OLIVER WYMAN

RESPONDING TO COVID-19

Primer, Scenarios, and Implications

April 16, 2020 UPDATE

CONFIDENTIALITY

OLIVER WYMAN'S CORONAVIRUS PRIMER

This Primer lays a foundation of epidemiologic background for COVID-19, explores keys to success to disease suppression and economic impacts during the pandemic, and reviews potential therapeutic resolution of the virus

01

Epidemiologic Perspectives

Coronavirus, declared a pandemic by the WHO in March 2020, has rapidly infected millions globally

The virus displays unique and deadlier characteristics than other annual flu viruses

The pace and maturity of infection is highly variable by region, largely hinging on speed and strength of government response

02

Suppression Scenarios

Many countries have effectively pursued social distancing, aggressive testing, contact tracing and quarantine to suppress the peak of the pandemic – but preconditions to relax suppression measures (recovered system and testing/management capacity) have not been met broadly

Government policies, which must strike the balance between economy recovery and maintenance of suppression, will shape the next phases of the pandemic

03

Oliver Wyman Pandemic Navigator

OW has developed a unique time-dependent SIR model to account for containment interventions

The model produces more accurate projections due to dynamic and frequently-calibrated infection transmission and resolution rates

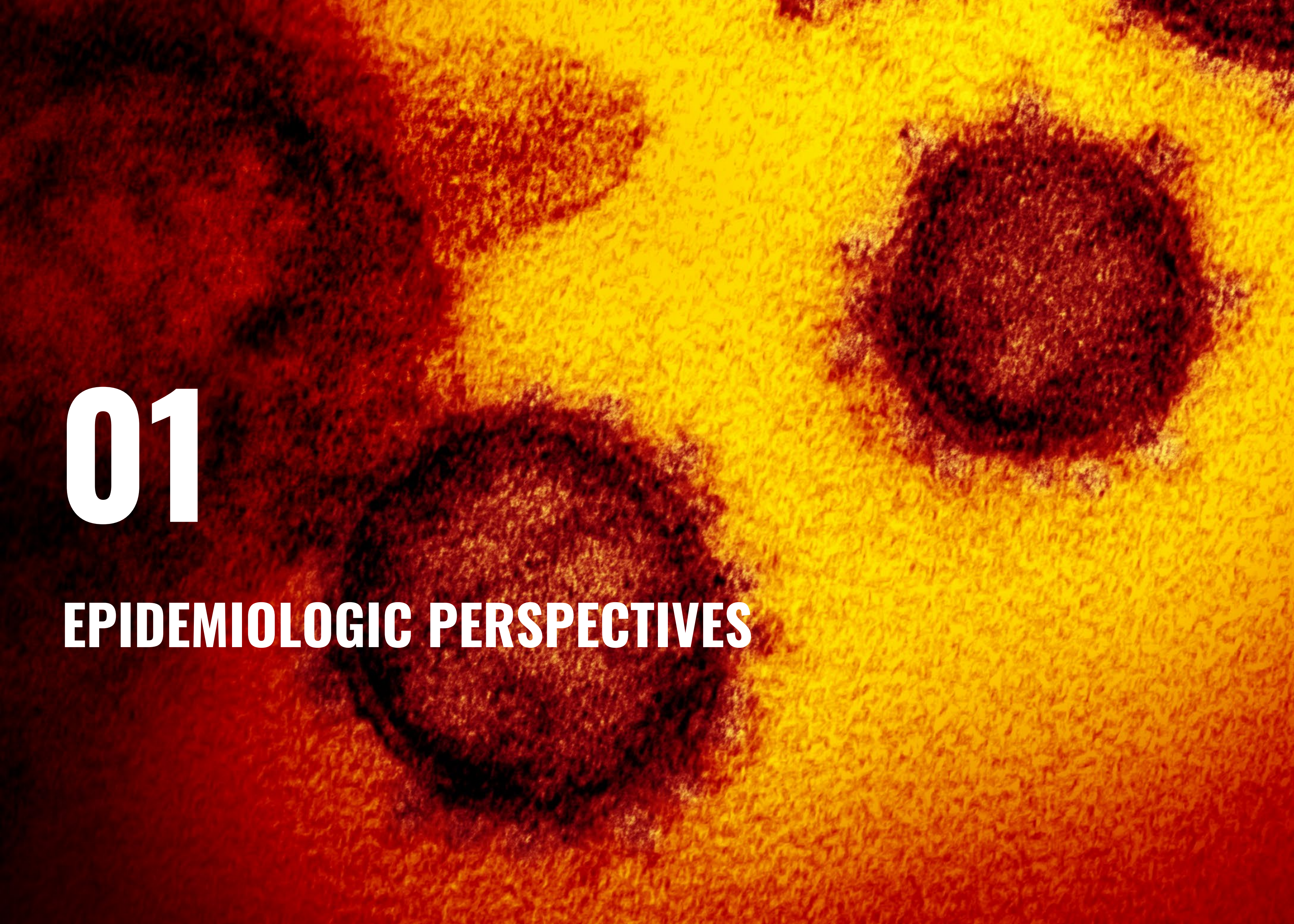
Our navigator will evolve to capture emerging data around the virus and containment approaches, among other factors

04

Vaccines & Therapeutics

Effective therapies and an eventual vaccine will be critical to bring economies and communities fully 'back to normal' -- further testing and drug development is to come, and timelines are long

In addition to typical hurdles for vaccine development, limited understanding of the immune response to COVID-19 propagates uncertainty around how and when the pandemic will resolve



01

EPIDEMIOLOGIC PERSPECTIVES

INTRODUCTION: COVID-19 PRIMER

The **novel coronavirus has infected hundreds of thousands of people globally and is taking a severe toll on individuals, families, and economies** as productivity drops and stock markets reflect increased global uncertainty

This document provides some b**aseline facts and guidance for business leaders as to critical questions to address in the immediate and near-term** to ensure the continuity of their business and the safety, health, and wellbeing of their workforce and customers

COVID-19 is the name for the illness caused by the novel coronavirus that originated in Wuhan, China in December 2019

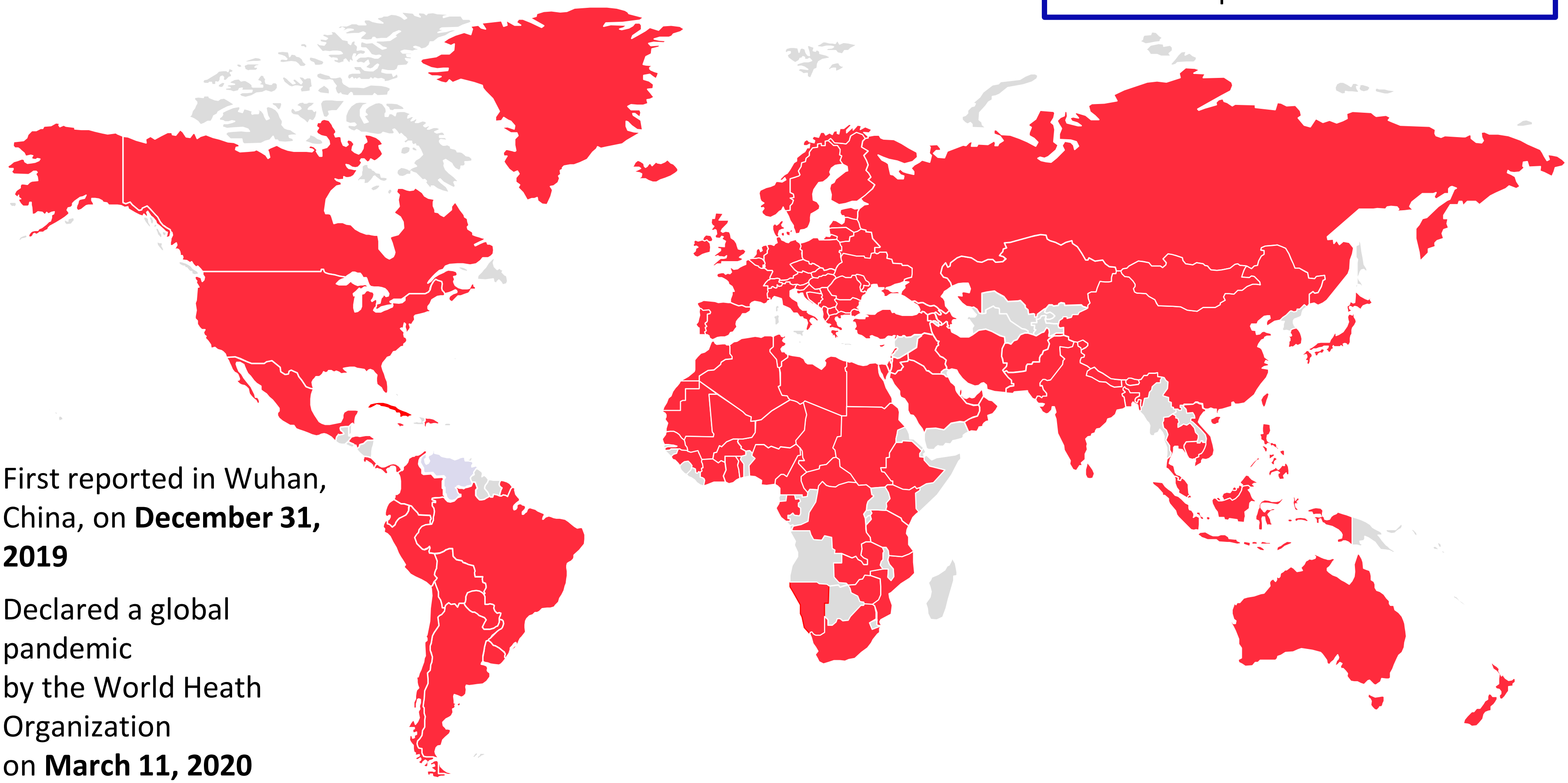
It is from the **same family of viruses that cause some common colds**, as well as Severe Acute Respiratory Syndrome (**SARS**) and Middle East Respiratory Syndrome (**MERS**)

It is considered **similar to other respiratory infections such as influenzas**; symptoms range from fever, cough, shortness of breath to more severe cases of pneumonia and organ failure

COVID-19 SPREAD GLOBALLY

As of April 16th, 2020

- >2M cases reported in 185 countries and territories
- ~138 K reported deaths



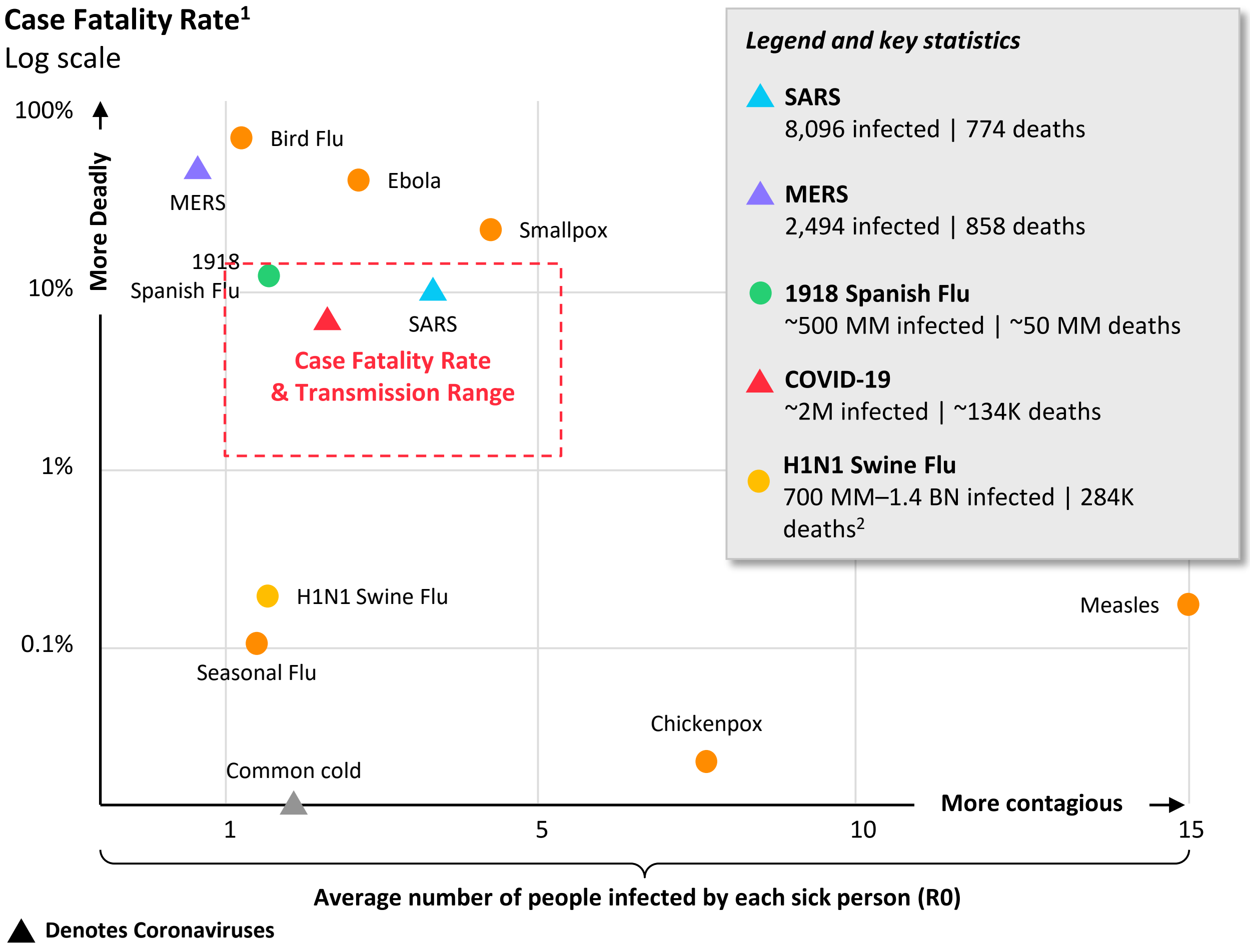
- First reported in Wuhan, China, on **December 31, 2019**
- Declared a global pandemic by the World Heath Organization on **March 11, 2020**

1. Countries included: All Countries in "European Region" Sub-region in WHO Situation Report
Source: Map from CDC (link), Numbers from John Hopkins University & Medicine (link)

Information as of 4/15/20

HOW DOES COVID-19 COMPARE TO OTHER DISEASE OUTBREAKS? (1 OF 2)

COVID-19 is currently more deadly that the Flu, but the science on transmission and mortality continues to evolve



Additional details

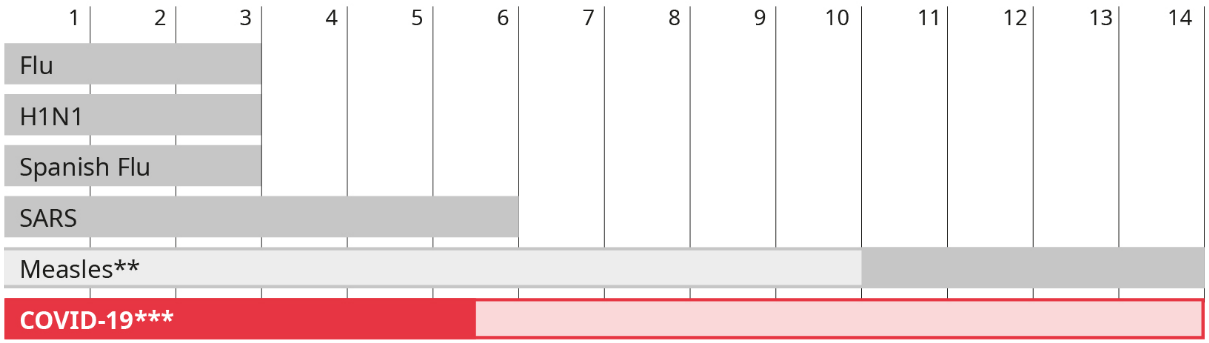
- R-naught (R0) represents the number of cases an infected person will cause
  - Initial estimates suggested COVID-19 R0 is between 2 and 3 (with edge of range estimates closer to 1.4 and 3.6), which means each person infects 2-3 others[3]; R0 for the seasonal flu is around 1.3[4]
  - New emerging estimates suggest R0 may be closer to 5.7 (edge of range 3.8-8.9)[6]
- The global case fatality rate for confirmed COVID-19 cases is currently 6.53%[5] according to WHO's reported statistics versus 0.1% for the seasonal flu; the rate varies significantly by country (e.g., Italy – 13.1%, South Korea – 2.1%[5])
- We expect case fatality rates to fluctuate as testing expands identifying more cases and as existing cases are resolved

1. New York Times (link) for fatality and R-naught comparisons, CDC timelines for case numbers (selected link: CDC SARS timeline); 2. Updated CDC estimates (link); 3. The R0 for the coronavirus was estimated by the WHO to be between 1.4 -2.5 (end of January estimate) (link), other organizations have estimated an R0 ranging between 2-3 or higher (link); 4. CDC Paper (link); 5. Calculated as Number of Deaths / Total Confirmed Cases as reported by John Hopkins University. 6. Emerging Infectious Diseases (link)

HOW DOES COVID-19 COMPARE TO OTHER DISEASE OUTBREAKS? (2 OF 2)

The infectious cycle of COVID-19 is unlike that of any other outbreak we have seen before

Incubation Timeline (Days)*, [1]



*All but SARS have the potential for asymptomatic transmission
**Symptoms most commonly appear on Days 10-14
***The median incubation period for COVID-19 is 5.5 days, but symptoms can develop as late as 14 days post exposure

Why does this matter?

- The combination of a longer incubation period with asymptomatic transmission means that there is a longer window of time during which infected individuals are unaware that they are contagious

Why is quarantine 14 days?

- While the median incubation period is 5.5 days, symptoms have been documented to occur over a longer time frame; 14 days should capture 99% of all cases[2]
- Ideally, asymptomatic individuals should be tested during quarantine to ensure they have not been infected

What do we still not know?

- We still do not accurately understand the full infectious period for COVID-19

What we know about the infectious cycle?

- Multiple sources confirm asymptomatic transmission, but the exact timing of when an exposed individual becomes contagious is not known [3, 4, 5]
- Initial reports suggest a latency period of 3 days (with substantial variability) prior to an individual becoming infectious[7]
- Viral loads build rapidly and continue to shed until 6-12 days after symptoms have cleared[6]
- New reports of patients testing positive after recovery raise more questions on potential length of infectious cycle[8]

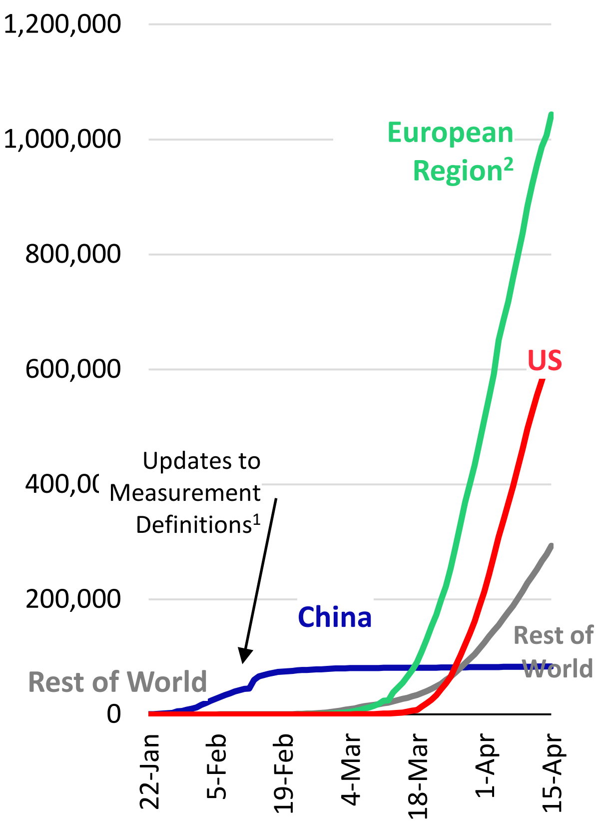
1. CDC 2. Annals of Internal Medicine (link) 3. JAMA (link) 4. NEJM (link) 5. Science (link) 6. medRxiv (link) 7. SARS-CoV2 by the numbers (link) 8. DownTo Earth (link)

Information as of 4/15/20

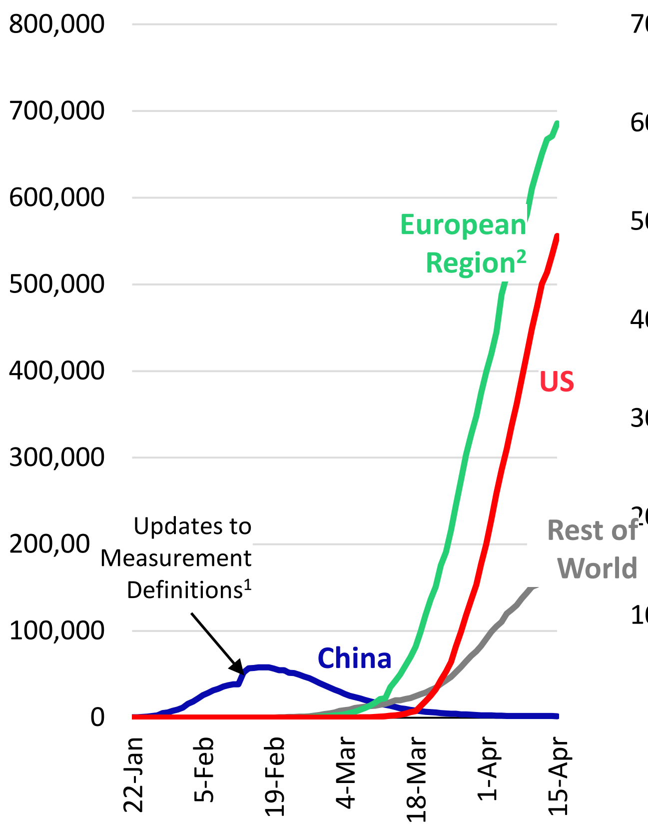
COVID-19 TRENDS AND SPREAD OF THE DISEASE

The number of new cases in China has slowed – likely due to significant containment measures – as the outbreak spreads to other countries

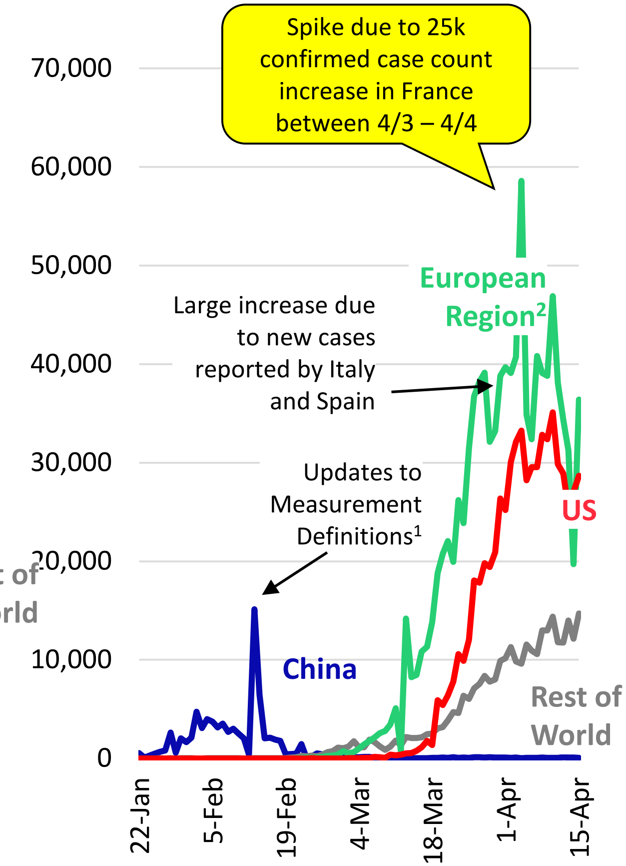
Cumulative Confirmed Cases of COVID-19



Active cases per day of COVID-19



New Cases Per Day of COVID-19



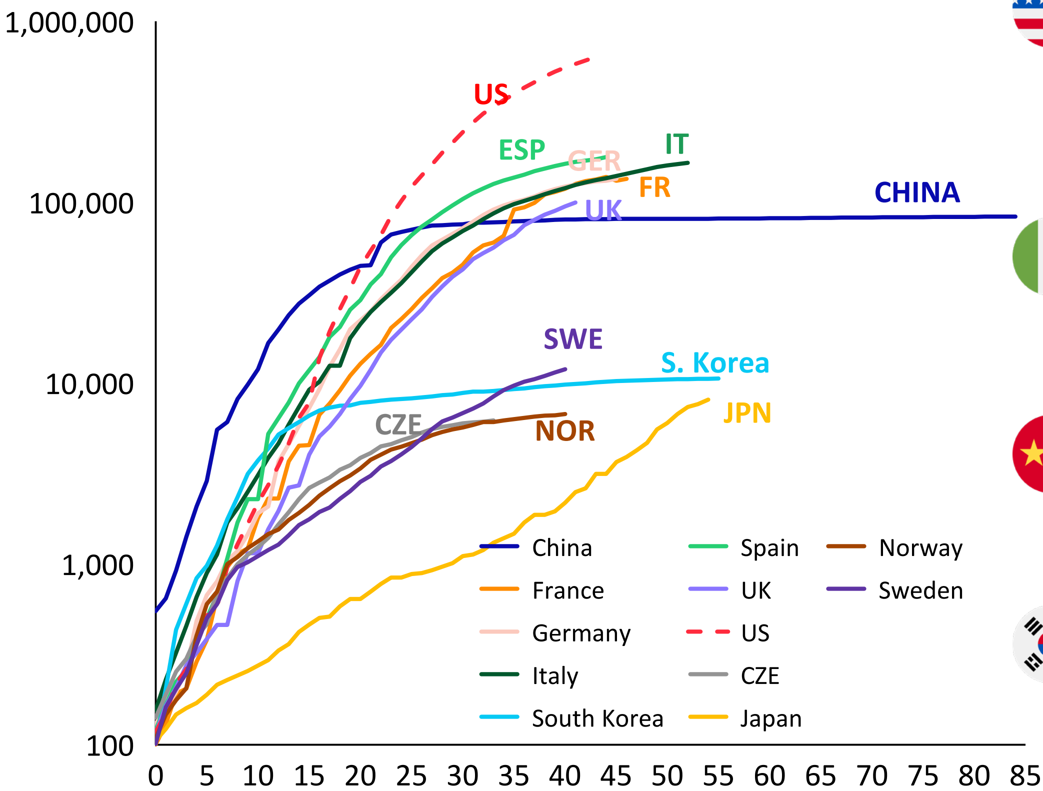
Source: John Hopkins University & Medicine Coronavirus Resource Centre

1. Until February 17, the WHO situation reports included only laboratory confirmed cases causing a spike in total cases. Some sources include this update as of February 13. The jump due to inclusion of non lab confirmed cases is not included in the new cases data in WHO situation reports.; 2. Includes countries categorized under "European region" based off of latest WHO Situation Reports

Information as of 4/15/20

MOST COUNTRIES – INCLUDING THE US – CONTINUE TO SEE EXPONENTIAL GROWTH; CHINA AND SOUTH KOREA HAVE FLATTENED THE CURVE

Cumulative confirmed cases by country
Log scale



Days since 100th confirmed COVID-19 case

- Lack of broad testing early, followed by rapid ramp-up may explain part of steep growth rate
- Response left largely to individual states, the majority of which have implemented stay-at-home orders
- Some regions with early first peaks are beginning to plan for relaxation, though no hard dates are set

- Extensive shutdown, first in Lombardy then nationwide imposed after outbreak had become unmanageable
- Relaxation of some restrictions has begun, as new cases reach a first peak and testing capacity expands

- Enforced city-wide quarantine of Wuhan post-outbreak
- Mobile monitoring / enforcement (via WeChat, etc.)
- Wuhan lockdown ended this week, though schools and many business remain closed

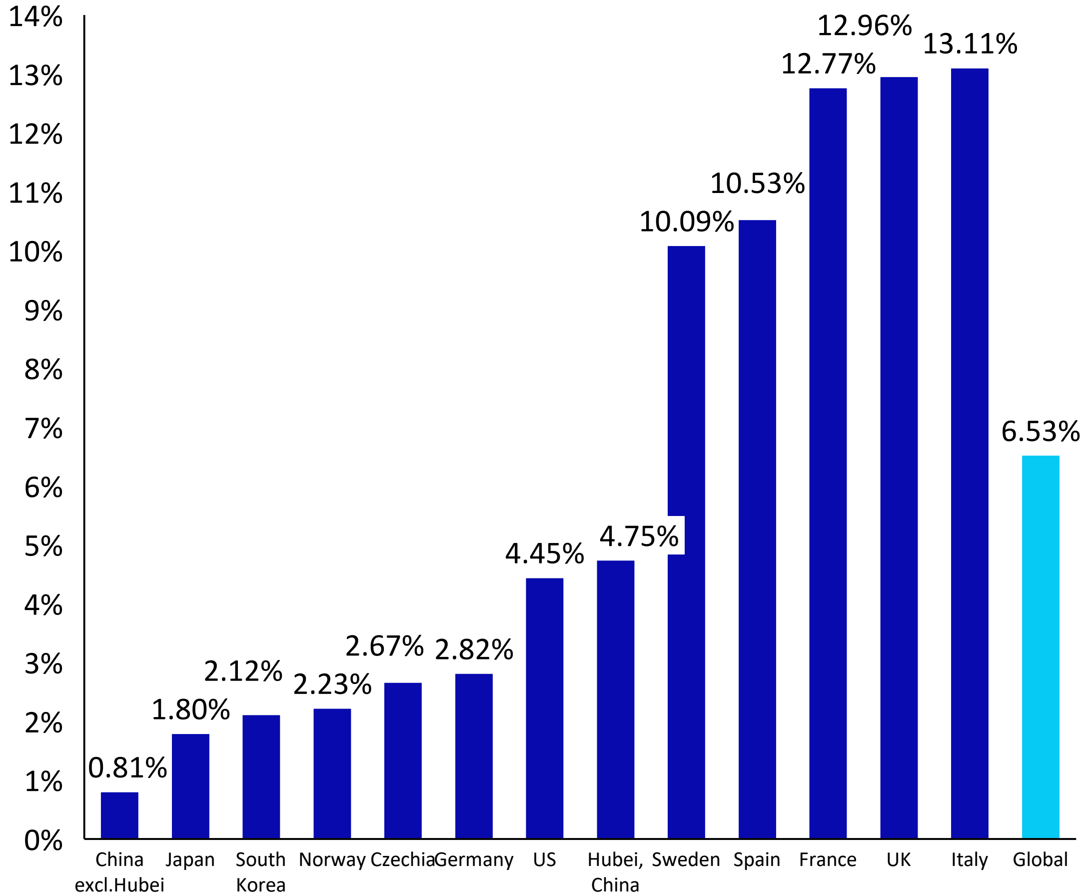
- Massive early testing (as of 3/28, >6.5k tests per million vs. US estimated ~2k tests per million people)
- Quarantined patients monitored via mobile app
- Epidemic response in place from SARS outbreak

Sources: JCSSE (Johns Hopkins), local news and county health departments, as of 3/17. Pre-WHO China data from NHC) Containment sources: China, S. Korea, US and testing stats, Italy
100th case on: Italy: 2/23, S. Korea: 2/20, US: 3/3, China: before 1/18, UK: 3/5, France: 2/29, Germany: 3/1; Spain 3/2, Czechia: 3/13. Data from JHU 4/15/2020.

CASE FATALITY RATE (CFR) BY COUNTRY

While the global CFR is a useful metric to understand COVID-19, country-specific CFRs range by an order of magnitude

CFR by country[1]



What is driving the variation?

- **Position along the trajectory of the outbreak:** For many countries (e.g., Europe, US), the vast majority of cases have not yet resolved and the CFR is changing rapidly
- **Breadth of testing:** Broader testing leads to a larger confirmed base of patients, decreasing CFR
- **Distribution of key risk factors within the population:** Age, gender and pre-existing conditions have a significant influence on mortality (see next page); countries with higher CFRs have a population skewed towards these risk factors (e.g., Italy has the second oldest population on earth)
- **Health system threshold:** Every country has a health system capacity, that when exceeded, will result in the inability to provide sufficient support to all patients thereby resulting in a higher CFR

Note that case fatality rates are still unstable as greater than 80% of cases outside of China are still active

1. Calculated as Number of Deaths / Total Confirmed Cases as reported by Johns Hopkins University

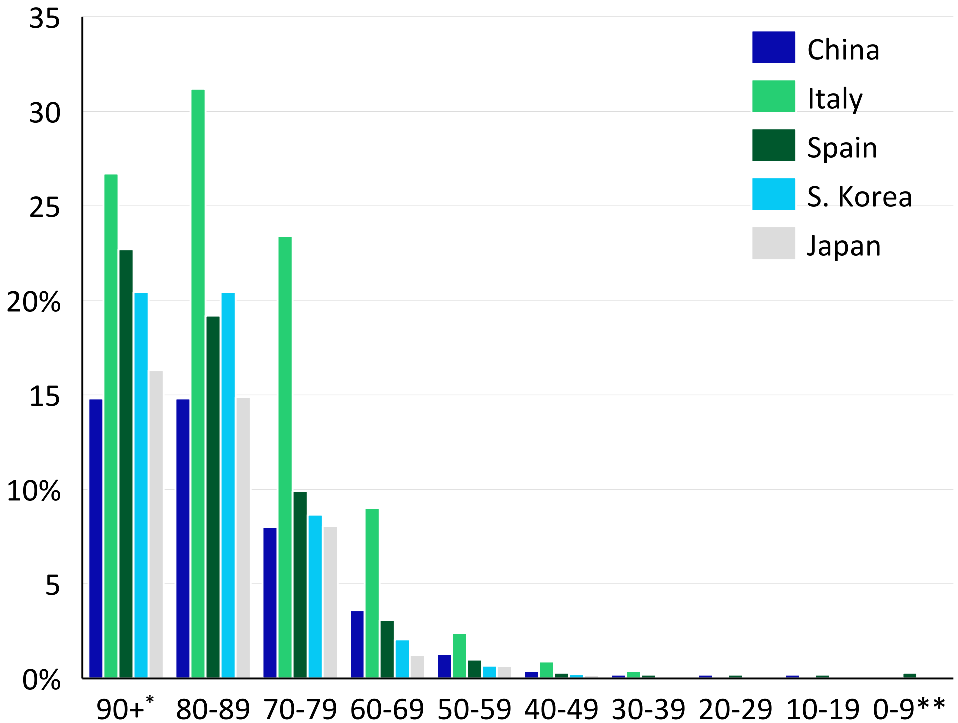
Latest data available, varies by country

CASE FATALITY RATE (CFR) BY PATIENT CHARACTERISTIC

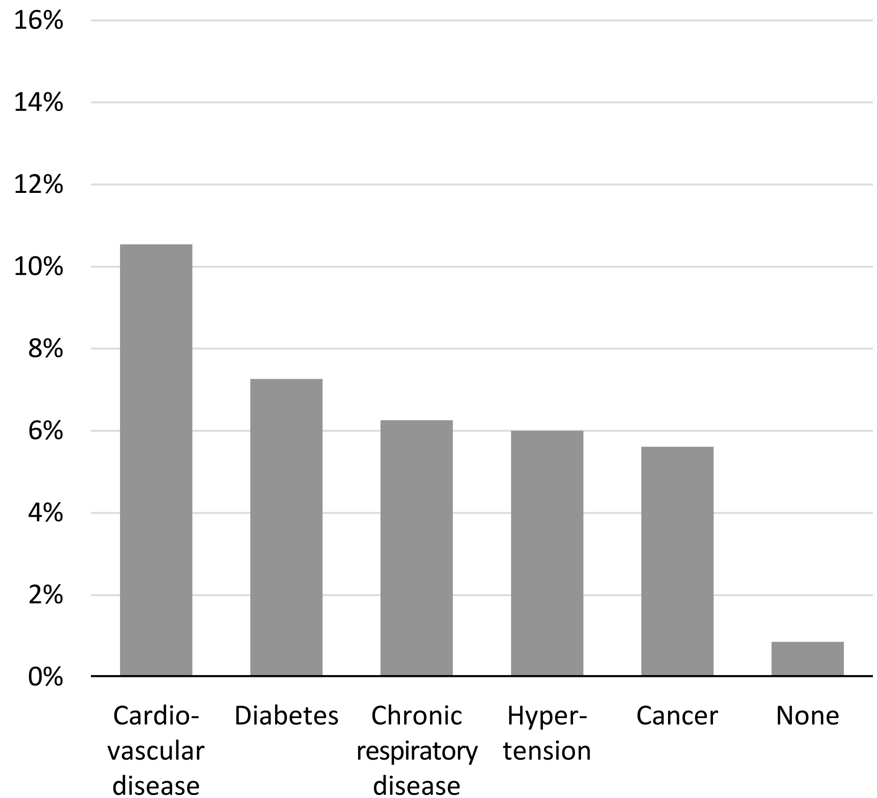
Significantly higher death rates occur among the elderly and those with underlying conditions

Case Fatality Rate by Specific Patient Characteristics

by Age[1,2,3]



by Comorbid Condition[1]



1. China data as of 02/11/2020 (link) 2. Italy data as of 04/08/2020 (link) 3. S. Korea data as of 04/08/2020 (link) 4. Spain data as of 04/08/2020 (link) 5. Japan data as of 04/06/2020 (link)
Notes: Data from China includes 72,314 confirmed cases reported through February 11, 2020, which is the latest data available as of 04/08/20.
* China and South Korea do not provide data for ages 80+, same percentage has been listed for 80-89 and 90+ for those two countries ** Italy does not provide data for ages 0-9 and 10-19 separately, the same percentage has been listed for both ranges. ***Japan and Italy data includes a small proportion of cases without a specified age, these were not included

EARLY DATA SUGGEST RACE AND GENDER-BASED DISPARITIES

These may arise largely from existing differences in underlying conditions

In the US: African Americans are harder hit

- CDC report covering 3/1-3/30 for 14 states: 33% of COVID-19 hospitalizations are of African Americans, though only 18% of total population in relevant states is African American[1]
- Dovetails with earlier piecemeal reports:

For cases in which race is available, % African American:

Region	% of Cases	% of Deaths	% Total Pop
Milwaukee[2]	50%	81%	26%
Michigan[2]	35%	40%	14%
Chicago[3]	Unavailable	70%	29%
North Carolina[4]	38%	39%	22%

- **Likely causes**
  - Higher proportion of pre existing conditions (*e.g.* 40% of African Americans have hypertension vs. 29% of total pop[5])
  - Lower income and likely to have hourly jobs that do not allow work from home[6]
  - Racial bias in treatment: review of lab billing information suggested African Americans with coronavirus symptoms were less likely to be tested[7]

Globally: Men are at higher risk

- Illness rates are higher among men than women globally, though the extent depends on the dataset[8]
  - Chinese CDC reported that 53% of cases are male
  - WHO found 51%
  - Wuhan-specific study found 58%
  - Recent US CDC report noted higher COVID-19 hospitalization rates for males (5.1 vs. 4.1 per 100K population)[1]
- An even clearer difference is observed in death rate[8]
  - China saw a 1.7% fatality rate for women vs. 2.8% for men
  - In Spain, men make up 65% of deaths
  - In Italy 8% of male patients died vs. 5% of women
- **Likely causes**
  - Women often have stronger immune systems potentially mediated by estrogen activity
  - Men may exhibit more behaviors associated with contracting COVID-19 (more travel, more outside-of-home work)
  - Men are more likely to have underlying conditions that increase risk of COVID-19 hospitalization and death

1. States include CA, CO, CT, GA, IA, MD< MI, MN, NM, NY, OH, OR, TN, UT; 2. As of 4/3, ProPublica (link); 3. As of 4/5, NPR (link); 4. As of 4/9, NCDHHS (link); 5. CDC brief (link); 6. StatNews (link); 7. Kaiser Health News (link); 8. StatNews (link)

AT A GLANCE: SUMMARY FACTS

	Key facts	Implications
Contagion	• Initial estimates suggested COVID-19 **R0 is between 2 and 3** (with edge of range estimates closer to 1.4 and 3.6), which means **each person infects 2-3 others**[3]; R0 for the seasonal flu is around 1.3[4] • New **emerging estimates suggest R0 may be closer to 5.7** (edge of range 3.8-8.9)[14]	COVID-19 is at least twice as contagious as the seasonal flu
Current human immunity	• No herd immunity exists yet as **the virus is novel in humans**	Social distancing (quarantines, WFH, school closures) is the **only "brake" to slow the spread**
Incubation period	• **The incubation period is a median of 5.5 days (up to 14 days)**[1, 10] while the annual flu is commonly a 3-day period[1]; data suggests that viral shedding continues beyond symptom resolution[6]	People are contagious for longer periods than the flu or other illnesses, requiring longer bouts of quarantine to truly suppress spread
Fatality	• **Case fatality rates are trending at 6.0% globally**[8] (vs. 0.1% for the flu)[9] • Estimates for **infected fatality rate are 0.3%-1.3%** based on assumptions around the number of undiagnosed individuals[13]	Fatality is orders of magnitude higher than typical influenzas
Portion of cases asymptomatic but contagious	• COVID-19 can be **spread asymptomatically**[5] • Of those people tested and confirmed positive for COVID-19, experts estimate **18-30% are asymptomatic**, with another 10-20% with mild enough symptoms to not suspect COVID-19[11] • Early indicators from comprehensive testing of small populations (e.g., Vo, Italy; Iceland) **suggest as many as 50% of cases could be asymptomatic**[12]	People who feel "fine" are capable of – and are -- transmitting COVID-19 to others
Portion of cases reaching "critical/ "severe" infection	• Approximately **19% of confirmed cases are considered "severe" or "critical", requiring hospitalization,** and 1/4th of those need ICU beds[7]	Hospital systems risk being overtaxed (ICU beds, ventilators, PPE) meaning case fatality rates could rise further

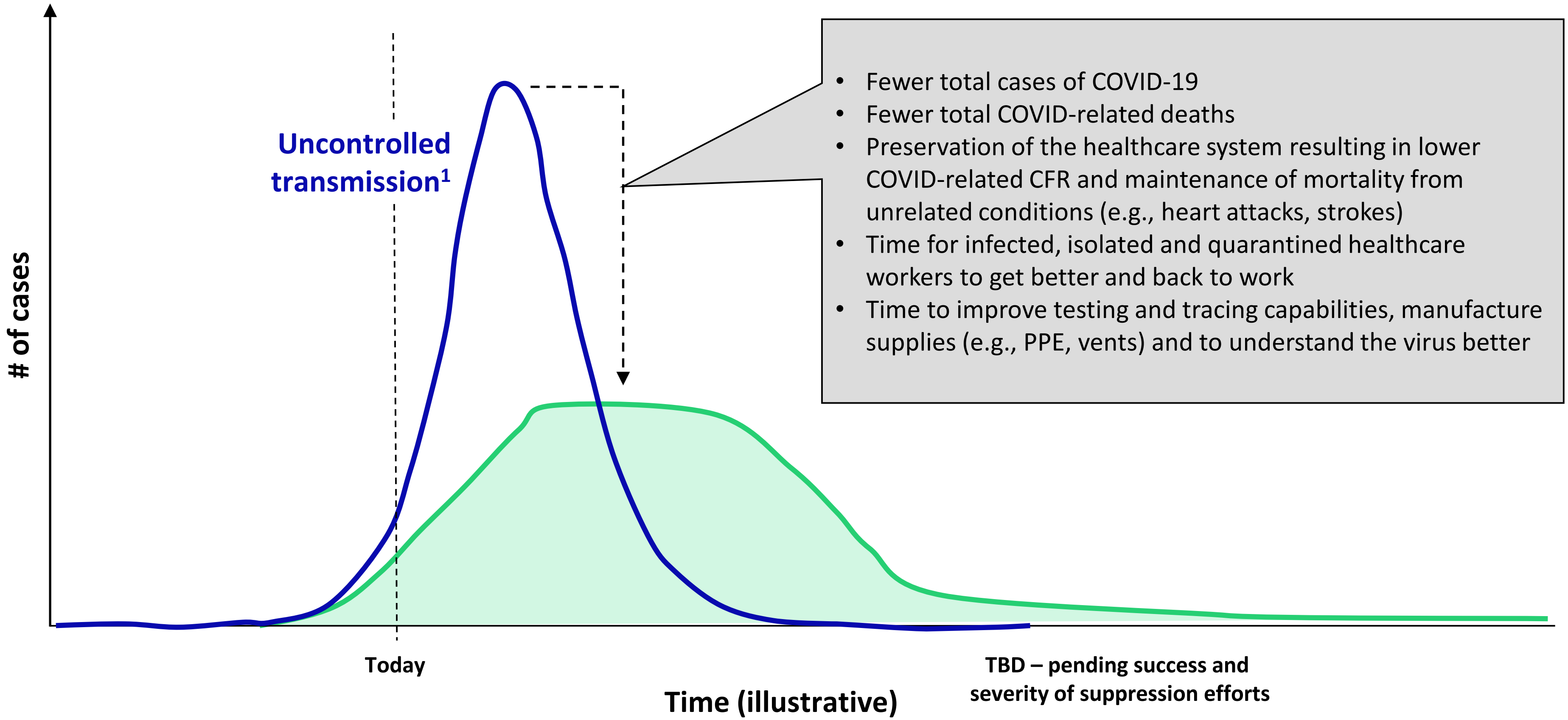
1. CDC. 3. The R0 for the coronavirus was estimated by the WHO to be between 1.4 -2.5 (end of January estimate) (link), other organizations have estimated an R0 ranging between 2-3 or higher (link); 4. CDC Paper (link); 5. JAMA. "Presumed Asymptomatic Carrier Transmission of COVID-19" 6. MedRxIv. "Clinical presentation and virological assessment of hospitalized cases of coronavirus disease 2019 in a travel-associated transmission cluster". Mar 8. 2020. 7. China CDC, JAMA (link). 8. JHU. 9. CDC. 10. Annals of Internal Medicine (link) 11. Nature article (link), Eurosurveillance Paper (link) 12. ZMEScience report (link) 13. SARS-CoV2 by the numbers (link) 14. Emerging Infectious Diseases (link)

HOW CAN SUPPRESSION MEASURES LOWER THE BURDEN OF THE PANDEMIC?

Leaving the disease unconstrained is not an option; aggressive suppression measures can ease the impact of the disease on health systems

Illustrative COVID-19 transmission with and without suppression measures

Timing and width of first peaks may vary between countries



1. Assuming case-based isolation only

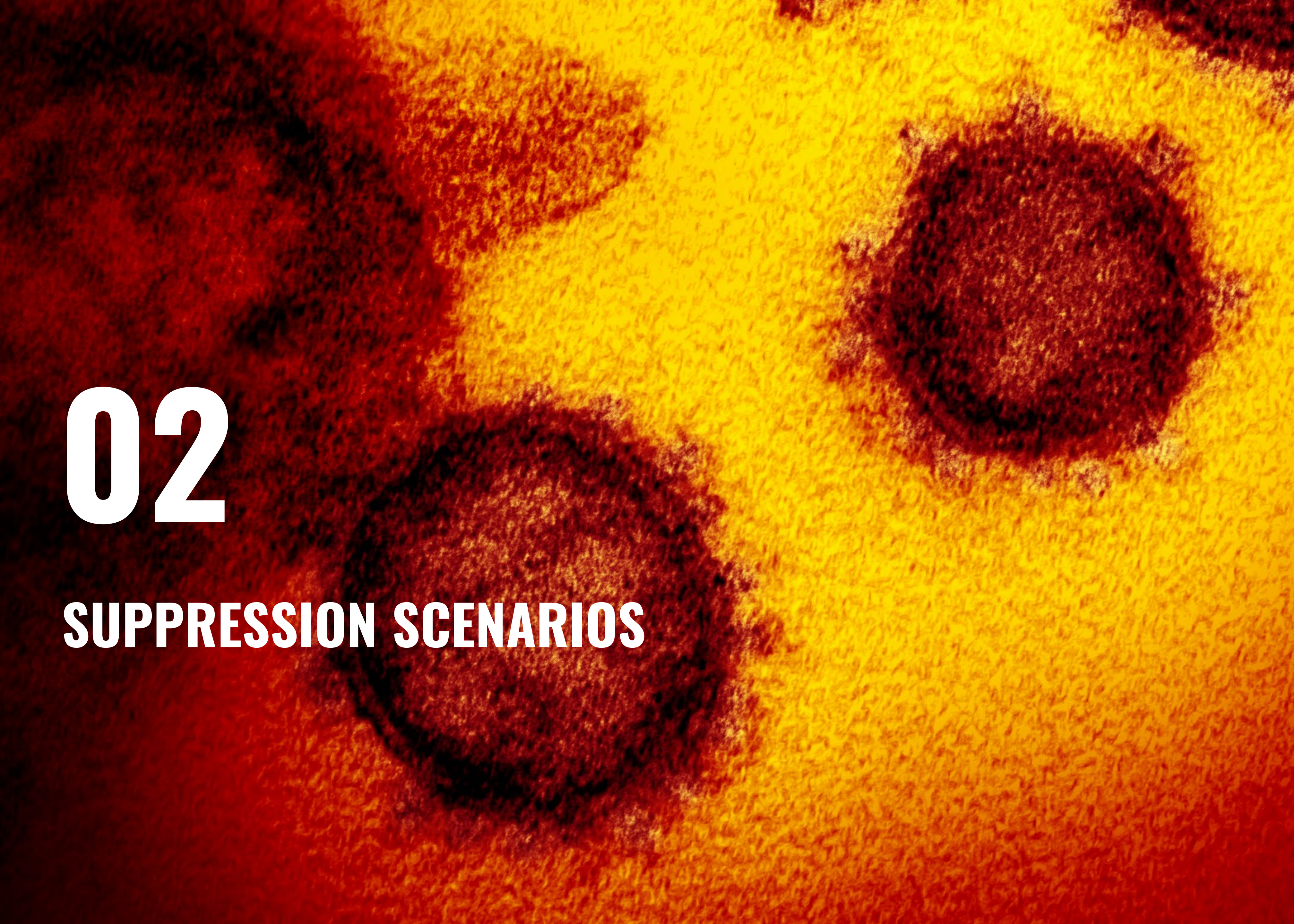
Source: Adapted from "How will country-based mitigation measures influence the course of the COVID-19 epidemic". Lancet. Mar 6 2020. https://doi.org/10.1016/S0140-6736(20)30567-5. Concepts sourced from Tomas Puyeo.

WHAT LEVERS CAN HELP SUPPRESS THE PANDEMIC?

Two approaches to initial suppression exist; but given the progression of the disease and the currently available tools the only current option for most countries/ regions is aggressive social distancing

Levers in response to pandemic[1, 2, 3]	Outcomes	Requirements for success
Testing, contact tracing and quarantine of infected	• Delays or prevents full scale outbreak • Demonstrated to work successfully in S. Korea, Taiwan and China outside of Hubei	• **Early initiation:** In order to use this lever to prevent an outbreak, the methodology needs to be applied as soon as cases are identified (e.g., S. Korea implemented nearly immediate action after initial case was identified on 01/20/20[4]) • **Robust capabilities:** Broad testing capacity with rapid results, sophisticated contact tracing and sufficient control over population to ensure quarantine compliance
Aggressive social distancing of entire population	• Decreases R0 of the virus, decreasing daily growth rates and flattening the peak of cases • Demonstrated to work successfully in Wuhan	• **Decisive, early action:** 'Wait and see' or fragmented approaches only worsen outcomes • **Comprehensive plan:** Closing bars, schools, restaurants, gyms, churches to maintain social distancing, restricting non-essential travel and quarantining all infected patients including asymptomatic ones • **Compliance (enforced if necessary):** Experience in the US and Europe demonstrates that lack of compliance worsens outcomes

Sources: 1. Adapted from "How will country-based mitigation measures influence the course of the COVID-19 epidemic". 2. Lancet. Mar 6 2020 (link) 3. Concepts sourced from Tomas Puyeo. 4. Center for Strategies and international Studies (link)



02

SUPPRESSION SCENARIOS

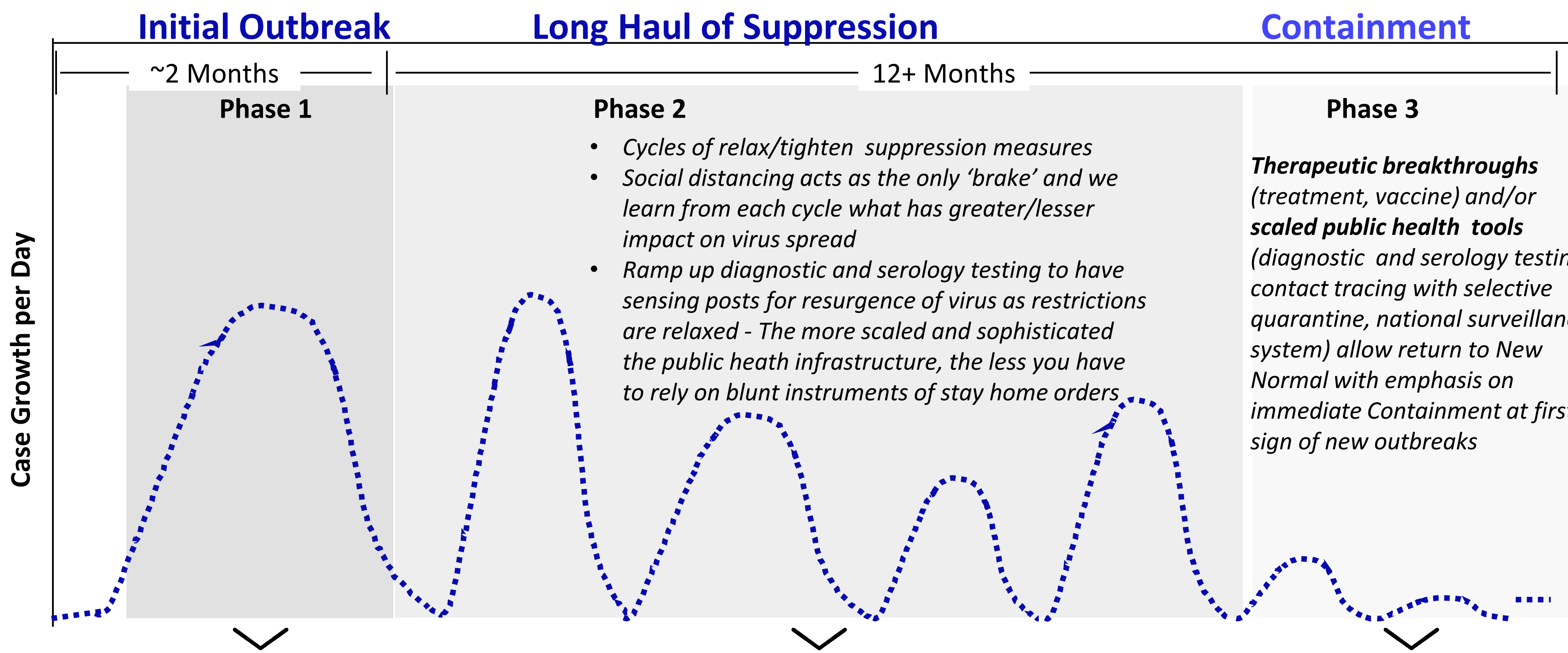
EPIDEMIOLOGY AND SUPPRESSION MEASURES SUMMARY

- **The epidemiology of the novel coronavirus impacts containment efforts**
  - R0 estimates range between 2 and 5.7, meaning each infected individual infects at least 2, and up to 5-6 others
  - Median 5.5 day incubation period (from exposure to symptom onset) is longer than that of a disease like the flu, which means a longer window when unsuspecting individuals can infect others
  - Studies suggest that anywhere between 18 and 30% of infected individuals remain asymptomatic for the duration of the disease, further complicating containment efforts
  - Individuals have been shown to test positive and demonstrate viral shedding for 6-12 days (or more) post resolution of symptoms, creating a large window during which an individual is contagious
- Several capabilities can enable countries to relax suppression and avoid a severely damaging second wave
  - Healthcare system capacity recovered to the extent that normal care can be provided without overburdening facilities or personnel
  - The capacity to do extensive testing, both for presence of the virus as well as for antibodies to indicate who may have already had the disease, in order to manage the spread of the disease in a controlled manner as we try to begin opening parts of the economy
  - Contact tracing, to allow a more surgical approach to managing the disease
  - A centralized surveillance system, at the regional or national level, that will provide an early warning and allow quick management of new outbreaks
- Preliminary analyses suggest that parts of the US and much of Europe is several weeks to a month from scaling these capabilities

Illustrative

COVID-19 WILL EXERT ITS INFLUENCE ON OUR ECONOMY FOR MANY MONTHS AHEAD

Current State	Likely case over the next 12+ months	Ideal Case
Limited capability to deploy tools driving more specific management: **Full suppression**	Significant tools exist, but not operating at full capacity: **Trial and error relaxation as tools come online**	Tools for managing outbreak at the case level are fully operational: **Suppression relaxed**



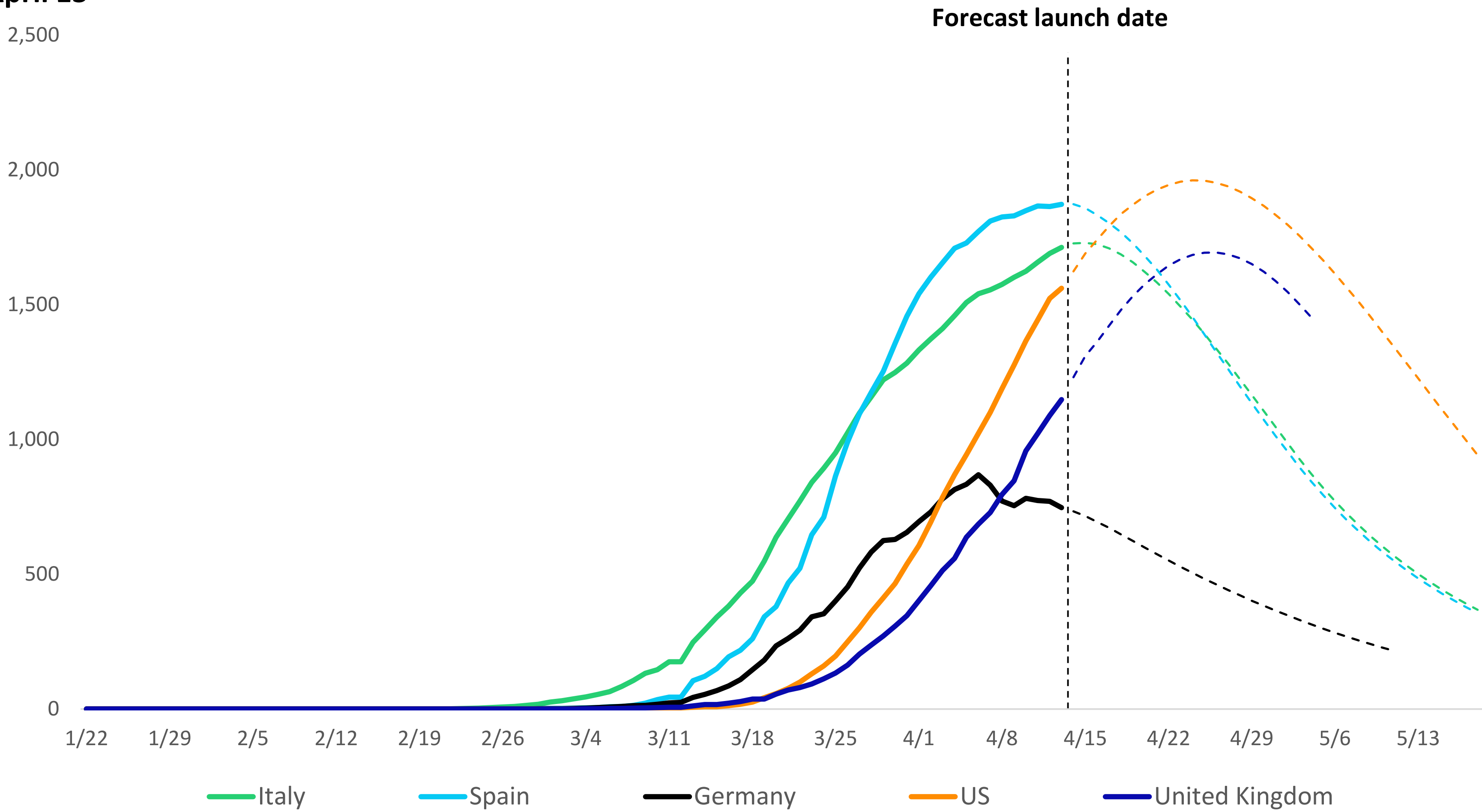
Mitigation/Economy

Phase 1	Phase 2	Phase 3
• Closure of non-essential businesses • Community-wide stay-at-home mandates • Widespread remote work • Border closures and travel restrictions	• Gradually reopen some business *(e.g., retail / restaurants/ manufacturing with social distancing and cleaning/protection protocols)* • Strict quarantine guidelines for confirmed cases, close associates and travelers • Stay-at-home order for at-risk people • Remote work and mask-wearing still the norm • No large gatherings (e.g. no events >50 people) so churches, sports, entertainment venues remain closed • Travel to / from hot spots restricted	• All businesses re-open, under mandated safety protocols • Stay-at-home reinstated in areas with renewed outbreaks • Prevalent use of vaccines, perhaps annually

WHERE ARE WE TODAY?

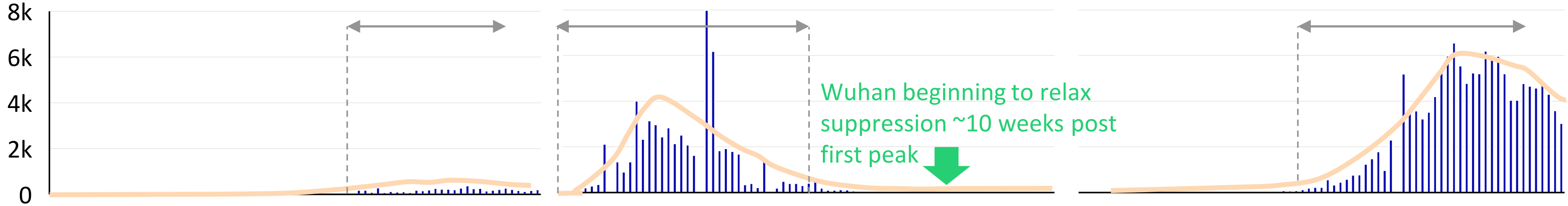
Official new case counts paint manageable picture of infections vs. healthcare system capacity, but regions in Italy, Spain, the UK, and the US particularly are facing severe capacity issues, particular in the ICUs

OW COVID-19 Projections (select European countries) – *Total* active cases per million
April 13th



HOW LONG MUST WE LIVE WITH CURRENT SUPPRESSION MEASURES?

Local pandemic progression archetypes[1]



	Norway ~ 4+ weeks Case growth flattened immediately	**Hubei ~ 7-8 weeks** Sharp peak of very high case load, sharp decline	**Italy ~ 7+ weeks** Sharp incline, just now beginning to decline from first peak
What was closed:	• Schools • Non-essential businesses • International travel • Intra-country regional travel • Public gatherings >10 • Mandatory quarantine for sick/contacts/suspected	• Incoming/outgoing travel restrictions • Public transportation shutdown • Public gathering closures • Non-essential business closures • Stay-at-home mandatory • School closures (after existing Lunar new year holiday)	Lombardy lockdown, later extended nationally: • Incoming/outgoing travel restrictions • Public transportation shutdown • Public gathering closures • Work from-home mandatory • School closures • All outdoor activity banned • Non-essential businesses closed
What has re-opened:	• Nothing yet, but health minister has declared an end to the outbreak and kindergartens will reopen and intra-country travel restrictions will be released 4/20 • All schools and "one-to-one" businesses (e.g. hairdressers) reopen 4/27	• Public transport resumes • Some businesses reopen (manufacturing & industrial) • Outgoing travel restrictions lifted • Stay-at-home mandate eased	• Lombardy still in total lockdown • Elsewhere in Italy - some businesses reopened: bookshops, children's clothing stores, laundromats • Plan additional reopening on 5/3
What to watch for next:	• Will reopening schools cause a resurgence or can they safely be an early measure to relax?	• Many restrictions still exist (schools closed, WFH encouraged, large gatherings prohibited): will the outbreak return even with these restrictions in place?	• Active cases are still high, healthcare system is exhausted; can even a minor renewed outbreak be managed?

WHAT WE WOULD NEED TO RELAX SUPPRESSION *AND* AVOID A SUBSEQUENT LARGE PEAK OF CASES (1 OF 2)

Precondition	Description	Target	Current Status
New case count	Total number of positive tests; conservatively also include persons under investigation (PUI) and any deaths with compatible symptoms	Sustained drop in new cases for *at least* 14-day period (full incubation period), conservatively 1.5-2 incubation periods	**US:** New cases hit a first peak at national level approx. April 10th. **Europe:** Early hot spots Italy and Spain appear to have had first peaks ~3 weeks ago (~3/21), with active cases peaking on 4/15. Later hot spot UK new cases peaked 4/10, active cases peaking 4/26
Active cases	Measure of burden on health system	Active cases is below health system capacity; likely to require several weeks post-peak to clear ICU	**US:** Hot spots remain severely burdened, with exhausted staff, and scarce PPE **Europe:** High CFR of hot spots suggests continued overcapacity, others (e.g., Germany, Norway, Czechia, and Finland) have maintained capacity
Testing	• Viral testing (PCR) • Serological	• Widespread viral testing such that <5% of tests are positive for the novel coronavirus • Widespread serological testing to characterize true disease extent and (potential) immunity profile	**US:** Tests per day have plateaued at 150K, likely not enough to meet the 5% threshold at least through May, though some assert a 750K/week capacity would be adequate[4] **Europe:** Italy plateauing at less than 50K per day, not adequate until May– other countries such as Germany and Norway, are already there
Contact Tracing	Identifying, intervening, and testing positive patient contacts	• Past epidemics suggest an 80% success rate in IDing and tracing contacts[1] • Assuming R0 ~2, COVID-19-specific modeling suggests 75% success rate is acceptable if *all* found positives are successfully isolated and all contacts are found w/in 2 days, and little to no hope of control if tracing takes >2 days[2], for greater R0s, higher success rates may ne needed[3]	**US:** At least 30K workers would be necessary as a low end estimate, with current available workforce <2K[3]. Creative use of volunteers and labor sources and digital tracing app produced by Apple and Google, ready in May, will supplement **Europe:** PEPP-PT program in Europe provides hope for higher success rates and faster tracing times but must be supplemented by a massive increase in contact tracing capacity

Sources: 1. New Yorker (link); 2. Science Magazine (link); 3. StatNews (link), 4. Duke University (link), 5. Lancet (link)

WHAT WE WOULD NEED TO RELAX SUPPRESSION *AND* AVOID A SUBSEQUENT LARGE PEAK OF CASES (2 OF 2)

Precondition	Description	Target	Current Status
Surveillance System	Centralized infrastructure allowing new case tracking and decision-making	• At least regional infrastructure with ability to detect potential new COVID outbreaks in real time or minimal time delay • Access to data and analytics capacity to identify COVID outbreaks based on symptoms, COVID-specific age distribution of illness, and other clinical notes • Ideally, availability of widespread random, rapid-turnaround testing that can feed central, real time database	**US:** Existing National Syndromic Surveillance System provides a framework, as does the CDC's plan for a modernized surveillance system but neither operate at the level necessary for full COVID management currently.[1] Multi-state regional discussions are occurring but no regional infrastructure exists yet **Europe:** European countries vary in readiness, with the ECDC acknowledging that some nations will be unable to share data more than weekly[2]
Social Distancing Measures	Long-term changes in social and work behaviors and business infrastructure post-suppression	Sustainable reduction in behaviors that can spread the novel coronavirus	**US:** Attitudes vary by region, with some still skeptical of the need for social distancing **Europe:** Evidence that attitudes have changed through the pandemic (e.g., reports that many Swedes are voluntarily socially distancing in the absence of government mandate, keeping growth below Spain and Italy, if higher than Nordic peers)

Sources: 1. Duke University (link); 2. ECDC (link)

TESTING IS A CRITICAL TOOL TO PINPOINT INFECTION AND UNDERSTAND SPREAD NOW AND AS WE RELAX SUPPRESSION MEASURES

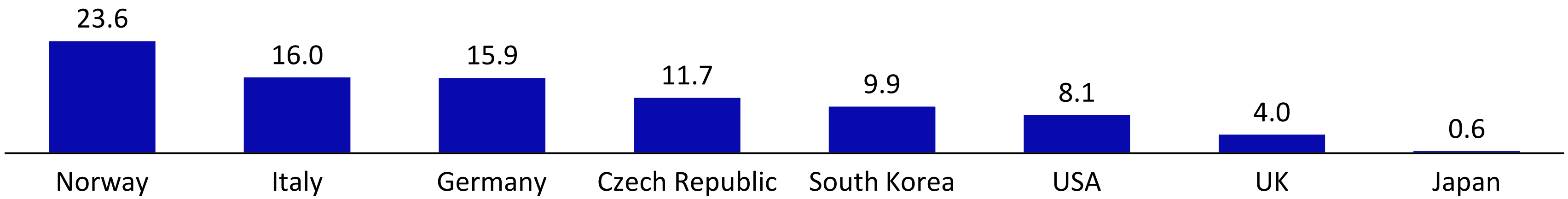
Two types of COVID-19 tests will play a critical role in COVID-19 management

	COVID-19 Genetic Material (mRNA) Polymerase Chain Reaction Swab Tests	Antibody Serology Test
Description	• **Best for diagnosis -** Used to detect active infections through COVID-19 mRNA identification via PCR tests	• **Best to identify prior contraction of disease -** Blood tests to detect antibodies, innately created to fight COVID-19 infections by the body
Importance	• Rapid tests to diagnose COVID-19 are needed to allow swift countermeasures • Widely available and routine testing protocols are needed to identify emerging outbreaks • Once social distancing has had its effect, testing will be a return-to-normalcy tool	• Serological tests will elucidate true scope of the pandemic post-hoc – testing gaps and asymptomatic patients to date have stymied understanding • Will also give insight into what happens to people who have been infected in terms of future immunity and/or infectiousness (currently unclear if infection confers future immunity)
Status	• Testing capacity, effectiveness, and rapidity is increasing • As of 4/9, 31 companies have received FDA emergency authorization to conduct their rapid tests[1]	• Many companies still in test development • As of 4/9, only 1 company has received FDA emergency authorization to conduct their rapid tests (Cellex)[1]

Source: 1. FDA (link).

MANY COUNTRIES HAVE EXPANDED TESTING CAPACITY BUT ADDITIONAL CAPACITY IS STILL REQUIRED TO SAFELY END SUPPRESSION

Tests per thousand people (Data as of 4/9/20)[1]



	Norway	Italy	Germany	Czech Republic	South Korea	USA	UK	Japan
Tests/ Confirmed case	22	7	13	26	50	7	5	21
Day 0: 100 confirmed cases	3/6	3/1	2/23	2/20	3/13	3/3	3/5	2/21
Target test/day[2]	2.8 K	54K	62K	2.9K	6.2K	290K	57K	6.3K

	Managing the Outbreak	**Beginning to Open Up**	**Broader Relaxation**
Where we need to be	Test all symptomatic patients and close contacts, rapid results	Test all, or a high proportion of employees returning to work and intracountry travelers	Test a broad enough portion of the population to yield <5% positive rate
Where we are	• US alone would need >750K tests per day total, but capacity may be sufficient outside major hot spots; **currently plateaued at 150K/day with decrease in daily tests recently**[3] • UK and Italy also under capacity • Czech Republic, Norway, Germany, have maintained low enough daily new cases to avoid overwhelming test capacity	• US employs ~30M in retail, education, entertainment, transport and other priority non-WFH industries: at current testing rate, that would require 200 days to test all: acceleration is necessary- even a random sample of 25% would require >1 month • Assuming similar employment patterns, European countries face similar needs to accelerate	• Conservative test/day target to allow broader relaxation is double current US rate • Most European countries are also well below the required rate, with Norway and Czech Republic, with relatively small outbreaks, the closest • Expansion of testing capacity and reduction in new cases may result in adequate testing in the next 4-6 weeks

1. Our World in Data (link) – testing units vary by country as different types of data are reported; 2. Assuming target 5% positive rate. Based on daily new case rate of 50% of the peak three day average of new cases, and that 90% of active cases are identified; 3. NBC News (link)

EFFECTIVE CONTACT TRACING ALLOWS TARGETED ISOLATION TO AVOID THE NECESSITY FOR BROAD SUPPRESSION

Contact tracing and selective isolation: general approach

- Scaled tracing capabilities (using existing data sources or new technology) and a significantly increased public health workforce
- Scaled abilities to enforce and support quarantine (e.g., food delivery, isolation support, community-based treatment for quarantined individuals)
- China, S. Korea, Israel, and Singapore have used highly sophisticated approaches to surveillance and contact tracing
- S. Korea demonstrated that mass messaging is critical as the outbreak grows[3]
  - Encouraging those with potential exposure to get tested
  - Targeted broadcast of the movement of infected individuals to alert those who were exposed

What does it take to be successful?

- Depending on speed to isolate contacts and success in isolating infected individual, models suggest a 70-85% success rate is necessary to control spread, if R0 is ~2[1], with higher R0s requiring higher success rates[3]
  - If all infected individuals are successfully isolated and all contacts are found in <2 days, the low end of the range is sufficient
  - If fewer than 80% of infected individuals are isolated or tracing takes 2 days, the higher end of the range is necessary
  - If tracing takes >2 days on average, control is nearly impossible to obtain
- Rapid tracing requires a massive workforce (at least 30K in US)
- Speed and manpower deficits can be addressed with digital tools in development for mid-May in US, already deployed in Europe and Asia

Where are we today?

- US states and localities are already moving to expand capabilities Massachusetts hiring 1K workers in partnership with Partners in Health non-profit, SF training 100 librarians, med students, and nurses[2]
- Indication of European success: Germany's low CFR suggests high identification rate, driven by high contact tracing capacity

State-level initiatives and promise of digital support by mid-May indicate contact-tracing in the US within weeks, sooner in Europe where digital tools and tracing workforces are already in place

Sources: 1. Science Magazine (link); 2. StatNews (link); 3. Lancet (link); 4. NY Times (link)

AN EFFECTIVE SURVEILLANCE SYSTEM IS CRITICAL TO DETECTING NEW OUTBREAKS EARLY ENOUGH TO MANAGE WITHOUT WHOLESALE SUPPRESSION

What do we need?

Data

- Enough COVID-specific testing is taking place to provide a reliable view of COVID prevalence
- Availability of additional clinical and other data that can indirectly ID COVID prevalence (e.g., disproportionately high hospitalization rates for older individuals with pneumonia, travel from hot spots)

Central Aggregation

- Infrastructure and processes to rapidly aggregate data at a geographic level that:
  - Is empowered to make COVID management decisions accounting for any delay in data reporting and aggregation
  - Is large enough to cover the extent of COVID outbreaks (i.e. beyond one state when there is significant interstate commuting)

Analytics

- Analysis that identifies when COVID outbreaks threaten to escape control and guides decisionmakers

When can we get there?

- Testing capacity is likely to remain below requirements for the US and many European countries at least for another month
- Additional clinical data may help fill gaps in testing but these data are difficult to aggregate effectively in the US and are unlikely to be a short term aid
- European countries with more centralized healthcare/ financing systems may be able to leverage additional data, as some Asian countries did in combining immigration with health information

- The US's National Syndromic Surveillance System has been deployed for COVID tracking, and covers the majority of hospitals in the US, but using it as an early warning system for outbreak resurgence requires broader data gathering and a reduced lag time
- State/multi-regional initiatives are underway but timing is unclear

- As experience with of COVID is gained during the first wave, modeling the second wave will become easier

TO AVOID THE USE OF BLUNT SHUTDOWNS, COUNTRIES NEED SURVEILLANCE SYSTEMS AND THE CAPACITY TO TRACE MOST INFECTED INDIVIDUALS' CONTACTS

← Most invasive ——— Least invasive →

Case Study: China[1]

- **The Alipay Health Code**:
  - Program originated in Hangzhou, China; as of 2/24 90% of the province's population had downloaded the app and 100 Chinese cities were using it
  - Uses big data to determine if an individual is a contagion risk or not
  - Individuals are assigned a green, yellow, or red color code that indicates health status
  - QR code on phone is required for entry into many common areas, public transportation, health checkpoints, etc
  - App shares personal data including location with the police

Case Study: South Korea[2]

- **Tracking**:
  - Retrace physical steps of anyone who tested positive
  - Used credit card records, GPS data and security-camera footage
- **Mass messaging:**
  - Emergency cell phone alerts any time there is a confirmed case in individual's district
  - Apps and websites list detailed timelines of infected individuals' travel
  - Anyone having potentially crossed paths with individual urged to go to testing center
- **Quarantine enforcement:**
  - Quarantined individuals required to have cell phone apps that alert officials if they venture out with fines for violations

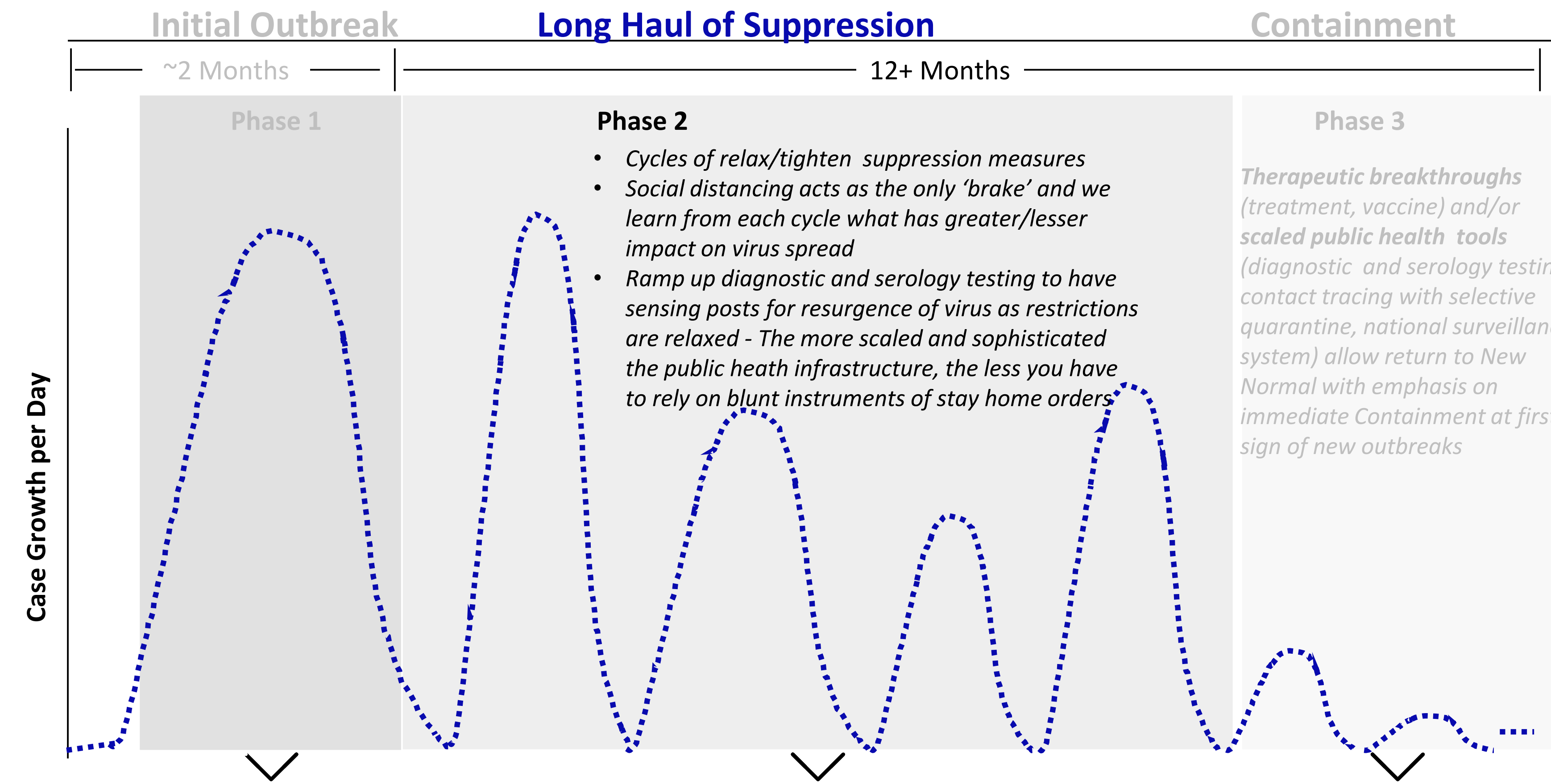
Case Study: Germany[3, 4]

- **Pan-European Privacy Preserving Proximity Tracing (PEPP-PT)**
  - Heavy focus on preserving individual privacy, while allowing tracking and tracing
  - Doctors would get permission from those who test positive and enter their information into a central server
  - System uses Bluetooth to log a user's proximity to other cellphones, without storing data from location tracking
  - Users then receive a message if they have been in close contact with someone who has tested positive for COVID-19
  - The German government is aiming to launch the app by mid-April

Sources: 1. NY Times (link) 2. NY Times (link) 3. NPR (link)

Illustrative

MANAGING THROUGH PHASE 2



Mitigation/Economy

- Closure of non-essential businesses
- Community-wide stay-at-home mandates
- Widespread remote work
- Border closures and travel restrictions

- Gradually reopen some business *(e.g., retail / restaurants/ manufacturing with social distancing and cleaning/protection protocols)*
- Strict quarantine guidelines for confirmed cases, close associates and travelers
- Stay-at-home order for at-risk people
- Remote work and mask-wearing still the norm
- No large gatherings (e.g. no events >50 people) so churches, sports, entertainment venues remain closed
- Travel to / from hot spots restricted

- All businesses re-open, under mandated safety protocols
- Stay-at-home reinstated in areas with renewed outbreaks
- Prevalent use of vaccines, perhaps annually

HOW DO WE DETERMINE WHAT TO REOPEN WHEN?

Premature relaxation of suppression would have obvious public health costs, but overlong suppression will be painful as well from economic and health perspectives; what is the balance point?

Continued Suppression

Positive effect

Greatly reduce risk of public health catastrophe

Economic implications

Failed businesses

Supply chain disruption creates true shortages

Massive long-term unemployment

Public health implications

Significant decline in mental health

Lower quality of life and premature death as important elective surgeries are canceled

Loss of key healthcare resources to financial ruin

Increase in lifestyle diseases as diet and exercise habits worsen

Near Term Relaxation

Positive effect

Near term economic boost

Public health implications

High levels of death and permanent disability

Crippling of the healthcare system through workforce exhaustion and illness and facility capacity strain

Economic implications

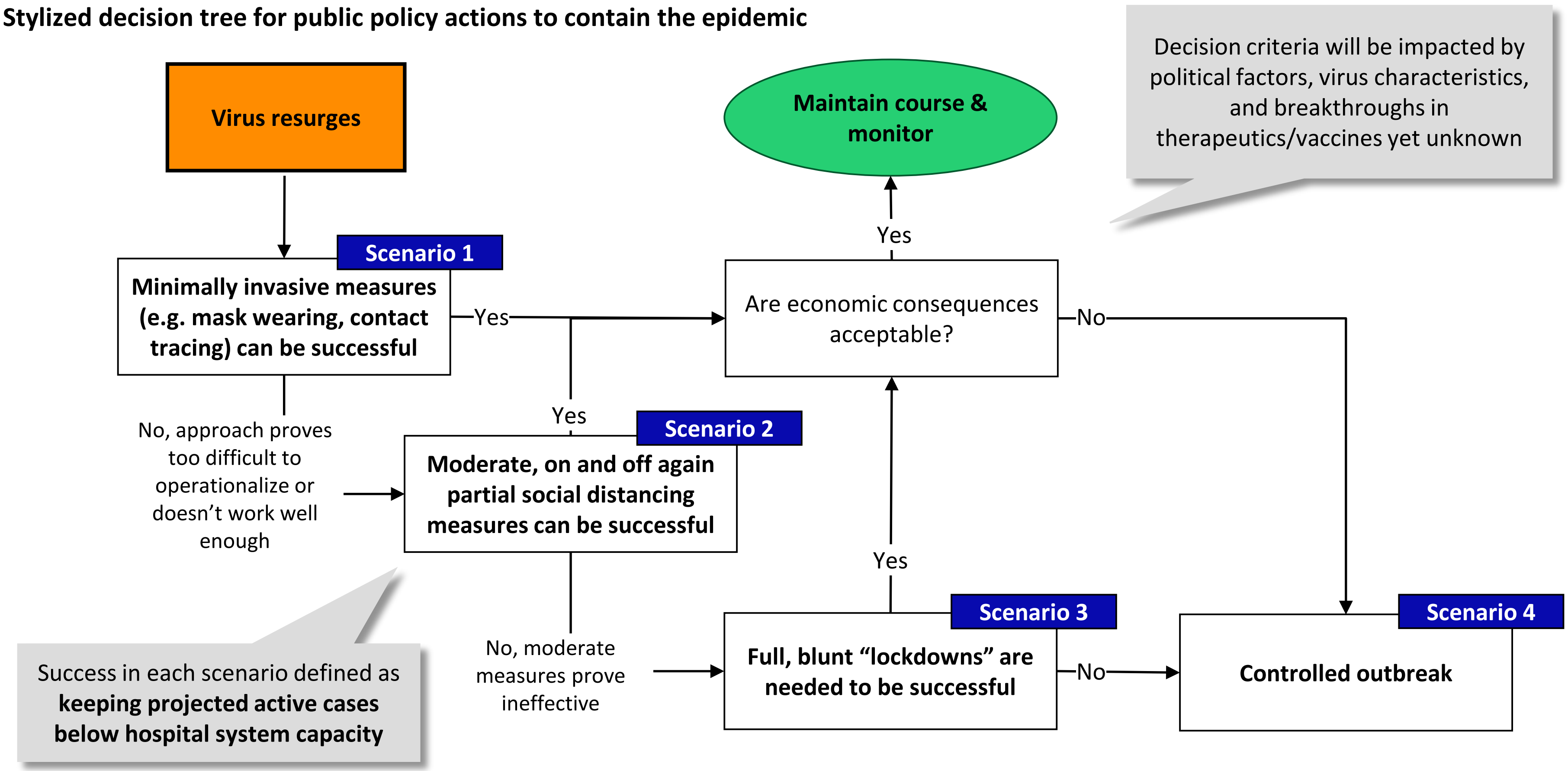
True shortages created by supply chain disruption due to illness

Many businesses fail regardless of relaxation due to customer mistrust

Uncertainty surrounding likelihood of returned suppression makes investment unattractive and creates a financial crisis

SOCIETIES AROUND THE WORLD WILL BE LOOKING TO CONTAIN THE PUBLIC HEALTH DISASTER WHILE MINIMIZING IMPACT ON THE ECONOMY UNTIL A VACCINE EMERGES

Stylized decision tree for public policy actions to contain the epidemic



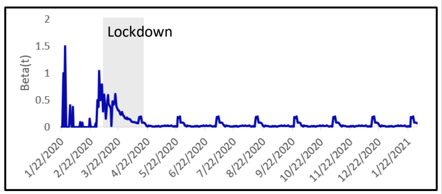
We are continuously monitoring global government responses and results across the world, incorporating them into our COVID-19 Pandemic Navigator, and creating sophisticated "what-if" scenarios

SMART SCENARIOS FOR THE FUTURE COURSE OF THE EPIDEMIC CAN BE DEVELOPED AT COUNTRY AND STATE LEVEL AND USED TO PROJECT CONSEQUENCES OF POLICY AND BUSINESS CHOICES

1

Minimally invasive measures

- We sacrifice privacy and some freedoms, but suppress the virus
- Regional borders remain controlled/closed to avoid contagion

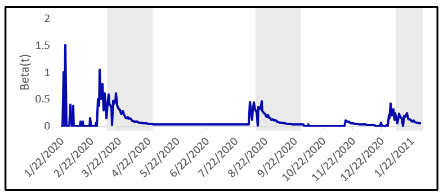


Targets for no future outbreaks occur, and we are able to maintain a reasonable level of economic activity

2

Moderate social distancing

- We have few slower-growth outbreaks over the next 18+ months
- When case counts reach a critical threshold against hospital capacities, stricter lockdowns imposed

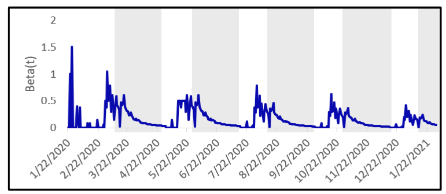


Economic impacts are significant but lower than that with minimally invasive measures

3

Blunt lockdowns

- We will periodically be in 'today's world' over the next 18+ months
- Fiscal and monetary stimulus measures expand significantly to account for future outbreaks

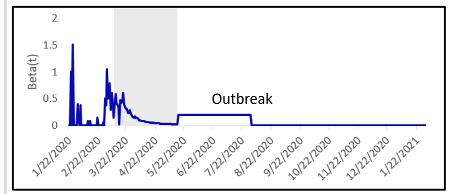


Impact on most affected sectors of the economy will be deep and long-lasting

4

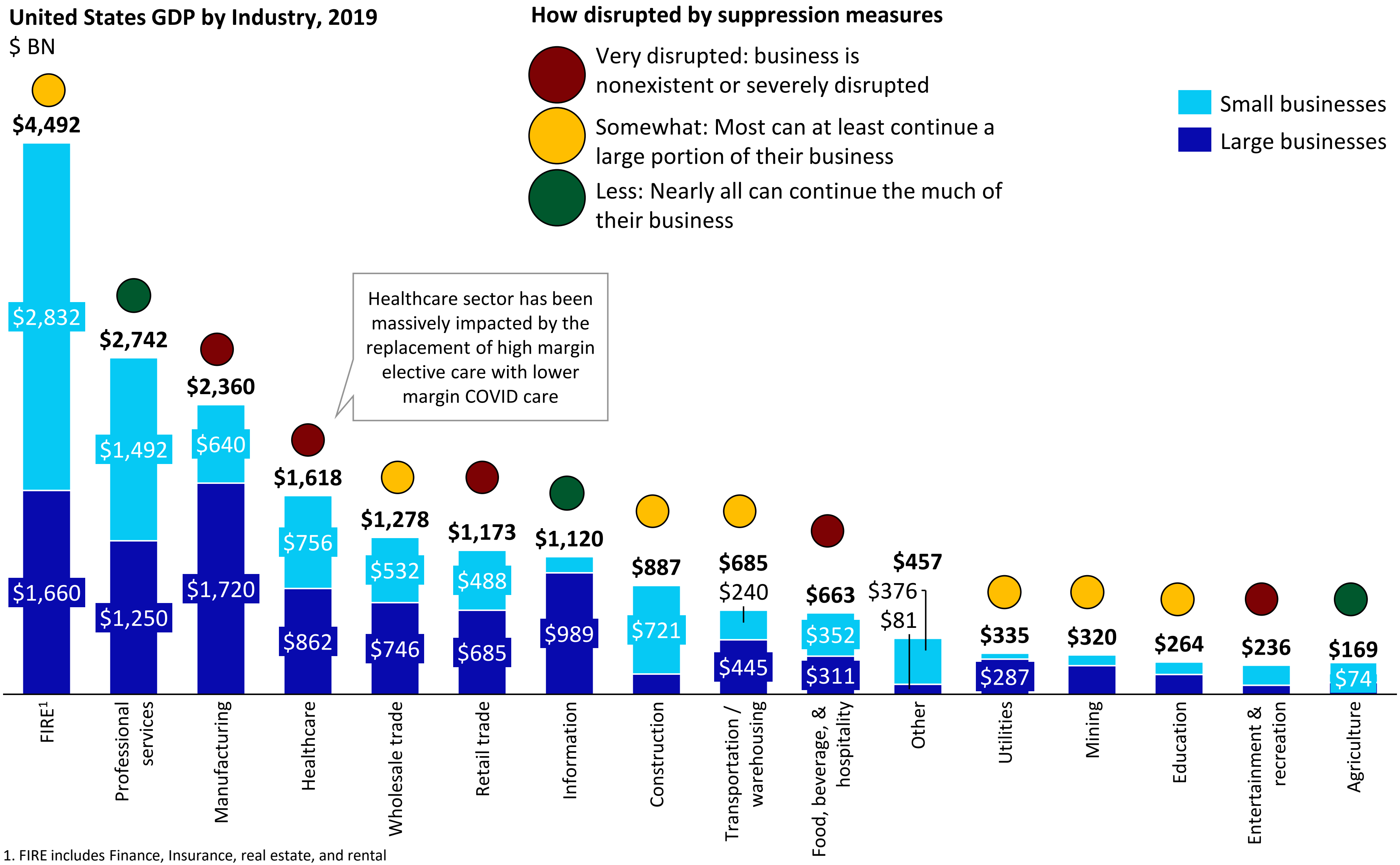
Controlled outbreak

- The virus spreads quickly through the general population
- Potential for future outbreaks depends significantly on the immunity of those previously infected



Immediate impact on economy is severe, but the pandemic is relatively short-lived

SCENARIOS SHOULD ACCOUNT FOR RELATIVE 'BANG FOR THE BUCK' ECONOMICALLY…

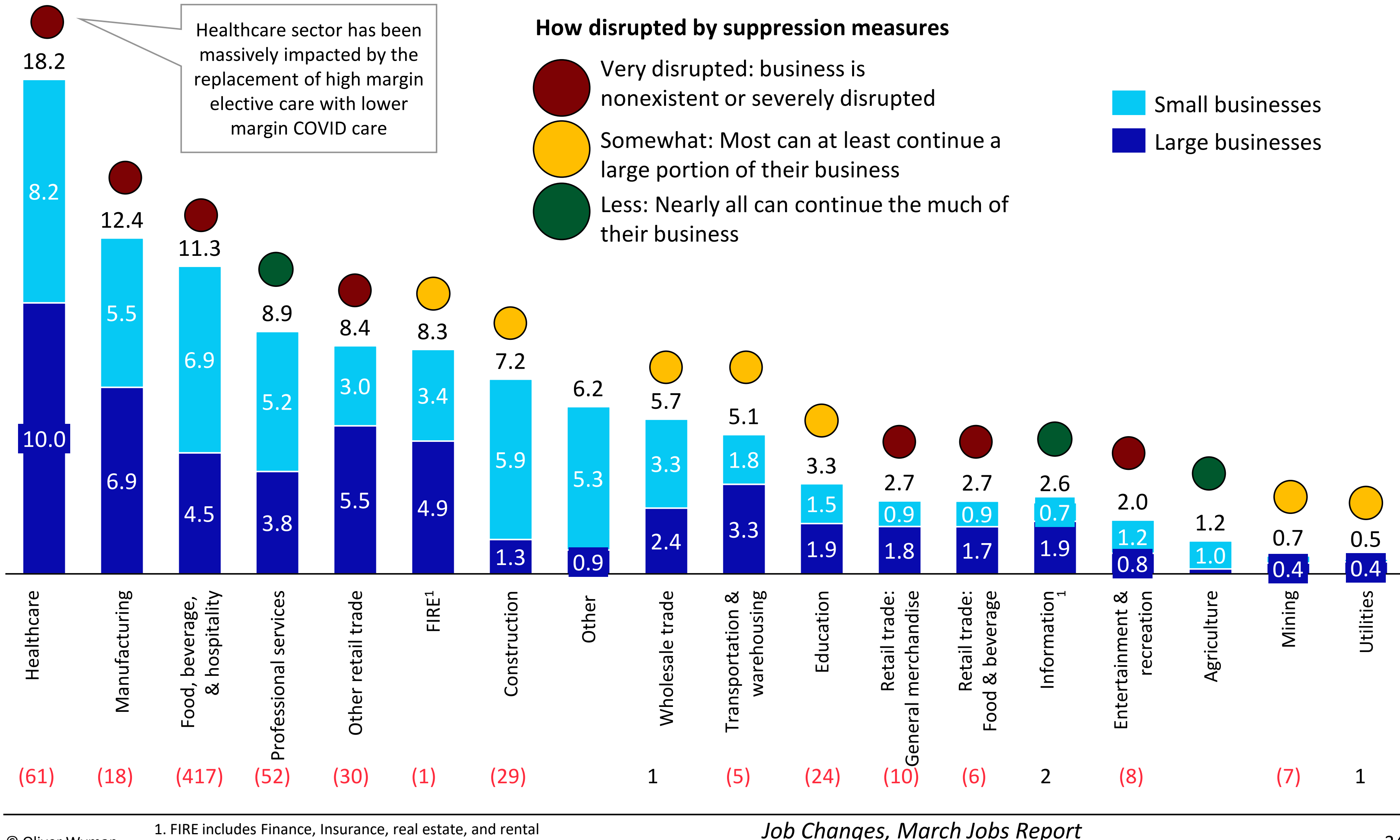


1. FIRE includes Finance, Insurance, real estate, and rental

Source: US Bureau of economic analysis; US small business administration

… AS WELL AS GETTING PEOPLE BACK TO WORK.

United States Employment by Industry, 2018
Full Time Employee equivalents, MM



1. FIRE includes Finance, Insurance, real estate, and rental
Sources: 1. US Bureau of economic analysis; 2. US small business administration

CASE STUDIES: WHAT ARE GOVERNMENTS PLANNING?

Israel and California have both released plans outlining their philosophies and approaches to reopening

Israel has a specific by-industry cascade but no set timeline or criteria for moving from phase to phase[1]

- Four phases, potentially starting as early as April 16, each lasting at least two weeks, depending on COVID resurgence

1	• High employment industries that are easier to enforce social distancing rules within: tech, finance, import/export • Public transit • Preschool
2	• Retail, except malls • Elementary schools
3	• Restaurants, hotels • All schools
4	• Entertainment (including sports) • Flights

California, in-contrast, has begun to outline criteria, but has no set plan for what to reopen in what order[2]

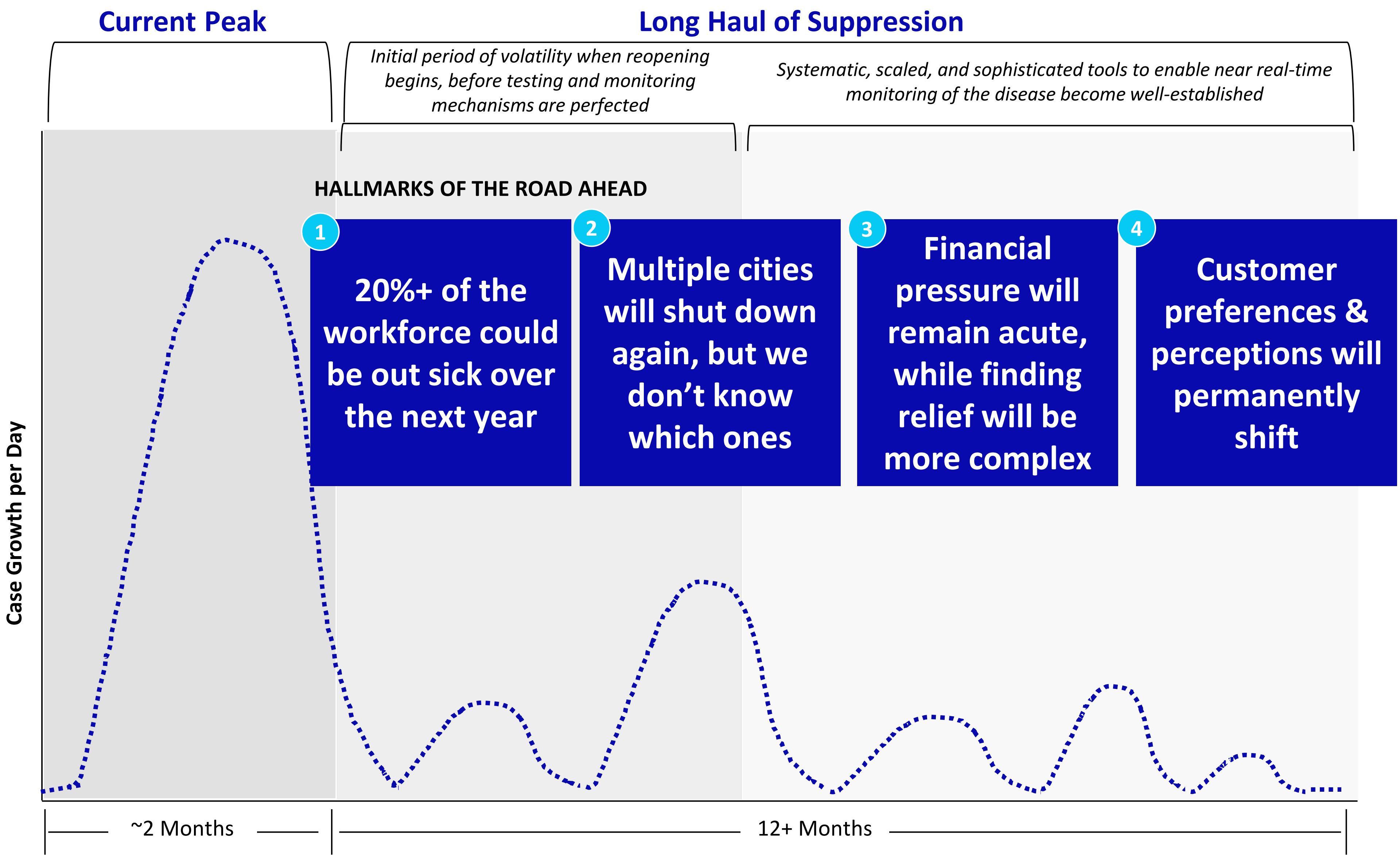
- Six criteria for reopening

1	Capacity to test all symptomatic individuals and their contacts
2	Ability to predict medically vulnerable populations from infection
3	Capacity of health systems to manage potential surges
4	Existence of therapeutics that can be produced at scale
5	Ability of business and other public places to maintain social distancing
6	Existence of an early warning system to reimpose suppression if necessary

Sources: 1. Haaretz (link)

Illustrative

THE LONG HAUL OF SUPPRESSION IS MARKED BY PERVASIVE RISK OF DISRUPTION



PERVASIVE RISKS LEAD TO CRITICAL QUESTIONS FOR ALL BUSINESSES TO ANSWER

1. *20% of the workforce will be out sick*
2. *Multiple markets will be shut down again*
3. *Financial pressure will remain acute*
4. *Shifting customer preferences and perceptions*

Workforce Resiliency and Readiness

- What are my workforce risk exposures *(demog., health status, geo, skills)?*
- Am I prepared for unavoidable churn in of COVID in my workforce?
- Are my WFH solutions sustainable for me and my employees?
- How might we reorganize workspaces to mitigate risks?
- Are we appropriately maximizing use of alternative staffing models?
- Are we reinforcing our employee relationships through this experience?

Customer and Channel Strategy

- What customer activity is shifting to digital, and will that activity shift back?
- Am I positioned to win if the shift to digital accelerates?
- Am I preserving customer relationships to ensuring rapid return of demand?
- How do we ensure customer confidence in the safety of our sites?
- Are front-line staff prepared to tactfully deal with new concerns and new social norms?
- What emerging consumer concerns or pain points offer growth opportunities?

Operational Effectiveness

- Are we over-indexed in certain geos, can that be cost-efficiently reduced?
- Can we enhance portability of operations to relocate in a new surge?
- How might sites and processes be redesigned for resilience, efficiency, and social distancing?
- Can automation alleviate critical risk points and boost efficiency?
- Are our infrastructure and IT configured to enable our plans?

Supply Chain Risk Management

- Are contingencies set to mitigate disruption if a key supplier or geo goes down?
- Are we equipped to monitor and respond quickly to such risks?
- Have we reset inventory targets to mitigate top risks while staying efficient?
- Is our sourcing and distribution durable to spot shocks?
- Are we sharing the right information to support mutual planning and risk monitoring?

What areas of risk are of highest concern to your organization?

ILLUSTRATIVE PLAYBOOK COMPONENTS ON WORKFORCE RESILIENCE AND READINESS

PHYSICAL WORK SPACE SAFETY

- Floor layout redesigns and foot traffic guidance to reduce congestion and maintain 6 ft distance
- Temperature checks upon entry and exit
- Mid-day spot cleaning break for all employees
- Bans on in-person meetings with 10+ people
- Masks/gloves at all times in public spaces
- ….

ALTERNATIVE STAFFING MODELS

- Formal separation of A-teams and B-teams to ensure backup availability
- ‘Flex pool’ or ‘pool of pools’ to plug live gaps
- Reallocation of workforce across sites to mitigate undue risk in one location
- All who can work from home do so
- Cross-training of all critical skill sets
- …

MANAGEMENT OF SPECIAL PEOPLE SITUATIONS

- Formal identification of higher risk employees *(demographics, health status, rare skills)*
- Alternative work rotations and extended WFH for populations at higher health risk
- Enhanced HR admin capacity for special employee circumstances *(e.g., sick days, PTO, furlough, alternative work arrangements)*
- …

PROACTIVE MONITORING AND INTERVENTION

- Elevation of centralized risk monitoring function
- Real-time tracking and evaluation of all key risks
- SWAT teams for rapid intervention
- Contingency plans for opening / closing / relocating operations based on evolving local risk
- Alerts and compliance monitoring
- …

SCALABLE EMPLOYEE SUPPORT

- Transportation burden assistance *(e.g. to avoid subway use)*
- Mental wellbeing coaching, accessible resources
- Productivity training for remote collaboration
- Policy & technology provision for extended work-from-home for large portions of workforce
- Child care assistance for remote workers
- …

FUNCTIONAL REDESIGNS

- Workflow redesign to reduce hand-offs, complexity, and intensity of rare skills
- Automation of critical processes and processes with higher personnel risks
- Infrastructure and IT configured for enablement of full program portfolio
- …

03

OW PANDEMIC NAVIGATOR: SCENARIO MODELING

OLIVER WYMAN HAS INVESTED HEAVILY IN DEVELOPING ANALYTICS TO PROJECT FUTURE WAVES OF THE PANDEMIC – WHY?

We are deeply uncomfortable with the models informing policy choices today	We have developed a unique Pandemic Navigator to inform our clients and policymakers
Flawed: static transmission rate parameters	**Dynamic:** transmission rate parameter calibrates to actual daily experience – 50 states, 40 countries
Unstable: wild variations in projection results week-to-week	**Accurate:** highly accurate predictive results over multiple weeks for a sustained strategy
Non-causal: inability to predict efficacy of policy measures	Implied from trends, however transmission rate **linked to observable physical distancing metrics**
Backward-looking: inability to inform future policy choices	**Forward-looking:** model learns from the past action/reaction cycle and enables individual policy choices to be projected into future pandemic waves

COVID-19 INSIGHTS ENGINE

Our model uses a time dependent version of the SIR approach to account for containment interventions

Too many models informing policy choices use simplistic, static parameters

Susceptible — Susceptible population at city, state, country or regional level

β — ***Static*** *rate at which Susceptibles become Infected*

Infectious — Population infected with virus

λ — ***Static*** *rate at which Infecteds become Removeds*

Removed — Population recovered or dead

These models are deeply flawed for analysis of the evolution of the pandemic

- Models ignore how large scale interventions will control the spread change the infection rate (β), e.g.
  - Quarantine
  - Social distancing
  - Air travel and border shutdown
  - Public shutdown
  - Lockdown
- … and do not allow resolution rates to be studies relative to health system capacity

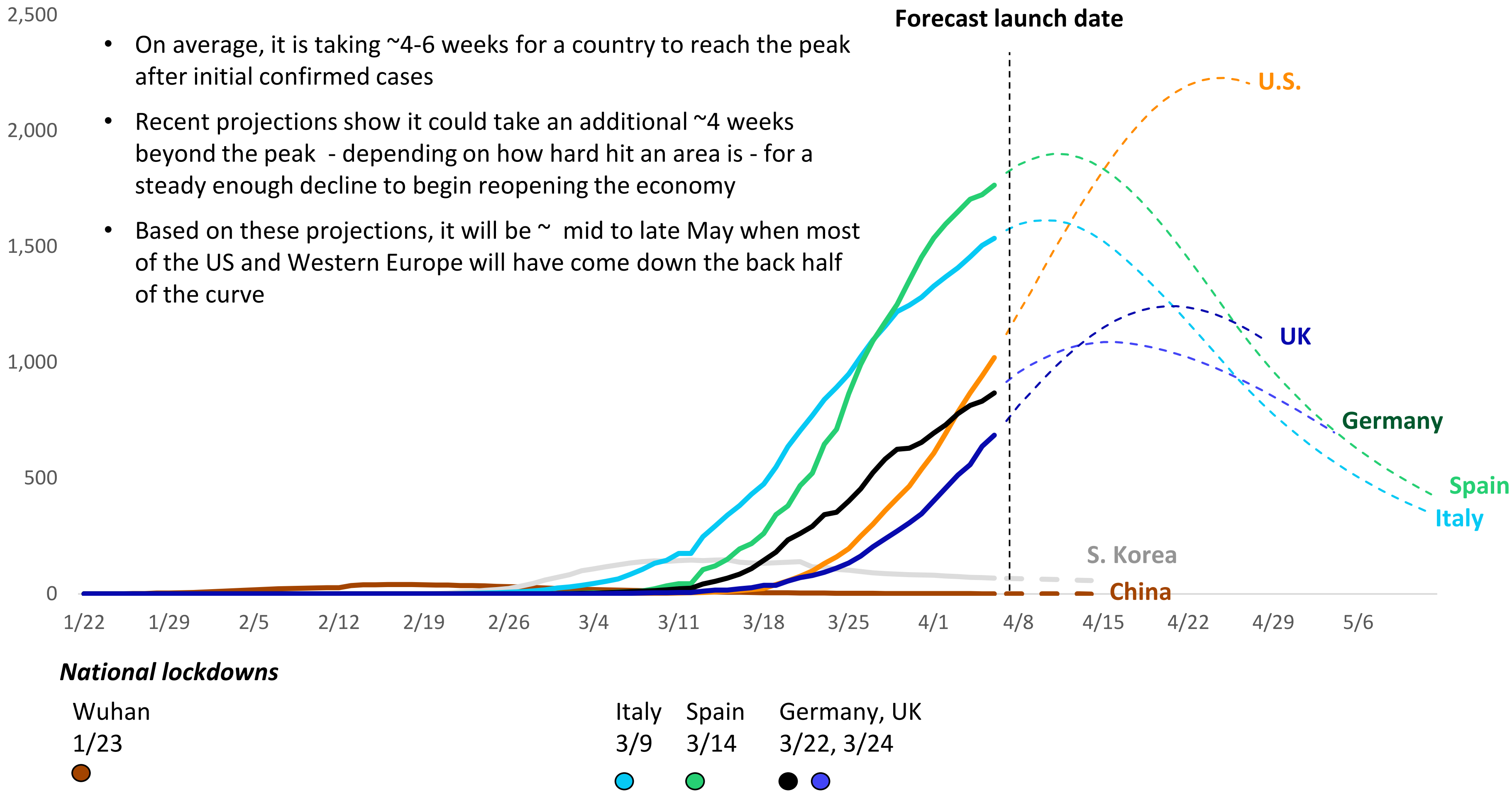
The Oliver Wyman Model is robust

- *Time dependent* transmission rate captures the dynamic impact of containment measures by country
- We focus on confirmed universe first. Extensions to asymptomatic universe is still assumption based
- Transmission rates ($\beta(t)$) and resolution rates ($\lambda(t)$) calibrated daily to live data for 40 countries and the 50 US states
- We are linking real-time data sets such as mobile phone location and traffic volumes to $\beta(t)$ which provides us with leading indicators which will be predictive as to the efficacy of containment measures going forward
- We have also linked government actions to slow down $\beta(t)$

ACCURATE: WE HAVE BEEN CORRECTLY PREDICTING INITIAL COUNTRY PEAKS FOR SEVERAL WEEKS

OW COVID-19 Projections (select countries) – <u>Active cases per million</u>
6 April 2020

- On average, it is taking ~4-6 weeks for a country to reach the peak after initial confirmed cases
- Recent projections show it could take an additional ~4 weeks beyond the peak - depending on how hard hit an area is - for a steady enough decline to begin reopening the economy
- Based on these projections, it will be ~ mid to late May when most of the US and Western Europe will have come down the back half of the curve



RECENTLY, GOOGLE INDICES BECAME AVAILABLE TO MAKE COMPARIONS TO OW COVID-19 TRANSMISSION RATE

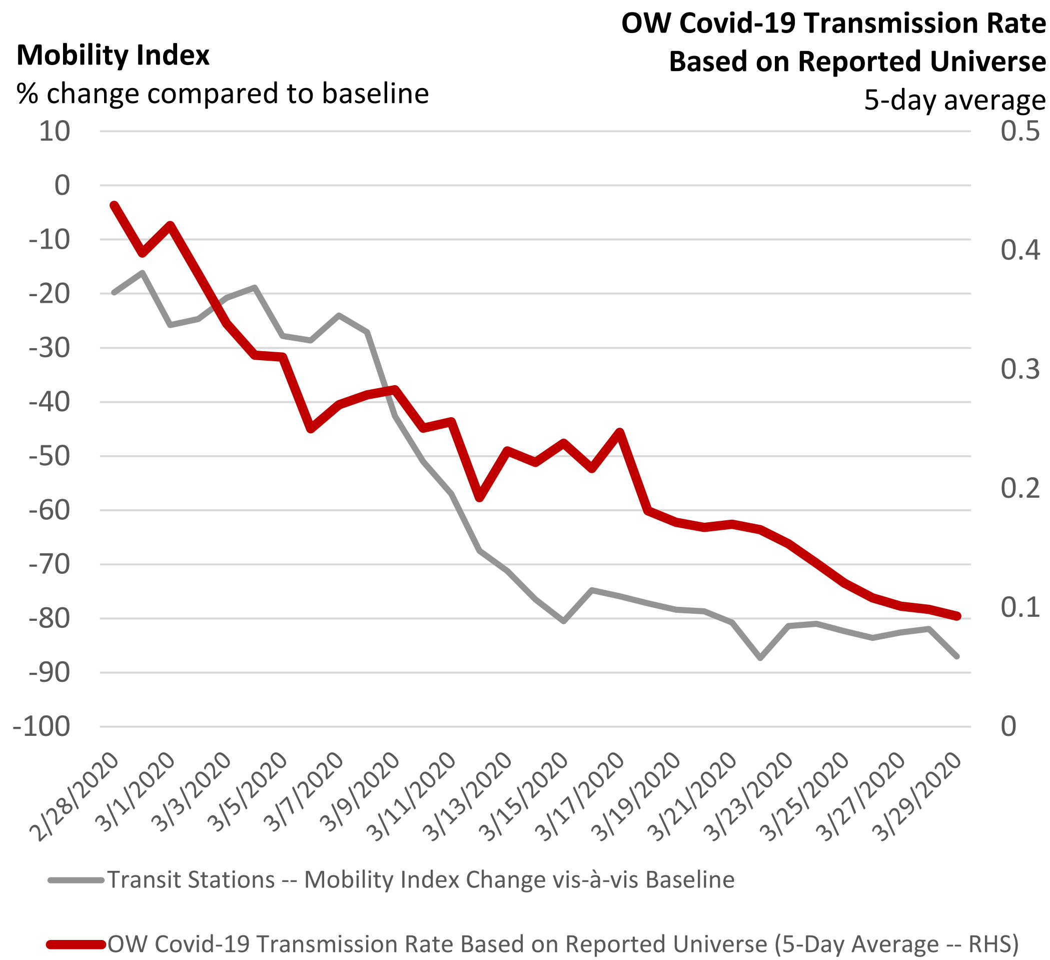
GOOGLE MOBILITY INDICES REVEAL WHAT HAS CHANGED IN MOVEMENT ACTIVITY; OLIVER WYMAN COVID-19 TRANSMISSION RATE MEASURE CONFIRMS THAT SOCIAL DISTANCING WORKED IN REDUCING SPREAD OF COVID-19 IN CONFIRMED/DETECTED CASES

Pick a region

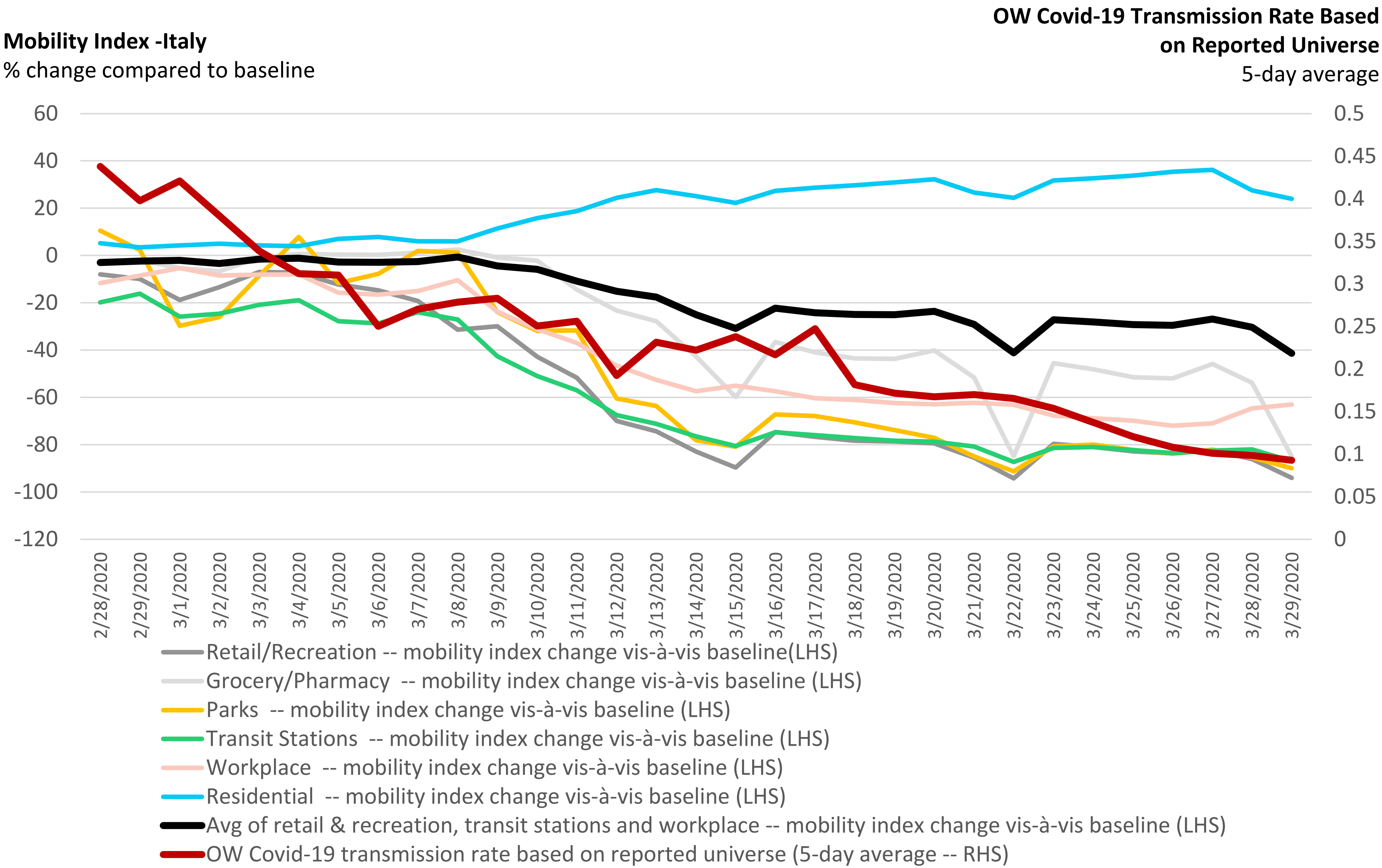
- Pick a region
- Italy
- United Kingdom
- Sweden
- Czechia
- Brazil
- New York

Pick a mobility index

- Pick a mobility index
- Retail & recreation
- Grocery & pharmacy
- Parks
- Transit stations
- Workplace
- Residential
- Average of retail & recreation, transit stations and workplace

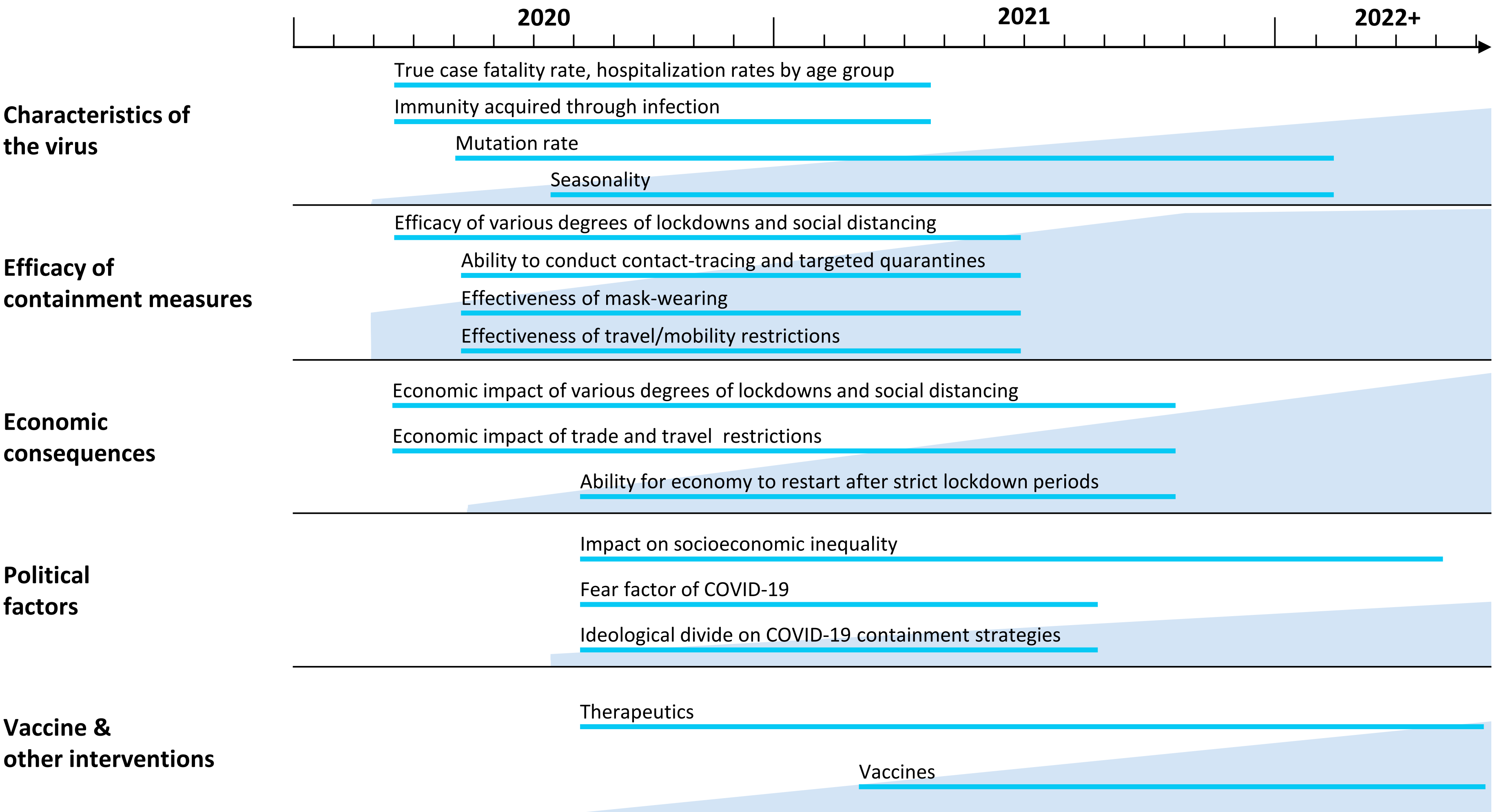


SUPPRESSION MEASURES HAVE WORKED: BUT WHICH ONES ARE MOST EFFECTIVE?



CRITICAL INFORMATION ON EACH OF THESE FACTORS WILL EMERGE AT DIFFERENT SPEEDS OVER THE NEXT 12-18 MONTHS AND WILL BE CAPTURED BY OUR MODEL

Major unknowns by factor and illustrative timing on path to certainty



04

AN END TO THE CYCLE: VACCINE AND THERAPEUTICS

THREE CATEGORIES OF THERAPEUTICS COULD SPEED UP ERADICATION OR AT LEAST LESSEN THE BURDEN OF SEVERE DISEASE AND MORTALITY

Product type	Description	Examples	Current state
Antivirals and products with antiviral effects	• Products either **directly target the virus or prevent it from targeting** / entering cells • Many of these **products have already been proven safe** as a result of clinical trials for efficacy against other diseases • These products generally **work best when given early** in the course of the disease	• Remdesivir (Ebola) • Chloroquine / Hydroxychloroquine (Malaria) • Kaletra (HIV) • Favipiravir (Influenza) • Avigan (Influenza) • Lopinavir (HIV) • Galidesivir	• Clinical trials on-going with Remdesivir (results in April / May), Avigan (results April / May), Galidesivir and are planned for Kaletra • Initial reports from small studies suggest positive results with Chloroquine (France) and Favipiravir (China) • Subsequent physician reports on efficacy of Hydroxychloroquine have been mixed • FDA granted emergency use designation for Chloroquine and Hydroxychloroquine (3/31)
Passive immunization	• Products **help the immune system fight** the virus • This type of product is common in treating cancer, rheumatoid arthritis and Ebola • These would be **the first generation of therapeutics specific to COVID-19**	• Convalescent plasma (from recovered patients) • Plasma-derived products • Monoclonal antibodies (e.g., Leronlimab, Tocilizumab) • Natural Killer cells (e.g., CYNK-001)	• Initially positive reports on use of convalescent plasma (China)[1,2] and multiple on-going trials at more than 40 institutions in the US coordinated by Mayo clinic • Early clinical trials for many new and existing monoclonal antibodies as well as CYNK-001 • Big pharma players have joined forces to work on a plasma-derived product (unnamed)
Symptom and complication relief	• A **broad category** of products that **lessen the effect of the disease or the complications** resulting from it (e.g., severe inflammatory response in the lungs)	• Actemra, Kevzara • Sylvant • Blood purification	• Phase III clinical trials with Actemra and Kevzara testing drugs' potential in reducing severe inflammation from COVID-19 infection • Clinical trial with Sylvant testing ability to reduce need for ventilation and shorten ICU length of stay • FDA granted emergency use for blood purification devices (4/10)

Sources: Adapted from Business Insider (link), Journal of Chinese Medicine Association (link), Archives of Emergency Medicine (link), Healthline (link)
1. JAMA (link) 2. PNAS (link)

HOW AND WHEN WILL WE RECOVER COMPLETELY?

A successful vaccine manufactured and deployed at scale is the only certain path to eradication

How long could that take?

- In short, 18+ months is likely for development, trials, approval and mass production
- The best comparison we have is the development of H1N1 vaccines under similar circumstances:

H1N1[1]

6 months until vaccine approval; 12 months critical conditions; 18 months until end of pandemic

MAR 2009	APR 2009	Summer 2009	July 2009	Sep 2009	Dec 2009	Aug 2010
First world-wide case emerges	US Gov declares state of emergency	Source region possibly under control	Vaccine clinical trials begin	FDA approves four H1N1 vaccines	Vaccine available broadly	WHO declares end of pandemic

What is the current status?

- Several vaccine types are being considered for COVID-19: **1) traditional protein-based** (longer development, manufacturing timeframe but proven approach), **2) mRNA-based** (quick to design but less proven technology and efficacy, **3) DNA-based** (quick to design but less proven technology)
- There are currently **78 confirmed active programs** to produce a COVID-19 vaccine; of them **5 are in clinical trials**:
  - **Moderna** – first patient was dosed on 3/16/20; results are expected late spring or summer. If successful, vaccine could potentially be available for high-risk healthcare workers in the fall (emergency use) in parallel with pivotal trials, with commercial availability perhaps as early as Q2 2021
  - **CanSino Biologicals** – first patient also dosed on 3/16/20; company announced intent to move into Phase II trials soon based on preliminary Phase I data
  - **Inovio Pharmaceuticals** – first patient dosed on 4/6/2020
  - **Shenzen GenoImmune Medical Institute** - 2 different vaccine candidates

Sources: H1N1 timeline (link) , Credit Suisse Equity Research and Nature (link)

LIMITED UNDERSTANDING OF THE IMMUNE RESPONSE TO COVID-19 CREATES ADDITIONAL UNCERTAINTY BEYOND TYPICAL HURDLES OF VACCINE DEVELOPMENT

Key questions:

1. **Are individuals who have recovered from COVID-19 immune?**
   - **While the initial assumption was "yes", emerging evidence suggests more data is needed**
   - *Positive tests after clearance[1]:* S. Korea (116 cases), China and Japan have all reported cases who tested positive after being cleared – could be due to reinfection, viral reactivation or testing errors
   - *Varying levels of neutralizing antibodies[2]:* A study examining presence of neutralizing antibodies in recovered COVID-19 patients identified significant variation in levels of produced antibody with 6% of patients producing no detectable antibody

2. **If immunity is conferred, how long will it last?**
   - **Best estimates are based on other coronaviruses and range from months up to 3 years[3]**
   - Survivors of SARS outbreak had antibodies that lasted up to 3 years
   - Survivors of MERS had antibodies that lasted just under a year

3. **Is the virus stable enough for a single vaccine?**
   - **Thus far, mutations have been minor, making it unlikely that a more flu-like strategy will be required**
   - Minor mutations have been identified thus far in COVID-19 and none have been significant enough to cause concern among vaccine scientists[4]
   - The virus has been accumulating an average of 1-2 mutations per month vs 2-4x that rate for the flu[5]
   - There are structural differences between the genome of the flu and SARS-CoV-2, which make it easier for flu to mutate[5]

1. DownTo Earth (link) 2. Medrxiv (link) 3. Time (link) 4. HealthLine (link) 5. Business Insider (link)

PRODUCTION OF AN APPROVED VACCINE AT SCALE AND ENSURING EQUITABLE GLOBAL DISTRIBUTION REPRESENT ANOTHER SET OF HURDLES

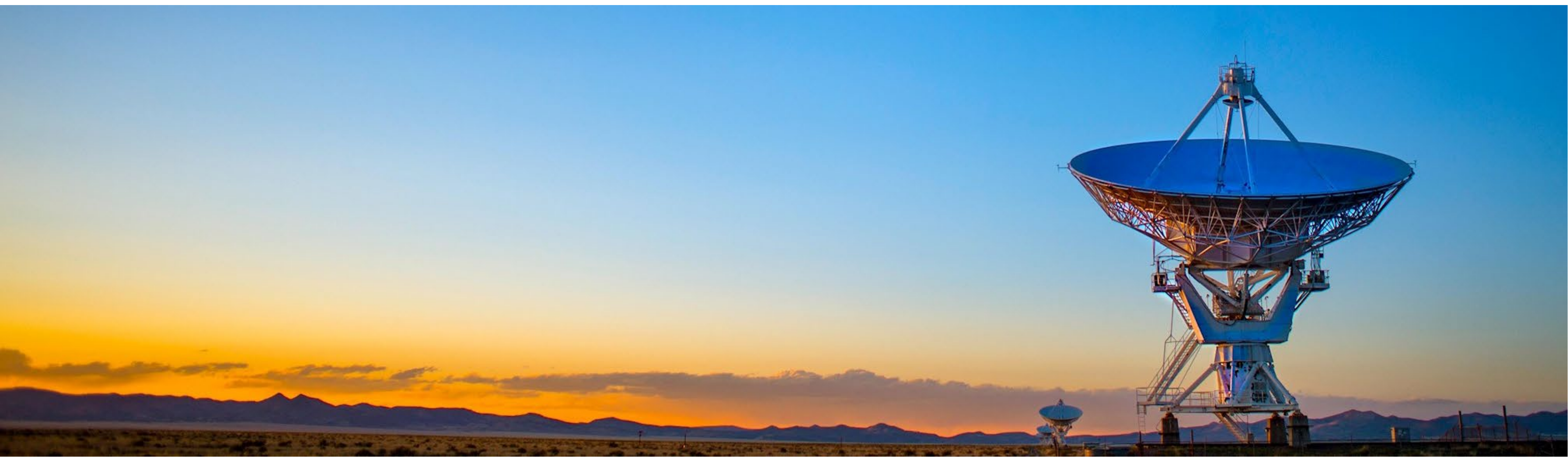
1. **Vaccine volume required is staggering**
   - Vaccination will be required globally, given current spread of COVID-19 across the globe
   - 60-85% of the population will need to be immune (either through vaccination or through acquired immunity post infection) given an R0 of 2-5.7
   - Assuming two doses per patient, vaccinating 60% of just the adult population is ~6.5 billion doses (this is equivalent to the WHO's estimates of annual global pandemic flu vaccine production capacity)
2. **Production of current vaccines must remain uninterrupted**
   - Annual flu vaccine production currently requires total vaccine capacity for ~ 6 months each year
3. **Which processes, components and facilities will be needed at scale is an unknown**
   - Vaccines under development span a broad array of types (e.g., RNA, DNA, inactivated virus, surface protein) and each carries different requirements for scaled manufacturing
   - Some, like Moderna's RNA vaccine require simpler processes, but will rely on entirely new infrastructure since no RNA vaccines are currently approved
   - Others, may leverage existing infrastructure (e.g., inactivated vaccine particle) but may have much more complex processes
4. **Production of vaccine is not sufficient, it must also be distributed and administered equitably**
   - Vaccine production is centered in the US, China and Western Europe
   - People living in low and middle income countries account for 79% of the world population
   - Achieving vaccination in these populations requires prevention of hoarding by wealthier countries producing the vaccines, adequate supplies (e.g., syringes, needles) and people to administer the vaccines as well as ability to maintain appropriate conditions (e.g., cold chain) while delivering vaccine to all areas

 Source: Adapted from Nature (link) and Vaccine (link)

READ OUR LATEST INSIGHTS ABOUT COVID-19 AND ITS GLOBAL IMPACT ONLINE

Oliver Wyman and our parent company Marsh & McLennan (MMC) have been monitoring the latest events and are putting forth our perspectives to support our clients and the industries they serve around the world. Our dedicated COVID-19 digital destination will be updated daily as the situation evolves.

Visit our dedicated COVID-19 website



QUALIFICATIONS, ASSUMPTIONS AND LIMITING CONDITIONS

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