Day 5
Lecture 1:
What do we now about SARS-CoV-2

Short course on modelling infectious disease dynamics in R

Ankara, Türkiye, September 2025

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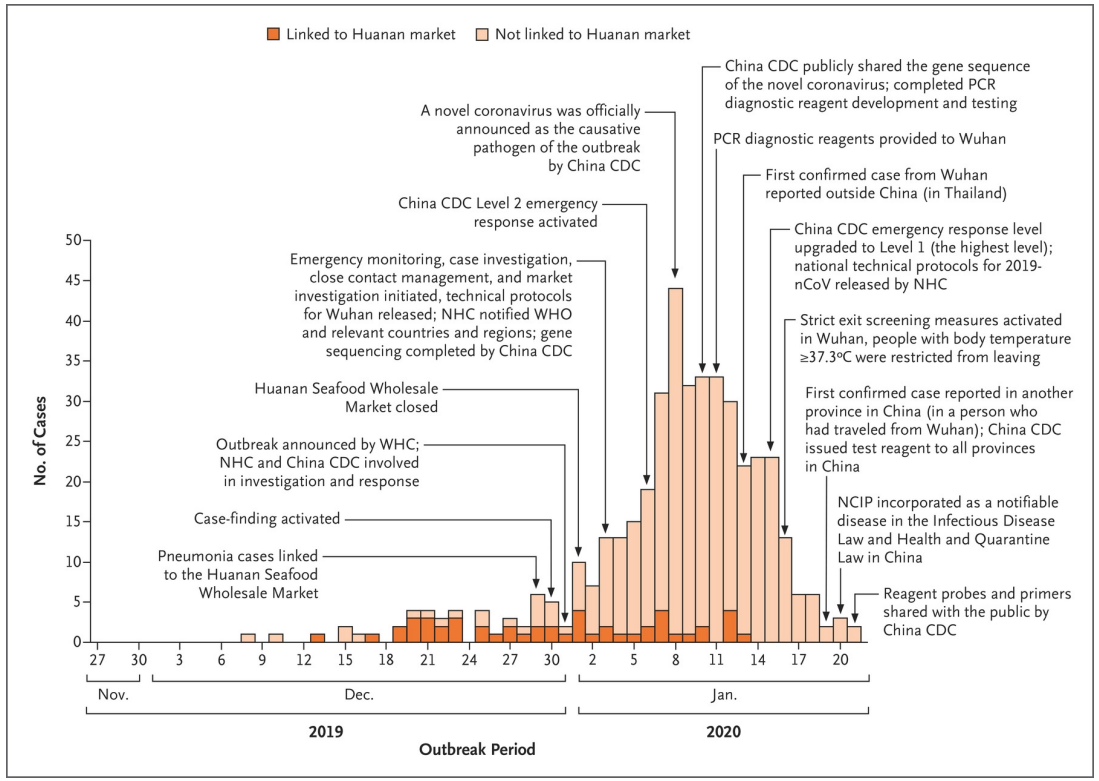
Aims of the session

- Briefly review the evidence for the main epidemiological parameters on SARS-CoV-2
- Understand what are the minimum requirements for designing a model for COVID-19
- Understand the challenges forward for the rest of the pandemic

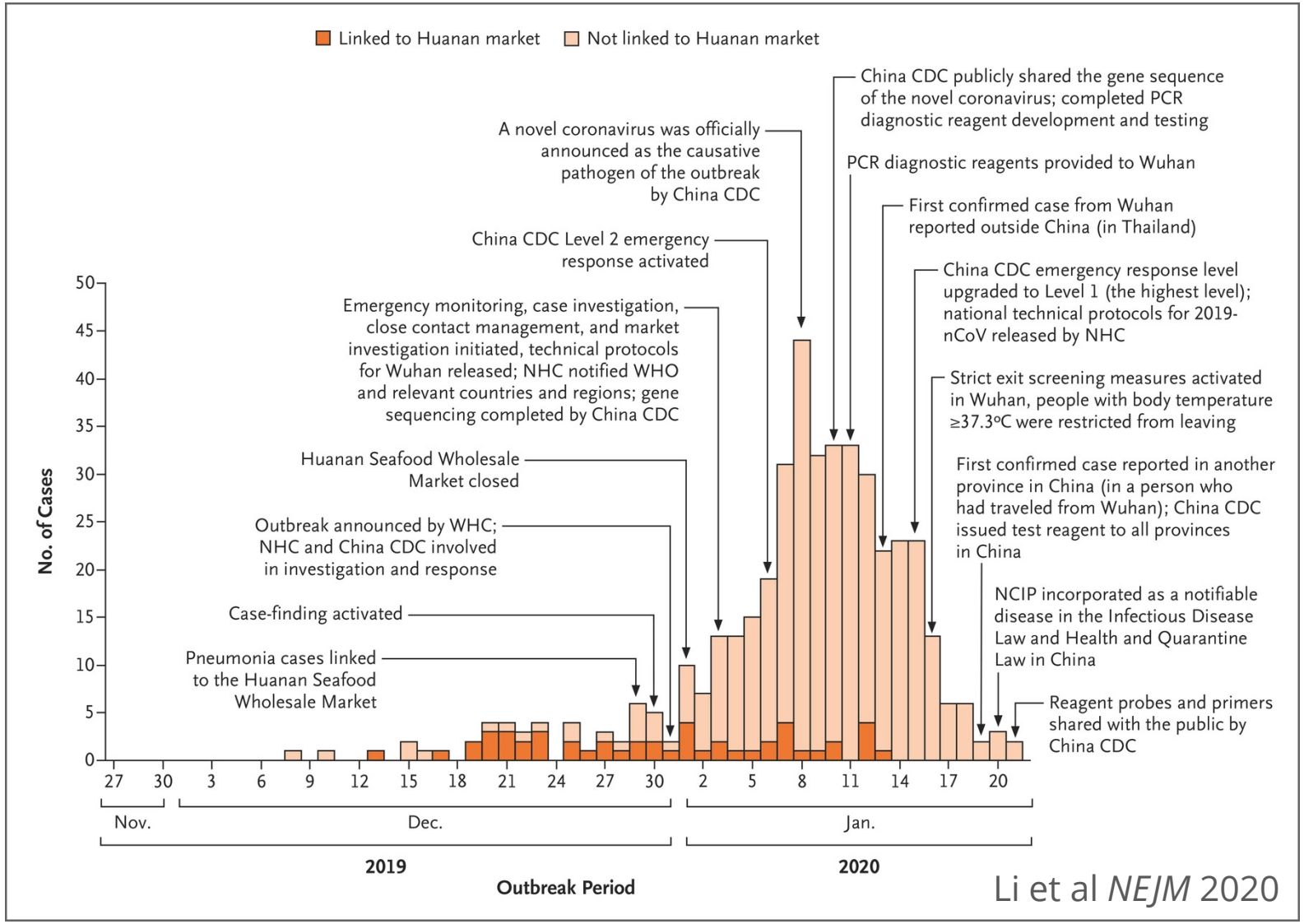
SARS-CoV2 : the start of a pandemic

- In Dec 2019 China CDC announces an outbreak investigation for a new respiratory syndrome in Wuhan
- Cases linked to a food market
- Human to human transmission becomes evident
- A coronavirus is identified as the culprit
- First restrictions imposed Wuhan in mid-Jan 2020



Li et al *NEJM* 2020

SARS-CoV2 : the start of a pandemic



Li et al *NEJM* 2020

Transmission of SARS-CoV2

- Zoonotic origin has been suggested and linked to a seafood market, but investigation is ongoing
- This was followed by evident human to human transmission

Li et al *NEJM* 2020

- Previous evidence of SARS and other coronaviruses indicated that aerosols, droplets and direct contact with infectious people is the main route of transmission

Transmissibility of SARS-CoV2

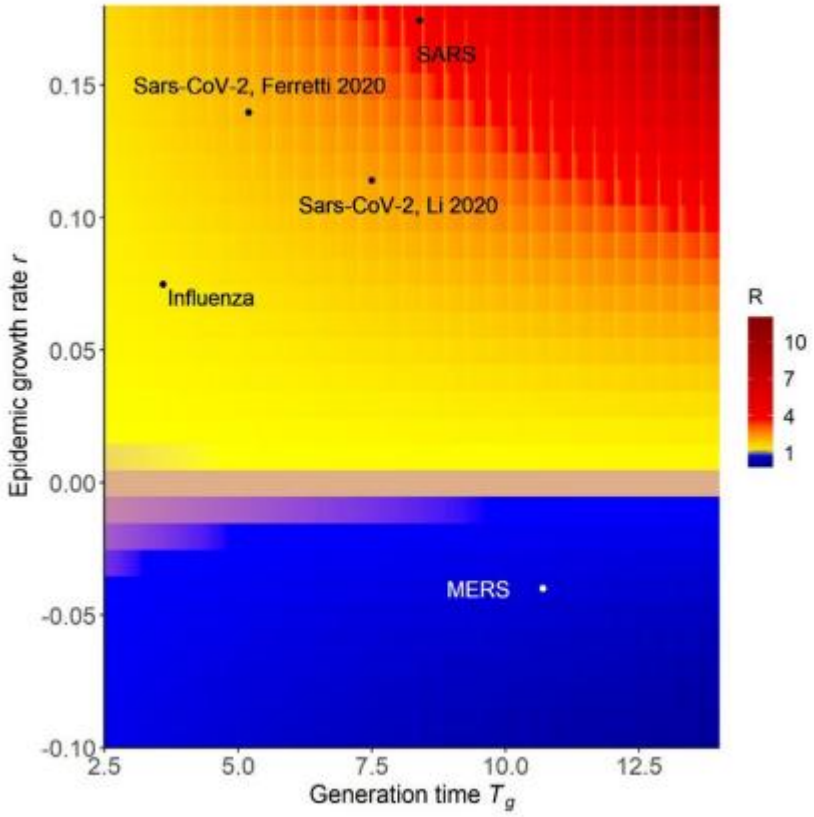
- SARS-CoV2 appears highly transmissible and initial estimations of R0 suggest a R0 of 2.2 ; range [1.4 – 3.9] Li et al *NEJM* 2020

- Higher end of the range is highly discussed and depends on specific settings
- Comparison with other pandemics puts COVID-19 at the upper end

	SARS-CoV-2	SARS-CoV	Pandemic influenza 1918	Pandemic influenza 2009	Interpretation
Transmissibility, R_0	2·5	2·4	2·0	1·7	SARS-CoV-2 has the highest average R_0

Petersen K et al *Lancet* 2020

Transmissibility of SARS-CoV2



The Royal Society at https://royalsociety.org/-/media/policy/projects/set-c/set-covid-19-R-estimates.pdf

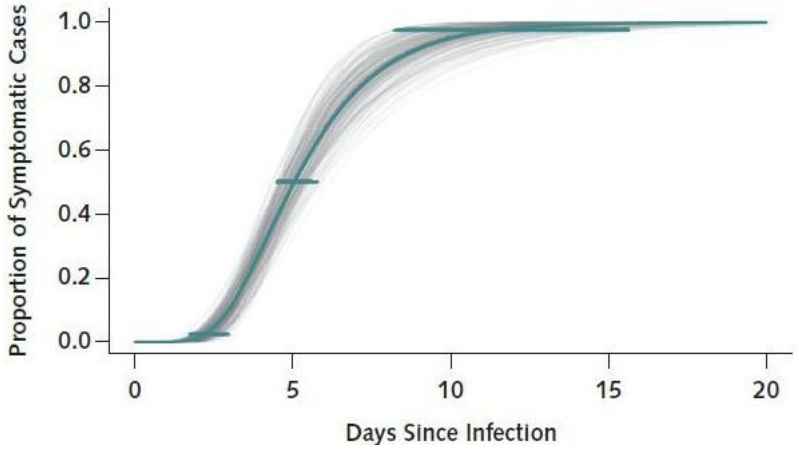
Table 1
Estimated Mean Values of $\mathcal{R}_0$ from Data.

Disease outbreak and location	$\mathcal{R}_0$	Reference
Smallpox in Indian subcont. (1968–73)	4.5	Anderson and May (1991)
Poliomyelitis in Europe (1955–60)	6	Anderson and May (1991)
Measles in Ghana (1960–68)	14.5	Anderson and May (1991)
SARS epidemic in (2002–03)	3.5	Gumel et al. (2004)
1918 Spanish influenza in Geneva		
Spring wave	1.5	Chowell, Ammon, Hengartner, and Hyman (2006)
Fall wave	3.8	Chowell et al. (2006)
H2N2 influenza pandemic in US (1957)	1.68	Longini, Halloran, Nizam, and Yang (2004)
H1N1 influenza in South Africa (2009)	1.33	White, Archer, and Pagano (2013)
Ebola in Guinea (2014)	1.51	Althaus (2014)
Zika in South America (2015–16)	2.06	Gao et al. (2016)

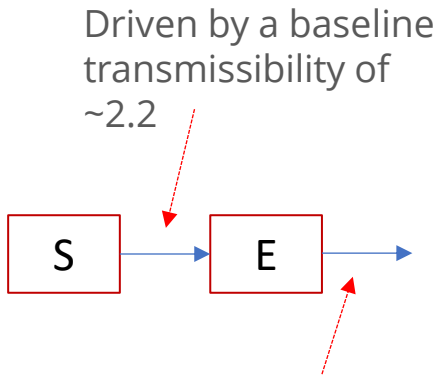
van den Driessche *IDM* 2017

Course of disease

- Infection is followed by a non-infectious period of “incubation”

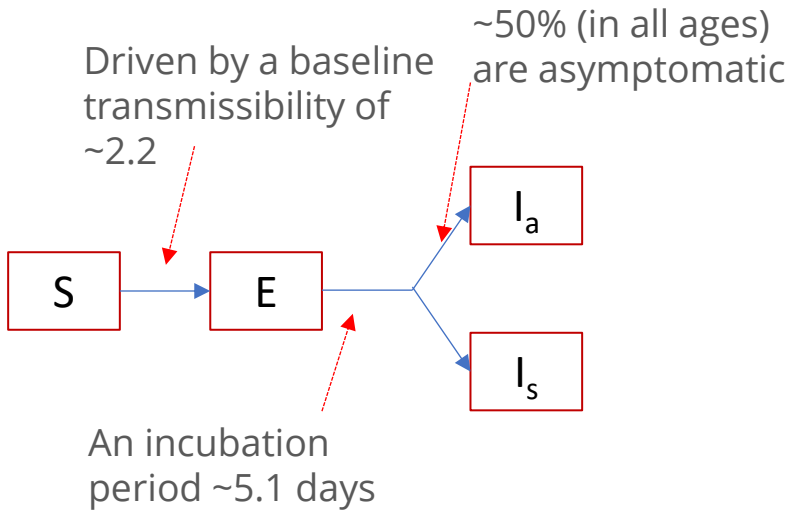


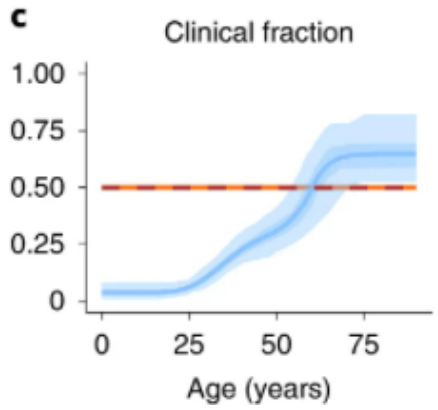
Lauer et al *Ann Intern Med* 2020



Course of disease

- Those exposed become symptomatic after ~5.1 days
- A fraction will not develop symptoms. This can ~ 79% in 10-19 yr old , and 31% in > 20yr old

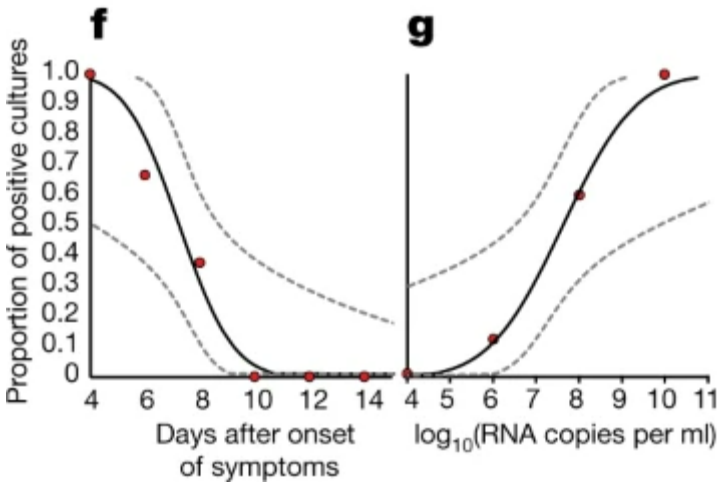




Davies et al *Nature medicine* 2020

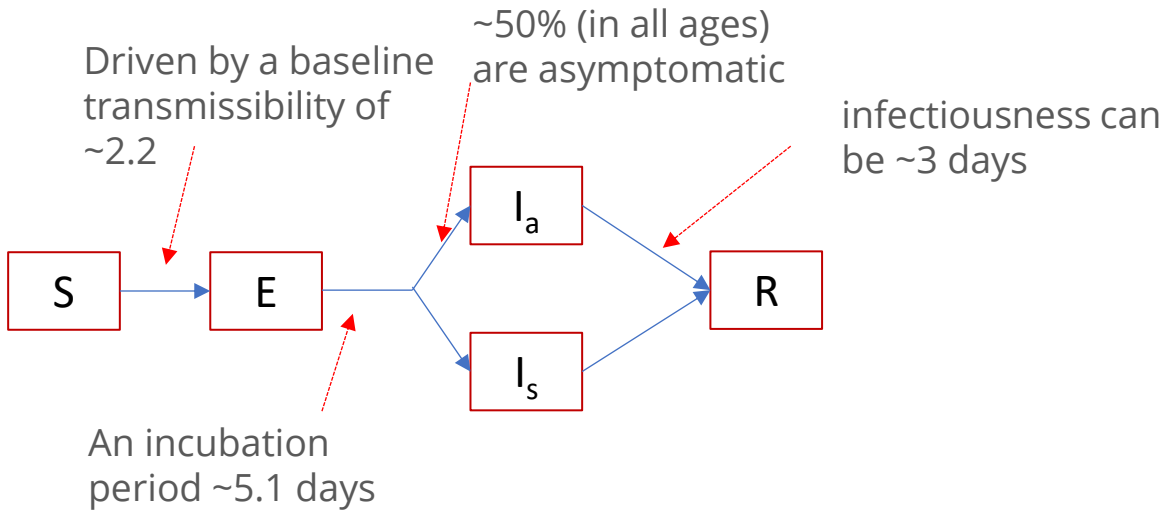
Course of disease

- Evidence says that virus shedding can be around 3 days, and in some cases as long as 15



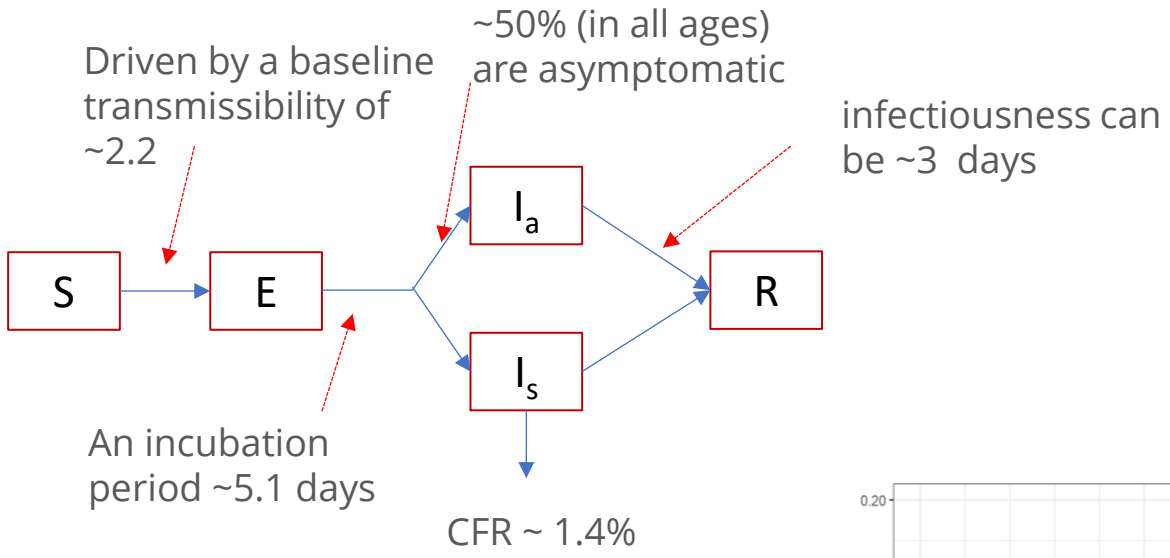
Wölfel R et al *Nature* 2020

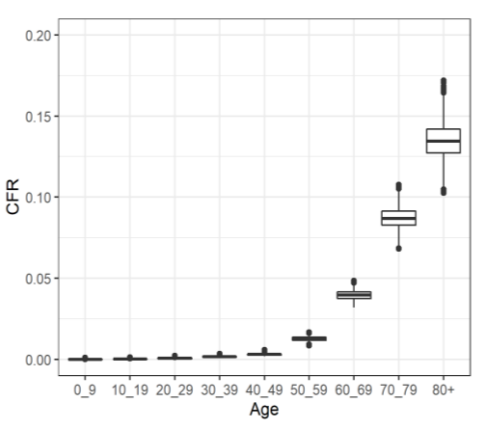
Liu W-D et al *Journal of Infection* 2020



Course of disease

- From China (February 2020):
  - ❑ Case fatality ratio 1.4%
  - ❑ Infection fatality ratio 0.7%
  - ❑ Steep rise from age 50 upwards
- Case fatality ratios for other respiratory diseases
  - ❑ SARS ~10%
  - ❑ H1N1 flu (2009) ~0.01%
  - ❑ Spanish flu (1918) ~ 2%
- UK, EU and US data giving similar estimates – UK saw 0.8-1.2% IFR

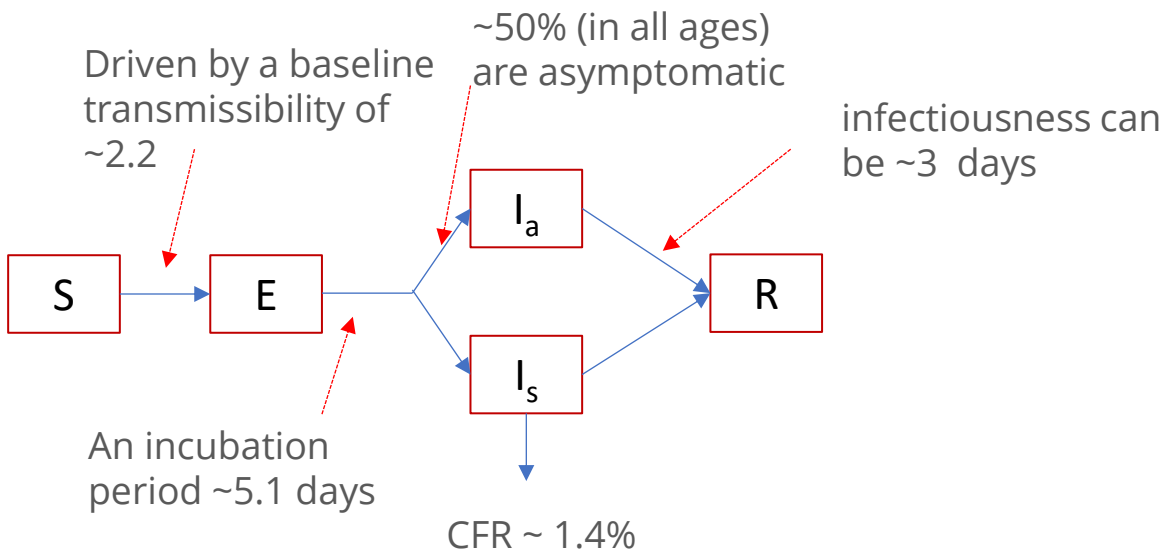




Verity et al *Lancet ID* 2020

We have a model!

- A simple SEIR model can be used to digest the core epidemiology of SARS-CoV2
- Every parameter is subject to further interpretation and added complexity
- The main mechanics of infection control can roughly be simulated with this initial approach



What can we say so far ?

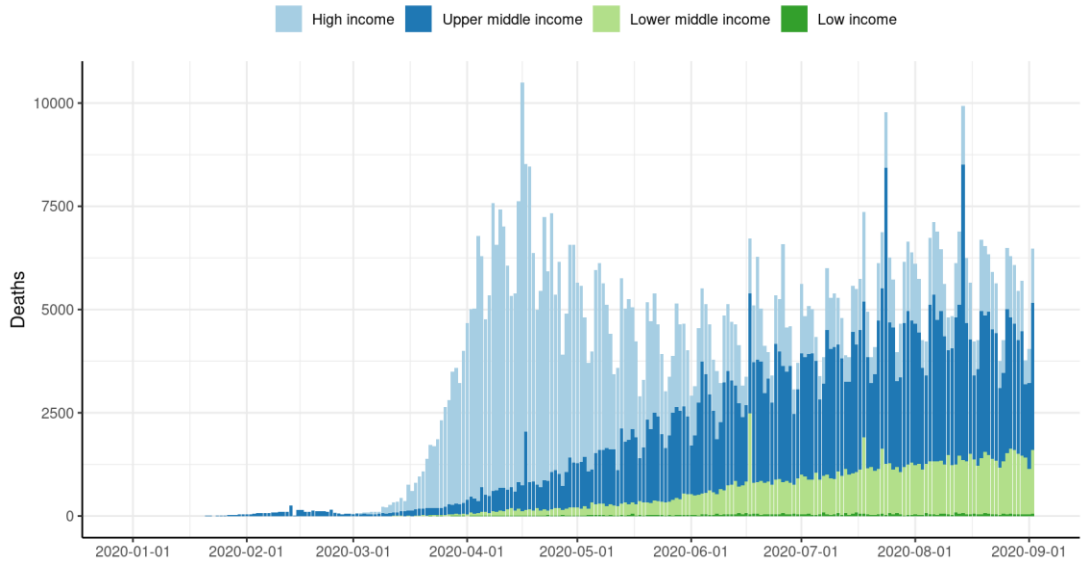
- Highly infectious: R_0~2.5-4, doubling time 2-5 days without controls
- Lethality high (~1% of those infected)
- Age plays a central role in defining severity
- Understanding infectivity did not stop in Jan 2020! New variants can change the game

Challenges

- Is not only about CFR, healthcare demand higher (2-3% require hospitalisation)
- Without control measures, health systems can be overwhelmed anywhere, increasing mortality further
- But only available control measures are either economically costly or difficult to scale
- Four strategies:
  - ❑ Mitigation – managing but not stopping the epidemic
  - ❑ Suppression – stopping (or delaying) the epidemic
  - ❑ Vaccination
  - ❑ Improved medical care

Mitigation

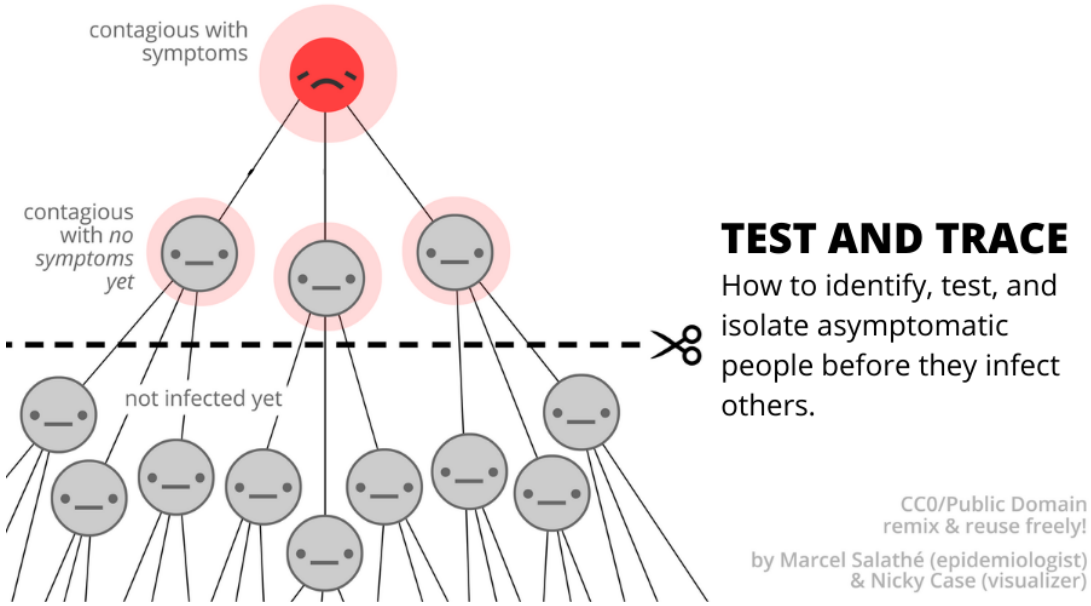
- LMICs implemented earlier in their epidemics than higher-income countries – so more effectively prevented early exponential growth
- Suppression less easy to sustain
- Europe, North America, Latin America, Middle East and South Asia all experiencing epidemics
- Africa appears less affected to date – with exceptions (e.g. South Africa)



Walker et al *Science* 2020

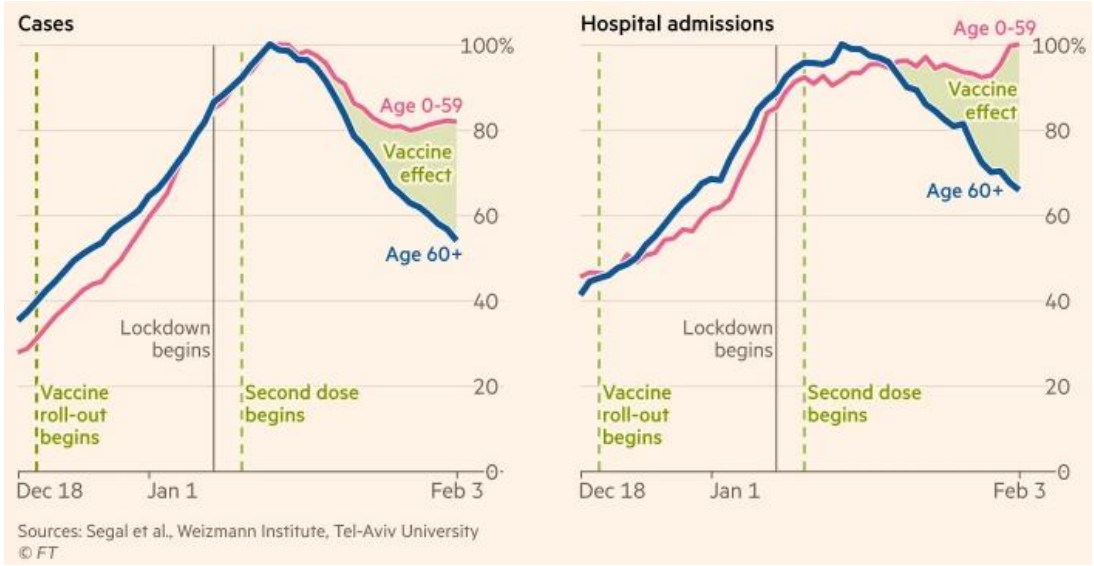
Suppression (pre-vaccination)

- Mostly worked as intended, but hugely costly and therefore unsustainable
- But just lifting measures risks all the gains made
- Relaxation will inevitably push us into R>1 eventually
- Only alternative to episodic lockdown is controlling individual local chains of transmission
  - ❑ Test and trace
  - ❑ Early cluster detection
  - ❑ Local lockdowns



Vaccination

- Unprecedented scale up of immunization programmes globally
- Effect observed almost immediately
- Protection from hospitalization has been observed to be ~60% for most vaccines
- Most vaccines protect against mortality >99%



Financial Times Feb 2021

Improved medical care

- It is thought that improved in ICU medical care for SARS-CoV2 together with new algorithms of care has reduced mortality
- New formulations of antivirals (Remdesivir) can improve outcomes of severe disease

Summary

- From the day of epidemic start, we have gathered useful metrics to understand epidemiology of COV1D-19
- The SEIR model fits the case, with some slight modifications
- More complexity should be added to accurately reproduce transmission
- SARS-CoV2 is highly infectious compared with previous pandemics
- A high lethality and severity makes it even more challenging