Epidemics & infectious disease dynamics

Ngozi Erondu, MPH, PHD

Associate Fellow

Centre for Universal Health, Global Health Programme

Chatham House

Session objectives

1. Understand terms and key concepts of transmission often used in media reporting on outbreaks and epidemics

2. Understand epidemic parameters and types of data needed to understand the dynamics of contagion

What does infectious disease dynamics cover?

Study of contagion

- Who gets infected?
- At what rates?
- How does transmission occur?
- What factors affect transmission?
- What are the impacts of interventions or control measures?
- What is the temporal progression?

Defining endemic, outbreak, epidemic, and pandemic

Endemic: disease is consistently present in a particular region or population

Outbreak: Number of cases of a disease in a population increases above the normally expected (baseline) level.

Epidemic: when the disease spreads to a large proportion of the population in a certain area or region.

Pandemic when it spreads globally or across multiple countries or regions.

Image Source: https://www.technologynetworks.com/immunology/articles/epidemic-vs-pandemic-323471

Endemic diseases: Malaria and Plague

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HEALTH NEWS ✓ Fact Checked

Yes the Bubonic Plague Is Still Around, Why You Don't Need to Worry

Cases of bubonic plague are reported every year

"Worldwide, we tend to see between one to two thousand cases of plague per year, and most of these will be the bubonic form."

"In the US, we expect about seven cases every year, which are mostly seen in the western part of the country – California, Colorado, New Mexico, Arizona. Most cases will appear in Africa – particularly Madagascar and the Democratic Republic of Congo – as well as Peru. Urban outbreaks are very uncommon, with most infections occurring in rural areas."

Human-to-human transmission is rare

10.1371/annotation/a7ab5bb8-c3bb-4f01-aa34-65cc53af065d.

Source: Imperial college London

How the Plague Outbreak in Madagascar Got So Bad, So Fast

By Dyani Sabin October 18, 2017

A council worker sprays disinfectant in a market in Antananarivo, the capital city of Madagascar. (Image: © Rijasolo/AFP/Getty)

Source: Livestrong.com

Pathogens and mode of transmission

Pathogen- a disease causing organism/agents

Agent	Disease example
Virus	Rabies, Common cold, Influenza, Measles, HIV
Bacteria	Staphylococcus, meningitis, Chlamydia
Parasites	Malaria, Leishmaniasis, Hookworm
Fungi	Ringworm, Invasive Candidiasis, Athletes Foot

Mode of transmission

Direct – e.g. person to person

Airborne transmission (influenza, TB)

Sexual transmission (HIV)

Indirect – intermediate carrier

Fomite transmission (e.g. doorknobs)

Water-borne transmission (e.g. cholera & diarrheal diseases)

Vector-borne disease (malaria – mosquitos, plague: fleas> rats> people)

The epidemiological triangle

Agent

What agent is causing the disease?

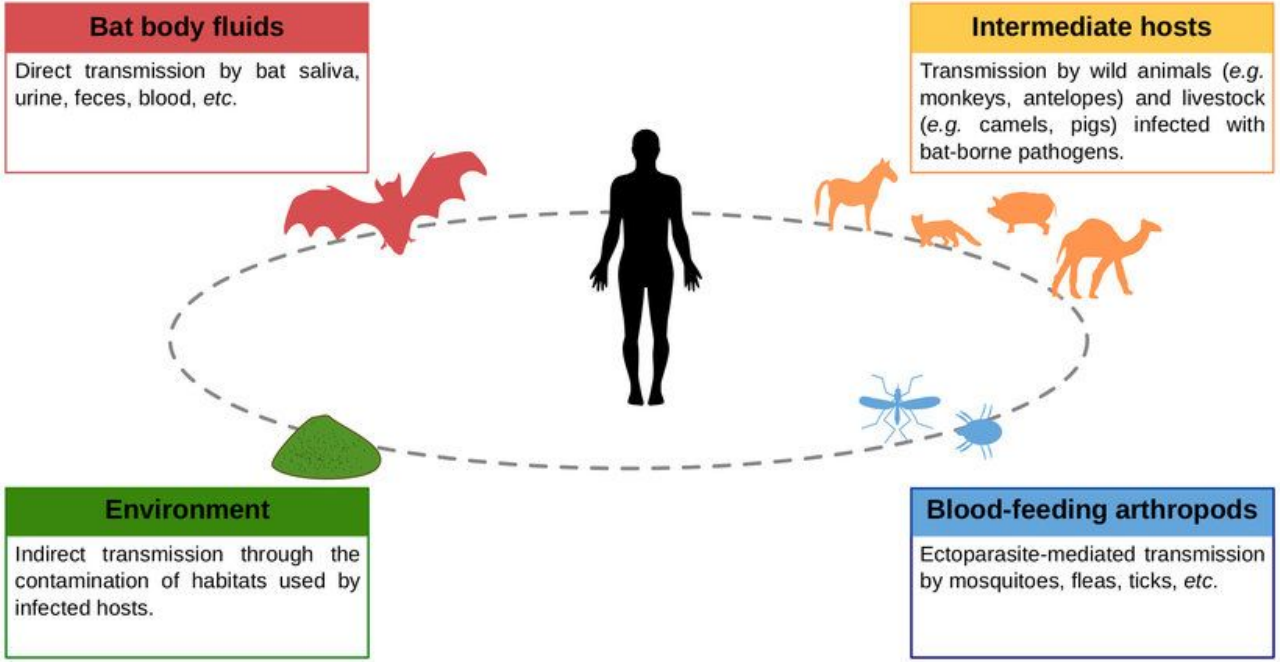
Who is the host that is either exposed to and harbor the disease?

Where are the favourable surroundings and conditions external to the host that cause or allow the disease to be transmitted?.

Host

Environment

Example: Multiple transmission routes from bat pathogens



Source: Joffrin L, Dietrich M, Mavingui P, Lebarbenchon C (2018) Bat pathogens hit the road: But which one? PLoS Pathog 14(8): e1007134. https://doi.org/10.1371/journal.ppat.1007134

Transmission dynamics: Basic reproduction number (R_0)

New disease/ susceptible population:

R_0 (R naught) = $R0=\beta*\kappa*D$

β is the risk of transmission per contact

κ is the contact rate

D is the duration of infectiousness

R_0 establishes a threshold for an epidemic to occur in a totally susceptible population:

If R0>1, disease can spread and an epidemic can occur

If R0 = 1, disease spread is stable, or endemic, and the number of infections is not expected to increase or decrease

If R0<1, each infection does not (on average) replace itself, so the disease can't spread

Adapted from presentation by Derek Cummings, Johns Hopkins University

Transmission dynamics: Basic reproduction number (R_0)

New disease/ susceptible population:

R0 (R naught) = $R0=\beta*\kappa*D$

β is the risk of transmission per contact → Pathogen and individual factors
Vaccine, drug therapy, exposure at work

κ is the contact rate → Human behavior
Social distancing

D is the duration of infectiousness → Innate to pathogen
Nothing for COVID19, drug therapy for others

Adapted from presentation by Derek Cummings, Johns Hopkins University

Transmission dynamics: Basic reproduction number (R_0)

Initial infected patient ● — • Person he or she has infected

R_0	**12 to18**	12 to 17	6 to 7	5 to 7	5 to 7	4 to 7	2 to 4	1 to 4 people	R_0
DISEASE	**Measles**	Pertussis (Whooping cough)	Rubella	Polio	Smallpox	Mumps	SARS	Ebola	DISEASE
HOW IT SPREADS	**Airborne**	Airborne droplets	Airborne droplets	Fecal-oral route	Airborne droplets	Airborne droplets	Airborne droplets	Bodily fluids	HOW IT SPREADS

Source: Reuters graphics

Caution when reporting R_0

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PERSPECTIVE

Complexity of the Basic Reproduction Number (R_0)

Paul L. Delamater, Erica J. Street, Timothy F. Leslie, Y. Tony Yang, Kathryn H. Jacobsen

The basic reproduction number (R_0), also called the basic reproduction ratio or rate or the basic reproductive rate, is an epidemiologic metric used to describe the contagiousness or transmissibility of infectious agents. R_0 is affected by numerous biological, sociobehavioral, and environmental factors that govern pathogen transmission and, therefore, is usually estimated with various types of complex mathematical models, which make R_0 easily misrepresented, misinterpreted, and misapplied. R_0 is not a biological constant for a pathogen, a rate over time, or a measure of disease severity, and R_0 cannot be modified through vaccination campaigns. R_0 is rarely measured directly, and modeled R_0 values are dependent on model structures and assumptions. Some R_0 values reported in the scientific literature are likely obsolete. R_0 must be estimated, reported, and applied with great caution because this basic metric is far from simple.

R_0 estimates for Measles

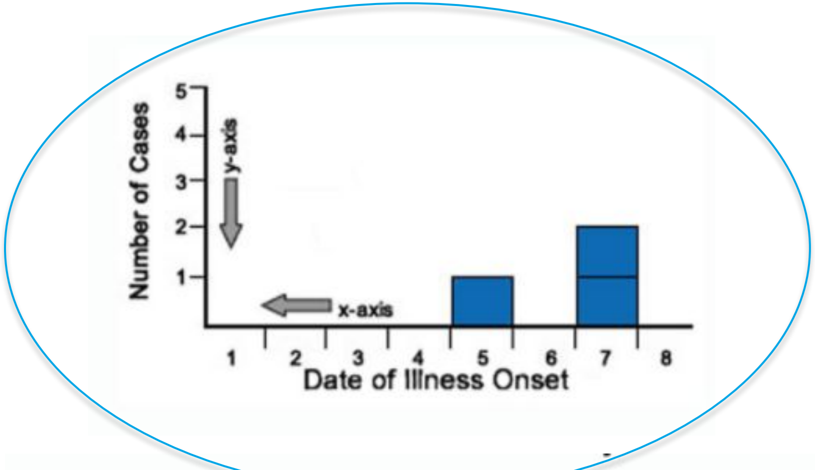
– England and Wales, 1950-1968	16-18
– Ontario, Canada, 1912-1913	11-12
– Kansas, USA, 1918-1921	5-6
– Ghana, 1960-1968	14-15
– Niger, 2003	5-6

Transmission dynamics: Effective reproductive number (R_e or R_t)

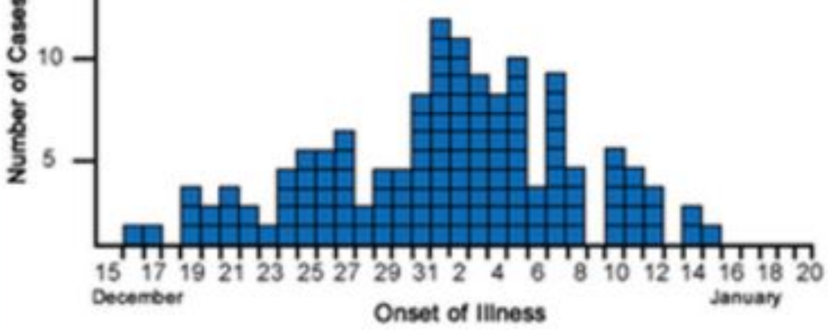
Norway's response three weeks from R_e=3.8 to R_e=0.6

Source: nationalgeographic.com

Epidemic curve – What is it and what can it tell us?



Continuous common source



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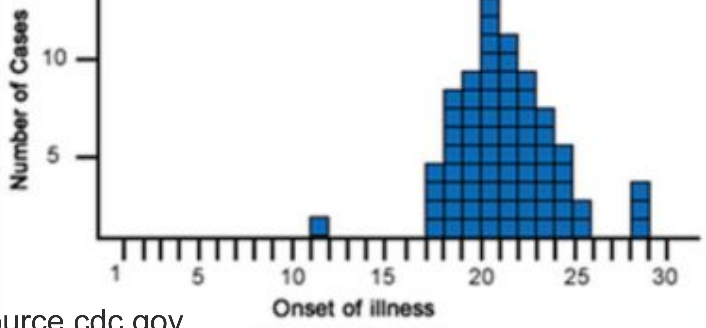
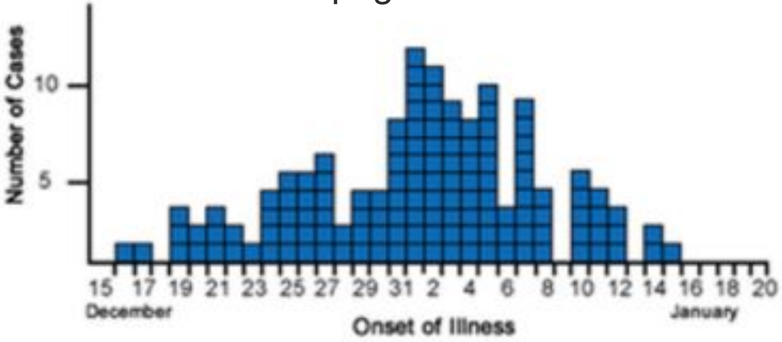
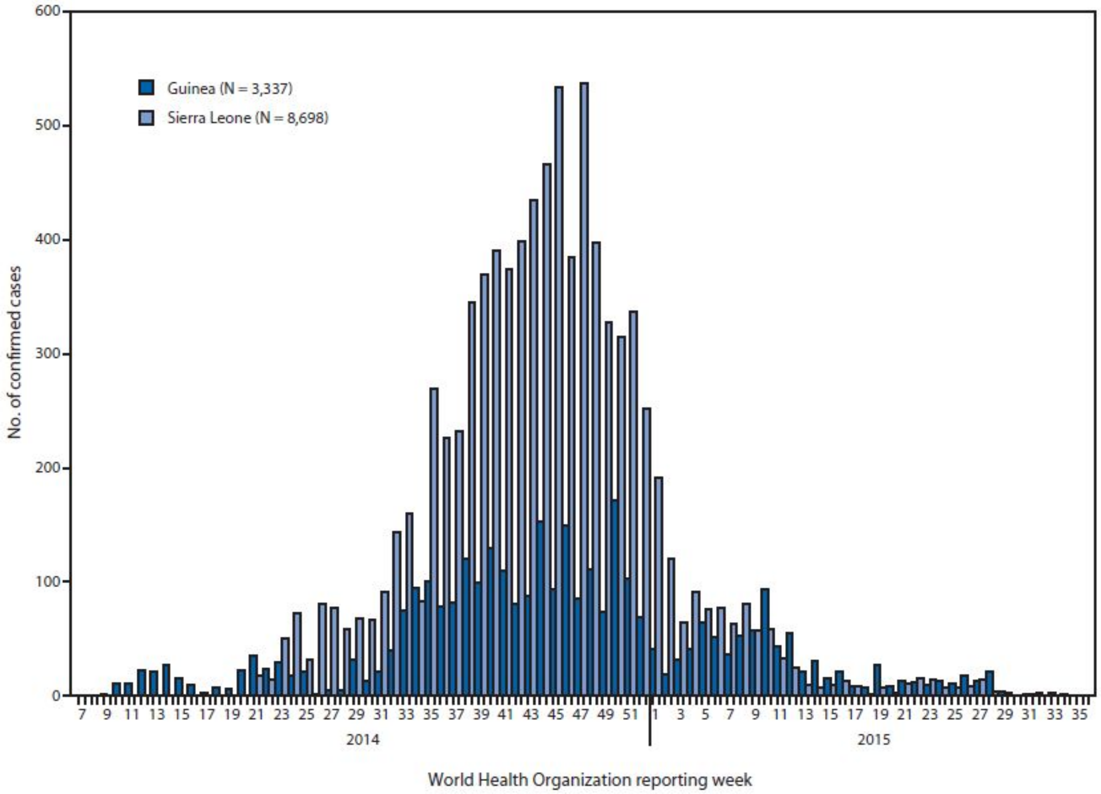


Source cdc.gov

Propagated outbreak



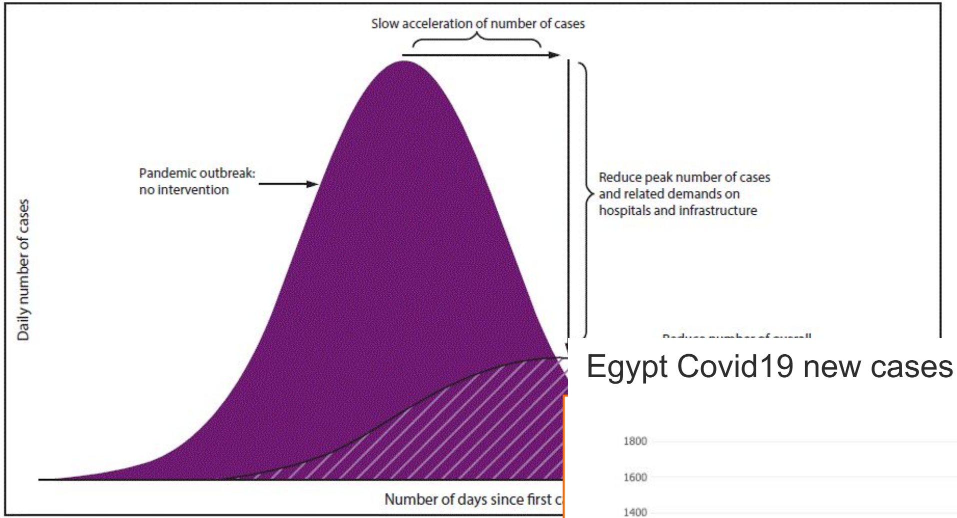
Epidemic curve – What is it and what can it tell us?



Epi-curve for Ebola cases in Sierra Leone and Guinea, August 2015

Source: CDC, Morbidity and Mortality Weekly Report (MMWR), Ebola Virus Disease — Sierra Leone and Guinea, August 2015

Flattening the (epidemic) curve



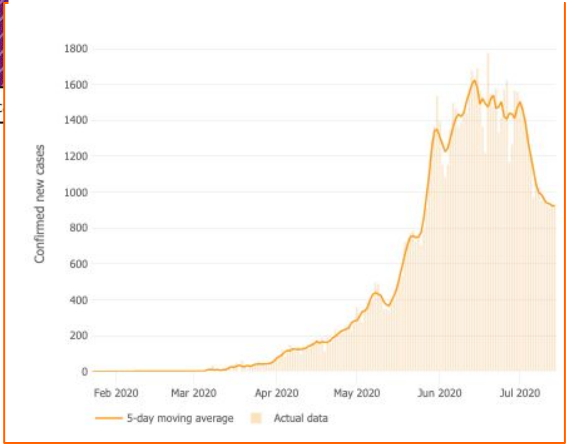
Source: CDC

We usually see cumulative case curves

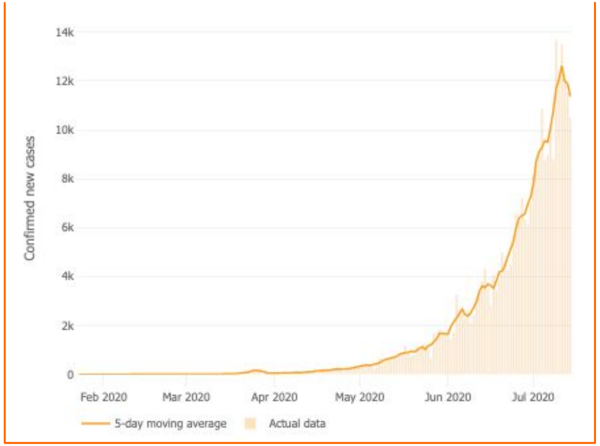
Flatter cumulative case curves indicate less new cases

Not good enough for new cases to be constant. To stop pandemic new cases must decrease (downward slope)

Egypt Covid19 new cases



South Africa Covid19 new case



Source: John Hopkins coronavirus tracker

Speed of an outbreak depends on two factors

1. The number of individuals infected by each infectious case. ($R_{0,}$ R_t)

2. The time it takes between when a case is infected and when that case infects other people (serial interval)

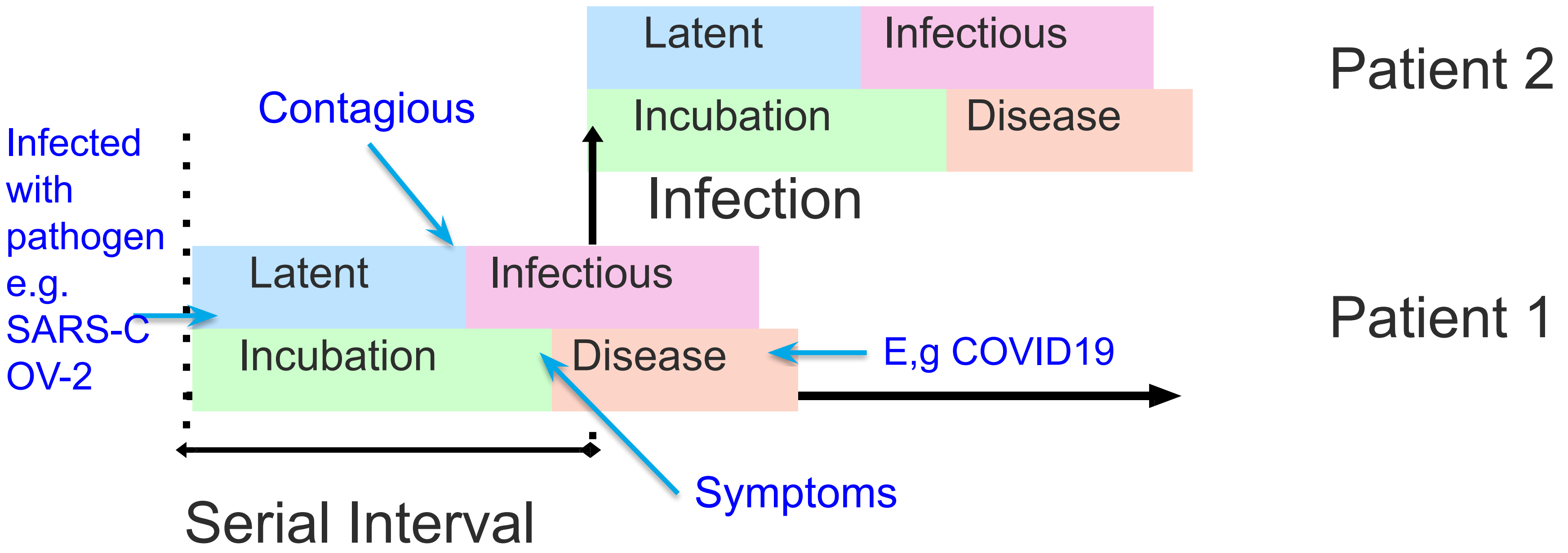
Epi-curves help us understand time intervals of disease transmission

Incubation Period – average length of time between infection and the onset symptoms in each case

Latent Period – average length of time between infection and the onset of transmissibility

Serial Interval – average length of time between a case being infected and that case infecting subsequent cases (also called the Generation Time)

Transmission parameters

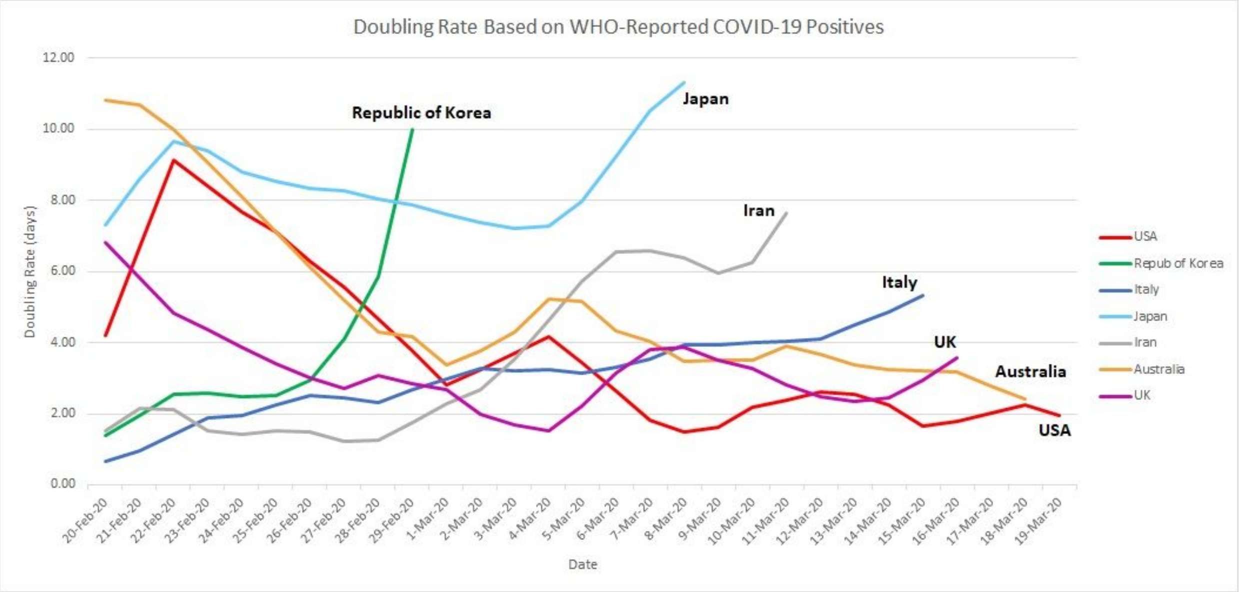


Adapted from presentation by Derek Cummings, Johns Hopkins University

Measures of transmission: Doubling time

Time interval in which the cumulative incidence of a disease doubles If rate of testing and reporting remains the same

Its often used to compare the rate of increase in cases across settings.



Source: Nunes-Vaz, R., 2020. Visualising the doubling time of COVID-19 allows comparison of the success of containment measures. *Global Biosecurity*, 1(3), p.None. DOI: http://doi.org/10.31646/gbio.61

Herd immunity

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- The resistance to the spread of a contagious disease within a population that results if a sufficiently high proportion of individuals are immune to the disease, especially through vaccination.
- When more people are immune, the effective reproductive number (R) is less than 1
- Can be achieved through widespread infection or vaccination

WHO and partners vaccinate over 94 019 children against measles in Aweil

The campaign that ended on 3 July 2020 was implemented within the national and WHO guidelines for implementing mass vaccination campaigns in the context of COVID-19.

Devdiscourse News Desk | Aweil | Updated: 10-07-2020 17:32 IST | Created: 10-07-2020 17:32 IST

Measures of death

Mortality rate: The number of people who died in a defined population for a given time interval. For this reason, it is often expressed as x deaths per 100,000 people.

Case fatality rate - the ratio of the number of deaths divided by the number of *confirmed* (preferably by nucleic acid testing) *cases* of disease.

East Africa: Kenya Has Highest Rate of Deaths in the Region

Kenya's Covid-19 death toll is high and continues to rise compared to other countries in the Eastern Africa region.

With over 10,000 cases, Kenya has registered 197 deaths-- nearly five times more than the second highest death toll in the region -- South Sudan at 38.

Challenges reporting case fatality rate

$$CFR = \frac{\text{Number of cause-specific deaths among incident cases}}{\text{Total number of incident cases}}$$

What is the denominator?

How do we account for pre-symptomatic or asymptomatic cases?

Lower levels of testing (missed infections)?

Lack of contact tracing

Can lead to both over and under estimation

Next week we will go through the 10 steps of outbreak investigation

1. Confirm the diagnosis
2. Confirm that an epidemic exists
3. Define a case and count them
4. Descriptive epidemiology: arrange the data
5. Determine who is at risk of disease
6. Implement methods of control and prevention
7. Analytic epidemiology: develop a hypothesis and test it
8. Environmental and laboratory investigation
9. Implement a surveillance system
10. Communicate your findings