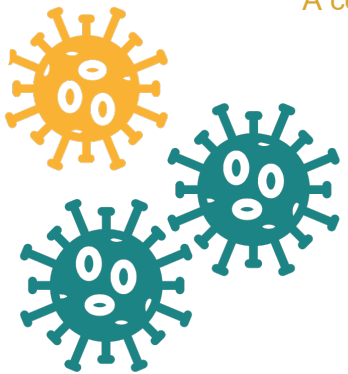
Modelling COVID-19 epidemics

A course organized by ISBE-NL, ELIXIR-LU, and EOSC-Life



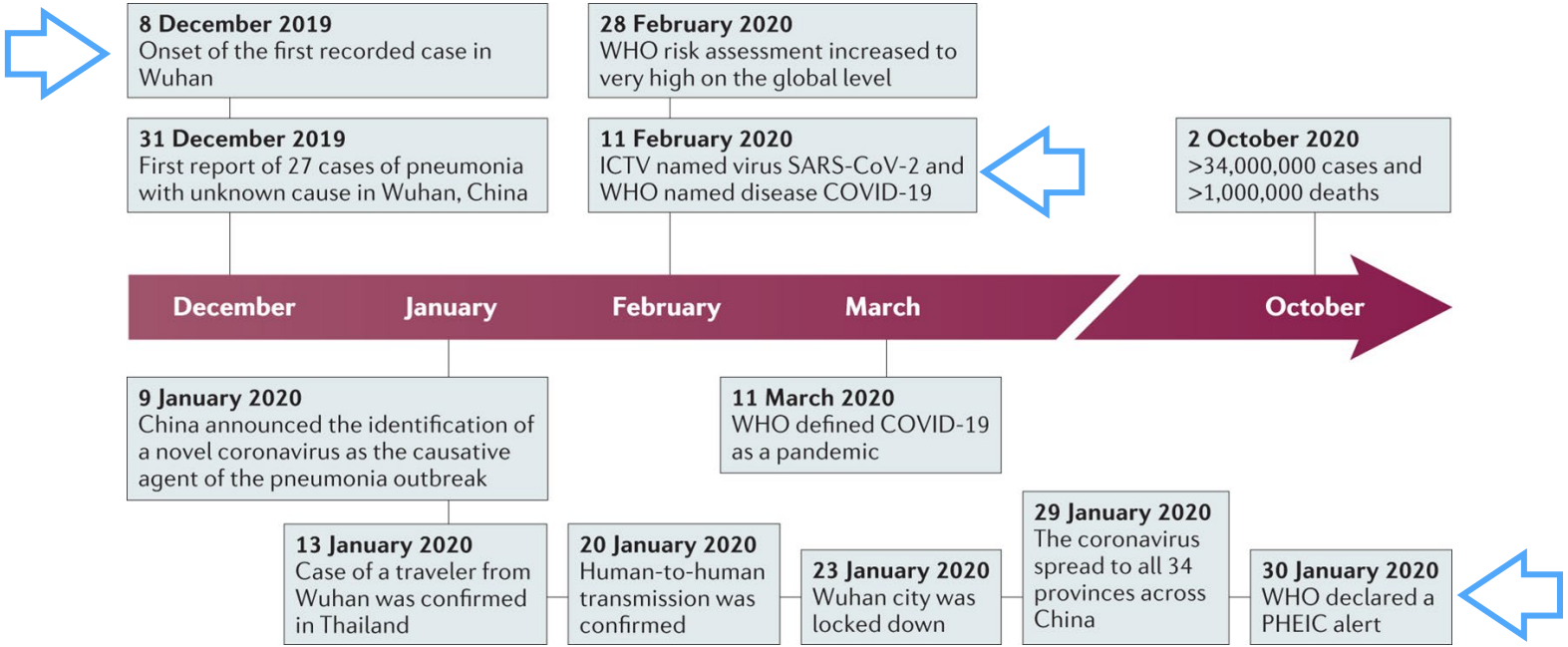
Biology & Epidemiology

Module I

November 30- December 2, 2020

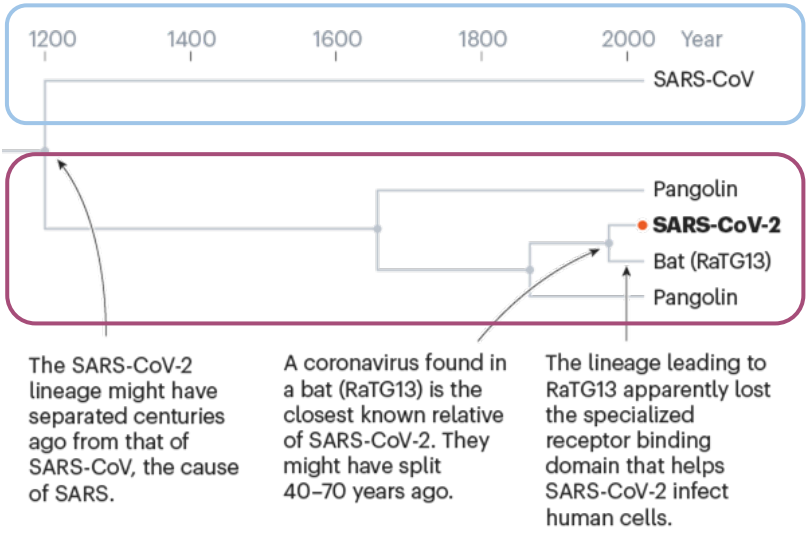
Stefan Astrologes & WESTERHOFF

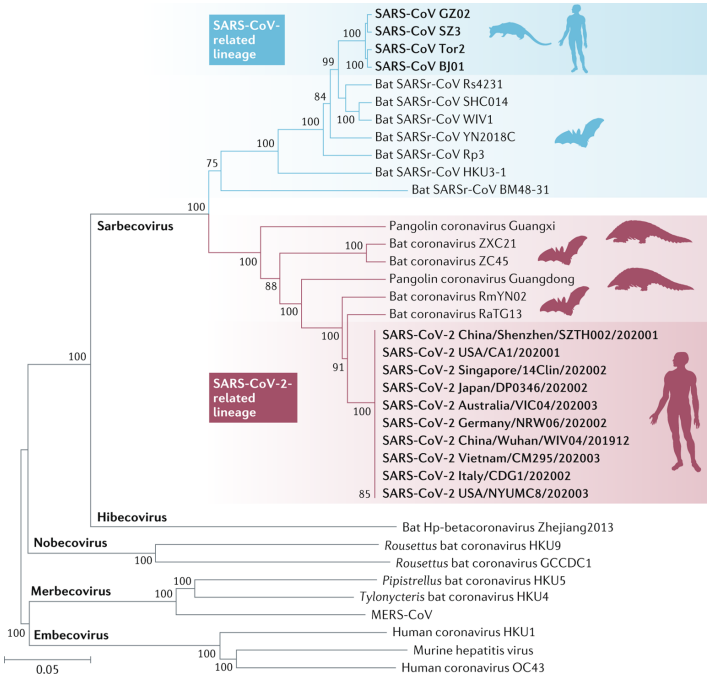
Timeline of COVID-19 outbreak



Hu et al.,2020, *Nature Reviews Microbiology*

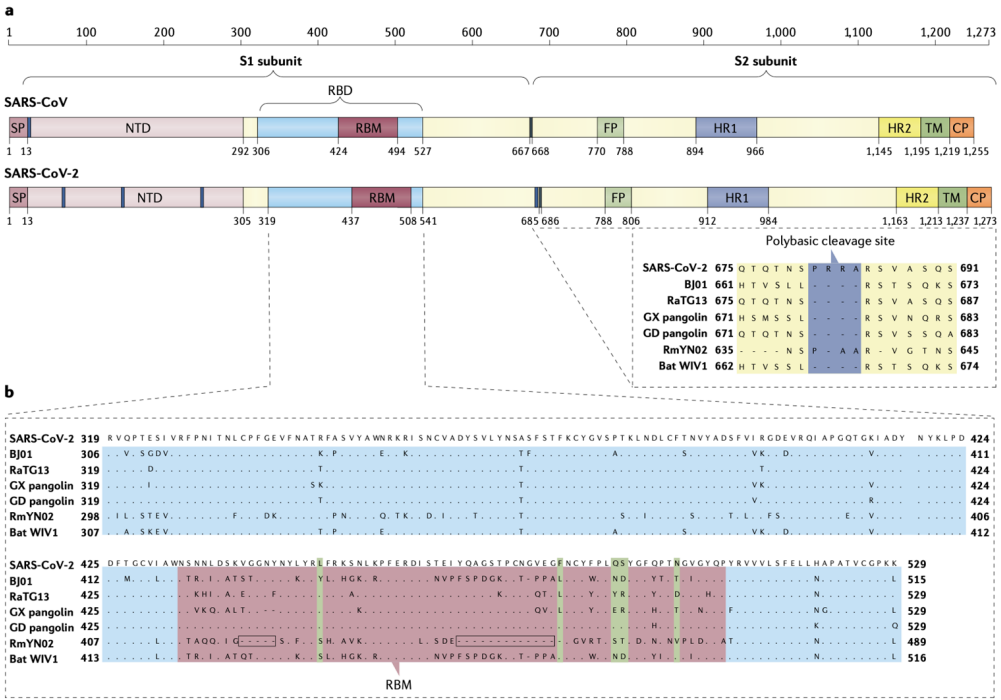
January 31, 2020 first sequencing SARS CoV2





Hu et al.,2020, *Nature Reviews Microbiology*

Sequencing : **Features** of SARS-CoV2



Hu et al.,2020, *Nature Reviews Microbiology*

Features of SARS CoV2 (virus structure)

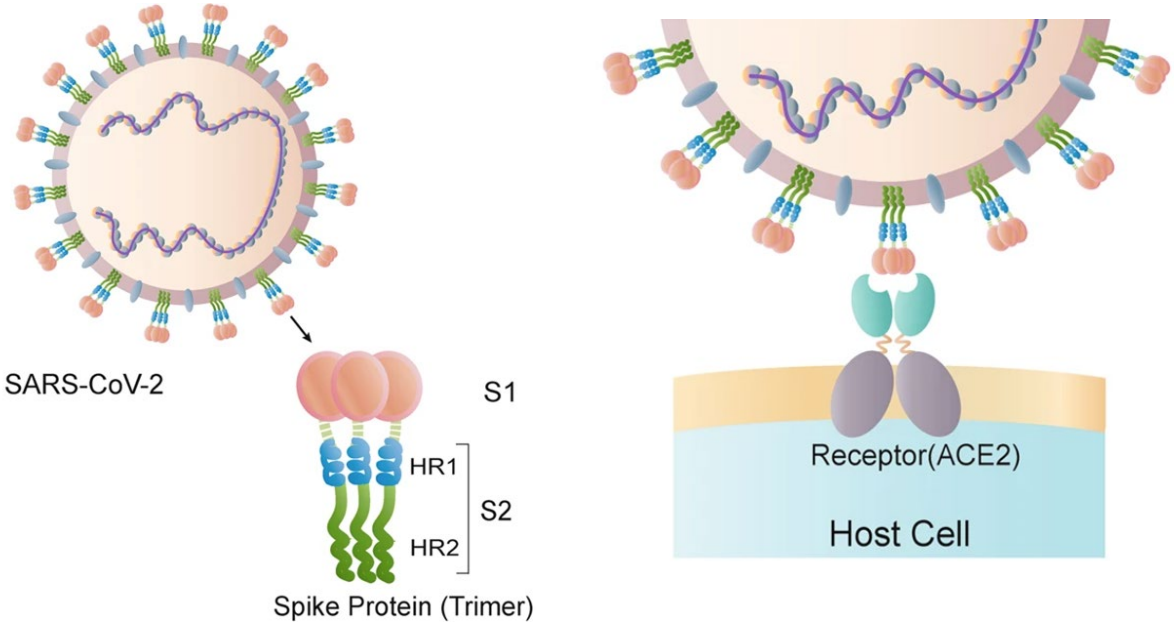
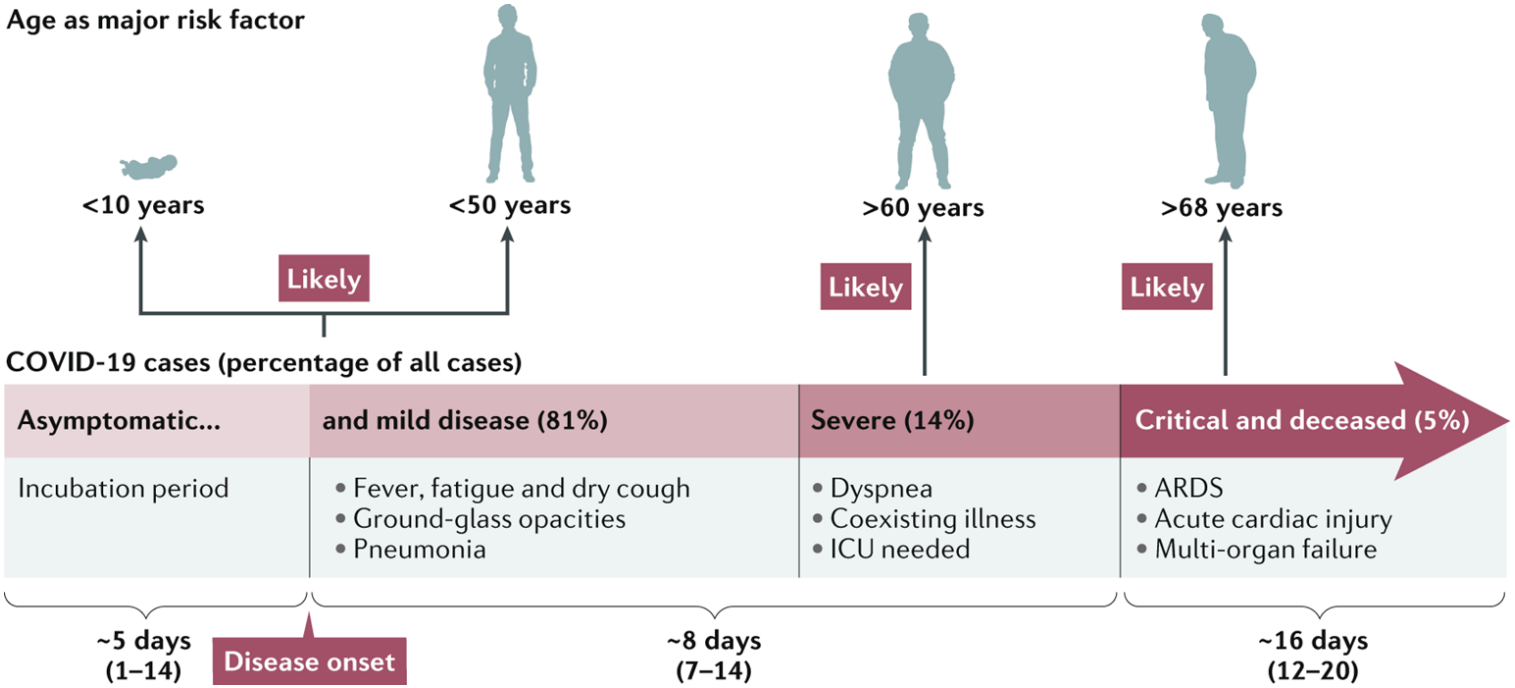


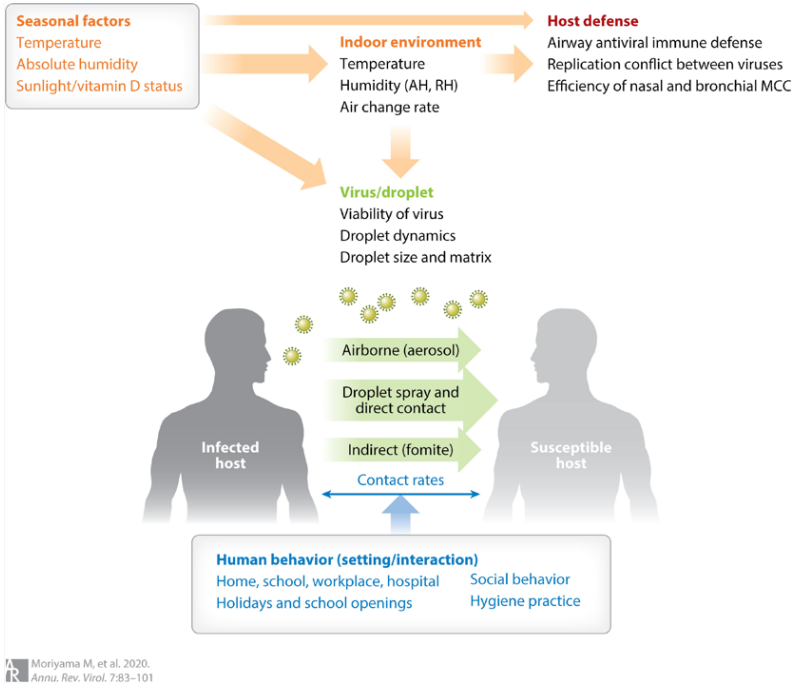
Figure adapted from https://www.nature.com/articles/s41401-020-0485-4

Clinical features of COVID - 19



Hu et al.,2020, *Nature Reviews Microbiology*

Transmission routes



Moriyama M, et al. 2020. *Annu. Rev. Virol.* 7:83–101

Obvious measures to prevent spreading

Personal Protective measures:

➔ Hands hygiene

➔ Cough and Sneeze into your elbow or a tissue.

➔ Wear masks and PPE

Environmental measures:

➔ Frequently clean used surface, clothes and objects

➔ Minimize sharing objects

➔ Ensure appropriate ventilation

Figure from www.condalab.com

Social distancing

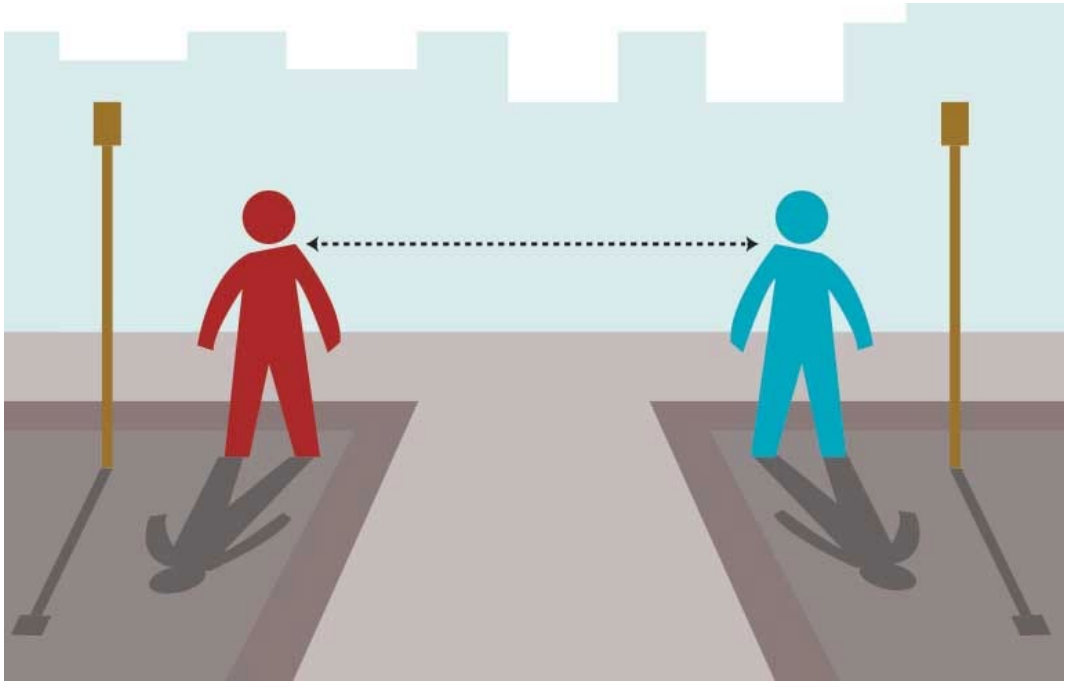


Figure from safetyandhealthmagazine.com

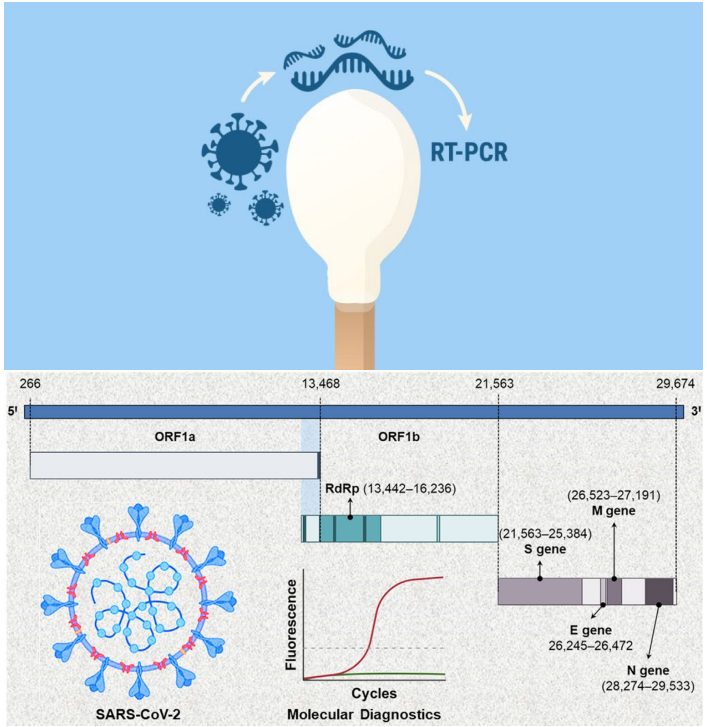
COVID-19 testing basics

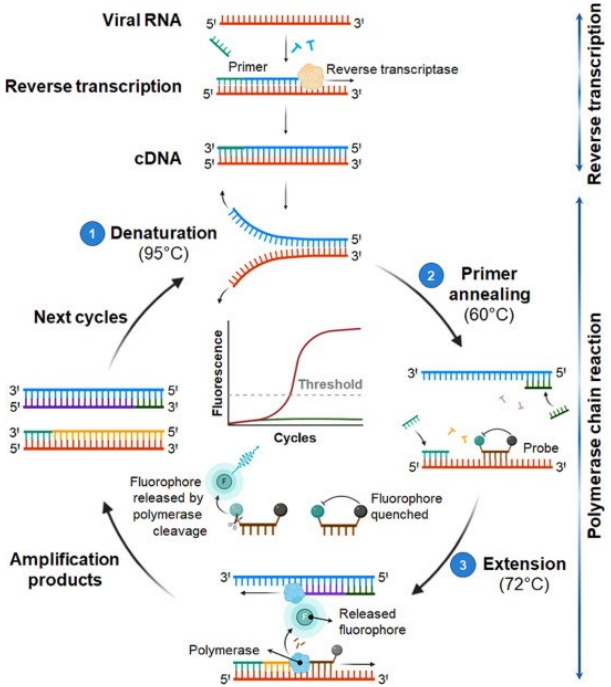
There are two different types of tests – **diagnostic tests** and **antibody tests**.

	Virus RNA	Virus protein	Host immunity
How the sample is taken...	Saliva (a few tests)	throat swab	Finger stick or blood draw
How long it takes to get results...	Same day (some locations) or up to a week	One hour or less	Same day (many locations) or 1-3 days
Is another test needed...	This test is typically highly accurate and usually does not need to be repeated.	Positive results are usually highly accurate but negative results may need to be confirmed with a molecular test.	Sometimes a second antibody test is needed for accurate results.
What it shows...	Diagnoses active coronavirus infection	Diagnoses active coronavirus infection	Shows if you've been infected by coronavirus in the past
What it can't do...	Show if you ever had COVID-19 or were infected with the coronavirus in the past	Definitively rule out active coronavirus infection. Antigen tests are more likely to miss an active coronavirus infection compared to molecular tests. Your health care provider may order a molecular test if your antigen test shows a negative result but you have symptoms of COVID-19.	Diagnose active coronavirus infection at the time of the test or show that you do not have COVID-19

“gargle” testing in Vienna

Molecular test (RT-PCR)





Afzal 2020, *Journal of Advanced Research*

➔ there are ~ 150 kits … available

➔ The majority close to 100% specificity

➔ Still there are false negatives …

Timing in testing

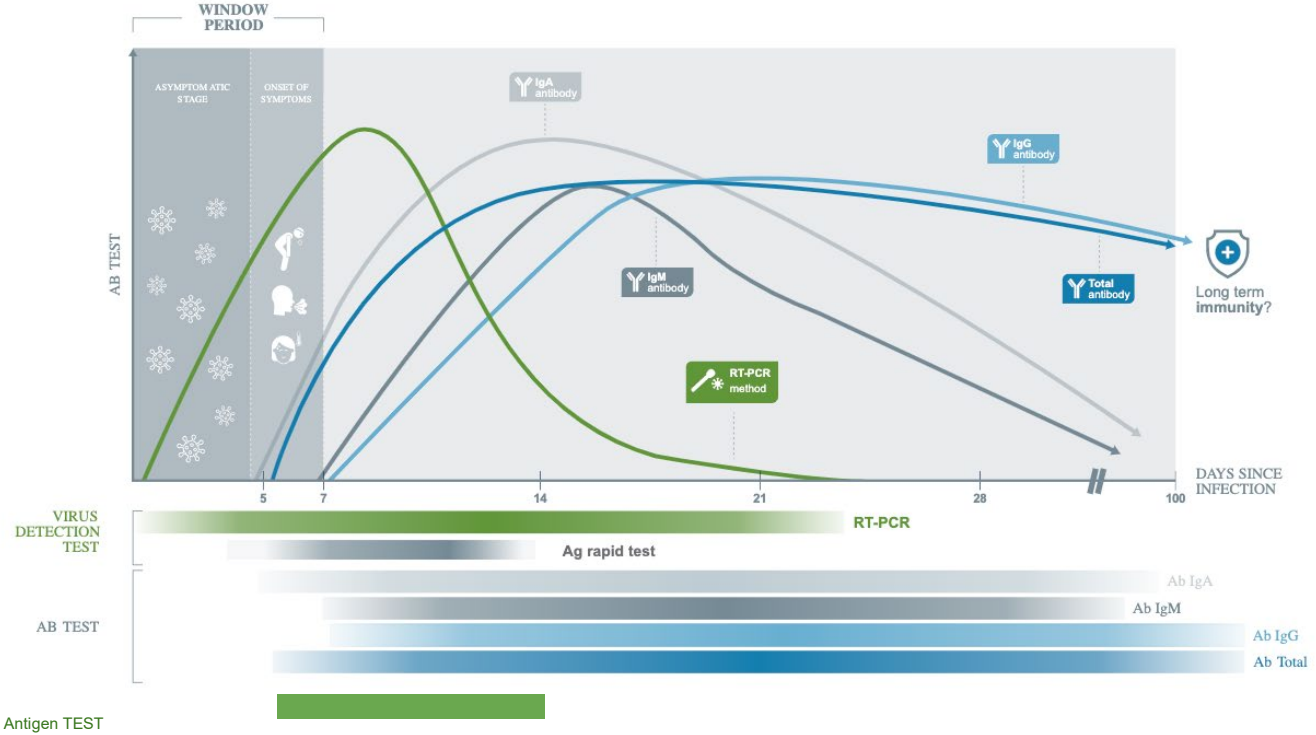
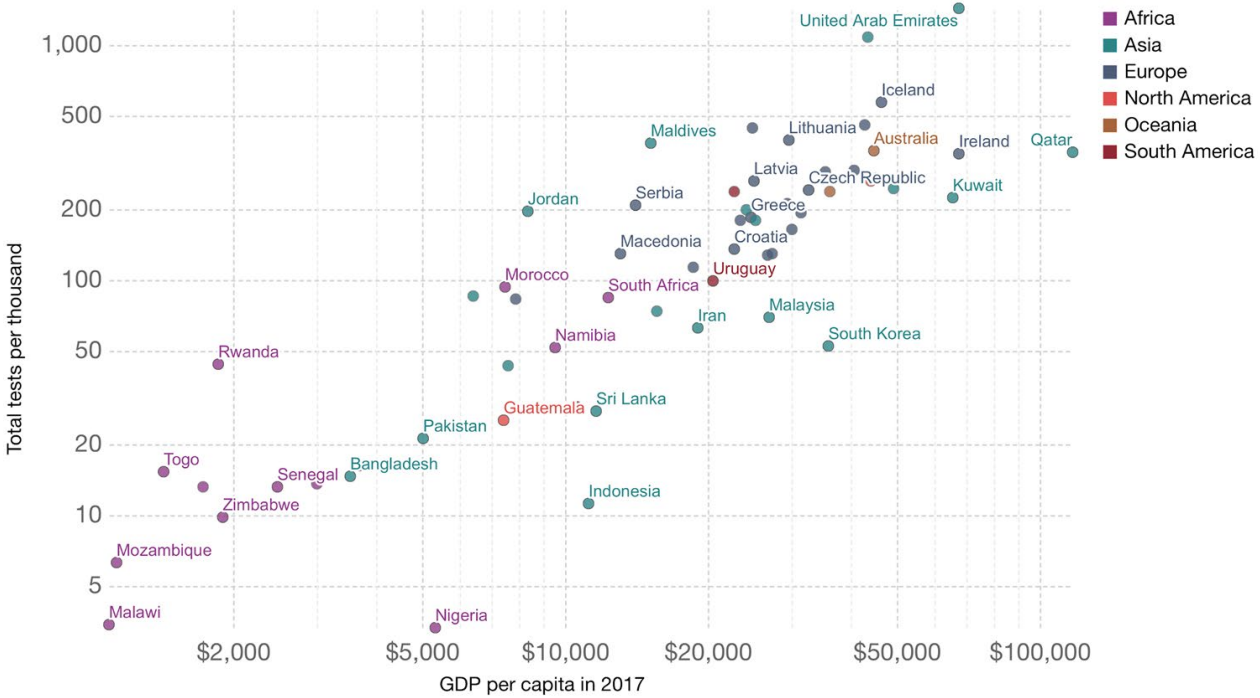


Figure from https://www.synlab.com/news-publications/sars-cov-2/antigen-tests-for-sars-cov-2-detection

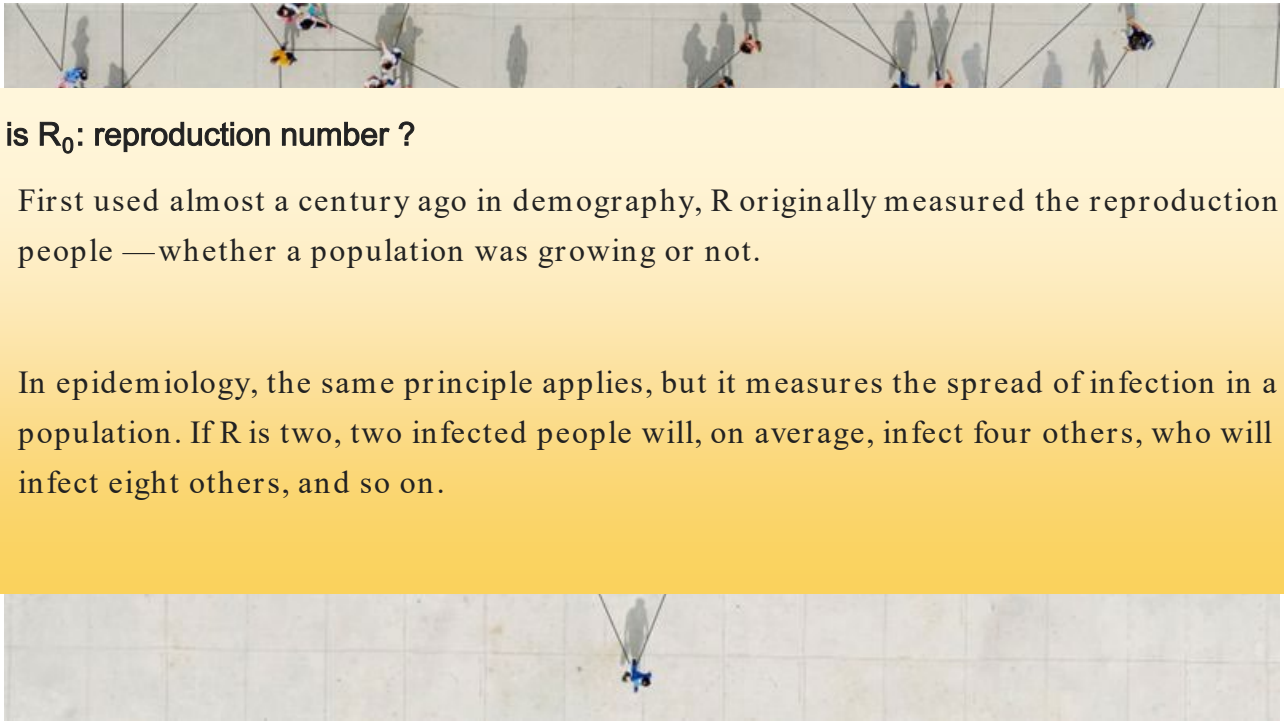
Why it is so important to develop *cheaper* tests?



R_0: *reproduction number*

Figure from https://www.bbc.com/news/health-52473523

R_0: *reproduction number*



What is R_0: reproduction number ?

- First used almost a century ago in demography, R originally measured the reproduction of people —whether a population was growing or not.

- In epidemiology, the same principle applies, but it measures the spread of infection in a population. If R is two, two infected people will, on average, infect four others, who will infect eight others, and so on.

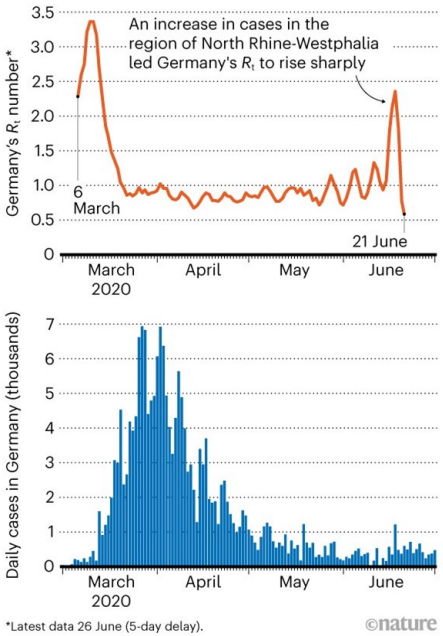
Figure from https://www.bbc.com/news/health-52473523

What R_0 *can* and *can't* tell us about managing COVID-19

Figure from https://www.nature.com/articles/d41586-020-02009-w

What R_0 *can* and *can't* tell us about managing COVID-19

Regional Outbreak



superspreaders

Shincheonji Church of Jesus in Daegu, South Korea

The *fallacy* of **herd** immunity

(© Laurinson Crusoe/Shutterstock)

The *fallacy* of **herd** immunity

➔ **What is herd immunity?**

"Herd immunity happens when a virus can't spread because it keeps encountering people who are protected against infection. "You don't need everyone in the population to be immune —you just need enough people to be immune,"

(© Laurinson Crusoe/Shutterstock)

The *fallacy* of **herd** immunity

Figure from https://www.bbc.com/news/uk-51677846

A cemetery in Manaus, Brazil, in June.

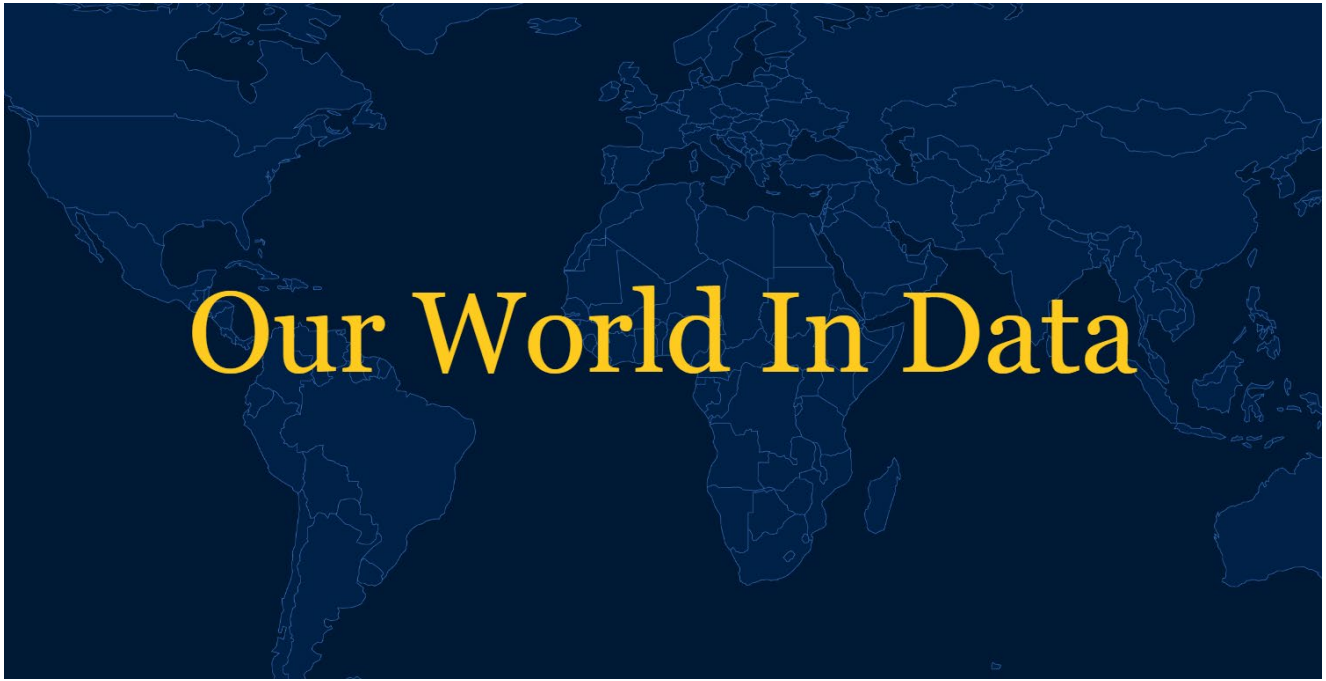
https://www.nature.com/articles/d41586-020-02948-4

The cost of herd immunity

~ 747 million

1-3% deaths

~ 11 million



Hasell, J., Mathieu, E., Beltekian, D. et al., 2020

Our World Data → Coronavirus Pandemic (COVID- 19)

They built 207 country profiles which allow you to explore **the statistics on the coronavirus pandemic for every country in the world** .

Each profile includes **interactive visualizations** , **explanations** of the presented metrics, and the details on the **sources of the data** .

Every country profile is **updated daily** .

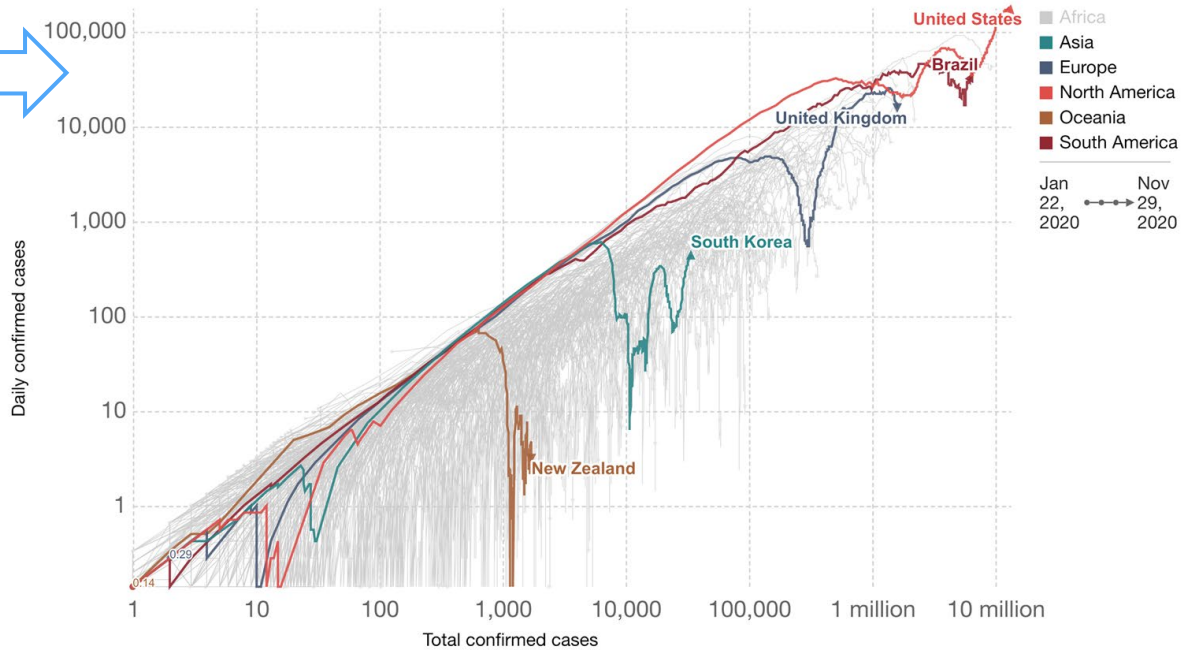
Every profile includes four sections:

1. **Deaths**
2. **Testing**
3. **Cases**
4. **Government responses**

Hasell, J., Mathieu, E., Beltekian, D. et al., 2020

When did countries bend the curve?

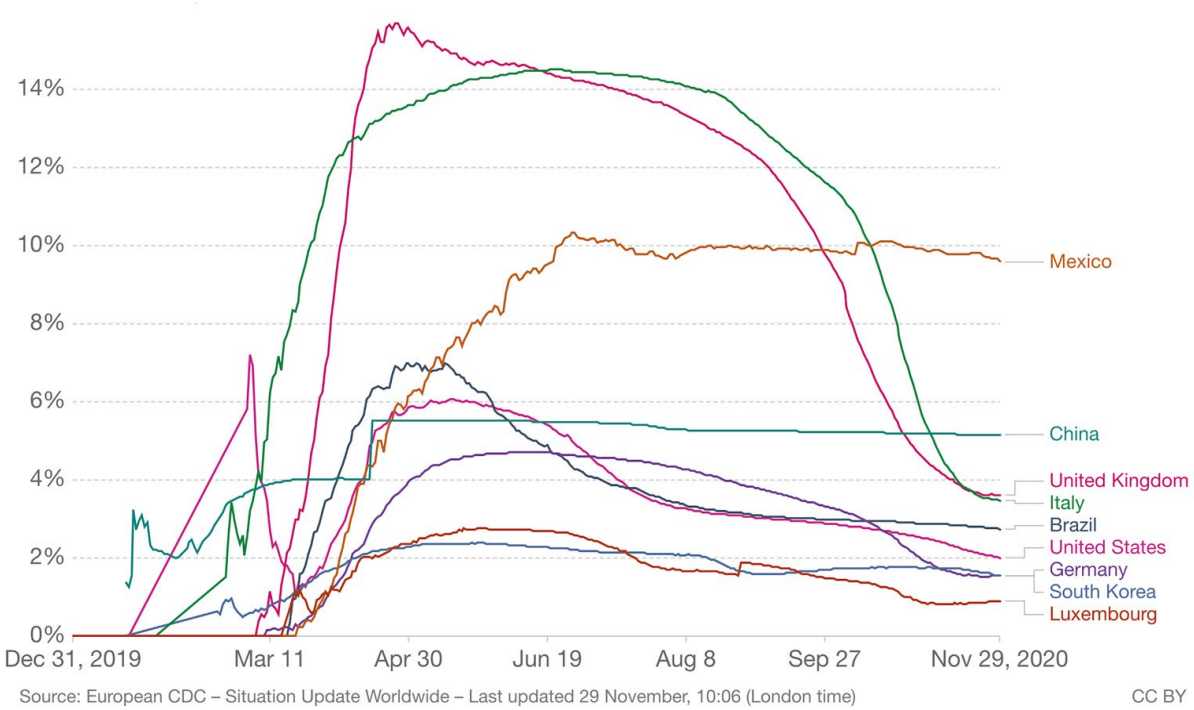
Log- scale



Source: European CDC – Situation Update Worldwide – Last updated 29 November, 10:06 (London time), Our World In Data
OurWorldInData.org/coronavirus • CC BY

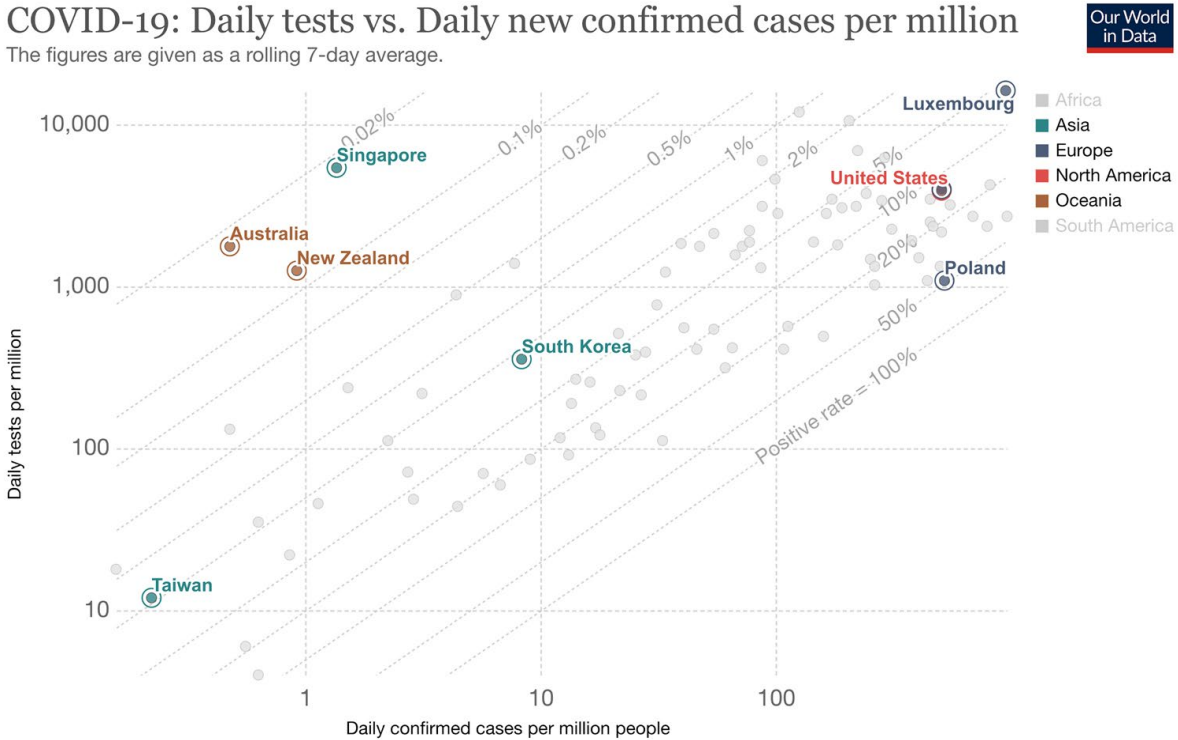
OurWorldInData.org/Coronavirus

Case fatality rate



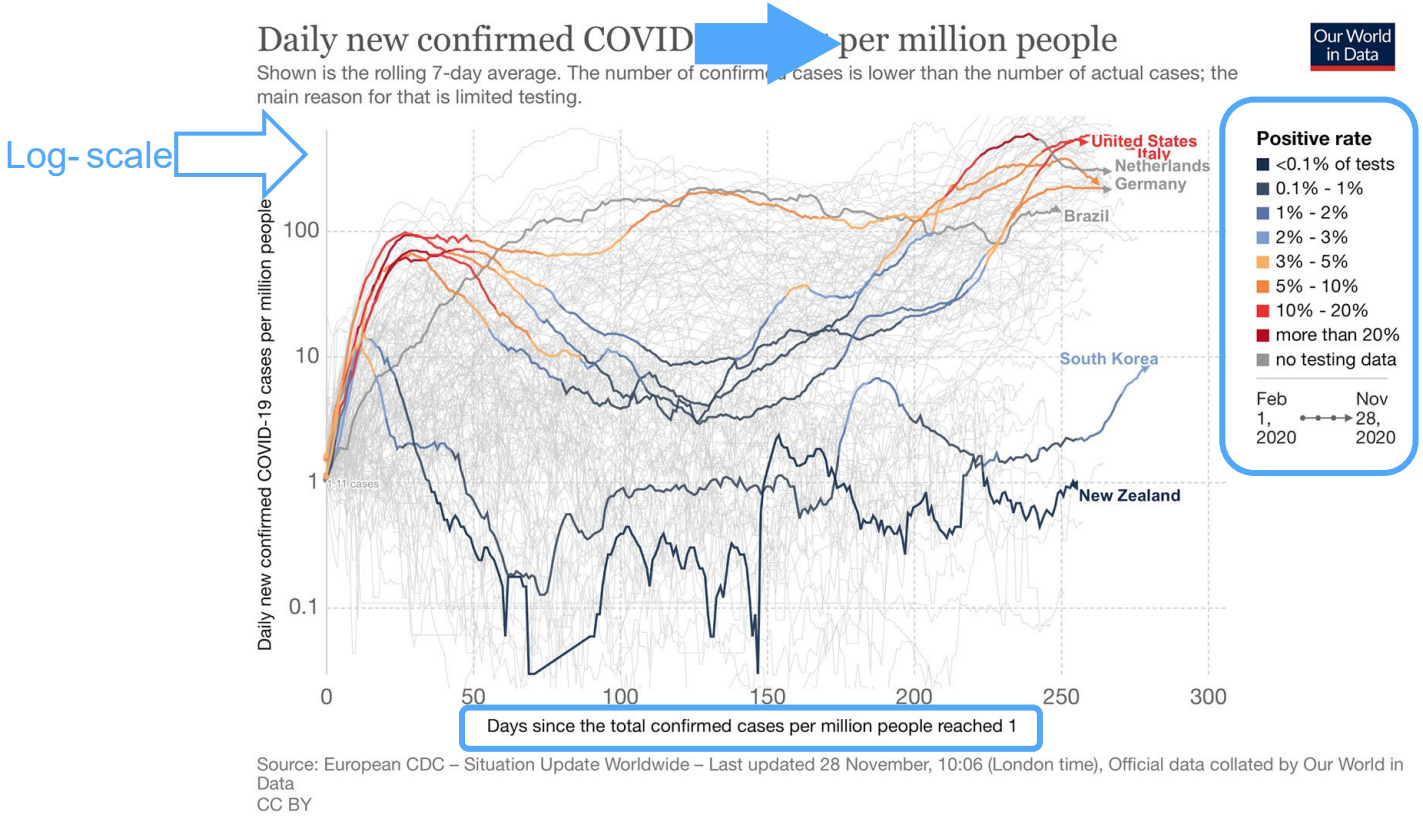
OurWorldInData.org/Coronavirus

Positivity rate



OurWorldInData.org/Coronavirus

Daily (confirmed) cases



Source: European CDC – Situation Update Worldwide – Last updated 28 November, 10:06 (London time), Official data collated by Our World in Data
CC BY

Vaccines & Therapeutics

Vaccines & Therapeutics

SCAN ME

Therapeutic Drugs

446 +2 TOTAL

359 +2 IN HUMAN TRIALS

Vaccines

183 +1 TOTAL

59 +1 IN HUMAN TRIALS

Categories

1. Inactivated virus
2. Live attenuated virus
3. Protein Subunit
4. DNA-Based
5. RNA-Based → BNT162b2 (Pfizer and BioNTech)
6. Replicating Viral Vector
7. Non-Replicating Viral Vector
8. Virus-like particle
9. Other vaccine

→ Sputnik V
→ AZD1222 (Astrazeneca)

Modelling COVID-19 epidemics

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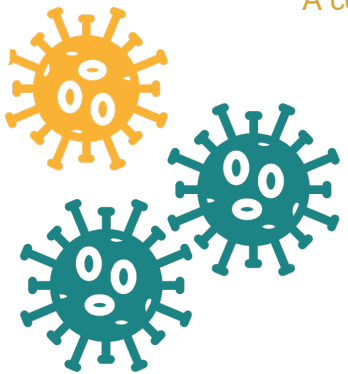


Policies of COVID-19

Module I

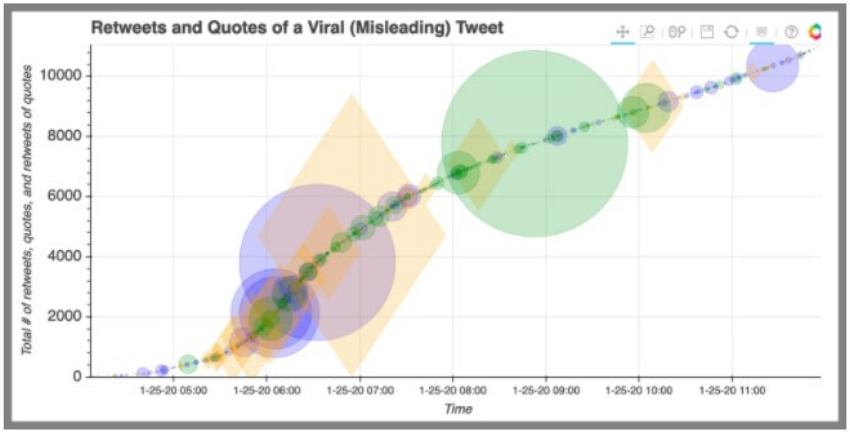
November 30- December 2, 2020

Stefania Astrologo & HAns WESTERHOFF

The scientist' duty

Provide data, facts, scientific knowledge, tests, … vaccine

All to support *rational* policy making



University of Washington professor Kate Starbird used a database of tweets about Covid-19 to create this chart showing how retweets (blue circles), quotes (orange diamonds), or retweets of quotes (green circles), boosted a tweet sharing inaccurate scientific claims about the novel coronavirus. COURTESY OF KATE STARBIRD

Just a cold!

Brazil's President Jair Bolsonaro

The scientist' task

Provide data, facts, scientific knowledge, tests, … vaccine

All to support *rational* policy making

The Corona epidemic

(Why) is it (so) bad?

The world is seeing many *crises* ...

Hunger

Poverty

Cancer

Diabetes

Global warming

War

Covid-19

...

Still perspectives are sobering ...

worldometers.info/coronavirus

Normal death rate: $\frac{112618 \cdot 366}{7825172174} \cdot 100 =$
$0.53\ \%/year$: **112,000** per day

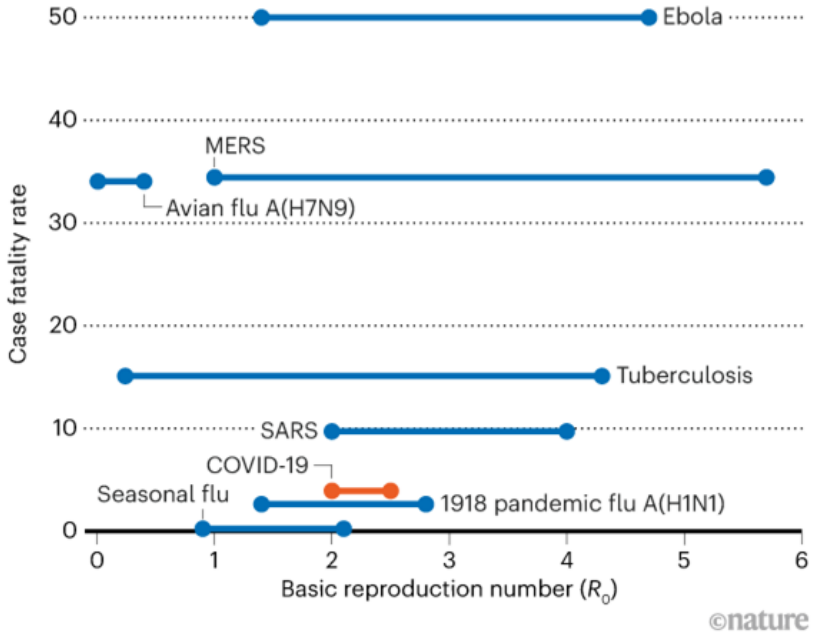
Corona death rate:
$\frac{1303830}{7825172174} \cdot 100 = 0.017\ \% =$
one thirtieth of a normal yea
7 months; per day **9,333**

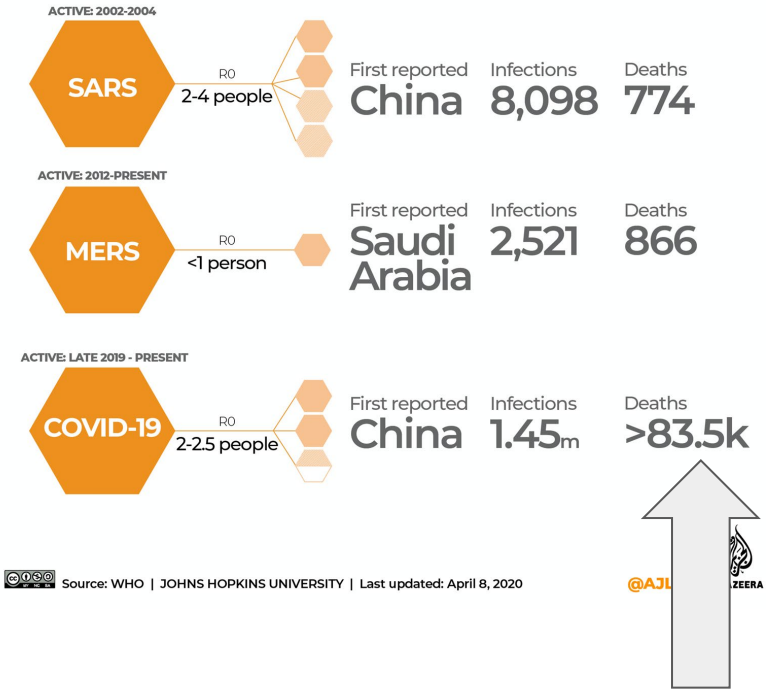
Hunger:
847,418,234 Undernourished people in the world
769,803,040 Obese people in the world
19,973 People who died of hunger today

Well, what is the Corona problem then?

- Exponential growth with doubling time of 3.5 days
- Herd immunity is around 60%
- 1.865395 million active cases as of 13 November to world population of 7.825172131 billion = 12 doubling times, i.e. 6 weeks.
- By the end of the year 60% of the world population could have been infected.
- Fatality rate will be higher than USA (2%), assume 3%
- Then: **120 Million deaths between now and the end of the year.**
- 4 times higher rate for 2020 than normal.
- **50 times higher rate than normal per day.**
- Swamping of all facilities
- **And this time it is also the rich who die**

COVID-19 *vs other 'influenzas'*





J[redacted] cold!

Brazil's President Jair Bolsonaro

Just[redacted]er influenz

Last updated: November 15, 2020, 11:57 GMT

Coronavirus Cases:

54,443,746

view by country

Deaths:

1,320,154

Recovered:

37,960,169

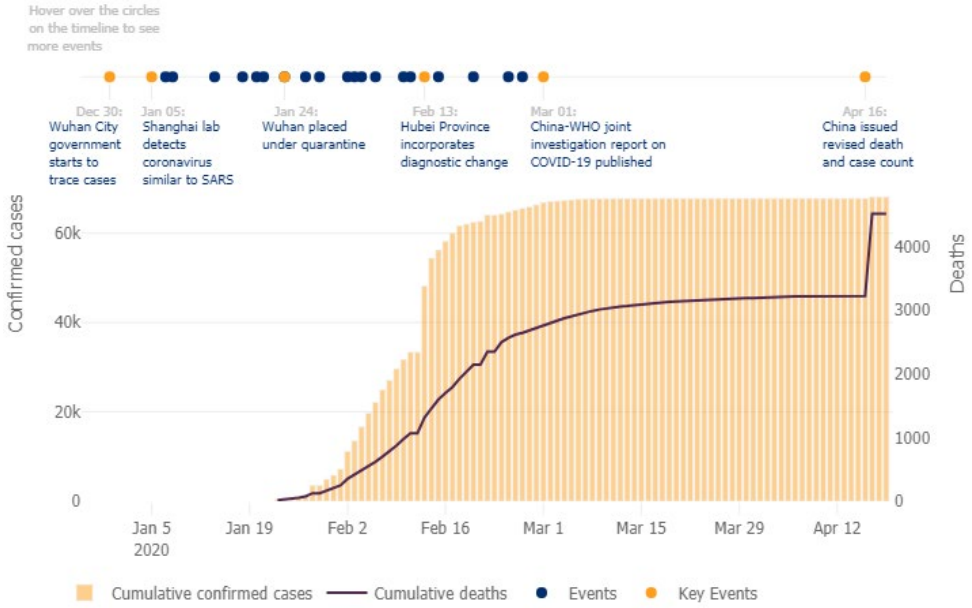
worldometers.info/coronavirus

More policy fallacies

- ‘There are no cases in my country’ (Bolsonaro)
- ‘We just have to wait for herd immunity’ (Boris J.)
- I am healthy and strong so I won’t get it (Bolsonaro)
- RIVM, Netherlands:
  - ‘Mouth masks’ merely promote the epidemic
  - 1.5 meter distance should suffice
  - Children do not contract the disease, hence the schools can be kept open
  - Nurses in old-age homes can keep working if they are non symptomatic
- The virus is only transmitted through droplets in air
- We can save the economy by preventing lockdown
- The people will not accept lockdown
- We can just wait and see and adjust our measures as the epidemic worsens

Can **rash government policy** *help*?

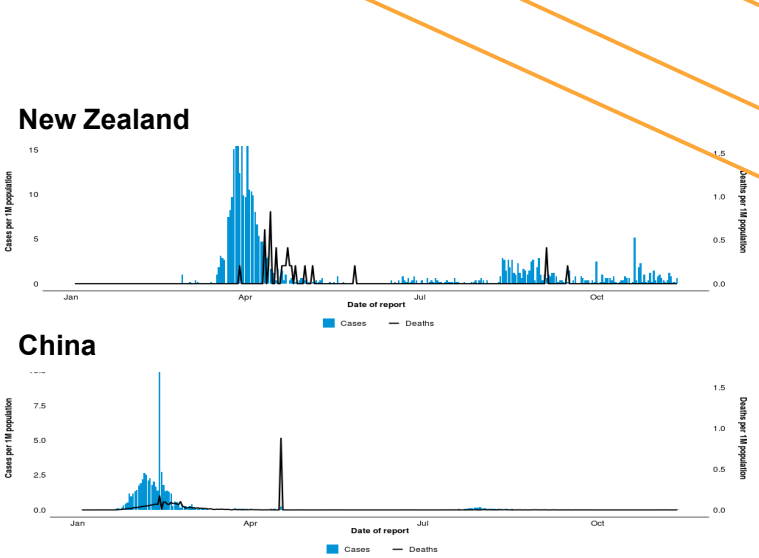
It correlated in **China** CN and **New Zealand** NZ. This may be sufficient evidence of a cause-effect relation?

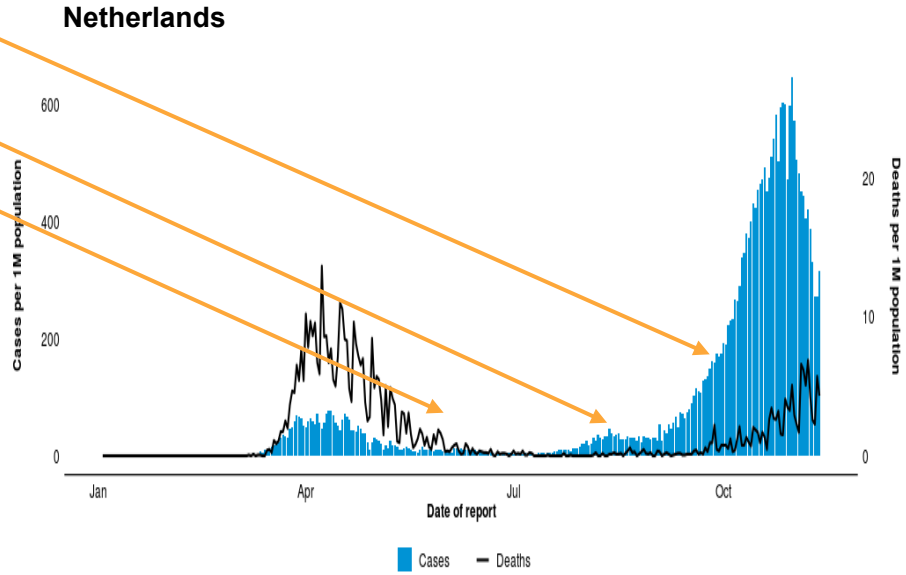


https://coronavirus.jhu.edu/data/hubei-timeline

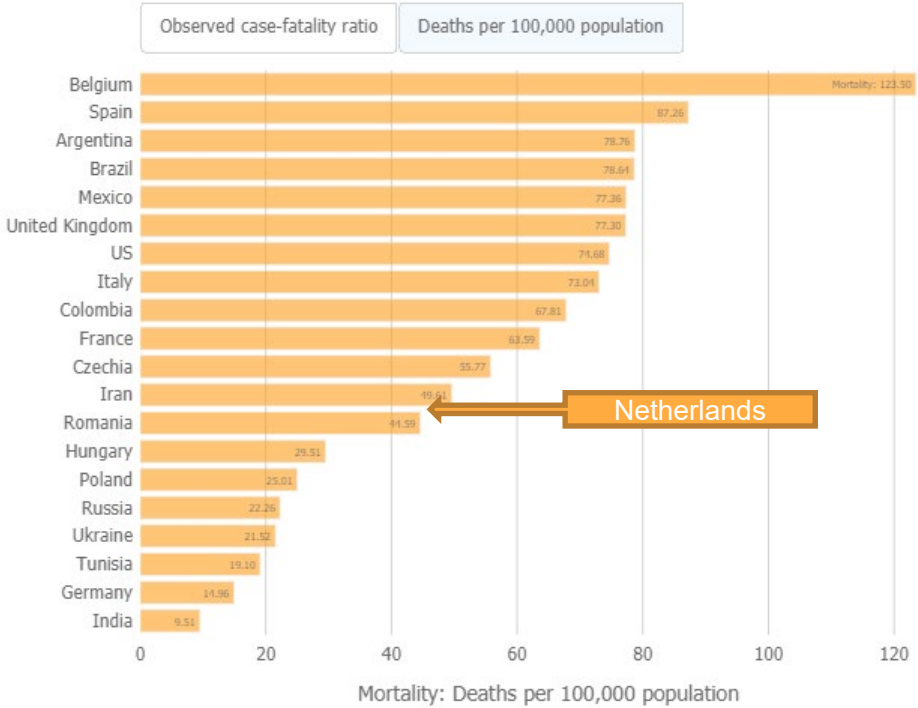
Comparing countries one finds ***two*** *scenarios*:

1. Single wave, then flares (China, New Zealand, Taiwan)
2. First, second and third wave (Belgium, Netherlands, USA)





The Ill-performing countries on top
Why these countries?



20201114: https://coronavirus.jhu.edu/data/mortality

Large differences not just due to:

- Genes
- Religiousness
- Public health quality
- GNP per capita
- Difference in virus strains
- Political system
- Being an island
- People's government/rules obedience?

Perhaps due to:

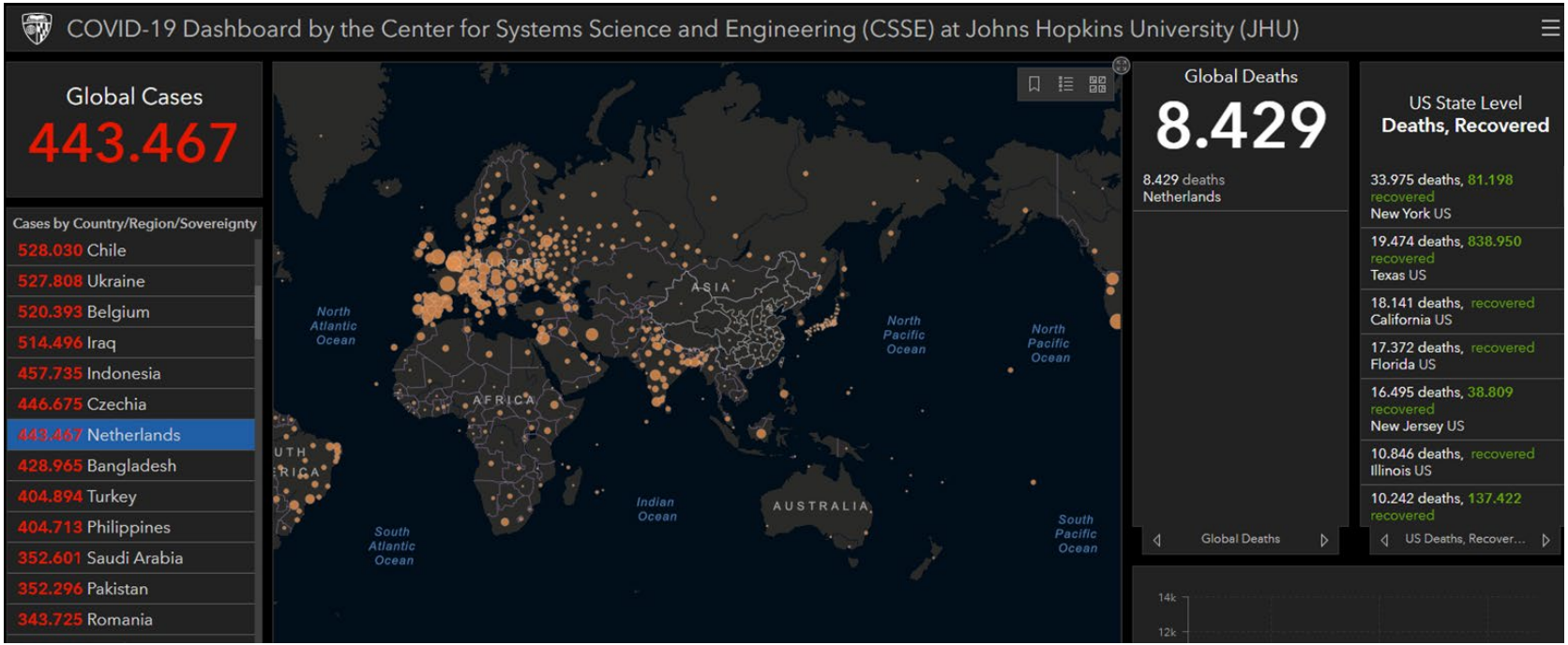
- Language (??)
- Disinterested government?
- Elastic government: Trump/Johnson versus Merkel/Ardern
- Amicable social behaviour?
- Privatized health care?

The correlations between policies and persistence of the epidemic is still not clear.

Topic for projects next **week?**

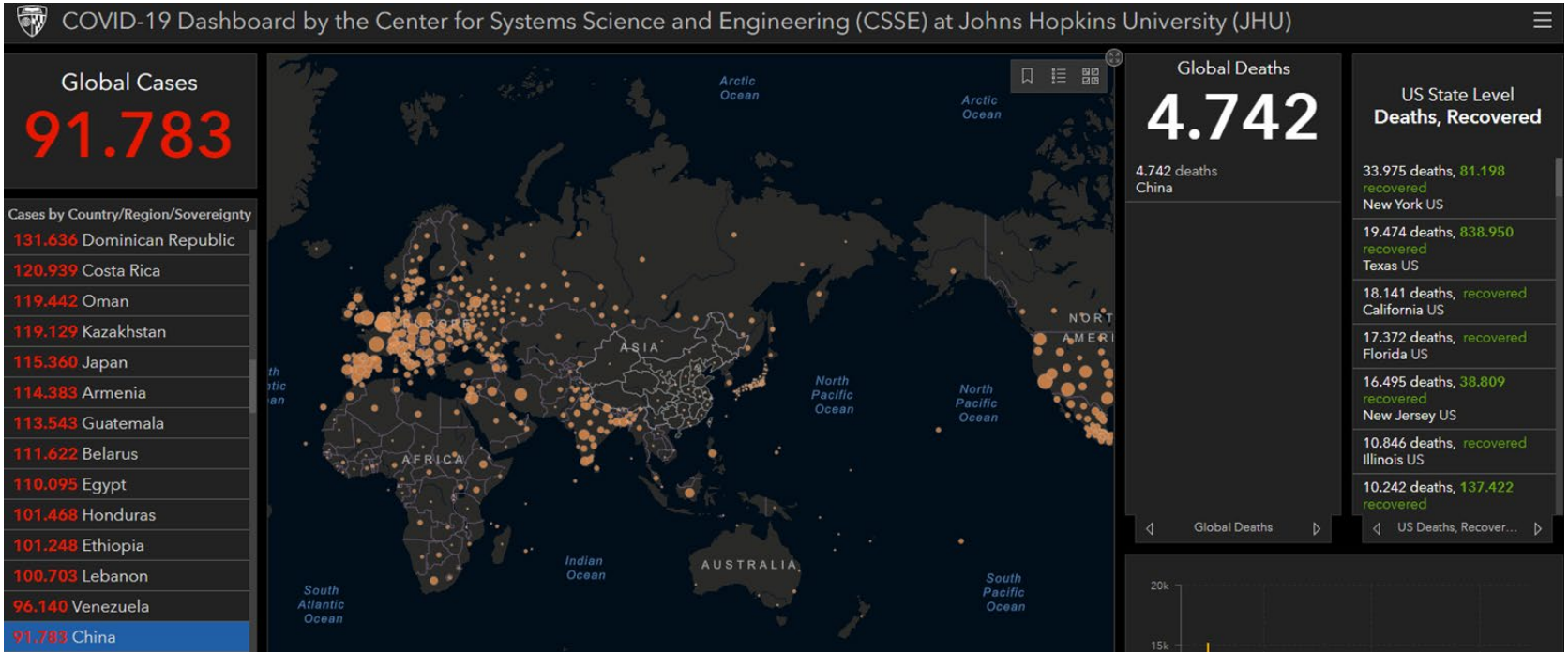
The Netherlands and Corona

(20201113 15h25)



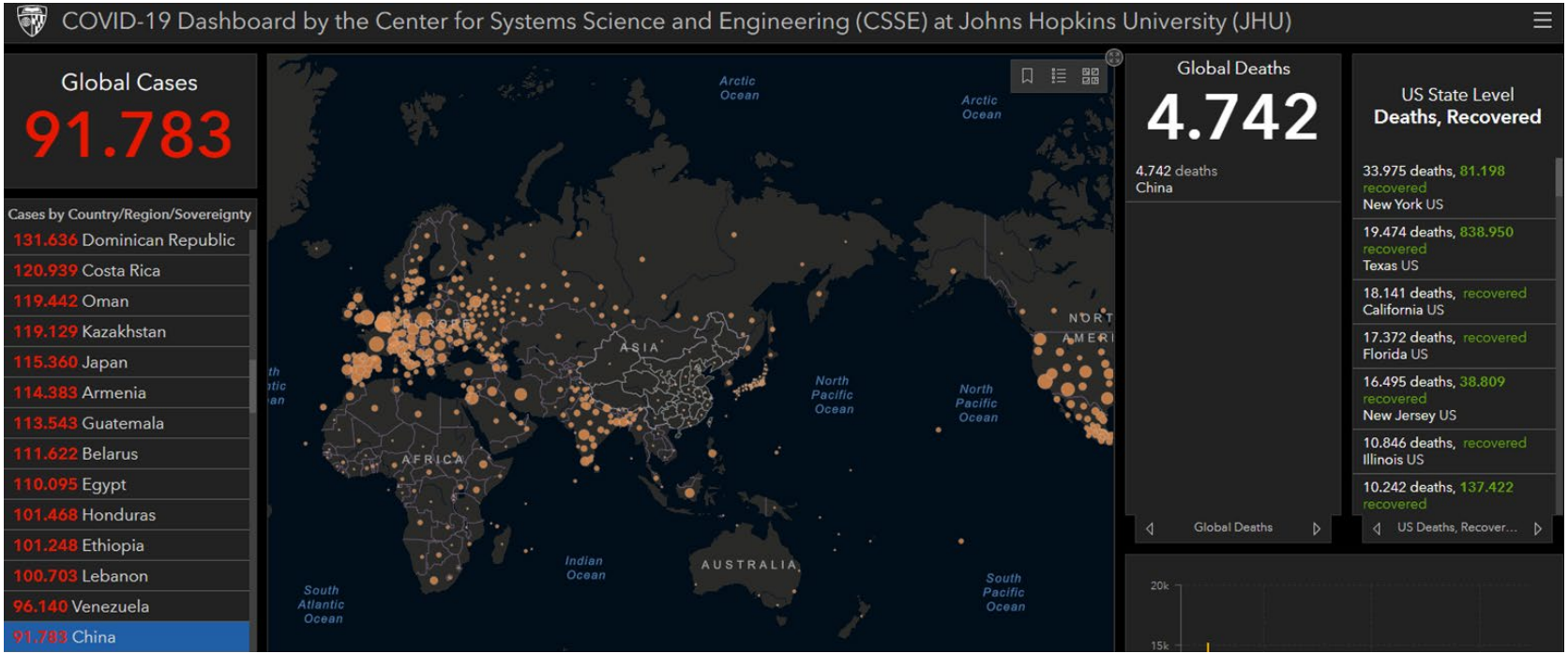
China: where it originated and 60 times more populous: worse or better ?

(20201113 15h25 CET)



China: where it originated and 60 times more populous: > 60 times better !

(20201113 15h25 CET)

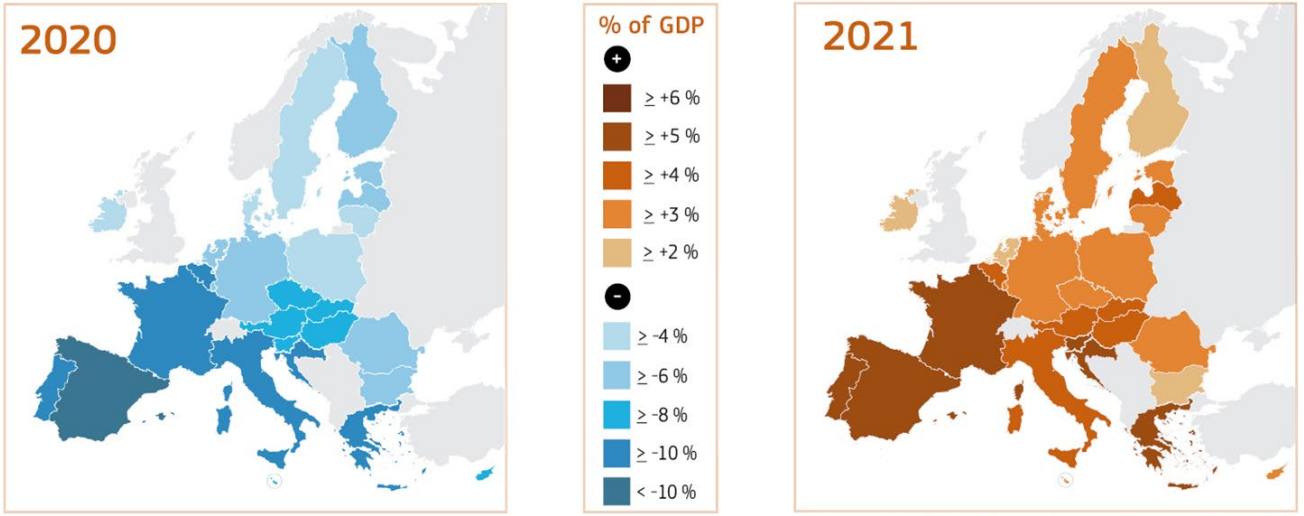


Economic impact

- ➔ **Influenza**: The total annual economic burden of influenza epidemics in the United States across all age groups was $90 billion per year.
- ➔ My estimate **for COVID-19**: lockdown by 10% for 6 months: 1.2 trillion for USA, i.e. some **15 times influenza**

Projected economic *consequences*

Growth map

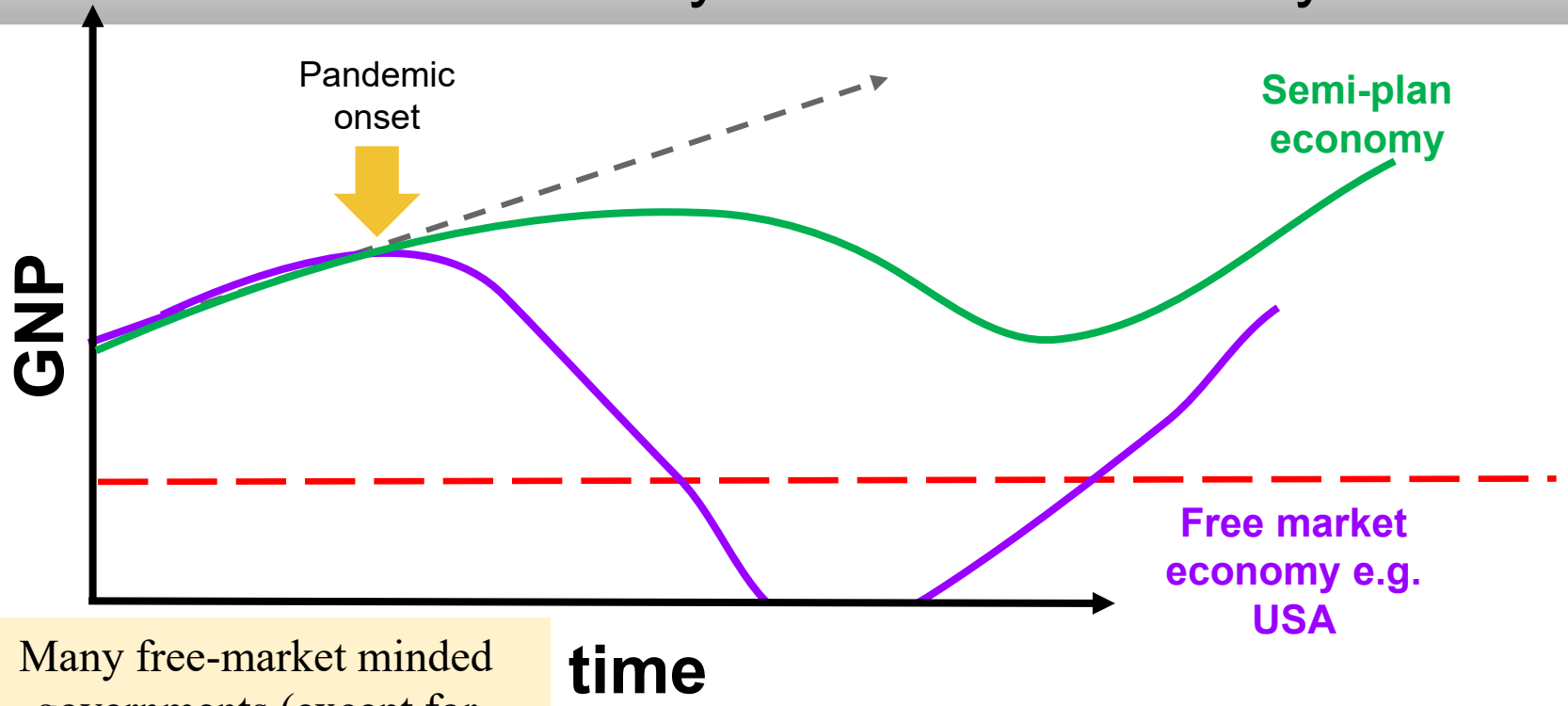


Source: European Economic Forecast, Autumn 2020

Economic and Financial Affairs

European Commission

Plan economy *vs* market economy



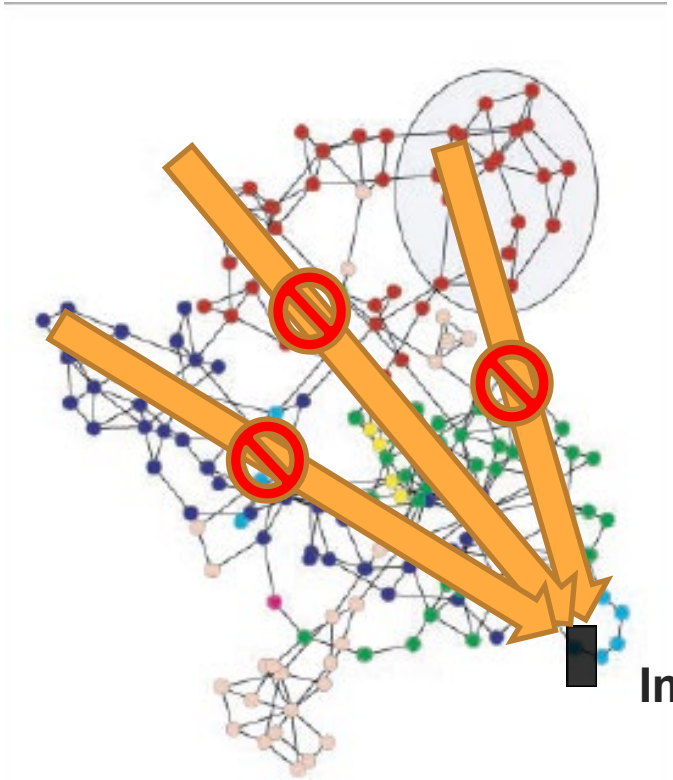
Many free-market minded governments (except for Trump's) used the plan economy option ...

Transmission routes

- ➔ Corona virus secreted from:
  - Lungs
  - Throat
  - Intestines
  - Urine
  - Post mortem material
- ➔ Hence transfer through:
  - Coughing, shouting, singing: droplets
  - Speaking breathing in close space: aerosols

Which of these is the one that should be dealt with?
'Which is the rate limiting step?'

Lesson 1 from Systems Biology



Diseases tend to have multiple (co-) causes

Both
Simultaneous
and
Alternative causes

Multiple causation: all factors matter

Impaired function

References: in file

Websites:

- ourworldindata.org/coronavirus
- worldometers.info/coronavirus
- biorender.com/covid-vaccine-tracker (slide)

Scientific articles:

- Profile of a killer: the complex biology powering the coronavirus pandemic
- A guide to R - the pandemic's misunderstood metric

Conclusions

The epidemic is complex (many factors, nonlinear)

Policy making is all too often irrational

Can we support this by understandable, open-science, modelling?

Let us see during this course and thereafter

Thansk for your attention and thanks

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