. v. Am. States Ins. Co.*, 110 P.3d 733 (Wash. 2005) (taking broad view of pollution exclusion as precluding coverage for policyholder negligence in application of sealant exposing apartment resident to noxious fumes). *See* William P. Shelley & Richard C. Mason, *Application of the Absolute Pollution Exclusion to Toxic Tort Claims: Will Courts Choose Policy Construction or Deconstruction?*, 33 TORT & INS. L.J. 749 (1998) (detailing a prominent insurer counsel advocate's broad application of the exclusion to cover claims of policyholder negligent injury with any involvement of chemicals).

[90] *See* Cabnell v. Markham, 148 F.2d 737, 739 (2d Cir. 1945) ("But it is one of the surest indexes of a mature and developed jurisprudence not to make a fortress out of the dictionary; but to remember that statutes always have some purpose or object to accomplish, whose sympathetic and imaginative discovery is the surest guide to their meaning.") By this, Judge Hand sensibly meant that words should be construed in accord with party intent and overall purpose rather than through textual assessment alone. We agree and also note that there may well be extrinsic evidence supporting the insurance industry's view that when drafting property policies, it intended to provide coverage only for the sort of tangible structural injury that comes from external forces such as fire, windstorm, a sudden flooding, vandalism or other actions that wreak palpable destruction on property. But to date, insurers have not done so, preferring to fight on the metaphorical "hill" of ahistorical, acontextual textualism. In COVID decisions to date, they have been holding that hill. Should they start to die on the hill (*e.g.*, if courts begin in greater degree to recognize that "physical loss or damage" does not inexorably mean tangible destruction), one would expect them to proffer supporting extrinsic evidence that this is what was meant or intended or required by sound risk management practice. If they cannot provide such evidence, policyholders deserve to win on the "physical loss or damage" question, even in jurisdictions with a weak application of the *contra proferentem* principle.

"physical loss or damage" is sufficiently ambiguous that policyholders should enjoy the benefit of the *contra proferentem* principle and avoid dismissal of their claims on this basis unless insurers can proffer sufficient extrinsic evidence to support their preferred meaning of the term—something insurers have not done to date.

2. Dictionary Definitions Support Policyholders as Least as Much as Insurers

In arguing that coverage requires tangible destruction that can not be easily rectified, FC&S refers to the Merriam-Webster dictionary, editions of which are on our respective desks, but selects and presents the definitions in a pronouncedly anti-policyholder fashion. The more complete excerpt of key terms presented below provides an alternative meaning of "loss" that distinguishes it from "damage."

> **damage** [means] **1** : loss or harm resulting from injury to person, property, or reputation . . .
> **loss** [means] **1** : DESTRUCTION, RUIN **2 a** : the act of losing possession **b** : the harm or privation resulting form loss or separation **c** : an instance of losing . . . **4 a** : failure to gain, win, obtain, or utilize . . . **5** : decrease in amount, magnitude, or degree. . .
> **lose** [means] **1 a** : to bring to destruction . . . **3** : to suffer deprivation of: part with esp. in an unforeseen or accidental manner . . . *vi* **1**: to undergo deprivation of something of value . . .
> **physical** [means] **1 a** : having material existence : perceptible esp. through the senses and subject to the laws of nature . . . b : of or relating to material things . . .[91]

Applying this mix of Merriam-Webster definitions suggests that one might reasonably find a "physical loss" when a policyholder is deprived of something material—such as use of one's business, especially if the loss takes place in an unanticipated manner through something like a pandemic that spurs government-ordered use of the business property.

Similarly, it is perfectly reasonable to state that one's physical property has been lost or harmed or injured by a virus on surfaces or in the air on the property. Insurers argue that because the virus can be "wiped off," there has been no loss or

[91] MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY 291, 689, 689, 877 (10th ed. 1996).

damage. The "virus damages lungs, not property"[92] has become an insurance industry aphorism akin to "the CGL [commercial general liability] policy is not a performance bond," a cliché invoked by CGL insurers seeking to avoid coverage for damage inflicted by defective construction.[93] Actually, the damages-lungs-not-property mantra is more misleading.

The not-a-performance-bond trope is true as a general rule. But, as courts have come to recognize almost uniformly, this general rule is not applicable where a CGL policyholder's negligence inflicts damage (defined as "physical injury to tangible property") upon other property and the CGL coverage is not based on merely correcting substandard work but compensating victims for damage done to other property by the substandard work.[94]

The damages-lungs-not-property trope is not true—period—or is only true if one excises the word "loss" from the trigger term "physical loss or damage." Even under the view that a cleaning will make infected property "as good as new" (which may not be the case), the property has nonetheless been lost to its owner for at least some period of time, perhaps a significant period of time depending upon the cleaning and public health requirements to which the property is subject (let alone serious public relations issues with regard to perceived safety of the premises).

Further, a facility in which COVID has been found is, at least temporarily, "damaged" goods. The susceptibility of COVID to cleaning is relevant to questions of the degree of injury and the period of restoration required for a COVID-infected business. COVID infection is not the same as a fire or explosion, and in many cases is more easily rectified than water damage from a burst pipe. But there nonetheless is at least some physical damage and considerable physical loss of property if the cleaning and disinfecting is time-consuming or if government authorities restrict operation of the facility.

In addition, remediation of COVID damage to property is likely to be fleeting in many situations. COVID-inflicted injury may be susceptible to

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[92] Transcript of Teleconference Order to Show Cause at 5:3–4, Soc. Life Magazine, Inc. v. Sentinel Ins. Co., No. 20 Civ. 3311 (S.D.N.Y. May 14, 2020).

[93] *See* Jeffrey W. Stempel, *Rediscovering the Sawyer Solution: Bundling Risk for Protection and Profit*, 11 RUTGERS J. OF L. & PUB. POL'Y 170, 210, n. 89 (2013) (noting the prevalence of this argument by liability insurers in defective construction cases). *See, e.g.*, Nationwide Mut. Ins. Co. v. Wenger, 278 S.E.2d 874 (Va. 1981) (exemplifying a general liability insurer arguing to receptive court that coverage for construction defects, absent injury to non-policyholder property, would improperly convert the liability policy into a performance bond).

[94] *See* STEMPEL & KNUTSEN, *supra* note 33, at § 14.13; STEMPEL, SWISHER, & KNUTSEN, *supra* note 77, 657–61. *See, e.g.*, Am. Family Mut. Ins. Co. v. Am. Girl, 673 N.W.2d 65 (Wis. 2004).

disinfection but may be repeated within hours as customers or employees return to a restaurant, bar, retail outlet, or factory. COVID damage may even be re-imposed almost as quickly as it first struck if members of the cleaning crew are COVID-positive, which may be the case even if the workers show no detectible symptoms of infection.

A brief survey of other dictionaries reveals a nesting of definitions of the key words of COVID coverage disputes that is more consistent with our broader view of the meaning of the terms "physical loss or damage" than the seemingly cherry-picked FC&S emphasis on irreversible tangibility as a prerequisite to finding such loss or damage. Consider the following entries, all from mainstream sources.

> **damage** [means] [i]mpairment of the usefulness or value of person or property . . .
> **loss** [means] **b.** The condition of being deprived or bereaved of something or someone . . .
> **lose** [means] **2.a.** To come to be deprived of the ownership, care, control of (something one has had) . . . [95]

or

> **damage** [means] **1.** Harm or injury to property or a person, resulting in loss of value or the impairment of usefulness.
> **loss** [means] **1.** The act or an instance of losing . . . **b.** The condition of being deprived or bereaved of something or someone.
> **lose** [means] **2a.** To be deprived of (something one has had).
> **physical** [means] **2.** Of or relating to materials things . . . [96]

or

> **damage** . . . See breakage, harm [as a noun]. See injure [as a verb].
> **loss** [means] The act or an instance of losing something : losing, misplacement. . . . See also deprivation.
> **deprivation** [means] The condition of being deprived for what one once had or ought to have : deprival, dispossession, divestiture, loss, privation.
> **lose** [means] To be unable to find : mislay, misplace.

[95] THE AMERICAN HERITGAE COLLEGE DICTIONARY 350, 801, 1031 (3rd ed. 1993).
[96] THE AMERICAN HERITAGE COLLEGE DICTIONARY 357, 817, 818, 1050 (4th ed. 2004).

> **physical** [means] **1.** Composed of or relating to things that occupy space and can be perceived by the senses: concrete, corporeal, material, objective, phenomenal, sensible, substantial, tangible.[97]

or

> **damage** [means] **1.** Impairment of the worth or usefulness of person or property: harm.
> **loss** [means] **1.** The damage or suffering that is caused by losing. **2.** One that is lost.
> **lose** [means] **3**. To be deprived of . . .
> **physical** [means] **1.** Of or relating to the body rather than the emotions or mind. **2.** Material rather than imaginary. **3. a.** Of, pertaining to, or produced by nonliving matter and energy.[98]

Perhaps most surprising is that many standard-fare dictionaries actually use the term "damage" in defining the term "loss" to indicate that "loss" can mean "loss of use" or deprivation of property.

3. Apt Use of Dictionaries in COVID Coverage Controversies Often Supports Coverage

This is perhaps the time to note that in most every dictionary, the order of definitions does not proceed from most popular to least used, as many people (including lawyers) often mistakenly think. Rather, the presentation proceeds from earliest usage to most recent usage.[99] The first definition presented is simply the oldest and not the primary or best or most widely used or accepted definition. In many cases, the oldest definition may be considerably less popular or representative or "correct" than definitions listed later in the dictionary entry. As a result, we believe it is inappropriate for courts or commentators to argue that a term is clear and unambiguous based on presentation order in the dictionary. For example, a lawyer's argument that definition number one is what was meant because it is the first definition seems to us quite misplaced.

Insurers might seize upon this to suggest that a definition of "loss" that includes "destruction" or "ruin" is *the* clearly correct definition because it emerged

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[97] ROGET'S II: THE NEW THESAURUS 105, 265, 117, 265, 314 (3d ed 1995).

[98] WEBSTER'S II NEW RIVERSIDE DICTIONARY 177, 407, 406, 515 (rev. ed. 1996).

[99] WEBSTER'S NINTH NEW COLLEGIATE DICTIONARY 19 (9th ed. 1984) (the "[o]rder of senses [in the dictionary] is historical.").

relatively later in the usage. But that is too ambitious a claim. Rather, each of the different definitions in a dictionary entry would appear to us to be per se reasonable constructions of the word, at least in the absence of context. Contextual material may make it clear that Definition X should prevail rather than Definition Y. But to claim that the words of the definitions themselves admit of clear choice strikes us as simply incorrect.

In examining dictionary definitions, it is also important to remember the dangers of motivated reasoning. As noted D.C. Circuit Judge Harold Leventhal apparently observed when discussing court use of legislative history, it can be a bit like "looking out over a crowd and spotting your friends."[100] But the same, of course, is true regarding selection of a preferred dictionary definition. Insurers (and, of course, policyholders as well) know what they want to be the answer and will naturally be drawn, at least subconsciously, to the definition that best meets their coverage dispute and litigation needs. In addition, dictionary use may mislead through simple happenstance when a judge (or law clerk or counsel writing a brief that influences the judge) reaches for the dictionary that just happens to be on the closest desk or shelf or reads only the first dictionary entry resulting from a browser search. To the extent that there are differences in dictionaries, this human foible of taking the path of least resistance may mislead. In addition, it has been our experience that many dictionary users operate under the false impression that the first definitional entry in a dictionary is the primary or main meaning of a term when, as noted above, it is merely the earliest use of the term.

Thus, decision by dictionary is more than a little problematic. Notwithstanding this human tendency, we think the above excerpts (and we could have listed another dozen or two of similar definitions or associations) establishes that the words "physical loss or damage" admit of construction quite favorable to policyholders.[101] FC&S and others supporting insurers in the COVID coverage

[100] *See, e.g.* Patricia M. Wald, *Some Observations on the Use of Legislative History in the 1981 Supreme Court Term*, 68 IOWA L. REV. 195, 214 (1983) (citing a conversation with Judge Leventhal), *quoted in* Exxon Mobil Corp. v. Allapattah Servs., Inc., 545 U.S. 546, 568 (2005); Conroy v. Aniskoff, 507 U.S. 511, 519 (1993) (Scalia, J., concurring) (paraphrasing Leventhal); Abner J. Mikva, *Statutory Interpretation: Getting the Law to Be Less Common*, 50 OHIO ST. L.J. 979, 981–82 (1989); Adam M. Samaha, *Looking Over a Crowd—Do More Interpretive Sources Mean More Discretion*?, 92 N.Y.U. L. REV. 554 (2017) (discussing the genealogy and meaning of the quote attributed to Judge Leventhal).

[101] Another possible avenue for assessing the meaning of text is corpus linguistics analysis, which involves assessing the collates and clusters of words as an aid to interpretation. *See* Lawrence M. Solan & Tammy Gales, *Corpus Linguistics as a Tool in Legal Interpretation*, 6 B.Y.U. L. REV. 1311, 1315 (2017). Although in our view, it would be a mistake to attach talismanic power to the use of big data in assessing insurance policy

battles are simply not being fair or reasonable in arguing that this key coverage provision "clearly" or "unambiguously" requires some sort of structural change of insured property as a prerequisite to coverage. Too many courts have accepted this unsupportable shibboleth. Even if their decisions finding no coverage are correct (due to the presence of a virus exclusion or other bar to coverage), these courts have done unnecessary "damage" to norms of insurance policy construction that impacts not only COVID coverage claims but construction of insurance policies as a whole.

As discussed below, insurers typically argue that "damage" entails a requirement of structural change in covered property and that "loss" is largely a synonym for "damage." In our view, the term "loss" connotes something quite different than "damage." For example, dictionaries commonly define "loss" as deprivation of something (whether as a result of "damage," or theft or something else). Government shutdown orders (described below) by definition deprive policyholders of the use of their property—property that is physical, corporeal, choate, and tangible. Although alternative definitions of loss are also common in dictionaries, definitions connoting deprivation, lack of access, or the like are sufficiently common that a reasonable interpreter must concede that the concept of "loss" proffered by a policyholder forced to curtail operations is at least a reasonable meaning of the term.

According to well-established ground rules for insurance policy interpretation, if both policyholder and insurer have set forth reasonable constructions of a term, the term is ambiguous and questions of meaning should be resolved against the insurer that drafted the policy and in favor of the policyholder.

When this interpretative debate takes place at the motion to dismiss stage of litigation, *contra proferentem* (which translates as "against the drafter") logically should have particular force. An early ruling favoring the insurer's implicit argument (that "loss" or "damage" requires structural change in property) effectively involved the court ruling as a matter of law that a definition of loss drawn from dictionaries is not reasonable—an absurd result. If such a construction of the term "loss" was not reasonable, it presumably would not be in a published dictionary.

4. Prior Insurer Industry Action Contradicts Insurers' Current Interpretation Angle

In addition to taking an insurer-serving approach to defining "physical loss or injury," the FC&S assertion that COVID claims fail to involve triggering loss is

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term meaning, this sort of broader based linguistic analysis may be superior to simply "looking it up" in the dictionary at random due to the potential unconscious bias or happenstance of dictionary use.

inconsistent with prior FC&S action. Consider, for example, the following FC&S assessment that predated the COVID pandemic by eight years. An insurance agent made the following inquiry.

> Our insured accidently threw away some digital x-ray sensors in the trash. Now, they want to be compensated for them. The BOP policy, Section 1 Property, Coverage agreement states, "We will pay for direct physical loss . . . ."
> I believe the coverage agreement precludes coverage as this is not "direct physical loss." Nothing happened to them—they were simply thrown away.
> Do you believe coverage exists?

Oregon Subscriber[102]

FC&S replied as follows.

> There is no exclusion that applies to this loss. There does not need to be any impact on or damage to the items themselves for there to be a direct physical loss—just like when items are stolen. But ***there is a loss in that they are no longer available to the insured***.[103]

If FC&S was being consistent with this prior analysis, it would have to acknowledge that businesses forced to close due to either site-specific infection or government mandate have suffered a loss in that the physical business facilities are "no longer available" to them, at least until a government order is lifted or infected property is cleaned and otherwise rehabilitated.

This prior inconsistent statement in the insurance press raises the spectre of how important it is to view all media on an issue in its context and not simply that purpose-built for a particular cause. If insurers wish to flood the current press with commentary, past press on the same and related issues will require defense or acknowledgement, to be fair.

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102 *Direct Physical Loss Under BOP*, NAT'L UNDERWRITER (June 27, 2011), https://www.nuco.com/fcs/2011/07/12/direct-physical-loss-under-bop-422-12966.

103 *Id.*

5. Prior Judicial Treatment of the "Physical Loss or Damage" Clauses Has Been More Favorable to Policyholders than Initial COVID Coverage Decisions Suggest

The COVID insurance coverage cases to date have shown that courts prefer some allegations of tangible physical harm to property that alters its essential character and structure in order to trigger business interruption or civil authority coverage for pandemic-related losses. "Direct physical loss of or damage to property" thus seems to require that some external force touches the property and alters it in order for insurance coverage to attach. There is no definition of the coverage clause or its individual composite words in any property insurance policy. In attempting to provide meaning to the coverage clause, courts may have inadvertently hyper-focused on the parsed-out words of the clause as standing alone (i.e. "physical," "loss' and "damage"). The dictionary sections noted in the prior section underline the problems with doing so, because dictionary definitions are inconsistent, are presented in chronological and not frequency order, and can be cherry-picked to "say" what one wants.

Review of the current batch of COVID coverage cases shows that it is possible in some jurisdictions that a policyholder does not need tangible structural harm to property in order to trigger the coverage clause in the policy. The virus does not need to "wreck" some property; it just has to be present to make the property unusable to the policyholder. This reasoning tracks the better-reasoned decisions of courts interpreting "direct physical loss" in other property insurance contexts.[104] Courts have held that the following causes of loss are covered as "direct physical loss or damage:"

a) noxious particles post-9/11 World Trade Center disaster;[105]
b) contamination with radioactive dust and radon gas;[106]

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[104] *See* Scott G. Johnson, *What Constitutes Physical Loss or Damage in a Property Insurance Policy?*, 54 TORT TRIAL & INS. PRAC. L.J. 95 (2019) (surveying caselaw and finding trend and dominance of better reasoned decisions finding loss or damage without palpable destruction or tangible structural alteration of property); Steven Plitt, *Direct Physical Loss in All-Risk Policies: The Modern Trend Does Not Require Specific Physical Damage, Alternation*, CLAIMS J. (Apr. 15, 2013), https://www.claimsjournal.com/magazines/idea-exchange/2013/04/15/226666.htm.

[105] Schlamm, Stone & Dolan, LLP v. Seneca Ins. Co., 800 N.Y.S.2d 356 (Sup. Ct. 2005).

[106] Am. All. Ins. Co. v. Keleket X-Ray Corp., 248 F.2d 920, 925 (6th Cir. 1957).

c) smoke from wildfires cancelling a theatre performance;[107]
d) unpleasant odor making premises uninhabitable (i.e. "locker room" smell, cat urine, or meth lab);[108]
e) drywall releasing poisonous gas rendering home uninhabitable;[109]
f) asbestos in carpeting impaired building's function;[110]
g) asbestos in buildings;[111]
h) mold spores and bacteria rendering home uninhabitable;[112]
i) release of unknown substance in sewage treatment plant causing plant shutdown;[113]
j) hidden building decay due to seawater damage;[114]
k) e-coli contamination in a well;[115]
l) carbon monoxide poisoning;[116]
m) trace amounts of benzene in beverages;[117]
n) metal parts contaminated with lead;[118]
o) salad dressing exposed to vaporized agricultural chemicals;[119]

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[107] Or. Shakespeare Festival Ass'n v. Great Am. Ins. Co., No. 1:15-cv-01932-CL, 2016 WL 3267247, at *5 (D. Or. June 7, 2016).

[108] Essex Ins. Co. v. BloomSouth Flooring Corp., 562 F.3d 399 (1st Cir. 2009) ("locker room" smell); Mellin v. N. Sec. Ins. Co., Inc. 115 A.3d 799 (N.H. 2015) (cat urine odor); Farmers Ins. Co. of Or. v. Trutanich, 858 P.2d 1332 (Or. 1993) (meth lab odor).

[109] TRAVCO Ins. Co. v. Ward, 715 F. Supp. 2d 699, 708 (E.D. Va. 2010).

[110] Sentinel Mgmt. Co. v. Aetna Cas. & Sur. Co., 615 N.W.2d 819, 826 (Minn. 2000).

[111] Yale Univ. v. Cigna Ins. Co., 224 F. Supp. 2d 402, 413 (D. Conn. 2002); Bd. of Educ. of Twp. High School Dist. No. 211 v. Int'l Ins. Co., 720 N.E.2d 622, 625–26 (Ill. App. Ct. 1999).

[112] Sullivan v. Standard Fire Ins. Co., 956 A.2d 643 (Del. 2008); Prudential Prop. & Cas. Ins. Co. v. Lillard-Roberts, No. CV-01-1362-ST, 2002 WL 31495830, at *8–10 (D. Or. June 18, 2002) (applying Oregon law).

[113] Azalea, Ltd. v. Am. States Ins. Co., 656 So. 2d 600, 602 (Fla. Dist. Ct. App. 1995).

[114] Three Palms Pointe, Inc. v. State Farm Fire & Cas. Co., 250 F. Supp. 2d 1357, 1360–61 (M.D. Fla. 2003).

[115] Motorists Mut. Ins. Co. v. Hardinger, 131 F.App'x 823, 823 (3d Cir. 2005).

[116] Matzner v. Seaco Ins. Co., No. Civ. A. 96-0498-B, 1998 WL 566658 (Mass. Super. Aug. 12, 1998).

[117] National Union Fire Ins. Co. of Pittsburgh v. Terra Indus., 346 F.3d 1160 (8th Cir. 2003).

[118] Stack Metallurgical Servs., Inc. v. Travelers Indem. Co. of Conn., No. 05-1315-JE, 2007 WL 464715, at *2 (D. Or. Feb. 7, 2007).

[119] Henri's Food Prods. Co. v. Home Ins. Co., 474 F. Supp. 889, 892 (E.D. Wis. 1979) (applying Wisconsin law).

p) loss of soil supports due to adjacent landslide, even though home itself not damaged;[120]
q) buildup of gas beneath church rendering church uninhabitable;[121]
r) ammonia release;[122]
s) infestation of brown recluse spiders;[123]
t) organisms in canned creamed corn;[124] and
u) cereal oats treated with a non-FDA approved pesticide, even though chemically identical to approved pesticide.[125]

There are also a much smaller group of cases which deny claims for what appear to be very similar or even identical causes of loss like:

a) mold, which apparently could be removed by cleaning;[126]
b) odors or bacteria in an HVAC system;[127] and
c) asbestos contamination which apparently did not alter the structure of the building.[128]

The reasoning featured in the first list of cases finding coverage for more ephemeral physical losses also tracks the better-reasoned decisions in recent cases involving coverage for cyber-losses under property policies. Insurance claims for electronic data losses also went through a similar wave as COVID insurance claims as courts wrestled with whether or not electronic data stored on a computer could experience a "direct physical loss or damage" because it appears to be intangible and

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[120] Hughes v. Potomac Ins. Co. of D.C., 199 Cal. App. 2d 239, 248 (1962).

[121] W. Fire Ins. Co. v. First Presbyterian Church, 437 P.2d 52, 55 (Colo. 1968).

[122] Gregory Packaging, Inc. v. Travelers Prop. & Cas. Co. of Am., No. 2:12-cv-04418, 2014 WL 6675934 at *5–6 (D.N.J. Nov. 25, 2014) (applying New Jersey and Georgia law).

[123] Cook v. Allstate Ins. Co., No. 48D02-0611-PL-01156, 2007 Ind. Super. LEXIS 32, at *7–9 (Ind. Super. Ct. Nov. 30, 2007).

[124] Pillsbury Co. v. Underwriters at Lloyd's, 705 F. Supp. 1396, 1401 (D. Minn. 1989).

[125] Gen. Mills, Inc. v. Gold Medal Ins. Co., 622 N.W.2d 147, 152 (Minn. Ct. App. 2001).

[126] Mastellone v. Lightning Rod Mut. Ins. Co., 884 N.E.2d 1130, 1144–45 (Ohio Ct. App. 2008).

[127] Universal Image Prods. v. Chubb Corp., 703 F. Supp. 2d 705, 713 (E.D. Mich. 2010).

[128] Great N. Ins. Co. v. Benjamin Franklin Fed. Sav. & Loan Ass'n, 793 F. Supp. 259 (D. Or. 1990), *aff'd*, 953 F.2d 1387 (9th Cir. 1992).

is unseen by the naked eye, existing as data on a hard drive or in the online cloud.[129] Courts have treated losses relating to electronic data and computer equipment in sometimes strange ways.

The more reasonable and now widely accepted approach has been to find that electronic data losses are capable of being covered as a "direct physical loss" under a property policy when the data is corrupted, lost or damaged. Many courts have found that, although data cannot be seen or touched, it nevertheless exists in some fashion electronically and microscopically as property and can suffer a direct physical loss.[130] Indeed, it would be foolish to have a property policy cover data loss if the data were stored in hard paper copy and destroyed, but then deny coverage for a similar loss if the data exists in electronic form. That would make for perverse record-keeping incentives.

Holding that a virus like COVID-19 can at least potentially damage property makes sense in this regard. The virus does render surfaces unusable to humans for a period of time. It is potentially deadly and spreads quickly, through touched surfaces or the air. One would assume insurers would not want business owners putting employees and customers in infected stores if such would vastly increase the risk of an even larger claim if a person became ill or died (though such a claim would be made under a different insurance product: liability insurance or workers compensation).

The long list of cases that have considered various external forces' impact on property as a "direct physical loss" demonstrate that courts are willing to find coverage if the force is a disease-causing agent or poison, if it is purely airborne, and if it does not permanently affect or even alter in any way the physical property insured. "Loss" or "damage" can mean "lost to the policyholder" in terms of use, in a variety of ways that do not involve actual physical destruction of the property.

The case law supports a conclusion that physical damage from a virus does not have to be permanent; it can be transient.[131] With a virus like COVID-19, an

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[129] *See* Stempel & Knutsen, *supra* note 33, at §23; Erik S. Knutsen & Jeffrey W. Stempel, *The Techno-Neutrality Solution to Navigating Insurance Coverage for Cyber Losses,* 122 PA. STATE U. L. REV. 645, 646–47 (2018).

[130] *See, e.g.*, Ashland Hosp. Corp. v. Affiliated FM Ins. Co., No. 11-16-DLB-EBA, 2013 WL 4400516, at *5 (E.D. Ky. Aug. 14, 2013) (finding disk drive damage due to excessive temperatures is a "direct physical loss" at a microscopic level); Se. Mental Health Ctr., Inc. v. Pac. Ins. Co., 439 F. Supp. 2d 831, 837 (W.D. Tenn. 2006) (finding data corrupted by power loss at pharmacy is a covered "direct physical loss").

[131] *See, e.g.*, Phibro Animal Health Corp. v. Nat'l Union Fire Ins. Co. of Pittsburgh, No. A-5589-13T3, 2016 WL 3884255, at *9–10 (N.J. Super. Ct. App. Div. July 14, 2016) (finding that medicine given to chickens that stunted their growth constituted

insured property may be impacted, and a loss may ensue in two typical scenarios: immediately after an infected customer or employee becomes ill on the premises or, more broadly, while the virus itself is highly prevalent in the community in question and therefore must be on the premises.

For the first scenario—that of immediate infection of an employee—it would seem that physical loss or damage would be simple to prove. There was virus present on the property. No one can tell where it spread or on what surfaces. It may well be in the air or ventilation system. Entry to the property is thus dangerous until the illness reasonably subsides, decontamination has occurred, and it is again safe to enter.

But for the second scenario—that of virus generally prevalent in the community—**can coverage attach simply because the illness is potentially 'out there?'** In **that instance,** reasoning such as that featured in the *Studio 417, Inc. v. Cincinnati Insurance Company*[132] case is helpful: where the virus is so highly prevalent such that a large proportion of the population is ill (and sometimes without any knowledge of being ill) to the degree that civil authorities are making orders **restricting both use of property and peoples' movemen**t, then one can probably assume actual presence of virus on the property somehow, especially at a place of business open to the public. At a certain point in time, the harm will of course subside. Those cases holding that physical damage does not have to be permanent to trigger coverage support reasoning that coverage would last as long as the danger is rendering the property unfit for use.

A number of cases have found coverage due to the imminent threat of physical loss or damage:

a) government shutdown due to impending riots;[133]
b) evacuation from an imminent building collapse;[134]
c) an impending hurricane;[135]

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property damage, despite the possibility of the chickens being restored to their original conditions, because property damage need not be permanent).

[132] No. 20-cv-03127-SRB, 2020 WL 4692385 (W.D. Mo. Aug. 12, 2020) (applying Missouri law).

[133] *See, e.g.*, Sloan v. Phoenix of Hartford Ins. Co., 207 N.W.2d 434, 437 (Ct. App. Mich. 1973) (finding loss of use due to government shutdown in response to riots is covered even though there is no direct physical loss to property).

[134] *See, e.g.,* Hampton Foods, Inc. v. Aetna Cas. & Sur. Co., 787 F.2d 349, 352 (8th Cir. 1986).

[135] *See, e.g.*, Houston Cas. Co. v. Lexington Ins. Co., No. H-05-1804, 2006 WL 7348102, at *6 (S.D. Tex. June 15, 2006) (finding coverage for business interruption due to

d) imminent landslide;[136]
e) imminent threat of release of asbestos fibres.[137]

However, other cases have found that fears of future threats did not constitute a covered loss because there was no loss to property.[138]

The threat of something can make property uninhabitable. The threat of COVID-19 is quite serious: the virus is highly contagious, spreads through the air and surfaces, and can be deadly. Those in close indoor quarters to the virus also have a high possibility of contracting the disease. To that end, the COVID-19 situation perhaps differs from those cases that have found that future threats did not equate to a loss in property. The possibility of damage in the COVID-19 situation is relatively high if virus is in the vicinity. It is not like taking a preventative measure after an event out of concern for a follow-up event (like ordering a curfew after a socially disruptive event). Rather, it is a highly likely scenario that putting someone in close indoor proximity to the virus will make that person ill. It is more similar to the impending earthquake and hurricane cases where one knows the event is on its way, than it is to those where losses stemmed from concerns of more vague future events occurring. With COVID-19, a significant number of people sufficiently exposed indoors will get sick.

This highlights one other area of coverage concern: actual physical damage versus loss of use or function of property to the policyholder. There is support in

evacuation arising from impending Hurricane Floyd, even though policyholder did not suffer physical damage to property from hurricane).

[136] *See, e.g.*, Murray v. State Farm Fire & Cas. Co., 509 S.E.2d 1, 16–17 (W. Va. 1998) (finding threat of imminent landslide enough to satisfy "direct physical loss" for coverage to attach).

[137] Port Auth. v. Affiliated FM Ins. Co., 311 F.3d 226, 236 (3d Cir. 2002).

[138] *See, e.g.,* United Air Lines v. Ins. Co. State of Pa., 439 F.3d 128, 133–35 (2d Cir. 2006) (finding no civil authority coverage where a government halt of airport operations is based on fears of future attacks after Sept. 11, 2001 and no property damage to adjacent property); Paradies Shops, Inc. v. Hartford Fire Ins. Co., No. 1:03-CV-3154-JEC, 2004 WL 5704715, at *6–8 (N.D. Ga. Dec. 15, 2004) (finding no property damage from air ground stop order after Sept. 11, 2001 as the order did not prohibit access to airports and their businesses); Syufy Enters. v. Home Ins. Co. of Ind., No. 94-0756 FMS, 1995 WL 129229, at *2 (N.D. Cal. Mar. 21, 1995) (finding curfews imposed to curb looting were not the result of damage to adjacent property); Two Caesars Corp. v. Jefferson Ins. Co. of N.Y., 280 A.2d 305, 307–08 (D.C. Cir. 1971) (finding acts of avoiding civil unrest had no causal relation to damage to property).

case law such as *Gregory Packaging*[139] where loss of use or function of a particular property can equate to direct physical loss without tangible physical harm to the property. While property may not be permanently damaged by COVID-19, a policyholder loses the use of that property in a reasonable fashion if there is an infection on the premises or the virus present in the surroundings. Some courts have held that the disjunctive "or" between "physical loss of or damage to" property must mean that "loss" must mean something different than "damage" (typically it is held to mean an absence of property, as in theft). In that regard, "loss" could mean "loss of use" or "loss of function" such that it renders the property useless to the policyholder (i.e. if you lost the useful use of the property, it is as if you lost it, even though it did not physically go away). In fact, the textualist dictionary analysis as noted above also provides support for "loss" equating to "loss of use."

There is, however, a line of cases often cited by courts adjudicating this first wave of COVID insurance coverage cases—from *Source Food Technology, Inc. v. United States Fidelity and Guaranty Co.*[140] and *Mama Jo's, Inc. v. Sparta Insurance Co.*[141]—that would hold that only tangible physical alteration of property would qualify as "direct physical loss or damage." But unlike in those cases, where the courts held respectively that an import ban did not damage imported beef or construction dust did not damage music speakers, the COVID-19 situation has a dangerous substance actually physically present on the property, either in the air or through employees and customers spreading it. This tracks the reasoning in COVID insurance coverage cases finding for the policyholder like *Studio 417,*[142] *Blue Springs Dental Care v. Owners Ins. Co*[143] and *Mudpie, Inc. v. Travelers Casualty Ins. Co. of America*,[144] where the courts there held that pleading actual physical presence of the virus made the analytical difference in proving coverage through a "direct physical loss."[145] Indeed, in many of the past non-COVID cases that found a "direct physical loss" due to the invasion of some harmful substance, the substance

[139] Gregory Packaging, Inc. v. Travelers Prop. Cas. Co. of Am., No. 2:12-CV-04418 WHW, 2014 WL 6675934, at *8 (D. N.J. Nov. 25, 2014) (applying New Jersey and Georgia law).

[140] 465 F.3d 834 (8th Cir. 2006) (applying Minnesota law).

[141] 823 Fed. App'x 868 (11th Cir. 2020) (applying Florida law).

[142] 2020 WL 4692385 (W.D. Mo. Aug. 12, 2020) (applying Missouri law).

[143] No. 20-CV-00383-SRB, 2020 U.S. Dist. LEXIS 172639 (W.D. Mo. Sept. 21, 2020).

[144] No. 20-CV-03213-JST, 2020 WL5525171 (N.D. Cal. Sept. 14, 2020) (applying California law).

[145] We discuss these cases, particularly *Studio 417*, *supra* note 142, in more detail in the next section, *infra*, as we find their reasoning quite superior to that of most of the courts dismissing policyholder claims on grounds of no physical loss or damage—as a matter of law.

merely resulted in the property owner not being able to use the property until decontamination occurred. This strongly suggests that dismissing COVID claims merely because property can be disinfected is incorrect.

In some jurisdictions, merely partially restricted access to a property does not equate to a prohibition of access by civil authority.[146] In other instances, a recommendation from a civil authority (as opposed to a direct command) may be not enough to provide coverage because access was not "prohibited."[147] For COVID-19-related losses, it can be challenging to argue that government ordered alterations in service provision—such as a mandated move from in-person dining to take-out and delivery only—results in lost or restricted access to the property or even use of the property.[148] However, on balance, a restaurant faced with this imposed condition could certainly argue that a large proportion of its property typically used for dine-in customers has been rendered entirely unusable by a civil authority.[149]

As the cases now stand, courts appear to be receptive to finding coverage for direct physical loss or damage if the policyholder alleges some factual aspects of physical presence of the virus on the commercial premises. The courts in *Studio 417* and *Blue Springs Dental Care* found the possibility of coverage for this reason and

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[146] *See, e.g.*, Ski Shawnee, Inc. v. Commonwealth Ins. Co., No. 3:09-CV-02391, 2010 WL 2696782 (M.D. Pa. July 6, 2010) (stating there is no coverage when Department of Transport closed main route to policyholder's ski resort because customers could travel to the resort via an alternate route); Abner, Herrman & Brock, Inc. v. Great N. Ins. Co., 308 F. Supp. 2d 331 (S.D.N.Y. 2004) (noting that after World Trade Center disaster, civil authority coverage only provided where order completely prohibited access to property and not during periods where traffic restrictions made access merely more difficult); 54th St. Ltd. Partners v. Fid. & Guar. Ins. Co., 306 A.D.2d 67 (asserting that although traffic to property was diverted, the public was not denied access).

[147] *See, e.g.*, Kean Miller LLP v. Nat'l Fire Ins. Co. of Hartford, No. 06-770-C, 2007 WL 2489711, at *6 (M.D. La. Aug. 29, 2007) (holding that an advisory to stay off streets during Hurricane Katrina did not prohibit access; no civil authority coverage).

[148] *See, e.g.*, Phila. Parking Auth. v. Fed. Ins. Co., 385 F. Supp. 2d 280 (S.D.N.Y. 2005) (finding that government order eliminated need for policyholder's parking services but did not prohibit access to its garage).

[149] Although this line of argument was unsuccessful in Henry's La. Grill, Inc. v. Allied Ins. Co. of Am., No. 1:20-cv-2939-TWT, 2020 WL 5938755 (N.D. Ga. Oct. 6, 2020) (applying Georgia law), where the policyholder restaurant argued that a physical change to the property had occurred because the restaurant had to reconfigure its premises for take-out, not dine-in, as a result of governmental orders. The court held that "loss" means "total destruction" and simply moving things around was not a "loss" or "damage." *See also* Hajer v. Ohio Sec. Ins. Co., No. 6:20-cv-00283, 2020 WL 7211636 (E.D. Tex. Dec. 7, 2020) (applying Texas law) (finding no damage and dismissing case after policyholder argued it had to physically alter its rug business to follow governmental safety order).

the court in *Mudpie* notes it would have, had the policyholder alleged the presence of the virus.

At its heart, this logic follows the case law stemming from *Gregory Packaging* as opposed to the ***Source Foods/Mama Jo's*** line of reasoning. Whether or not there needs to be tangible physical damage to property in order for coverage to be triggered, there must be some invasion of the virus physically on the premises in question for coverage to attach.

IV. THE DISAPPOINTING EARLY CASELAW CONCERNING COVID-19 BUSINESS INTERRUPTION CLAIMS

A. THE PREVAILING ANALYSIS

Cases testing the extent of business interruption insurance coverage for COVID-19 pandemic-related losses are still winding their way through the legal system. To date, court decisions have been made largely in the context of motions to dismiss a policyholder's claim on the pleadings, with no factual record except the pleadings taken by the court as true. Thus, the emerging caselaw is currently limited in its predictive ability as a fulsome canvassing of the issues.

Two distinct lines of reasoning and factual trends have emerged thus far in the case law. Courts are split as to whether the main coverage clause which requires "direct physical loss of or damage to" covered property is even triggered as a result of COVID-19 business interruption losses.

The majority of decisions to date have held that, for "direct physical loss of or damage to" property to have occurred, the property in question must have been physically altered in some tangible fashion. As COVID-19 does not permanently alter the physical characteristics of property, but rather makes people ill by infecting through the air or on touchable surfaces, most courts have found that there is thus no coverage for business interruption losses unless the policyholder specifically alleges the actual physical presence of the virus was on its premises (i.e. on surfaces, in the air, or through infected customers or employees).

If a policyholder alleges physical presence of the virus, some courts to date have found that the covered property was requisitely affected directly and physically by the alleged presence of the virus, even though the virus is microscopic and the property itself appears to be capable of decontamination. The loss of use of the property either through necessary decontamination or as a result of virus presence was enough for those courts to hold that business interruption coverage was triggered as a result of "direct physical loss of or damage to" property.

When determining coverage for losses resulting from civil authority orders, courts have split along the same line. If a policyholder can allege the actual physical presence of the virus on adjacent property that resulted in the order being made, the claim is not dismissed. However, if there are no allegations of the physical presence of the virus on other or adjacent property that prompted governmental authorities to restrict property access, governmental orders to quell the spread of the virus are not enough to trigger loss of use of the property to a degree that it is "direct" and "physical." These courts denying coverage rest their reasoning on a causation analysis: the virus, not the orders, caused the loss and the virus does not cause direct physical loss unless actual tangible property damage is alleged.

If a property policy has an exclusion for losses caused by viruses or bacteria, courts appear to be ready to deny coverage to policyholders on the face of the exclusionary language, without much more than a cursory analysis. Courts appear to link the cause of any governmental orders restricting property access to the reason for those orders: the virus, an excluded cause of loss. If the virus exclusion has an anti-concurrent cause clause, courts appear even more ready to deny coverage for business interruption or civil authority claims without much substantive analysis.

The cases wrestling with coverage for pandemic-related losses due to COVID-19 commonly engage with lines of reasoning from three prior precedents: the 11th Circuit 2020 decision in ***Mama Jo's, Inc. v. Sparta Insurance Co.***[150] (applying Florida law), the 2014 U.S. District Court for the District of New Jersey case of *Gregory Packaging, Inc. v. Travelers Property and Casualty Co. of America*[151] (applying New Jersey and Georgia law), and the 8th Circuit 2006 decision in *Source Food Technology, Inc. v. United States Fidelity and Guaranty Co.*[152] (applying Minnesota law). These cases highlight the tension between two possible approaches to pandemic-related insurance coverage issues: a strict requirement that the insured property suffer tangible physical alteration to property as a result of some external force (the ***Mama Jo's*** and *Source Food* approach) versus the notion of loss of "use" of the property equating to physical loss or damage to property, even though the physical property itself is not permanently altered by some external force (the *Gregory Packaging* approach).

In ***Mama Jo's***, the policyholder restaurant was denied its business interruption and remediation claims when the restaurant's lighting and audio equipment was coated with dust from outside road construction. Under Florida law, the court held that surfaces that can be cleaned have not suffered a direct physical

[150] 823 Fed. App'x 868 (11th Cir. 2020) (applying Florida law).

[151] No. 2:12-CV-04418, 2014 WL 6675934 (D. N.J. Nov. 25, 2014) (applying New Jersey and Georgia law).

[152] 465 F.3d 834 (8th Cir. 2006)(applying Minnesota law).

loss: the damage must be tangible and physical, resulting in an actual change in the property. Although dust in the accumulations involved in that case is a tangible contaminant, the court regarded the property as undamaged because it could be wiped away, even though cleaning on this scale exceeded that required for normal business operations.

In *Source Food Technology*, a beef wholesaler brought a claim for business interruption insurance due to lost revenue resulting from an embargo of Canadian beef after reports of "mad cow" disease. Source Food's sole supplier of beef was located in Ontario, Canada. The beef was not contaminated by mad cow disease. The claim for losses was as a result of the inability to ship the beef across the border. The court held that there was no direct physical loss or damage to the beef—it simply could not be shipped across the border. Thus, there was no coverage for the loss. The court specifically refused to adopt the position that "direct physical loss or damage is established whenever property cannot be used for its intended purpose."[153]

A different approach was taken by the court in *Gregory Packaging*.[154] In that case, the accidental release of ammonia in a juice box manufacturing plant required that the facility be decontaminated and evacuated. According to the court, the ammonia release physically transformed the air within the manufacturer's facility to make it unsafe. Because the facility was unusable for a period of time, the court held that the property suffered a direct physical loss. Even though, under Georgia law, coverage requires an actual physical change in property, the court held that that requirement was satisfied because the ammonia release physically changed the facility's condition to such a state that it needed repair.

B. MISAPPLYING TRADITIONAL CONTRACT AND INSURANCE LAW

Our own preference is for the *Gregory Packaging* approach rather than the *Mama Jo's* or *Source Foods* approach. But we find the early cases dismissing policyholder COVID claims disturbing not only because of their doctrinal choices but also because they in our view reflect a reductionist view and absence of judicial humility. In particular, the courts finding no "direct physical loss or damage" have been insufficiently appreciative of the range of meanings for these words that in turn makes it inappropriate for courts to declare a lack of triggering loss or damage as a matter of law.

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[153] *Id.* at 838 (citing Marshall Produce Co. v. St. Paul Fire & Marine Ins. Co., 98 N.W.2d 280 (Minn. 1959)).

[154] 2014 WL 6675934 (applying New Jersey Law).

1. Glib Tautology and False Consensus Bias

Particularly troubling examples are *Social Life Magazine, Inc. v. Sentinel Insurance Company*[155] (in which the court blithely declared that there was no loss or damage to covered property because COVID "damages lungs. It doesn't damage printing presses"), *Sandy Point Dental, PC v. Cincinnati Insurance Company*,[156] *Gavrilides Managment Company. v. Michigan Insurance C*ompany,[157] and *Rose's 1, LLC v. Erie Insurance Exchange*.[158]

The *Social Life Magazine* statement may make for a clever punchline but it is not even particularly accurate as a medical statement, let alone as an analysis of potential insurance coverage.[159] COVID's impact is not confined to lungs but includes many other organs such as kidneys and the brain as well as senses of hearing and smell.[160] More to the point for insurance purposes, viral infestation of a printing

[155] No. 1:20-cv-03311-VEC (S.D.N.Y. Apr. 29, 2020).

[156] No. 20 CV 2160, U.S. Dist. LEXIS 171979 (N.D. Ill. Sept. 21, 2020).

[157] No. 20-000258-CB (Mich. Cir. Ct., Ingham Cty. July 1, 2020) (explaining that direct physical loss to property requires tangible alteration or damage that impacts the integrity of the property, and dismissing the case because plaintiff failed to allege that the coronavirus had any impact to the premises).

[158] No. 2020 CA 002424 B, 2020 WL 4589206, at *5 (D.C. Super. Aug. 6, 2020) (granting summary judgment for insurer on restaurant's claims of lost business caused by coronavirus closure orders because there was no direct physical loss to property).

[159] A similar sort of reasoning featured in Plan Check Downtown III, LLC v. Amguard Ins. Co., No. cv 20-6954-GW-Skx, 2020 WL 5742712 (C.D. Cal. Sept. 10, 2020) (applying California law), where a restaurant's claim was dismissed because the court anchored its finding that "loss" requires tangible alteration to property because otherwise any regulatory change from any governmental order that affected any business in any fashion would trigger business interruption insurance. It went further to opine that even a snowstorm interferes with "use" of premises for the business by customers and employees and surely covering losses from snowstorms would make business interruption coverage far too broad.

[160] The same concept was picked up by the court in Uncork & Create LLC, v. Cincinnati Ins. Co., No. 2:20-cv-00401, 2020 WL 6436948 (S.D.W. Va.) (applying West Virginia law) which denied coverage and went so far as to state that it would deny coverage even if there was physical presence of the virus. The court held that COVID-19 does not harm inanimate structures, can be eliminated with disinfectant and routine cleaning. *Id.* at 5. The court went so far as to state that even the actual presence of the virus on the property is not enough to trigger the coverage clause "physical damage or physical loss to the property." *Id.* at 6. *See also* Promotional Headwear Int'l v. Cincinnati Ins. Co., No. 20-cv-2211-JAR-GEB, 2020 WL 7078735 (D. Kan. Dec. 3, 2020) (applying Kansas law) where the court (on a motion to dismiss on the pleadings!) does not accept the policyholder's allegations that the virus contaminated its property, citing both Source Food Technology, Inc. and Mama Jo's, Inc.;

facility does, for the reasons discussed above, damage the facility's air quality and its equipment. Although the "fix" may be relatively straight-forward cleaning, it is damage nonetheless and renders the facility unusable until cleaned—a process that may become so repetetive due to re-infection as to constitute long-term damage and loss of use. More important, if this and other pandemic injury result in government-ordered limitations on operation of the policyholder's property, this produces rather direct physical loss to the policyholder.

Sandy Point Dental makes a similarly breezy and overly restrictive reading of the direct physical loss or damage trigger. Although the court recognizes that Illinois law is applicable, it cites no Illinois cases regarding loss or damage[161] even though there are important state law decisions finding that adulterated air or surfaces can constitute physical damage to property.[162] If *Sandy Point Dental* had merely

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Terry Black's Barbecue, LLC v. State Auto. Mut. Ins. Co., No. 1:20-cv-665-RP, 2020 WL 7351246 (W.D. Tex. Dec. 14, 2020) (applying Texas law) (citing Uncork & Create, LLC and holding that, even assuming the virus is present, the court held it can be cleaned).

[161] The *Sandy Point Dental* court's citation of Illinois law is limited to general pronouncements, including the axiom that a court construing an insurance policy should be "giving effect to every provision, if possible, because it must be assumed that every provision was intended to serve a purpose." No. 20-cv-2160, 2020 U.S. Dist. LEXIS 171979, at *3-4 (quoting *Valley Forge Ins. Co. v. Swiderski Elecs., Inc.*, 860 N.E. 307, 314 (Ill. 2006). But this "surplusage" canon of construction (discussed *supra* text accompanying notes 85–86) augers in favor of giving "loss" a sufficiently distinct meaning from "damage." But instead of doing this, the *Sandy Point Dental* court treats the words as synonyms but then focuses only on the term "damage," which connotes more tangibility than "loss." The court also notes that Illinois requires words in a policy to be giving their "plain, ordinary, and popular meaning." *See* U.S. Dist. LEXIS 171979 at *4 (citing Central Ill. Light Co. v. Homes Ins. Co., 821 N.E.2d 206, 213 (Ill. 2004)). As previously discussed, (*see supra* test accompanying notes 90–99), there is ample evidence in dictionaries and thesauruses suggesting the plain and ordinary meaning approach augers in favor of finding loss when a policyholder's use of property is restricted by viral infection or government order.

[162] Illinois has had more than its share of asbestos coverage cases, the bulk of which have concluded that the presence of asbestos materials in a structure or in the interior air of a building constitutes physical damage. *See, e.g.*, J.R. French Auto. Castings, Inc. v. Factory Mut. Ins. Co., No. 02-c-9479, 2003 U.S. Dist. LEXIS 13060 (N.D. Ill. July 23, 2003) (noting that the presence of human remains in a press machine constituted contamination that was physical damage even though equipment not tangibly structurally altered but no coverage because of exclusionary language in policy); Affiliated FM Ins. Co. v. Board of Educ., No. 90-c-6040, 1992 U.S. Dist. LEXIS 15151 (N.D. Ill. Oct. 5, 1992) (noting that contaminated air is physical damage and the inability to use because of contamination is physical loss); Lapham-Hickey Steel Corp. v. Prot. Mut. Ins. Co., 655 N.E.2d 842 (Ill. 1995) (finding no duty to defend because a formal lawsuit was not filed but suggesting that contamination can

followed this applicable law, it would have reached a correct decision on the motion to dismiss. But the court simply failed to locate (whether due to deficient advocacy or something else) or examine these precedents.

In addition, the *Sandy Point Dental* court seems to have forgotten that even in a world of heightened pleading requirements, the court faced with a Rule 12(b)(6) motion to dismiss must (absent extreme circumstances) treat the allegations of the plaintiff's complaint as true.[163] Instead, the court in essence second-guessed those allegations, with the judge refusing to accept them at face value.

And in perhaps its lowest moment of judicial craft, *Sandy Point Dental* sought to distinguish an important decision favoring the policyholder.

> Plaintiff heavily relies on *Studio 417 Inc. v. The Cincinnati Insurance Company, 20 C 3127-SRB, 2020 U.S. Dist. LEXIS 147600 (S.D. Mo. Aug. 12, 2020)*, a Missouri case that found that the coronavirus caused a physical loss to property warranting insurance coverage. That court rested its decision on that policy's expansive language, language very different from the policy in the instant case. The unambiguous language in the instant policy warrants a different conclusion—physical damage that demonstrably alters the property is necessary for coverage, and the coronavirus does not cause physical damage.[164]

Unfortunately, ***Sandy Point's*** characterization is simply not true. The Cincinnati policy form at issue in *Studio 417* (and the *KC Hopps* and *Blue Springs Dental* cases also decided in the Western District of Missouri) is the same (at least regarding the direct physical loss requirement and the absence of a virus exclusion) as the Cincinnati policy at issue in *Sandy Point*.

In an opinion read from the bench, *Gavrilides Management*,[165] like *Sandy Point*, conflates the term "loss" and the term "damage," robbing them of their respectively different connotations and emphases. Worse yet, it engrafts on the term

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be physical damage and lack of access can be physical loss of property); Universal Underwriters Ins. Co. v. LKQ Smart Parts, Inc., 963 N.E.2d 930 (Ill. Ct. App. 2011) (noting that the deprivation of use of a vehicle is physical loss) (but there was also tangible physical damage to vehicle); Board of Educ. v. Int'l Ins. Co., 720 N.E.2d 622 (Ill. Ct. App. 1999) (finding that the presence of asbestos fibers in air constituted physical damage to property).

[163] *See* Ashcroft v. Iqbal, 556 U.S. 662 (2009); BROOKE D. COLEMAN, ET AL., LEARNING CIVIL PROCEDURE 285–302 (3d ed. 2018).

[164] No. 20-cv-2160, 2020 U.S. Dist. LEXIS 171979, at *7 n. 2.

[165] No. 20-000258-CB (Mich. Cir. Ct., Ingham Cty. July 1, 2020).

(having collapsed loss and damage into one) a requirement that property must have been permanently, structurally altered to be considered sufficiently "damaged" to merit coverage from the property insurer that, in return for premium dollars (sometimes years of premium dollars), promised to indemnify the policyholder from property loss and attendant business revenue loss.

Although one can argue that this was a correct reading of Michigan law, we are not convinced in that there appears to be no controlling Michigan precedent requiring this approach, which essentially denies coverage unless property is crushed.[166] Consequently, although not compelled to take a more nuanced view of the loss-or-damage requirement, the *Gavrilides Management* judge could (and in our view should) have done so.

Rose's 1, LLC v. Erie Insurance Exchange,[167] is disturbing in that, as that court acknowledges, the policyholder proffered definitions of the terms "loss" and "damage" that supported its position. But the court essentially ignored these definitions and adopted definitions it prepared—refusing to recognize that reasonable alternative constructions of a term or provision create ambiguity requiring resolution against the insurer. This is certainly true at the pleading stage. Although ***Rose's 1*** was a summary judgment decision, we think the same caution in terminating a case in the face of reasonable conflicting constructions of a policy should govern.

It appears that despite the summary judgment posture of the case, the record before the court did not include any extrinsic or discovery-unearthed evidence illuminating the meaning of policy language. Rather, the parties appear to have briefed the case based on textual argument alone, making the posture of the case akin to a 12(b)(6) motion. But instead of deferring to the facts as alleged and resolving any reasonable doubts against the nonmovant, the ***Rose's 1*** court granted summary judgment after it concluded—based on nothing we can discern—that "loss" requires "a direct physical intrusion on to the insured property."[168] As we

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[166] Although there are federal trial court cases requiring structural change to property to constitute sufficient physical loss or damage, there does not appear to be state court precedent binding on the *Gavrilades* court. *But see* Universal Image Prod. v. Chubb Corp., 703 F. Supp. 2d 705 (E.D. Mich. 2010) (finding that intangible harms such as odor or mold contamination insufficient to constitute physical loss or damage even though property was rendered unusable).

[167] No. 2020-CA-002424-B, 2020 WL 4589206 (D.C. Super. Ct. Aug. 6, 2020) (granting summary judgment for insurer on restaurant's claims of lost business caused by coronavirus closure orders because there was no direct physical loss to property).

[168] *Id.* at *7.

hope we have demonstrated, government orders limiting or forbidding use of physical facilities constitute a physical loss to the owner.

Diesel Barbershop, LLC v. State Farm Lloyds[169] displays a similarly disturbing approach to textual analysis. The court, like others finding for insurers, collapses what should be the distinct terms "loss" and "damage" and despite the many dictionary and thesaurus entries supporting a reading of the policy favorable to policyholders, selects the entries most favorable to the insurer contention requiring tangible and rather substantial, long-lasting, structural and character altering injury before there can be coverage. Likewise, the real loss of a physical facility due to COVID-spurred government restriction is given short shrift. To be fair, the *Diesel Barbershop* court recognizes cases that "some courts have found physical loss even without tangible destruction to the covered property."[170] However, "[e]ven so," *Diesel Barbershop* found "that the line of cases requiring tangible injury to property are more persuasive here."[171] That was in essence the scope and depth of the court's "analysis."

The problem with the court's conclusion is that it was to a large degree not the court's decision to make if it was following the rules of insurance policy construction. Because ambiguities are to be resolved in favor of the policyholder that did not draft the language at issue, a policyholder that proffers a reasonable construction of disputed language (such as "loss" or "damage") is entitled to the benefit of the doubt—at least regarding a Rule 12(b)(6) motion where another well-established "rule" is that the allegations of plaintiff policyholder's complaint must be accepted as true. Discovery may later provide information refuting those allegations and supporting the defendant insurer. But until such time as such discovery takes place, the factual universe upon which the court decides is supposed to be limited to the complaint.

Although research (such as reading dictionaries or cases) may bring extrinsic material into the inquiry, the policyholder need not shoulder the ultimate burden of persuasion at this stage of the litigation. It need only set forth a reasonable construction of the policy language that supports its claim for coverage. Policyholders seeking COVID coverage have done that. They may ultimately lose

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[169] No. 5:20-CV-461-DAE, 2020 WL 4724305, at *5 (W.D. Tex. Aug. 13, 2020) (granting a motion to dismiss because the coronavirus did not cause a direct physical loss, and "the loss needs to have been a 'distinct, demonstrable physical alteration of the property.'") (citing Hartford Ins. Co. of Midwest v. Mississippi Valley Gas Co., 181 F.App'x 465, 470 (5th Cir. May 25, 2006)).

[170] *Id.* at *14–15.

[171] *Id.* at *15–16 (concluding that "the other cases [finding loss or damage] are distinguishable.").

due to further factual development establishing lack of loss or damage or due to application of a virus exclusion or other factors. But they should not lose on the loss/damage issue at this stage of litigation.

These and other decisions[172] in which courts are willing to declare as a matter of law that the words "direct physical loss or damage" require structural

[172] *See, e.g.*, Mark's Engine Co. No. 28 Rest., LLC v. Travelers Indem. Co. of Conn., No. 2:20-cv-04423-AB-SK, 2020 WL 5938689 (C.D. Cal. Oct. 2, 2020) (applying California law) (involving a restaurant that claimed losses due to orders requiring take-out or delivery service only); Promotional Headwear Int'l v. Cincinnati Ins. Co., No. 20-cv-2211-JAR-GEB, 2020 WL 7078735 (D. Kan. Dec. 3, 2020) (applying Kansas law) (citing both *Source Food* and *Mama Jo's* to hold that physical alteration of property required for coverage to attach); Infinity Exhibits, Inc. v. Certain Underwriters at Lloyd's London, No. 8:20-cv-1605-T-30AEP, 2020 WL 5791583 (M.D. Fla. Sept. 28, 2020) (applying Florida law); Hillcrest Optical, Inc. v. Cont'l Cas. Co., No. 1:20-CV-275-JB-B, 2020 WL 6163142 (S.D. Ala. Oct. 21, 2020) (applying Alabama law); Raymond H Nahmad DDS PA v. Hartford Cas. Ins. Co., No. 1:20-cv-22833-BLOOM/Louis, 2020 WL 6392841 (S.D. Fla. Nov. 2, 2020) (applying Florida law); Palmer Holdings & Invs., Inc. v. Integrity Ins. Co., No. 4:20-cv-154-JAJ, 2020 WL 7258857 (S.D. Iowa) (applying Iowa law); T&E Chicago LLC v. Cincinnati Ins. Co., No. 20 C 4001, 2020 Wl 6801845 (N.D. Ill. Nov. 19, 2020) (applying Illinois law); Whiskey River on Vintage, Inc., v. Ill. Cas. Co., No. 4:20-cv-185-JAJ, 2020 WL 7258575 (S.D. Iowa Nov. 30, 2020) (applying Iowa law); Zwillo V, Corp. v. Lexington Ins. Co., No. 4:20-00339-CV-RK, 2020 WL 7137110 (W.D. Mo. Dec. 2, 2020) (applying Missouri law); Water Sports Kauai, Inc. v. Fireman's Fund Ins. Co., No. 20-cv-03750-WHO, 2020 WL 6562332 (N.D. Cal Nov. 9, 2020) (applying Hawai'ian law); Long Affair Carpet & Rug, Inc. v. Liberty Mut. Ins. Co., No.: SACV 20-01713-CJC(JDEx), 2020 WL 6865774 (C.D. Cal. Nov. 12, 2020) (applying California law); Michael Cette, Inc. v. Admiral Indem. Co., 20 Civ. 4612 (JPC), 2020 WL 7321405 (S.D.N.Y. Dec. 11, 2020) (applying New York law); Real Hosp., LLC v. Travelers Cas. Ins. Co. of Am., No. 2:20-cv-00087-KS-MTP, 2020 WL 6503405 (S.D. Miss. Nov. 4, 2020) (applying Mississippi law); Henry's Louisiana Grill, Inc. v. Allied Ins. Co. of Am., No. 1:20-CV-2939-TWT, 2020 WL 5938755 (N.D. Ga. Oct. 6, 2020) (applying Georgia law); Newchops Rest. Comcast LLC v. Admiral Indem. Co., No. CV 20-1869, 2020 WL 7395153 (E.D. Pa. Dec. 17, 2020) (applying Pennsylvania law); Brian Handel DMD, PC v. Allstate Ins. Co., No. 20-3198, 2020 WL 6545893 (E.D. Pa. Nov. 6, 2020) (applying Pennsylvania law); Hajer v. Ohio Security Ins. Co., No. 6:20-cv-00283, 2020 WL 7211636 (E.D. Texas Dec. 7, 2020) (applying Texas law); Terry Black's Barbecue, LLC v. State Auto. Mut. Ins. Co., No. 1:20-CV-665-RP, 2020 WL 7351246 (W.D. Tex. Dec. 14, 2020) (applying Texas law); Santo's Italian Café LLC v. Acuity Ins. Co., No. 1:20-cv-01192, 2020 WL 7490095 (N.D. Ohio) (applying Ohio law); Graspa Consulting, Inc. v. United Nat'l Ins. Co., No. 20-23245-CIV-WILLIAMS, 2021 WL 199980 (S.D. Fla. Jan. 20, 2021) (applying Florida law); S. Fla. ENT Assocs, Inc. v. Hartford Fire Ins. Co., No. 20-23677-Civ-WILLIAMS/TORRES, 2020 WL 6864560 (S.D. Fla. Nov. 13, 2020) (applying Florida law); Plan Check Downtown III, LLC v. AmGUARD Ins. Co., No. Cv 20-6954-GW-SKx, 2020

alteration of the property only reflect judges succumbing to false consensus bias—the tendency of humans to be overconfident that others see things as they do. Significant research suggests this is a particular problem in the interpretation of contracts and other writings. For example, in one study, respondents were given contract language to read and construe. They then were asked whether they thought other readers could reach a different interpretation.[173]

Overwhelmingly, they expressed confidence that others would agree with their reading of the words and that there was no significant interpretive issue as to the document's meaning. Overwhelmingly, they were wrong. The same contract language was being read by other respondents who were reaching a different conclusion as to the meaning of the words.

This tendency, which also accords with cognitive traits such as self-serving bias (the tendency for people to think they are better at things than is actually the case),[174] can be particularly pernicious in judges who by job description need to be decisive (and move on to the next case), and are consistently the object of deference or even adulation (e.g., more likely to be invited to be graduation speakers or faculty in residence than all but a few celebrity lawyers), and who by definition in an adversary system have half the disputants praising each decision.

The net result can often be a brusque, reductionist, insufficiently reflective approach to reading documentary text, including but not limited to statutes, regulations, rules, exhibits, and contracts in addition to insurance policies. The judge, despite frequently reading the text in a vacuum without background contextual information, the aid of a linguist, or more than the closest dictionary or those cited by counsel, quickly determines that she "knows" what the disputed language means. More troublingly, the judge "knows" this so well that she dispenses with further inquiry and dismisses the case.

WL 5742712 (C.D. Cal. Sept. 10, 2020) (applying California law); Kirsch v. Aspen Am. Ins. Co., No. 20-11930, 2020 WL 7338570 (E.D. Mich. Dec. 14, 2020) (applying Michigan law); Mortar & Pestle Corp. v. Atain Specialty Ins. Co., No. 20-cv-03461-MMC, 2020 WL 7495180 (N.D. Cal. Dec. 21, 2020) (applying California law). *But see, e.g.,* Seifert v. IMT Ins. Co., No. 20-1102 (JRT/DTS), 2020 WL 6120002 (D. Minn. Oct. 16, 2020) (applying Minnesota law) (holding that Minnesota law does not require a showing of structural damage to qualify for coverage).

[173] *See* Lawrence Solan, et al., *False Consensus Bias in Contract Interpretation*, 108 COLUM. L. REV. 1268 (2008).

[174] *See* Linda Babcock & George Loewenstein, *Explaining Bargaining Impasse: The Role of Self-Serving Biases,* 11 J. ECON. PERSPECTIVES 109 (1997) (describing phenomenon and its impact in prompting disputants or negotiating parties to overvalue their own skills, conduct, and position in transactions or litigation).

Although this is troubling to us in any case, it is particularly troubling in the insurance context, where the ground rules of adjudication discussed below, if properly followed, are essentially designed to give policyholders the benefit of the doubt. To borrow a baseball term, "ties" are supposed to "go to the runner." But like the umpire whose right thumb jerks upward if the ball is in the vicinity of first base before the runner has clearly planted a foot, courts taking an aggressively self-reverential view about the meaning of policy language bend the rules in the opposite direction.

In a world where reasonable people may debate the meaning of "direct physical loss or damage" in various contexts, courts should be reluctant to declare meaning as a matter of law. In view of the differing dictionary definitions and case outcomes, such an approach ordinarily amounts to error in COVID claims.

We realize of course that where controlling law provides a clear precedent, it must be followed. If, for example, the Supreme Court of State X has declared in no uncertain terms that both "loss" and "damage" in the property insurance setting always requires tangible, permanent (unless repaired by more than cleaning) injury to the structure or character of property, that precedent must be followed by trial courts no matter how much a trial judge thinks it incorrect. But where case law is mixed, unclear, or absent, trial courts should be taking the more modest approach to perceived certainty of textual meaning.

To be fair, many, perhaps even most, of the courts dismissing policyholder COVID claims have at least considered caselaw taking the broader view of "direct physical loss or damage." But they have then quickly pivoted to the narrower view certainty unwarranted in light of the dictionary definitions favoring the broader view. Couple this with the established insurance policy interpretation principles favoring policyholders that have been given short shrift by courts dismissing COVID coverage claims and the result is error—at least on the questions of whether loss or damage has occurred (and most certainly at the motion to dismiss stage of litigation).

Depending on the specifics of each case, insurers may prevail on any number of other defenses to coverage such as the virus exclusion or non-COVID defenses such as misrepresentation or intentional destruction or insurers may limit their liability based on calculation of lost business income as well as policy limits or sub-limits. But they generally should not be prevailing on the loss/damage question to the extent reflected in opinions to date. A brief review of a few important insurance concepts underscores this assessment.

2. Reasonable Policyholder Expectations of Coverage for Pandemic-related Losses

Consider policyholder and insurer expectations of coverage for pandemic-related losses. If there is rampant confusion as to the scope of coverage such that litigation is arriving at mixed results, perhaps there is a more insidious problem with what is driving that litigation. The reasonable policyholder likely expected that a product marketed and labelled as "business interruption insurance" or "civil authority coverage" would extend coverage to the policyholder's income stream in the event the policyholder was unable to access or reasonably use its business premises. The reasonable policyholder purchasing an "all risk" policy likely would not have thought that such coverage would hang on how the damage—if any—to the property occurred. Rather, their focus would likely be on their income loss due to either virus contamination or prevention of use of their property due to governmental orders.

Particularly in the case of civil authority coverage, few policyholders would likely expect that, in many instances in order to trigger coverage, there would have to be some physical damage to adjacent property that would prompt a civil authority to restrict access to the policyholder's property. Policyholders may ironically be better off if their property or adjacent property had burned down, rather than operations ceased by a virus, strange though it may seem. By the mere label of the product alone—"business interruption insurance"—there are likely many policyholders who simply believe that the insurance insures their profit stream. The impetus for that belief may well, in the end, rest with issues of misleading nomenclature by insurers and misleading sales by brokers and agents.

From an insurer's standpoint, the reasonable insurer may well not have meant nor expected to cover losses relating to a pandemic like COVID-19 in the contexts of business interruption insurance included in commercial property policies. By its nature, a pandemic is a clash event that has the potential to seriously strain insurer resources. Yet surely the industry had modelled a pandemic because it has already seen the effects of SARS, MERS, Ebola, H1N1, swine flu, and HIV/AIDs. And there were products on the market specifically designed to cover pandemic-related losses. The existence of related products like event cancellation insurance makes the generalized insurer contention of "whoever would have predicted COVID-19?" a bit strained.

The more compelling insurer response to pandemic-related losses is perhaps to assert that the business interruption product was never meant to be "guaranteed profit insurance."[175] It is an insurance add-on coverage to property insurance. There surely must be some risks in commerce that are not covered by a property policy. For example, no one would expect business interruption coverage for profit losses in a nuclear war (though of course there are exclusions for nuclear causes of loss). But what of, say, a zombie apocalypse or alien invasion, that required governments to issue "stay at home" orders or risk being eaten by green beings? Would the standard business interruption coverage tied to commercial property policies kick in then? Is there then a direct physical loss of or damage to property? Likely not. There are zombies or aliens running about. The property is likely just fine. But again, property owners may have difficulty accessing their property or even be barred from it due to civil authority orders or otherwise.

Some insurers included a virus exclusion in their policy wording before the pandemic struck. Does that mean that those insurers without a virus exclusion did not mean to exclude such losses? Is the virus exclusion itself a rock-solid denial of coverage, under all loss scenarios?

Perhaps instead the business interruption (and by corollary, the civil authority) insurance product needs to be retooled and re-messaged to communicate precisely what is and what is not meant to be covered. Otherwise, in the insurance world, if coverage is unclear, ties go to the policyholder—or at least they should. The insurer must provide coverage until new policy language is drafted in new versions of insurance policies.

3. Causation, Civil Authority Coverage and the Virus Exclusion

The trigger of coverage for civil authority business interruption losses rests largely on arguments of insurance causation. Policyholders continue to allege that a civil authority order caused their pandemic-related business interruption losses by restricting their access to their property. To date, courts have perhaps incorrectly declined coverage because they have held that the cause of the policyholder's losses is not the order and that no physical loss or damage occurred to prompt the order in the first place.

It is important to keep in mind how causation works in the insurance law context and how it is different than principles of tort causation. In assessing insurance causation in a property loss context, one should work backward from the

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[175] A notion picked up by the court in Real Hosp., LLC v. Travelers Cas. Ins. Co. of Am., No. 2:20-cv-00087-KS-MTP, 2020 WL 6503405, at *8 (S.D. Miss. Nov. 4, 2020) (emphasis omitted) (applying Mississippi law), which held that "this is a commercial property policy, not a stand-alone business interruption policy—Plaintiff's operations are not what is insured—the building and the personal property in or on the building are."

loss claimed (here, the loss of profit) and ask what external force affected the property to result in the loss and thus potentially trigger the coverage claimed? The analysis is not a temporal one (i.e. last in time) but rather one of effect: what "hurt" the policyholder such that it suffered the loss claimed? For property claims, the answer to insurance causation questions is usually straightforward: what external force damaged the property? The insurance causation analysis does not involve analyzing chains of causation, as one might do in a tort analysis. Fault, blame, or responsibility play no part in insurance causation. Instead, a court is to determine what external force "hurt" the policyholder such that it triggered the particular loss claimed. The inquiry is decidedly contractual.

The loss to the policyholder is the lost profit from an inability to operate the business. The "hurt," so to speak, in the civil authority coverage case, is actually arising from the order of the civil authority restricting access to the property (whether employee or customer access). The virus did not need to touch any of the policyholder's property to result in the economic loss that affected the policyholder. Even the threat of the virus is not necessary. The cause of the loss is thus the civil authority order which restricted access to the policyholder's property.

In a jurisdiction that adheres to the proximate cause doctrine of insurance causation, the proximate cause of the loss in this scenario—for civil authority coverage insurance purposes—is the governmental order. It is analytically incorrect to chase down what made the governmental authority issue the order in the first place—unless the coverage provisions specifically require such a causal inquiry.

In some cases, such an inquiry is necessary if—and only if—the coverage grant requires a finding that the loss must flow from a covered cause which results in direct physical loss or damage to adjacent property. Only if the coverage granting language specifically asks for such an analysis should a court attempt to ask "why" a governmental order was issued. And even then, it should only ask the simple question: was the order issued due to a covered cause which resulted in direct physical loss or damage to property adjacent to the policyholder?

In the case of a civil authority coverage case where there is a virus exclusion in the policy, the causation analysis is a bit more nuanced. If the coverage grant for civil authority insurance does not require direct physical loss or damage to property, but merely the restriction of access to the property, then the virus exclusion has no effect on coverage for the policyholder. The cause of the loss is the governmental order, not the virus.

While the prevention of the virus was the impetus for the order, coverage cannot be ousted simply because the "topic" of the order was "about" the COVID-19 virus. The topic did not harm the policyholder, nor did the virus; the actual effect of the order did. Policyholders should not lose coverage because of the topic of the times behind a governmental order or even the reasoning behind the order. Coverage should only be ousted when the order did not cause the harm claimed.

However, if the coverage grant for civil authority insurance requires direct physical loss or damage to property, then the policyholder would apparently need to prove that the reasoning behind the civil authority order was indeed related to property damage which occurred. Such can be alleged with the COVID-19 virus by indicating the virus was present in frankly any adjacent property that was in an area affected by COVID-19, so long as that jurisdiction will consider that the presence of the virus can constitute direct physical loss or damage.

The issue is, of course, less clear if the property policy contains a virus exclusion. Some virus exclusions have an anti-concurrent cause clause such that coverage is ousted as long as virus contamination played some role in the ensuing loss. One can argue that the virus did not play a concurrent role in the loss (although it may have been a reason for the order—but the exclusion does not ask about the 'story' behind the order—its focus is the cause of the loss claimed for insurance purposes).

An example of such a scenario occurred when the policyholder massage spa in *Elegant Massage, LLC v. State Farm Mutual Automobile Insurance Company*[176] was forced to close due to a specific governmental order that mandated the closure of spas and massage services due to the inability of those particular businesses to maintain safe social distancing in a time of particularly serious virus spread. The spa and massage business was thus forced to close as a direct result of this specific order. The spa also voluntarily closed even after the order was lifted, because it could not maintain the required social distancing measures and still conduct its business. The policyholder argued the order, not the virus, caused its losses. The court agreed, because the policyholder's specific type of business was targeted by the order—it was not just a general health measure. The court also noted that Virginia does not support anti-concurrent causation clauses; insurers must draft specific language to oust coverage and there must be a direct connection between the exclusion and the loss (not some tenuous connection anywhere in the chain of causation).

The catch-22 is realized when a coverage grant tied to direct physical loss to property is coupled with a virus exclusion. In that instance, alleging that the civil authority coverage is a result of virus contamination may well trigger the virus exclusion.[177]

[176] No. 2:20-cv-265, 2020 WL 7249624 (E.D. Va. Dec. 9, 2020) (applying Virginia law).

[177] Professor Dan Schwarcz has been quoted as taking the view that where a policy has a virus exclusion, the case against coverage is "open and shut." Caroline Glenn, *Insurers Are Telling Businesses Their Policies Don't Cover Coronavirus Shutdown. John Morgan Attorneys Say They're Wrong*, ORLANDO SENTINEL (May 4, 2020),

4. Ambiguity in Property Coverage for Pandemic-related Losses

It may well be that the coverage clause "direct physical loss of or damage to property" is by now so tortured and unpredictable in caselaw as to be rendered ambiguous in terms of insurance policy construction. Indeed, three courts have found just that.

In *Elegant Massage, LLC v. State Farm Mutual Automobile Insurance Company*,[178] the court noted that the coverage clause does not overtly require structural damage for coverage to attach. Because there was such a "spectrum" of meanings of "direct physical loss of or damage," the court interpreted the clause in a light most favourable to the policyholder. If the property (here, a spa which requires close contact with, and touching of, patrons) was deemed uninhabitable, inaccessible and dangerous to use as a result of governmental orders because of the high risk for spreading COVID-19, then the policyholder suffered direct physical loss. The court drew analogies to those cases where the policyholder could not use its property due to toxic gasses from drywall or odor or asbestos.

In *North State Deli, LLC v. The Cincinnati Insurance Co.*,[179] the court scoured the wide variety of dictionary definitions and determined that "loss" can equate to the loss of a full range of rights and advantages of property use. It held the coverage clause was ambiguous and thus settled on a reasonable definition which favours coverage: that "direct physical loss" can mean loss of use or access, even if the property is not structurally altered.

Finally, in *Hill and Stout PLCC v. Mutual of Enumclaw Insurance Company*,[180] the court held that physical "loss" must mean something different than physical "damage." "Loss" could mean "deprivation." The dental practice at issue in that case had direct physical deprivation of its premises as a result of the

https://www.orlandosentinel.com/coronavirus/jobs-economy/os-bz-coronavirus-insurance-denials-morgan-lawsuits-20200504-pbrpq6z7ofbevau67cpgq4nzqi-story.html. Although one of us (Stempel) tends to agree that coverage is probably inapt in most such cases, the other (Knutsen) is hesitant. In any event, we think the issue is closer than commonly thought because of the long history of causation doctrine that tends not to look beyond the immediate cause of loss if the cause is a sufficiently dominant factor in bringing about the loss. *See* Erik S. Knutsen, *Confusion About Causation in Insurance: Solutions for Catastrophic Losses*, 61 ALA. L. REV. 957 (2010); Peter Nash Swisher, *Insurance Causation Issues: The Legacy of* Bird v. St. Paul Fire & Marine Ins. Co., 2 NEV. L.J. 351 (2002).

[178] 2020 WL 7249624 (E.D. Va. Dec. 9, 2020) (applying Virginia law).

[179] North State Deli, LLC v. The Cincinnati Ins. Co., No. 20-CVS-02569, 2020 WL 6281507 (N.C. Super. Oct. 9, 2020) (Trial Order).

[180] No. 20-2-07925, 2020 WL 6784271 (Wash. Super.) (Trial Order).

governmental order stopping dental visits because the practice could not see patients or practice dentistry. To that end, because the pleadings were silent about the meaning of "loss," the court held that physical "loss" is an ambiguous phrase, and the case could proceed.

A review of the various dictionary definitions above for these terms certainly should be leading other courts to also consider ambiguity. In some cases, asbestos contamination is a direct physical loss. In others, it is not. In some cases, prevention of access to property by a government order is a direct physical loss. In others, it is not. Under the doctrine of *contra proferentem*, a finding of ambiguity leads to the policy terms being interpreted in favor of the policyholder. If policyholders and insurers alike—and clearly courts—cannot predict the meaning of the phrase and what it is supposed to do as the main coverage trigger for perhaps the most prevalent insurance product on the market, and if so much litigation is produced resulting from this confusion, then ambiguity of the coverage clause may be a reasonable conclusion for courts to make.

C. THE POTENTIAL FOR COVID INSURANCE COVERAGE CASES AS A BLUEPRINT FOR BETTER DECISION-MAKING

A few cases (three decided by the same Western District of Missouri court) have found coverage for COVID-related losses, albeit in a motion to dismiss context and without a full factual record: *Studio 417, Inc. v. Cincinnati Insurance Company*,[181] *K.C. Hopps v. Cincinnati Insurance Company,*[182] *Blue Springs Dental Care v. Owners Insurance Company*,[183] and *Elegant Massage, LLC v. State Farm Mutual Automobile Insurance Company*.[184] The other cases denying coverage have attempted to distinguish these cases on a number of grounds primarily related to the specific facts plead by the policyholders (i.e. the presence of a virus-specific exclusion or the specific allegations of virus particles actually physically present on insured property).

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[181] No. 20-cv-03127-SRB, 2020 WL 4692385 (W.D. Mo. Sept. 12, 2020) (applying Missouri law).

[182] 2020 U.S. Dist. LEXIS 144285 (W.D. Mo. Aug. 12, 2020) (applying Missouri law). *K.C. Hopps v. Cincinnati* is a short opinion that incorporates the Court's analysis in *Studio 417* because that case "involves the same Defendant, similar insurance provisions, and similar factual allegations as those asserted in this case. Defendant also moved to dismiss *Studio 417* under Rule 12(b)(6) based on similar legal arguments that it presents in this case." *Id.* at *2.

[183] 2020 U.S. Dist. LEXIS 172639 (W.D. Mo. Sep. 21, 2020).

[184] 2020 WL 7249624 (E.D. Va. Dec. 9, 2020) (applying Virginia law).

The *Studio 417* and *Elegant Massage* cases remain the most analytically satisfying decisions to date,[185] as they most thoroughly deal with competing precedents and convey a broader understanding of the importance of insurance as a risk-based commercial product packaged to commercial policyholders. The other decisions denying coverage, in the main, tend to resort to a restrictive line of case precedents that narrow insurance recovery based largely on a purely textual parsing of insurance policy language, on a "know it when I see it" basis. Those decisions do not convey a broader understanding of what the coverage clause or property policies generally are meant to do in the consumer marketplace.

The *Studio 417* case more fully accounts for the historical caselaw interpreting the "direct physical loss or damage" coverage clause—both for and against coverage. The case also demonstrates the most doctrinally defensible analysis of the insurance causation elements of the claim. The policyholders in that case operated restaurants and hair salons. They claimed for pandemic-related losses under their business interruption and civil authority coverage contained in their all-risk property policies. Their claims were denied. The policy in question provided coverage for a "direct loss," which is defined as "accidental physical loss or accidental physical damage." Notably, there was no virus exclusion in this policy.

The policyholders alleged that customers and employees were infected with COVID-19 and the insured property became contaminated with the virus as a result. They argued that the virus is a physical substance that is active on tangible surfaces, and renders property unsafe and unusable. This quality of the virus forced the policyholders to suspend operations or at least reduce them. The policyholders also alleged that civil authorities in Missouri and Kansas issued orders that required suspension of businesses at various places, including closure orders. The policyholders alleged that both the presence of COVID-19 on the property plus the government closure orders resulted in direct physical loss or damage to the property and denied the policyholders the full use of the property.

The court found that there is a possibility of coverage despite the fact that the virus could be cleaned from physical surfaces or dies naturally within a few days. The fact that access to the property was prohibited or severely restricted was enough to find a possibility of coverage at this stage. In this regard, the court relied on the *Gregory Packaging, Inc. v. Travelers Property and Casualty Co. of America*[186] case,

[185] This is not said in derogation of *Blue Springs Dental v. Owners Ins.*, which unlike *K.C. Hopps* contains extensive discussion and analysis. Although *Blue Springs Dental* involved somewhat different policy language and business activities, its analysis is heavily shaped by *Studio 417*, discussed at length in this section.

[186] No. 2:12-cv-04418 (WHW)(CLW), 2014 WL 6675934, at *1 (D.N.J. Nov. 25, 2014) (applying New Jersey law).

where ammonia contamination at a juice packaging plant triggered insurance coverage because the manufacturer's buildings were uninhabitable due to the contamination. Even though the policyholders in *Studio 417* likely could not prove that COVID-19 was specifically on their premises, the fact that the virus was so widespread was enough to obviate the issue for the court.

The court held that COVID-19 is a physical substance which lives on surfaces and is transmitted through the air. COVID-19 makes property unsafe and unusable, resulting in "direct physical loss of or damage to" property. One does not need to prove tangible physical alteration of property to trigger coverage.

The court also held that loss of use of property is different than "damage;' otherwise, the word "damage" would be rendered superfluous in the coverage clause. The fact that the property could not be used due to COVID-19 was enough for the court to hold the policyholders had suffered a potential loss of the property. The court distinguished the line of cases that require policyholders to prove a tangible physical alteration to the property in order to trigger the coverage clause. The court distinguished the *Source Food Technology, Inc. v. U.S. Fidelity & Guarantee Co*mpany[187] case, which granted summary judgment to an insurer who denied coverage when the policyholder's meat could not cross the Canadian border due to meat infection concerns. The *Studio 417* court held that the policyholders' allegations posit contamination of the property with a physical substance: the COVID-19 virus. This was therefore a different situation than the *Source Foods* case where there was no evidence the beef was actually contaminated by mad cow disease.

The policyholders also had potential coverage under a claim for civil authority insurance. According to the court, government orders affected hair salons by forcing their closure and affected restaurants by not allowing diners to dine inside the premises. Only drive-through or pick-up or delivery orders were allowed for restaurants. This was sufficient for the court to find that access was prohibited to such a degree as to trigger the civil authority coverage. The court held that the virus was physically present in property other than the policyholder's, because it was "everywhere" and therefore that satisfied the "direct physical loss or damage" coverage requirement.

The court specifically held that the civil authority coverage clause required access to be prohibited but the language did not mandate that all access had to be fully prohibited. The fact that access to the policyholders' property was impeded to a significant degree was sufficient for coverage to attach. Along the same logic, the court held that the policyholders also had potential coverage under the property policy's ingress and egress, dependent property, and sue and labor provisions.

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[187] 465 F.3d 834, 835 (8th Cir. 2006) (applying Minnesota law).

The same federal court denied an insurer's motion to dismiss the claims of policyholder dental clinics in *Blue Springs Dental Care v. Owners Insurance Company*[188] The dental clinics claimed business interruption and civil authority losses when Missouri and corresponding counties issued 'stay at home' orders to quell the virus spread. Three dental clinics completely closed and one remained open only for essential and emergency dental cases. The policyholder pled that its property was damaged because of the presence of COVID-19 on and around its property such that it had to either end or reduce its operations due to actual contamination. It also alleged that employees, customers, and other visitors likely were infected with the coronavirus and thus operations were suspended to prevent physical damage to property and to the people on it. The 'stay at home' orders and general fear of infection or spreading COVID-19 on the property itself meant that customers could not access the property.

The insurer in this case argued that the fact that the one clinic was offering some services meant that its operations were not suspended within the meaning of coverage under the policy. The insurer also argued that the policyholder's clinics suffered no "direct physical loss of or damage to" property. As was the case in *Studio 417*, there was no exclusion for pandemics or communicable diseases in the applicable policy.[189]

The court found that COVID caused the policyholder's alleged physical loss in that the virus physically occupied and contaminated the dental clinics. This deprived the policyholder of use of the clinics, making them unsafe. The court also held that the policyholder necessarily suspended its operations to prevent physical damage from COVID. The COVID virus was the cause of the suspension and implicated business interruption coverage.

The court also held that the policyholder would be entitled to civil authority coverage because the orders by the state and counties do not need to be directed specifically at insured property or property adjacent to it in order to trigger coverage. The court cited *Studio 417* with approval, reiterating that policyholders do not need to completely lose all access to property—coverage could be had for partial impeded access. In this case, although three of the clinics closed entirely and the other had only limited dental services for emergency patients, access was prohibited to such a

[188] 2020 U.S. Dist. LEXIS 172639.

[189] Nor was there a virus exclusion in the policies at issue in K.C. Hopps v. Cincinnati Ins. Co., 2020 U.S. Dist. LEXIS 144285 (W.D. Mo. 2020). It thus appears that Cincinnati sold a significant number of policies without a virus exclusion and may face significant coverage responsibility in cases where courts take a similar view of the "direct physical loss or damage" requirement and where government orders mandated closure.

degree as to trigger coverage. The court left open the question as to the effect of the order that targeted essential versus non-essential businesses.

The important factor in the *Studio 417* and *Blue Springs Dental Care* cases is that the policyholders alleged specific physical damage through the presence of COVID-19 virus on the insured property in question. That allowed the court to find a direct physical loss, and thus the potential for coverage. The fact that contamination was not permanent was not an issue restricting the coverage analysis. The court also held that direct physical loss could be had through loss of use of the property. The court also had little issue with connecting the causal chain of the presence of COVID-19 virus on property, its prevalence in the community, and the inability of the policyholders to use their property as a result of governmental orders arising directly from the presence of COVID-19.

The court in *Elegant Massage* granted coverage to a massage spa when the spa was forced to close due to governmental orders. The spa's business model required the touching and close proximity to customers which was the very risk the orders were trying to quell in prevention of the virus. After the mandatory closure order ended, the spa still voluntarily closed as it was exceedingly difficult to comply with the mandated physical distancing requirements and still provide massage services. As mentioned above, the court found the coverage clause "direct physical loss of or damage to property" ambiguous because the clause does not specifically require distinct, structural damage for coverage to attach. If the insurer wished such a requirement, it could have added that language. Therefore, by interpreting the clause in a fashion most favorable to the policyholder, the court held that the loss of use of the policyholder's property qualified as a "direct physical loss." The court, however, denied civil authority coverage to the policyholder as it would not show a causal link between any damaged surrounding properties and its own. Simply put, there was no structural damage to the policyholder's premises—only loss of use and access.

V. CASELAW AND THE VIRUS EXLCUSION

As is by now clear, we are concerned, perhaps to the point of being dismayed, that so many courts have so credulously embraced the view that as an absolute matter of law viral infection of premises cannot be physical loss or damage to insured premises and that there is no coverage even where government authorities have deprived policyholders of use of their property. This reading of policy language—especially its cocksure construction that refuses to recognize alternative reasonable reading of the words—poses significant potential problems not only for COVID coverage cases but for property insurance disputes generally.

That said, this first wave of cases may be an example of erroneous judicial reasoning that nonetheless arguably reaches a correct result, at least in many instances. Of the COVID coverage decisions made as this article was written, all but a handful had favored insurers. In nearly all of these cases granting insurer dismissal motions on the basis of what we regard as incorrect application of the physical-loss-or-injury trigger, the policies at issue also contained a virus exclusion. As discussed below, the standard ISO virus exclusion is broadly drafted and was intended by insurers to preclude coverage for certain virus-related losses. In some cases, drafting, communication, or claims-handling errors of an insurer may make a virus exclusion ineffective. Or there may be particular facts of a claim that negate the virus exclusion, like issues of causation.[190]

As discussed below, despite the apparent clarity of the virus exclusion, it may well be ineffective in some loss situations. In addition, the prevalence of virus exclusions in policies is unclear. As noted above, in the decisions to date, a fourth of the policies at issue lacked a virus exclusion. A preliminary study of liability insurance policies suggests that the majority of these policies lack a virus exclusion.[191] Regarding property insurance, however, insurers contend that eighty percent or more of the policies contain virus exclusions. Although that figure that accords with the polices in court decisions to date,[192] it is a sufficiently high percentage that we harbor concerns that may be overstated. For example, the policies of Cincinnati Insurance Company, involved in nearly 200 cases filed, tend not to have a virus exclusion.[193]

Prior to the SARS tragedy of the early Twenty-first Century, insurance policies did not contain virus exclusions, although many did have bacteria, fungus, or mold exclusions. And there is, of course, the pollution exclusion that we think has no application to infection-related loss but that insurers continue to occasionally push as a defense to coverage. Insurers effectively accepted that their policies of the pre-SARS era did not exclude—at least not with sufficient clarity—viral infection losses and responded by drafting a rather comprehensive virus exclusion.

The exclusion and its rationale were presented to regulators in a 2006 ISO circular.[194] **The key operative phrase of the exclusion reads:** "We will not pay for

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[190] *See, e.g.*, Elegant Massage, LLC v. State Farm Mut. Auto. Ins. Co., No. 2:20-cv-265, 2020 WL 7249624 (E.D. Va. Dec. 9, 2020) (applying Virginia law) (finding no direct connection between exclusion and loss; governmental order, not virus, direct cause of loss; and exclusion inapplicable).

[191] *See* Baker, *supra*, note 10.

[192] *See id.* (identifying 174 cases filed against Cincinnati as of Oct. 21, 2020).

[193] *Id.*

[194] ISO VIRUS EXCLUSION, *supra* note 25.

loss or damage caused by or resulting from any virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease."[195] Some virus exclusions also contain an anti-concurrent cause clause, which attempts to exclude coverage regardless as to whether the damaged complained of is concurrently caused with another non-virus-related cause or not.[196] In particular, the circular stated:

> While property policies have not been a source of recovery for losses involving contamination by disease-causing agents, the specter of pandemic or hitherto unorthodox transmission of infectious material raises the concern that insurers employing such policies may face claims in which there are efforts to expand coverage and to create sources of recovery for such losses, contrary to policy intent.[197]

Case law to date has supported application of the ISO virus exclusion to exclude coverage for COVID-related losses in a near-automatic fashion, without subjecting the exclusion to any meaningful analysis.[198] The virus exclusion has been

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[195] *Id.*

[196] *See, e.g.*, the policy at issue in Diesel Barbershop, LLC v. State Farm Lloyds, No. 5:20-cv-461-DAE, 2020 WL 4724305 F.Supp.3d (W.D. Tex. 2020) (applying Texas law).

> 1. We do not insure under any coverage for any loss which would not have occurred in the absence of one or more of the following excluded events. We do not insure for such loss regardless of: (a) the cause of the excluded event; or (b) other causes of the loss; or (c) whether other causes acted concurrently or in any sequence with the excluded event to produce the loss; or (d) whether the event occurs suddenly or gradually, involves isolated or widespread damage, arises from natural or external forces, or occurs as a result of any combination of these: . . .
>
> **j. Fungi, Virus Or Bacteria**
>
> . . . (2) Virus, bacteria or other microorganism that induces or is capable of inducing physical distress, illness or disease.

Id.

[197] ISO VIRUS EXCLUSION, *supra* note 25.

[198] *See, e.g.*, Seifert v. IMT Ins. Co., No. 20-1102 (JRT/DTS), 2020 WL 6120002 (D. Minn. Oct. 16, 2020) (applying Minnesota law) (holding that losses resulted from order, not virus, but anti-concurrent loss provision in virus exclusion ousts coverage because virus is part of causal chain of loss); Founder Inst. Inc. v. Hartford Fire Ins. Co., No. 20-cv-04466-VC, 2020 WL 6268539 (N.D. Cal. Oct. 22, 2020) (applying California law) (rejecting

policyholder argument that governmental orders were about spread of saliva and respiration droplets, not virus; virus exclusion applies); Border Chicken AZ LLC v. Nationwide Mut. Ins. Co., No. CV-20-00785-PHX-JJT, 2020 WL 6827742 (D. Ariz. Nov. 20, 2020) (applying Arizona law); Chattanooga Prof. Baseball LLC v. Nat'l Cas. Co., No. CV-20-01312-PHX-DLR, 2020 WL 6699480 (D. Ariz. Nov. 13, 2020) (applying Arizona law); Franklin EWC, Inc. v. Hartford Fin. Servs. Grp., Inc., No. 20-cv-04434 JSC, 2020 WL 5642483 (N.D. Cal. Sept. 22, 2020) (applying California law); Mark's Engine Co. No. 28 Rest., LLC v. Travelers Indem. Co. of Conn., No. 2:20-cv-04423-AB-SK, 2020 WL 5938689 (C.D. Cal. Oct. 2, 2020) (applying California law); Raymond H Nahmad DDS PA v. Hartford Cas. Ins. Co., No. 1:20-cv-22833-BLOOM/Louis, 2020 WL 6392841 (S.D. Fla. Nov. 2, 2020) (applying Florida law); W. Coast Hotel Mgmt., LLC v. Berkshire Hathaway Guard Ins. Co., No. 2:20-cv-05663-VAP-DFMx, 2020 WL 6440037 (C.D. Cal. Oct. 27, 2020) (applying California law); Palmer Holdings & Invs., Inc. v. Integrity Ins. Co., No. 4:20-cv-154-JAJ, 2020 WL 7258857 (S.D. Iowa) (applying Iowa law); Whiskey River on Vintage, Inc., v. Ill. Cas. Co., No. 4:20-cv-185-JAJ, 2020 WL 7258575 (S.D. Iowa Nov. 30, 2020) (applying Iowa law); Natty Greene's Brewing Co. v. Travelers Cas. Ins. Co. of Am., No. 1:20-CV-437, 2020 WL 7024882 (M.D.N.C. Nov. 30, 2020) (applying North Carolina law); Wilson v. Hartford Cas. Co., No. 20-3384, 2020 WL 5820800 (E.D. Pa. Sept. 30, 2020) (applying Pennsylvania law); N&S Rest., LLC v. Cumberland Mut. Fire Ins. Co., No. 20-05289 (RBK/KMW), 2020 WL 6501722 (D.N.J. Nov. 5, 2020) (applying New Jersey law); Long Affair Carpet & Rug, Inc. v. Liberty Mut. Ins. Co., No.: SACV 20-01713-CJC(JDEx), 2020 WL 6865774 (C.D. Cal. Nov. 12, 2020) (applying California law); Real Hosp., LLC v. Travelers Cas. Ins. Co. of Am., No. 2:20-cv-00087-KS-MTP, 2020 WL 6503405 (S.D. Miss. Nov. 4, 2020) (applying Mississippi law); Newchops Rest. Comcast LLC v. Admiral Indem. Co., No. CV 20-1869, 2020 WL 7395153 (E.D. Pa. Dec. 17, 2020) (applying Pennsylvania law); Brian Handel DMD, PC v. Allstate Ins. Co., No. 20-3198, 2020 WL 6545893 (E.D. Pa. Nov. 6, 2020) (applying Pennsylvania law); Hajer v. Ohio Security Ins. Co., No. 6:20-cv-00283, 2020 WL 7211636 (E.D. Texas Dec. 7, 2020) (applying Texas law); Vizza Wash, LP v. Nationwide Mut. Ins. Co., No. 5:20-cv-00680-OLG, 2020 WL 6578417 (W.D. Tex. Oct. 26, 2020) (applying Texas law); Terry Black's Barbecue, LLC v. State Auto. Mut. Ins. Co., No. 1:20-CV-665-RP, 2020 WL 7351246 (W.D. Tex. Dec. 14, 2020) (applying Texas law); AFM Mattress Co. v. Motorists Com. Mut. Ins. Co., 2020 WL 6940984 (N.D. Ill. Nov. 25, 2020) (applying Illinois law); Boulevard Carroll Ent. Grp. v. Fireman's Fund Ins. Co., No. 20-11771 (SDW)(LDW), 2020 WL 7338081 (D.N.J. Dec. 14, 2020) (applying New Jersey law); Santo's Italian Café LLC v. Acuity Ins. Co., No. 1:20-cv-01192, 2020 WL 7490095 (N.D. Ohio) (applying Ohio law); 1210 McGavock St. Hosp. Partners, LLC v. Admiral Indem. Co., No. 3:20-cv-694, 2020 WL 7641184 (M.D. Tenn. Dec. 23, 2020) (applying Tennessee law); Boxed Foods Company, LLC v. Cal. Capital Ins. Co., No. 20-cv-04571-CRB, 2020 WL 6271021 (N.D. Cal. Oct. 27, 2020) (applying California law); LJ New Haven LLC v. AmGUARD Ins. Co., No. 3:20-cv-00751 (MPS), 2020 WL 7495622 (D. Conn. Dec. 21, 2020) (applying Connecticut law); Mortar & Pestle Corp. v. Atain Specialty Ins. Co., No. 20-cv-03461-MMC, 2020 WL 7495180 (N.D. Cal. Dec. 21, 2020) (applying California law).

held to oust coverage because courts have found that, even though some policyholders lost business income due to governmental orders closing or limiting access to their buildings, that access was lost because the governmental orders were issued due to a virus. In short, the courts link the causal chain back to the virus, an excluded cause. Courts summarily find no coverage in those cases where the virus exclusion has an anti-concurrent cause clause (and such a clause is permissible in that particular state).

We are not so certain the application of the virus exclusion to COVID-19-related cases is as straightforward as these court decisions suggest, especially those involving losses caused by governmental orders.[199] We are reminded of the similar path taken by courts first interpreting another seemingly impenetrable exclusion: the absolution pollution exclusion.[200] We might suggest that a more nuanced, contextual approach to the ISO virus exclusion is at least warranted, paying attention to drafting and underwriting history and what was meant in that 2006 ISO circular sent to insurance regulators. No court to date has examined what insurers actually meant to exclude in 2006 and how that plays out—or not—in the property insurance context of the 2019–2020 COVID pandemic. Keep in mind—the 2006 ISO virus exclusion was drafted in response to the SARS crisis, a very different disease scenario without the marked and intermittent governmental closures of the COVID-19 pandemic. It may be that, after such an analysis, the exclusion does exclude most if not all COVID-19-related business interruption losses. But we think it is at least intellectually honest to run the gauntlet with it, as was done with the absolute

But see Elegant Massage, LLC v. State Farm Mut. Auto. Ins. Co., No. 2:20-cv-265, 2020 WL 72496234 (E.D. Va. Dec. 9, 2020) (applying Virginia law) (holding virus exclusion not applicable because cause of loss for massage spa is government closure order, not virus); Taps & Bourbon on Terrace, LLC v. Underwriters at Lloyds London, No. 20093025, 2020 WL 6380449 (Pa. Com. Pl. Oct. 26, 2020) (Trial Order) (refusing to dismiss case at pleadings stage, even though virus exclusion at issue).

[199] At least one court appears to have had the same concerns, although in a context where the complete insurance policy was not supplied to the court. In Urogynecology Specialist of Fla., LLC v. Sentinel Ins. Co., No. 6:20-cv-1174-Orl-22EJK, 2020 WL 5939172 (M.D. Fla. Sept. 24, 2020) (applying Florida law), the court allowed the policyholder's case to proceed, despite the presence of a virus exclusion, because the court surmised that COVID-19 may be different than other "virus"-type claims and perhaps it may be inappropriate to lump it in with other environmental pollutants like fungi, bacteria, or dry rot.

[200] *See* Jeffrey W. Stempel, *Reason and Pollution: Correctly Construing the "Absolute" Pollution Exclusion in Context and in Accord with Its Purpose and Party Expectations*, 34 TORT & INS. L.J. 1 (1998); Jeffery W. Stempel, *Unreason in Action: A Case Study of the Wrong Approach to Construing the Liability Insurance Pollution Exclusion*, 50 FLA. L. REV. 463 (1998).

pollution exclusion before it (recall that exclusion was eventually found wanting, and certainly did not merit as broad an application as insurers enjoyed in the early years of the exclusion).

However, incredibly, a number of courts have dismissed cases at the pleadings stage because of a cursory read of the virus exclusion and, in so doing, also denied specific policyholder requests for discovery about the ISO virus exclusion and its genesis.[201] After raising what appear to be reasonable queries about what the ISO circular was meant to do, policyholders are apparently faced with a door slammed shut about further factual discovery on the issue. Still other courts have preferred instead to offer—without the assistance of any evidence or context beyond pleadings—their own guesses as to what the boundaries of the exclusion surely must be.[202]

Most noteworthy perhaps is this question: if a policy does not include a virus exclusion, must that then be taken to mean that it covers virus-related losses?[203] Such virus exclusion language has been available since 2006, in direct response to the SARS pandemic. If an insurer has not specifically excluded viruses as a cause of loss, then pandemic-related losses resulting from virus contamination or civil authority orders attempting to quell virus spread would appear to be within the concept of covered losses (as long as the policyholder can prove there was a "direct physical loss of or damage to" covered property).

A. Cases Without a Virus Exclusion

In those cases without a virus exclusion, courts did not outright dismiss the policyholder's claim and instead at least inquired about the potential for "physical loss or damage." Unlike the policyholders in *Studio 417*, the policyholder in *Mudpie, Inc. v. Travelers Casualty Insurance Company. of America*[204] did not allege the virus

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[201] *See, e.g.*, Mortar & Pestle Corp. v. Atain Specialty Ins. Co., No. 20-cv-03461-MMC, 2020 WL 7495180 (N.D. Cal. Dec. 21, 2020) (applying California law) (denying restaurant policyholder leave to discover genesis of ISO form and circular); Boxed Foods Co. v. Cal. Capital Ins. Co., No. 20-cv-04571-CRB, 2020 WL 6271021 (US Dist. Ct., N.D. Cal.) (applying California law) (denying discovery request about ISO circular and virus exclusion genesis on dismissal).

[202] *See, e.g.*, LJ New Haven LLC v. AmGUARD Ins. Co., No. 3:20-cv-00751 (MPS), 2020 WL 7495622 (D. Conn. Dec. 21, 2020) (applying Connecticut law) (citing ISO circular policyholder submits that exclusion likely limited to "on contact" or "on surface" contamination only; court disagrees and chastises policyholder for importing what is not in the policy (despite clause being an exclusion!)).

[203] *See* French, *supra* note 4.

[204] 2020 WL 5525171 (applying California law).

entered the property. Its business interruption claim rested solely on the governmental "stay at home" order in effect. Thus, the policyholder's putative class action was dismissed. The court held that the lead plaintiff policyholder, a children's clothing store, did not lose its property nor did it have that property damaged by the virus.

The court took a broad view of "direct physical loss of or damage to" property, in that it would consider loss of functionality as triggering coverage without requiring physical alteration of the property. However, to qualify for coverage, a policyholder would have to prove some intervening physical force made the premises uninhabitable or unusable (as was the case in *Gregory Packaging* with the ammonia).

The court did not accept that loss of property functionality or access due to governmental orders equated to "direct physical loss;" the policyholder could go back to its property after the "stay at home" order ended. Loss of use was thus held to be not a direct physical loss in this instance. The court distinguished this claim, based solely on the governmental order causing a loss of use, from that in *Studio 417* where the claimants had alleged actual physical virus microbes damaged the inside of their premises, rendering it unusable.

The court also denied coverage under the civil authority provisions of the store's policy because it found no causal link between any damage to adjacent property and the subsequent denial of access to the store. Because the "stay at home" orders were preventative, and did not involve actual physical damage, there was no causation between the policyholder's business losses and the government closure order.

The policyholder restaurant in *Malaube, LLC v. Greenwich Insurance Company*[205] alleged that Miami's order to close all restaurants to indoor dining (and thus permit only takeout and delivery) as a result of COVID-19, plus the Florida governor's statewide executive order closing all dining on-site restaurants, both resulted in prohibited access to its restaurants and thereby interrupted its business income. The policyholder argued that the full use of its property was limited by the government orders. The case did not survive a motion to dismiss.

The court cited ***Mama Jo's, Inc***. and *Source Foods* and held that, under Florida law, an actual, tangible change in insured property must accompany a claim for coverage for "direct physical loss of or damage to" insured property. It distinguished the *Studio 417* case because, in that case, the policyholders alleged the actual presence of virus microbes on the property. The only allegations of loss in *Malaube* involve losses arising from the two Florida emergency orders. Because

[205] No. 20-22615-CIV, 2020 WL 5051581 (S.D. Fla. Aug. 26, 2020) (applying Florida law).

there was no physical intrusion of the property that resulted in an actual physical change to the property, under the ***Mama Jo's/Source Foods*** line of authority, the court held there was no potential for coverage and the claim was dismissed.

A similar result was reached in ***Rose's 1 LLC v. Erie Insurance Exchange***,[206] on a motion for summary judgment in the Superior Court of the District of Columbia. Some DC restaurants were seeking business interruption coverage based on the DC mayor's order that closed all non-essential businesses (which included the restaurants) and told residents to stay inside except for essential reasons. The court held that there were no cases in this jurisdiction where a government edict, standing alone, is considered a direct physical loss, thereby triggering coverage, unless there was some physical damage to property. The court relied on *Brothers., Inc. v. Liberty Mutual Fire Insurance Company*,[207] a case where coverage was denied after a curfew was imposed in DC following riots after Martin Luther King's assassination. The curfew was held to be preventative in nature, and not a result of any physical damage to property. In fact, the point of the curfew was to prevent physical damage to property, so coverage could not possibly be triggered, according to the court.

The San Diego barbershop policyholder in *Pappy's Barber Shops, Inc. v. Farmers Group, Inc.*[208] had its claims for business interruption and civil authority coverage dismissed. The policyholder alleged that the local order banning non-essential gatherings plus then the state-wide "stay at home" order resulted in direct physical loss of or damage to their insured property. The policyholder argued that the precautionary measures taken by the government were the cause of the loss, not the actual presence of virus on any physical surface. The court held that the governmental orders did not prohibit access to the policyholder's place of business and the orders were not issued due to direct physical loss of or damage to either the policyholder's property or other property. Because there were no allegations of what the court considered were direct physical loss or damage, the claim was dismissed.

The overarching pattern is that cases without a virus exclusion at least prompt the courts to grapple with whether or not coverage is to be had for "direct physical loss of or damage to property." Nearly all cases which did not feature a virus exclusion have denied coverage if the policyholder did not allege actual physical loss on the premises.[209] And of course most right-thinking policyholders

[206] 2020 WL 4589206 (D.C. Super. Ct. Aug. 6, 2020).

[207] 268 A.2d 611 (D.C. 1970).

[208] No. 20-CV-907-CAB-BLM, 2020 WL 5500221 (S.D. Cal. Sept. 11, 2020) (applying California law).

[209] *See, e.g.*, Infinity Exhibits, Inc. v. Certain Underwriters at Lloyd's London, No. 8:20-cv-1605-T-30AEP, 2020 WL 5791583 (M.D. Fla. Sept. 28, 2020) (applying Florida law) (relying on Mama Jo's court requires actual physical damage for coverage; case dismissed

could not allege such loss because to do otherwise would bring the claim squarely within the virus exclusion. So, the common route taken by policyholders—if unsuccessful to date—has been to argue that the governmental orders closing or limiting property access are the cause of the business interruption loss, and not the virus.

B. CASES WITH A VIRUS EXCLUSION

As stated, insurers have been successful in having those cases that featured a virus exclusion dismissed by courts. In probably the earliest claim focusing on pandemic-related losses, a Michigan state court granted the insurer's motion to dismiss the policyholder's claim for business interruption losses in *Gavrilides Management Company v. Michigan Insurance Company*[210] The policyholder in that case owned two restaurants and alleged that it lost revenue due to COVID-19 related closure orders and restrictions. The court held that, because the restaurants only alleged loss of use of their facilities, and not physical loss or damage, the restaurants did not suffer any covered loss. The virus exclusion in the policy operated to oust coverage regardless of whether there had been direct physical loss or damage to property.

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as no facts plead to show physical property damage); Uncork & Create LLC v. Cincinnati Ins. Co., No. 2:20-cv-00401, 2020 WL 6436948 (S.D.W. Va. Nov. 2, 2020) (applying West Virginia law) (distinguishing Studio 417 as there was alleged virus contamination in that case; however, court goes on to state that even if virus was present, coverage would likely not attach as premises can be cleaned); Oral Surgeons, PC v. The Cincinnati Ins. Co., No. 2-20-CV-222-CRW-SBJ, 2020 WL 5820552 (S.D. Iowa Sept. 29, 2020) (applying Iowa law) (finding no allegations of direct physical loss); Promotional Headwear Int'l v. Cincinnati Ins. Co., No. 20-cv-2211-JAR-GEB, 2020 WL 7078735 (D. Kan. Dec. 3, 2020) (applying Kansas law) (declining to accept allegations that virus contaminated property court cites to Source Food and Mama Jo's to require physical alteration); Water Sports Kauai, Inc. v. Fireman's Fund Ins. Co., No. 20-cv-03750-WHO, 2020 WL 6562332 (N.D. Cal Nov. 9, 2020) (applying Hawai'ian law) (distinguishing Studio 417 and Mudpie, where actual threats of contamination were alleged, court finds no actual exposure at stores in this case); Terry Black's Barbecue, LLC v. State Auto. Mut. Ins. Co., No. 1:20-CV-665-RP, 2020 WL 7351246 (W.D. Tex. Dec. 14, 2020) (applying Texas law) (finding no allegations of virus on property; assuming virus there, it does not cause physical loss and can be cleaned); S. Fla. ENT Assocs, Inc. v. Hartford Fire Ins. Co., No. 20-23677-Civ-WILLIAMS/TORRES, 2020 WL 6864560 (S.D. Fla. Nov. 13, 2020) (applying Florida law) (finding no allegations of virus presence); Kirsch v. Aspen Am. Ins. Co., No. 20-11930, 2020 WL 7338570 (E.D. Mich. Dec. 14, 2020) (applying Michigan law) (finding no allegations of virus on property).

[210] No. 20-000258-CB (Mich. Cir. Ct., Ingham Cty. July 1, 2020).

In *Diesel Barbershop LLC v. State Farm Lloyds*,[211] a U.S. District Court in the Western District of Texas dismissed the policyholder barbershop's claims for pandemic-related losses. The policy featured a fungi, virus or bacteria exclusion, which had an anti-concurrent cause clause:

> 1. We do not insure under any coverage for any loss which would not have occurred in the absence of one or more of the following excluded events. We do not insure for such loss regardless of:
>
> (a) the cause of the excluded event; or
>
> (b) other causes of the loss; or
>
> (c) whether other causes acted concurrently or in any sequence with the excluded event to produce the loss; or
>
> (d) whether the event occurs suddenly or gradually, involves isolated or widespread damage, arises from natural or external forces, or occurs as a result of any combination of these:
>
> **j. Fungi, Virus Or Bacteria**
>
> . . .
>
> (2) Virus, bacteria or other microorganism that induces or is capable of inducing physical distress, illness or disease.

The policyholder sought business interruption coverage for COVID-related losses due to the state and county orders restricting access to, or closing altogether of, non-essential businesses. The court preferred the line of cases requiring a direct tangible injury in order to trigger property coverage for a "direct physical loss." It held that Texas law would mandate there be a tangible injury for coverage to be triggered. The policyholder did not allege that the virus was physically on its property and caused tangible harm. Rather, it alleged that the cause of its loss was the governmental orders restricting access to its properties. This was not sufficient to create the potential for coverage as no direct physical loss or damage was alleged, according to the court.

Regardless as to the issue of direct physical loss, the court found that the virus exclusion and its anti-concurrent cause clause would prohibit both business interruption and civil authority coverage for the policyholder. The underlying root cause of the alleged losses was the virus—an excluded cause—according to the court because the virus was the reason for the orders to be issued by the state and county in the first instance.

[211] No. 5:20-CV-461-DAE, 2020 WL 4724305, at *5 (W.D. Tex. Aug. 13, 2020) (applying Texas law).

The key to the court's reasoning in *Diesel Barbershop* was the view that the virus exclusion negated any possibility for coverage for COVID-19 related losses. The court also preferred to interpret "direct physical loss" as requiring not only a tangible injury to the property in question but a physical injury of sufficient magnitude that the property had been permanently structurally altered—an injury not alleged by the policyholder in that case.

A similar result to *Diesel Barbershop* was reached in *Turek Enterprises, Inc. v. State Farm Mutual Automobile Insurance Company*[212] in a motion to dismiss heard in the U.S. District Court for the Eastern District of Michigan. In that case, a chiropractic clinic's claim for business interruption coverage was dismissed. The clinic claimed for losses due to its inability to access its property as a result of governmental "stay at home" orders. Like *Diesel Barbershop*, the property policy in *Turek* had a similar virus exclusion with an anti-concurrent cause clause. The policyholder clinic specifically argued that COVID-19 virus particles did not attach to or damage any property (presumably to get around the virus exclusion). The court found that this case was similar to the *Source Food* case, in that there was no contamination of the insured property and therefore no possibility of coverage.

The court in *Turek* distinguished *Studio 417* and preferred the reasoning of *Diesel Barbershop* and *Gavrilides Management Company LLC v. Michigan Insurance Company*[213] in holding that Michigan law required a tangible injury to property to trigger the "direct physical loss or damage" coverage clause. The court did not accept the policyholder's argument that COVID-19 was not the proximate cause of the loss and the virus exclusion was only limited in its applicability to the costs of decontamination. Instead, the court held that the governmental orders preventing property access were not the sole cause of the policyholder's loss—the virus was also a cause, thus triggering the anti-concurrent cause portion of the virus exclusion. The court made this holding despite the policyholder raising the fact that the 2006 ISO virus exclusion circular submitted to insurance regulators indicated that the exclusion was meant to preclude losses due to contamination by disease-causing agents.

[212] No. 20-11655, 2020 WL 5258484 (E.D. Mich. Sept. 3, 2020) (applying Michigan law).

[213] No. 20-000258-CB (Mich. Cir. Ct., Ingham Cty. July 1, 2020) (holding that, when a city order prevented customers from dining in the restaurant, it did not suffer a direct physical loss because there was no physical alteration or tangible damage to the integrity of the building).

Similarly, in *10E, LLC v. Travelers Indemnity Company of Connecticut*,[214] a restaurant in downtown Los Angeles had its claim for business interruption and civil authority-related losses dismissed on motion after it alleged that the Los Angeles Mayor's public health restrictions prohibiting in-person dining at restaurants resulted in lost income. The insurance policy in this case had an exclusion for losses due to virus and bacteria.[215]

The court held that there was no direct physical loss or damage triggering coverage as nothing physically changed in the property. Under California law, the court held that losses from inability to use property do not amount to "direct physical loss of or damage to property." A distinct, demonstrable physical alteration to the property is required for coverage to attach. Furthermore, the court held that temporary impairment to property does not equate to direct physical loss. The policyholder's civil authority claim was dismissed because the virus exclusion ousted coverage for COVID-19 related losses. The government-ordered dining restrictions were entirely attributable to the virus, an excluded cause. Additionally, the court found that no particular adjacent property was damaged so the civil authority coverage could not be triggered in the first place.

The court in *Martinez v. Allied Insurance Company of America*[216] dismissed a dental office's claim for business interruption insurance because the policy contained a virus exclusion.[217] The policyholder claimed that the COVID-19 virus and Florida's emergency shutdown orders, including orders limiting non-essential dental procedures, caused the interruption of its income stream. It also alleged damages due to decontamination of its office. The court dismissed the claim solely on the language of the virus exclusion by holding that all of the office's losses were related to the virus, an excluded cause of loss. This is, in fact, the predominant pattern of courts faced with the virus exclusion when deciding pandemic-related coverage issues: a knee-jerk dismissal.

In perhaps the most shocking example of all, the United States District Court for the Western District of Missouri in *Zwillo v. Corporation. v. Lexington Insurance*

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[214] No. 2:20-cv-04418-SVW-AS, 2020 WL 5359653 (C.D. Cal. Sept 2, 2020) (applying California law).

[215] *Id.* at *1 (noting that the policy reads, "We will not pay for loss or damage caused by or resulting from any virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease.").

[216] No. 2:20-cv-00401-FtM-66NPM, 2020 WL 5240218 (M.D. Fla. Sept. 2, 2020) (applying Florida law).

[217] *Id.* at *3 (noting that the exclusion was for loss or damage caused "directly or indirectly," by "[a]ny virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease.").

Company[218] dismissed a policyholder's claim based on an extremely broadly worded pollution exclusion which included the word "virus" in a long list of possible pollutant contaminants. The court distinguished the *Studio 417*, *KC Hopps*, and *Blue Springs Dental* cases—cases in its own district!—on the basis that the word "virus" was here in an all-encompassing pollution exclusion and not a stand-alone "virus" exclusion. The court did not accept the policyholder's arguments that this pollution exclusion was obviously aimed at environmental or industrial pollution, not pandemic-related losses.

Where cases to date have ruled in favor of an insurer based on knee-jerk embrace of a faulty concept of direct physical loss or injury, the courts may nonetheless have blundered toward the right result in some situations involving the virus exclusion—if insurers win the causation battle. We think that is a big "if" but realize courts may decide to the contrary. If that becomes the majority rule, observers will tend to minimize the significance of judicial decisions construing the physical loss or injury trigger, at least where there is a virus exclusion. Notwithstanding this, we remain critical of the "no direct physical loss or damage" decisions even if they can be defended on the "no harm, no foul" grounds of a more persuasive basis such as the virus exclusion.

But it is far from clear how many policies at issue actually contain a virus exclusion or how that exclusion operates in all loss scenarios. Insurers have promoted the view that nearly all policies contain the exclusion but a quarter of the case law to date involves policies with no such exclusion. Consequently, better juridical reasoning regarding loss and damage may make thousands of policies and millions of dollars in coverage available to policyholders.

VI. CONCLUSION

Insurers have won the bulk of the early COVID coverage battles, with analysis in too many of these early decisions that mangles fundamental insurance policy interpretation doctrine. Fortunately, there is a cluster of better reasoned cases that one hopes will be persuasive to the appellate courts that will ultimately determine the outcome of the COVID coverage war.

The insurance industry's media thrust at the early stages of the COVID pandemic which pushed the no-coverage-for-COVID message appeared to set the stage for the early salvo of claim dismissals from courts across the country. Whether due to media influence or simple subpar analysis, many court decisions fall short in that they have, in varying degrees:

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[218] No. 4:20-00339-CV-RK, 2020 WL 7137110 (W.D. Mo. Dec. 2, 2020) (applying Missouri law).

a) ignored or wrongfully rejected state law precedents regarding the "direct physical loss or damage" coverage trigger;
b) read pro-insurer precedents too broadly, failing to distinguish the ubiquity, reach, and impact of COVID as compared to the more distant and non-physical loss of these precedents;
c) ignored or summarily distinguished similarly analogous cases of insurance coverage for contaminating substances, precedents which would have provided helpful guidance on the insurance coverage issue for COVID-related losses;
d) artificially distinguished insurance policy wording from the wording in past precedents when, in fact, the relevant policy wording is identical to the cases at hand;
e) provided no reasoning as to why one line of coverage cases is preferred over another;
f) fallen into a hyper-literalist dictionary-based argument which cherry-picks only certain dictionary definitions and ignores others which run counter to the conclusions reached;
g) refused to even consider insurance policy term ambiguity in the wake of conflicting dictionary definitions and case precedents, thereby failing to invoke the policyholder-friendly tools of insurance policy interpretation: *contra proferentem* and reasonable expectations;
h) refused to read pleading allegations at face value and as presumptively true, as required at the motion to dismiss stage of litigation; and,
i) dispensed with policyholder claims without any further factual findings or discovery, at the pleadings stage, in a context where factual knowledge of the COVID-19 virus is evolving on a near-daily basis, and where allegations should be enough to get the policyholder in the door of the litigation system.

In response to this list, insurers would certainly argue that the presence of a virus exclusion in the cases on which they have prevailed validates dismissal[219] even

[219] And, as reflected in the tally of decisions to date, courts are receptive to this insurer argument. *See* Baker, *supra* note 10; Erin Ayers, *Insurers Prevail in Two More COVID-19-related BI Lawsuits*, ADVISEN, (last visited Jan. 25, 2020) https://www.advisen.com/tools/fpnproc/fpns/articles_new_1/P/376369872.html?rid=376369872&list_id=1 (discussing Tracker findings); Mike Curley, *Travelers Ducks Counterclaims*

if judicial analysis of the loss or damage questions has been unduly abrupt and reductionist. We reject a "no harm, no foul" justification because there is harm when courts warp prevailing contract and insurance law in a rush to judgment.[220] In particular, the collapsing and narrowing of the concepts of directness, physicality, loss and damage sets unwise precedent sure to wrongfully deprive policyholders of coverage in future non-COVID cases. If the virus exclusion is conclusive, bully for insurers—but if that is the case, decisions should be made on the basis of this express exclusion rather than tortured reasoning about loss and damage.

The judiciary's excessively textual focus-cum-myopia also unnecessarily raises doubts about the correctness of the decisions. If it is fact correct that there cannot be loss or damage without structural change in tangible property or that the concept of damage requires a particularized showing of viral contamination of specific surfaces, one would expect supporting evidence in the drafting history of property policies or similar materials providing context and illuminating the policy purpose and coverage intent. But overconfident hermeneutics-lite decisions in favor of insurers deprive policyholders, the judicial system, and society of access to materials that can determine whether a court's reading of policy verbiage is correct.

Ironically, this type of background information might support the insurer position. The drafting history of the standard ISO virus exclusion, for example, does strongly suggest that insurers were seeking to avoid contamination liability, although the case against civil authority shutdown is less clear.[221] We understand that insurers, who think they can consistently win drafting wars, are reluctant to concede the usefulness of contextual materials and undermine future arguments seeking to restrict court consideration to only policy text. But the insurers' long term

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in Geragos COVID-19 Suit, LAW360, (last visited Jan. 25, 2020) https://www.law360.com/articles/1321151/travelers-ducks-counterclaims-in-geragos-covid-19-suit (California federal district court finds "a virus exclusion in [law firm] policy bars coverage.").

[220] In addition, it appears that many insurance policies lack a virus exclusion. *See* Baker, supra note 10 (last visited Oct. 21, 2020) (noting that in cases with decisions, one-fifth of policies lack virus exclusions); Josh Czaczkes, et. al., ***Why We Don't Need COVID-19*** *Immunity Legislation,* BALKINIZATION (Sept. 26, 2020), https://balkin.blogspot.com/2020/09/why-we-dont-need-covid-19-immunity.html (noting that the majority of general liability insurance policies lack virus exclusion). In the rush to enact limitations on liability for COVID claims, state legislatures appear not to have investigated the prospect that such limitations on liability inure to the benefit of insurers rather than policyholders, at least in the short term. Insurers would presumably argue that in the absence of such legislation, they will be force to raise premiums or restrict coverage.

[221] *See* ISO VIRUS EXCLUSION, *supra* note 25.

agenda should not strangle immediate judicial decision-making. Courts interested in correctly deciding COVID coverage cases would presumably be interested in seeing this material rather than making it moot through a Rule 12 dismissal.

Apart from its possible (we think probable) infection of the judiciary, the insurance industry's public relations narrative is troubling. The insurance industry claims that COVID coverage is a death knell even though it also claims that nearly all policies provide only four weeks of civil authority coverage while all policies of course have policy limits and perhaps even other sub-limits on business interruption coverage or applicable exclusions as well as conditions that policyholders may fail to meet. In light of the liability limiting tools at their disposal, the insurer claims of imminent poverty if COVID is covered seems melodramatic.

The insurer claim of disaster rings particularly hollow in light of the European experience more receptive to coverage. While insurer profitability may have declined for the moment, the insurance industry remains alive and well in both the E.U.[222] and the U.K., where a key test case went well for policyholders.[223] And in the U.S., insurers appear to be doing just fine in spite of—or in some cases because of—the pandemic.[224]

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[222] *See* ***Munich Re Reports €800M of COVID**-19-Related Losses During Q3*, INS. J. (Oct. 21, 2020), https://www.insurancejournal.com/news/international/2020/10/21/587446.htm. Although 800 million euros is of course a good deal of money, it is not the hundreds of billions of dollars American insurers claim they will lose (allegedly each month) if COVID business interruption claims must be paid. The Munich Re experience thus suggests that policy limits, sub-limits, and specific exclusions give carriers substantial economic protection eve if their defenses of no-direct-physical-loss-or-damage are rejected by courts.

[223] *See* Carolyn Cohn & Kirstin Ridley, *London Court Rules Some Insurers Should Not Have Denied Business Interruption Claims*, INS. J. (Sept. 15, 2020), https://www.insurancejournal.com/news/international/2020/09/15/582641.htm (describing Financial Conduct Authority v. Arch Insurance (UK) Ltd, [2021] UKSC 1.

[224] *See* Leslie Scism & Allison Prang, *Travelers More Than Doubles Quarterly Income*, WALL ST. J. (Oct. 20, 2020), https://www.wsj.com/articles/travelers-profit-rose-in-third-quarter-11603192181 (noting Traveler's $827 million third quarter profit compared to $396 million in 2019, which included $400 million in subrogation revenue from claims against Pacific Gas & Electric in connection with California fires; and how Travelers stock rose by $3.12 per share). Travelers was also aided in that its auto insurance business did better than usual because of pandemic-stimulated reductions in driving and hence in collisions. We realize that property insurance is expected to have a less successful 2020 than auto or liability insurance but note that insurers have multiple means of enduring difficult times and profiting over the proverbial long-haul, where their longevity records is considerably better than that of their small business policyholders.

Meanwhile, business policyholders appear to be experiencing the type of debacle insurers claim they face if coverage claims succeed. Insurers seem to sing this tune with ease when threatened. We have heard it before regarding asbestos, pollution, product liability, bad faith, and punitive damages claims. But even the massive asbestos mega-tort, Superfund, and other pollution claims—not to mention the credit swap defaults of the Great Recession—did minimal long-lasting damage to insurers and their ability to accumulate capital and regain profitability. In times of such stress, many more policyholders than insurers fail.

Although insurer claims of industry-wide doom tend to ring hollow, their means of survival is not without collateral consequence. The asbestos, pollution, and Superfund coverage wars produced broad exclusions in standard policies and made coverage more expensive and difficult (but not impossible) to obtain. COVID-19 will surely spur restrictions of coverage and increases in premiums—but this is likely even if insurers prevail in today's coverage battles.

The immediately relevant question is whether today's policyholders seeking coverage under policies issued prior to the pandemic—particularly those lacking a virus exclusion—are entitled to coverage. Too many initial decisions on the issue have implicitly embraced a flawed insurer narrative in abruptly turning policyholders away.

What we know about delays in coronavirus testing

A doctor prepares to test a patient at a drive-through coronavirus testing center at Lehman College in the Bronx on March 28. (John Moore/AFP/Getty Images)

By **Washington Post Staff**

APRIL 18, 2020

Reports of a respiratory virus spreading in Wuhan, China, emerged in late 2019. After the number of cases outside China increased rapidly, the World Health Organization declared the novel coronavirus a pandemic on March 11.

With no cure or vaccine currently available, diagnostic testing is crucial to containing the spread of the virus.

Opportunities to mitigate the pandemic's impact in the United States were lost amid bureaucratic delays and a breakdown in efforts to produce a reliable test kit at the Centers for Disease Control and Prevention.

Here are the major developments to understand what happened:

1. Contaminated tests

The failure by the CDC to quickly produce a test kit to detect the coronavirus was triggered by a glaring scientific breakdown at the CDC's lab in Atlanta. The CDC facilities that assembled the kits violated manufacturing practices, resulting in contamination of one of the three test components used in the detection process. The troubled segment of the test was not critical to detecting the novel coronavirus, experts said. After false-positive results emerged, CDC officials took weeks to remove the unnecessary step from the kits.

2. Early warning signs on flawed testing ignored

Trump administration officials continued to rely on flawed CDC tests even as many lab scientists eager to help grew increasingly alarmed and exasperated by the federal government's actions, according to emails and documents reviewed by The Washington Post. Scientists at academic, hospital and public health labs were frustrated by the bureaucratic demands that delayed their attempts to develop alternatives to the CDC test.

3. Limited testing

The initial decision to test only a narrow set of people and delays in expanding testing to other labs gave the virus a head start to spread undetected — and helped perpetuate a false sense of security that leaves the United States dangerously behind.

Initial guidelines were so restrictive that states were discouraged from testing patients exhibiting symptoms unless they had traveled to China and come into contact with a confirmed case, when the pathogen had by that point almost certainly spread more broadly into the general population. The limits left top officials largely blind to the true dimensions of the outbreak.

4. Complicated process and paperwork

As they struggled to make the test kit work, many public health labs realized they might succeed by eliminating one of its three main chemical components. But under the Food and Drug Administration's emergency rules, they could use the test only as it was approved. Public health labs spent much of their time and energy on the FDA's paperwork and data demands to win approval for their own tests.

5. Denial and dysfunction at the highest levels of government

The Trump administration received its first formal notification of the outbreak of the coronavirus in China on Jan. 3. And yet, it took 70 days from that initial notification for President Trump to treat the coronavirus pandemic seriously. The president consistently played down the threat and became a font of misinformation and confusion. While visiting the CDC in Atlanta on March 6, Trump incorrectly stated: "Anybody that needs a test, gets a test." In fact, the nation is desperate for more testing, leading some states to conserve testing for only health-care workers.

EDITOR'S PICKS

Contamination at CDC lab delayed rollout of tests

Inside the coronavirus testing failure

Denial and dysfunction plagued U.S. government

Tracking deaths and reported cases in the U.S.

Timeline of testing delays

Late December

Reports of a new virus causing mysterious pneumonia begin to trickle out of Wuhan, China.

Jan. 3

A Chinese official officially informs CDC Director Robert Redfield of the outbreak. Redfield relays the report to Health and Human Services Secretary Alex Azar, and Azar notifies the Trump administration of the outbreak of the coronavirus.

Jan. 7

The CDC begins planning for tests.

Jan. 8

The CDC issues a health advisory informing state and local health departments about the outbreak and requesting that health-care providers ask patients with severe respiratory disease about travel history to Wuhan.

Jan. 12

Chinese authorities submit to the World Health Organization the gene sequence data of the novel coronavirus, which is shared globally.

Jan. 15

The first known person in the United States to be infected with the virus arrives in Seattle from China.

Jan. 17

Nancy Messonnier, director of the National Center for Immunization and Respiratory Diseases at the CDC, says that Japan and Thailand are already using the genetic sequence to detect cases, adding: "We at the CDC have the ability to do that today — but we are working on a more specific diagnostic.”

Jan. 20

A report from the CDC references the first positive case of the coronavirus in the United States.

The CDC's laboratory test kit for the new coronavirus. (CDC/AP) (AP)

Jan. 21

A Seattle man who had recently traveled to Wuhan is confirmed as positive for the coronavirus, becoming the first known infection case on U.S. soil. Messonnier says the CDC's test kit was used to confirm the diagnosis of the man.

Technicians begin assembling a new batch of test kits, to be sent to 26 public health labs. In coming days all but two of those labs observe false-positive reactions that invalidate the test results.

Jan. 22

Trump receives his first question about the coronavirus. Asked whether he is worried about a potential pandemic, Trump says: "No. Not at all. And we have it totally under control. It's one person coming in from China. ... It's going to be just fine."

Jan. 24.

The CDC shares the details of the U.S. test publicly.

Jan. 27

The CDC raises its travel warning to the highest level, urging U.S. citizens to avoid all nonessential travel to China.

Jan. 28

Azar touts the CDC test development: "This was really a historic accomplishment. Within one week — within one week, the CDC had invented a rapid diagnostic test."

Health and Human Services Secretary Alex Azar speaks at a news conference on Jan. 28 in Washington. With him, from left, are CDC Director Robert Redfield, CDC official Nancy Messonnier and National Institute of Allergy and Infectious Diseases Director Anthony S. Fauci. (Patrick Semansky/AP)

Jan. 30

The WHO declares the outbreak a "public health emergency of international concern."

Jan. 31

The United States declares a public health emergency, triggering "emergency use authorizations." Although this process is designed to speed the development of diagnostic tests and intended to keep the quality of testing high, it would eventually lead to delays in the development of coronavirus tests at clinical labs. The policy discouraged labs from developing in-house testing because it required the approval of the FDA to do so.

Feb. 4

The CDC receives the first "emergency use authorization" from the FDA and prepares to distribute its test more widely. The CDC will ship out about 200 test kits to labs nationwide. It is the only test kit design available in the United States.

Feb. 5

The CDC informs clinical labs of the new test kit.

Feb. 6-9

The CDC begins to distribute 90 kits to state-run health labs. Meanwhile, the WHO reports it has shipped 250,000 test kits around the world.

Feb. 8

Additional CDC test kits arrive at labs in New York, Nebraska, Colorado, Minnesota and elsewhere. By the end of the day, lab directors share bad news: They aren't working properly. Through the weekend, lab directors share notes of the test and start to realize "this could be really bad."

Feb. 10

The CDC confirms the 13th coronavirus infection in the United States. At a political rally, Trump declared the virus will go away "by April, you know, in theory, when it gets a little warmer, it miraculously goes away."

Feb. 12

The first public hint of trouble with the test kits emerges when the CDC's Messonnier mentions unspecified "issues" at the public health labs. "Some of the states identified some inconclusive laboratory results," Messonnier tells reporters. "We have multiple levels of quality control to detect issues just like this one."

Feb. 13

Azar testifies in Congress that the CDC is working with five cities to add coronavirus testing to its regular flu surveillance to see whether "there is broader spread than we have been able to detect so far." The labs are in Chicago, Los Angeles, New York, San Francisco and Seattle. However, the tests do not work.

Susan Butler-Wu, director of medical microbiology at the Los Angeles County and University of Southern California Medical Center, warns in an email in response to an inquiry from Congress: "We're screwed from a testing standpoint if this thing takes off in the US."

A technician prepares coronavirus patient samples for testing at a laboratory on Long Island on March 11. (John Minchillo/AP)

Feb. 14

The United States has 15 confirmed cases, mostly in travelers returning from Wuhan.

Feb. 15

An Association of Public Health Laboratories lab alert reports that there are issues with the CDC's instruction for testing.

Feb. 18

The CDC warns clinical laboratories across the country against testing on their own without FDA approval. Meanwhile, it has still not provided public health labs with instructions on how to modify its test to make it work properly.

Feb. 23

Timothy Stenzel, a top FDA official for regulating diagnostic devices, meets with CDC officials in Atlanta to discuss the malfunctioning test kits. Stenzel will conclude that the problems are caused entirely by the CDC's in-house manufacturing. He soon advises the CDC to assign any additional manufacturing of the kits to an outside contractor.

Feb. 24

A coalition of public health labs asks the FDA for permission to make their own tests: "We are now many weeks into the response with still no diagnostic or surveillance test available outside of CDC for the vast majority of our member laboratories."

Feb. 25

In a congressional hearing, Sen. Patty Murray (D-Wash.) presses Azar, the HHS secretary, on whether the CDC test was faulty. He denies that the test does not work. But in a news briefing going on about the same time, the CDC's Messonnier says that she was "frustrated" about problems with the test kits and that the CDC hoped to send out a new version to state and local health departments soon.

[A faulty CDC coronavirus test delays monitoring of disease's spread]

Feb. 26

The FDA commissioner sends a letter to the coalition of public health labs that had asked for permission to make tests: "False diagnostic test results can lead to significant adverse public health consequences — not only serious implications for individual patient care but also serious implications for the analyses of disease progression and for public health decision-making."

The CDC announces to public health labs that a workaround for the test has been approved.

(Sarah Cahlan, Meg Kelly, Elyse Samuels/The Washington Post)

Feb. 27

Redfield, the CDC director, testifies to the House Foreign Affairs subcommittee on Asia, the Pacific and nonproliferation that the “CDC believes that the immediate risk of this new virus to the American public is low.”

On a conference call with a range of health officials, a senior FDA official lashes out at the CDC for its repeated lapses.

Jeffrey Shuren, the FDA’s director for devices and radiological health, tells the CDC that if it were subjected to the same scrutiny as a privately run lab, “I would shut you down.”

Privately, the CDC concludes that a “much broader” effort to testing is needed.

Feb. 28

Dozens of clinical laboratory scientists from across the nation write to Congress asking for permission to create new tests, saying “this regulatory process is significantly more stringent than that required for every other virus we test for.”

Forty-seven days after the Chinese had distributed the virus’s genetic sequence, the CDC abandons the test’s once-touted third component. Messonnier announces that the component “can be excluded from testing without affecting accuracy.”

Feb. 29

The CDC announces the first U.S. death from the virus, a man in his 50s in Washington state. So far, the CDC and public health labs have tested only 3,999 people nationwide.

The FDA announces a new policy to make it easier for hospital laboratories to develop their own tests.

March 1

New York confirms the state’s first case of the coronavirus, announcing that a woman in her late 30s contracted the virus after traveling to Iran.

March 6

Trump tours the facilities at the CDC wearing a red “Keep America Great” hat. He says that the CDC tests are nearly perfect and that “anybody who wants a test will get a test.”

March 11

The WHO declares the coronavirus a pandemic.

Redfield tells the House Oversight and Reform Committee that the malfunction with the test kits was caused by either “a li” or an unspecified “biologic” factor. When pressed, Redfield says, “This is currently under an investigation at this point, and I think I’m going to leave it there.”

March 12

Anthony S. Fauci, director of the National Institute of Allergy and Infectious Diseases, testifies to Congress about the testing: “The system does not is not really geared to what we need right now,” he said. “Yes, it is a failure, let’s admit it.”

Anthony S. Fauci, director of the National Institute of Allergy and Infectious Diseases, testifies during a House Oversight and Reform Committee hearing on March 12. (Win McNamee/Getty Images)

March 13

Trump declares a national emergency.

March 27

Federal health officials green light a point-of-care coronavirus test that can provide results in less than 15 minutes, using the same technology that powers some rapid flu tests.

April 5

Lack of widespread testing in the early weeks of the outbreak means the official U.S. death toll is an underestimation. The CDC count includes only deaths in which the presence of the coronavirus is confirmed in a laboratory test.

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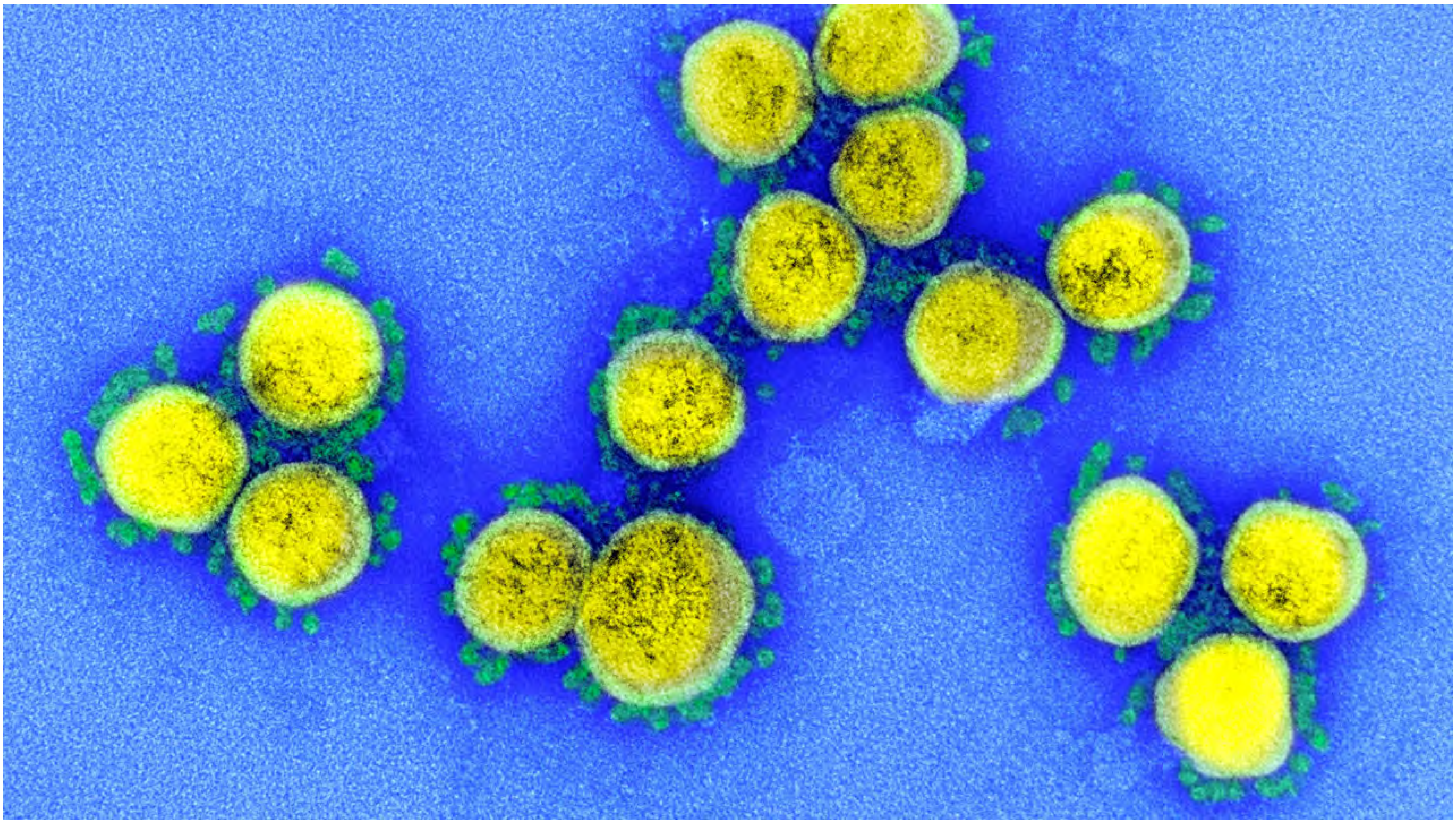
Coronavirus antigen tests: quick and cheap, but too often wrong?

Tests that detect coronavirus proteins raise hopes of widespread daily screening

22 MAY 2020 • BY ROBERT F. SERVICE



Cheap and easy antigen tests that detect proteins of the new coronavirus (yellow) in samples from a person are coming, but they aren't perfect. NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES

***Science*'s COVID-19 reporting is supported by the Pulitzer Center.**

After a painfully slow rollout of diagnostic testing for active coronavirus infections across the country, some 400,000 people a day in the United States may now receive such a test, estimates suggest. Yet a few public health experts say sending people back to work and school safely and identifying new outbreaks before they spread out of control could require testing much of the U.S. population of 330 million every day. Others suggest checking roughly 900,000 people per day would be enough.

Either way, nearly all the current tests to diagnose infections work by identifying the genetic material of the virus, a technology that will be difficult to scale up much further. "There will never be the ability on a nucleic acid test to do 300 million tests a day or to test everybody before they go to work or to school" Deborah Birx, White House coronavirus response coordinator, said at a press conference last month.

Birx and others have touted another option: antigen tests, which detect the presence of viral proteins in a biological sample, such as saliva or tissue swabbed from the nasal cavity. Antigen tests are typically cheap, return results in minutes, and, like the genetic tests, reveal an active infection. They already exist for strep throat, influenza, tuberculosis, HIV, and other infectious diseases. But so far, only one antigen test for SARS-CoV-2, the coronavirus that causes COVID-19, has received emergency use authorization from the U.S. Food and Drug Administration (FDA).

Can it or other antigen-based methods solve the testing problem? Some scientists are optimistic, whereas others remain skeptical, noting that such tests can be far less accurate than nucleic acid tests and may not be as easy to scale up as proponents claim. "What everyone wants is for a test to be cheap, accurate, and fast," says Geoffrey Baird, a laboratory medicine specialist at the University of Washington, Seattle. "You can only ever have two of those."

Developing an antigen test "is not that easy to do," says Werner Kroll, senior vice president for research and development at Quidel, a California-based company that received the greenlight from FDA for its test earlier this month. Rather than performing all the analytical steps inside an expensive dedicated machine at a lab or a doctor's office, as is done with tests for the DNA or RNA of virus, antigen tests build most, if not all, those steps into a paperlike strip that returns a simple yes or no answer, much like pregnancy tests.

"It's a lab on a swab," says Stephen Tang, president and CEO of Orasure, a diagnostics company developing its own antigen test for SARS-CoV-2. With most setups, a sample of bodily fluid is collected using a nasal swab or related procedure, then mixed with a few milliliters of a liquid, typically a sterile buffer solution. A few drops are spotted on one end of a test strip. Capillary forces pull the liquid over copies of two different antibodies specific for the same viral protein. If both antibodies spot their target—a positive test—the strip generates a signal, often a color change. This signal is generally read out by a person visually, although some setups use small readers to improve the accuracy.

What triggers the signal can differ—in some tests the antibody bindings set off a chemical reaction or expose a fluorescent marker joined to one antibody. Another test in contention for FDA approval produces an electrical readout after antibodies on an electrochemical sensor bind to their target antigen.

The challenge is finding the right antibodies, says Lee Gehrke, a virologist at the Massachusetts Institute of Technology, who has developed an antigen test for SARS-CoV-2 that E25Bio, a company he co-founded, is now evaluating. Both antibodies must bind to a single viral protein, such as the spike protein SARS-CoV-2 uses to enter cells, but at separate sites. "You have to find two antibodies that don't interfere with each other," Gehrke says. Those same antibodies also can't cross react to proteins from other coronaviruses—all of which have their own spikes, for example—or anything else. "Antibodies often stick to other things nonspecifically," Baird says.

Another challenge is weak signals. Genetic tests use the polymerase chain reaction (PCR) to amplify tagged DNA or RNA sequences, making it easy to reliably identify just a few copies of a virus. That gives PCR tests for the SARS-CoV-2 virus about a 98% sensitivity and near perfect selectivity, meaning almost every active infection is detected and only in very rare cases does someone uninfected receive a positive test. (Many false negatives, a result indicating an infected person is free of the virus, result not from the test's deficiencies, but from poor samples, which can be difficult to collect with nasal swabs.)

Antigen tests don't amplify their protein signal, so they are inherently less sensitive. To make matters worse, that signal gets diluted when samples are mixed with the liquid needed to enable the material to flow across test strips. As a result, most antigen tests have a sensitivity of anywhere between 50% and 90%—in other words, one in two infected people might incorrectly be told they don't have the virus. Last month, Spanish health authorities returned thousands of SARS-CoV-2 antigen tests to the Chinese firm Shengzhen Bioeasy Biotechnology after finding the tests correctly identified infected people only 30% of the time, according to a report by the Spanish newspaper *El Pais*.

Quidel executives say the company's initial SARS-CoV-2 test meets FDA's minimum of 80% sensitivity. (That means it could still generate false negative results 20% of the time.) A revised sample preparation protocol that doesn't require dilution of the nasal swab is expected to boost that figure to nearly 90%, but that's still below the 98% sensitivity of state-of-the-art PCR tests.

Antigen tests, however, bring advantages to the table as well. Because they don't require the expensive equipment and chemicals needed to perform PCR, they can be more easily used as point-of-care tests in doctor's offices, urgent care centers, hospitals, and even at companies and schools. They also don't require trained specialists, making them cheaper to administer—although there are a few point-of-care PCR tests, most still involve sending a sample to a lab for manual processing.

And the fast results from an antigen test mean that people who test positive can be isolated quickly, before they risk infecting others. Even if the tests have a 10% false negative rate, "people could easily be tested repeatedly, making it likely that anyone missed on the first round would be flagged on the second," says Doug Bryant, Quidel's president and CEO.

Another advantage is scalability. Once researchers settle on effective antibodies, the tests are easy to manufacture in bulk, and running them doesn't require additional reagents as PCR tests do. Quidel says it expects to ship 282,000 tests this week and 1 million tests per week by early June. Ultimately, Bryant says the company should be able to produce 84 million tests per year.

That's still well below the 300 million tests per day that would allow most every person in the United States to have a daily SARS-CoV-2 check, Birx's ambitious hope. (One recent model from the Harvard Global Health Institute said 900,000 diagnostic tests a day in the United States would be enough to have confidence most infections were being caught before an outbreak grew big.) But other companies, including OraSure, which expects to file for FDA emergency use authorization in September, say they expect to rapidly scale up to providing tens of millions of coronavirus antigen tests as well. The demand for such tests, which could cost as little as $1 or less, could be even greater in developing countries without a broad network of centralized labs.

Taken together, the advantages of antigen tests provide real hope that they "will be very valuable for stemming this pandemic," says Bettina Fries, chief of infectious diseases at Stony Brook University.

Baird and others are less confident. Not all antigen tests are as simple to read as a pregnancy test. Quidel's test requires using a $1200 toaster-size reader to achieve the relatively high sensitivity it has. And even though 43,000 Quidel readers already exist for other antigen tests, most are in the United States, making the test harder to put into use overseas.

Otto Yang, an infectious disease expert at the University of California, Los Angeles, says the tests' modest sensitivity is a bigger hurdle. Even a test with the 90% sensitivity and 100% specificity that Quidel is aiming for could misinform more than help. Assuming the virus has a prevalence of about 1% and such a test is given to 1000 people, nine people would correctly be told they are infected whereas one person would be mistakenly told they don't have the virus. Given how readily SARS-CoV-2 spreads, "a misdiagnosis is worse than no diagnosis," Yang says.

Fries doesn't agree. "Even if the sensitivity [of antigen tests] is not perfect, if you test over and over you will pick up those cases," she says. "We need to let go of the notion that all the tests have to be perfect."

Correction, 22 May.: *An earlier version of this story mistakenly identified the number of true positive and false negative results if an antigen test was 90% sensitive and 100% selective, and the presence of the virus was 1% in a population of 1000.*

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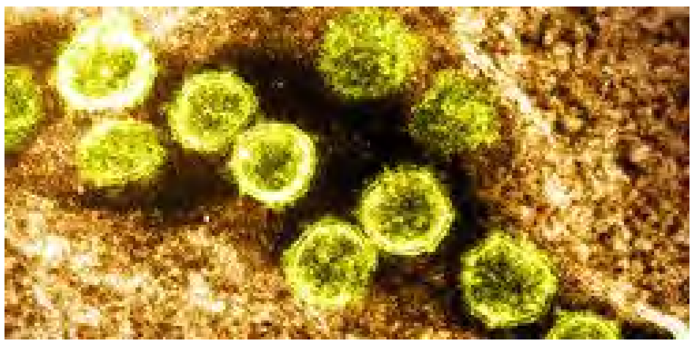

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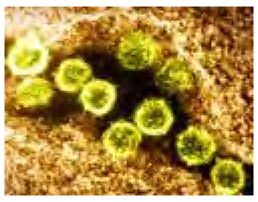

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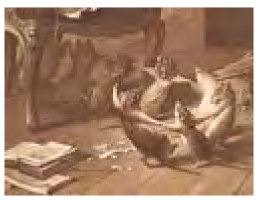

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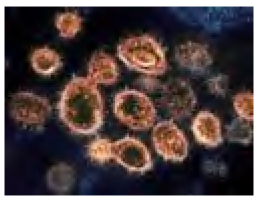

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