# Introduction to epidemiology

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# How is this section of the unit assessed?

- Assignment on epidemiological **modelling**
- Hand in after Easter
- Lectures before Easter will allow you to begin preparing your assignment
- Practical session will clarify concepts after the break

# What is epidemiology?

- The word is derived from two Greek components
- "Epi" = Upon
- "Demos" = Population (e.g. Democracy)
- So ... Epidemiology is the study of something that acts upon populations

# How does epidemiology compare with parasitology?

- ▶ Epidemiology tends to place the focus on the population affected by the disease.
- ▶ Parasitology tends more to focus on the parasite causing disease
- ▶ Historically bacteria and viruses were not treated as classic parasites (due partly to their invisibility)
- ▶ Bacteria and viruses tend to have simpler life histories,although they may still occur in multiple hosts
- ▶ Modern epidemiology also looks at non transmissible illnesses associated with life style and environment.
- ▶ Epidemiology provides guidance for **Public health policy**

# What are communicable and non-communicable illnesses?

▶ Transmissible (communicable) diseases pass from person to person, or organism to organism

▶ Contagious diseases spread within a population.

▶ A disease can be transmissible but not contagious, if the rate of spread is normally very low

▶ Not all transmissible diseases lead to epidemics

▶ A transmissible disease can persist at a low level in the population

▶ Animal reservoirs can play an important role (zoonoses)

# What do people usually die of?

- In a typical year, death as a direct result of a communicable illness has become relatively uncommon in the UK
- The most common causes of death are cardiovascular illnesses and cancer
- So .. many pubic health measures now concern altering life styles associated with risks of non communicable illnesses (smoking, obesity, lack of exercise)
- However . . . . as we have now been reminded . . . communicable diseases can still have major societal impacts (Bloom and Cadarette 2019)
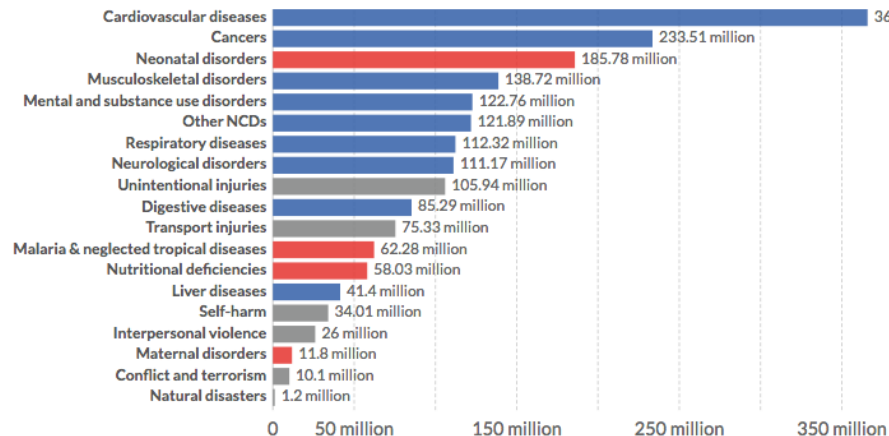- They can cause epidemics/pandemics

# What do we suffer from most?

(Naghavi and Abajobir 2017)

## Burden of disease by cause, World, 2017

Total disease burden, measured in Disability-Adjusted Life Years (DALYs) by sub-category of disease or injury.
DALYs measure the total burden of disease – both from years of life lost due to premature death and years lived with a
disability. One DALY equals one lost year of healthy life.

⇄ Change country

| Cause | Value |
|---|---|
| Cardiovascular diseases | 36 |
| Cancers | 233.51 million |
| Neonatal disorders | 185.78 million |
| Musculoskeletal disorders | 138.72 million |
| Mental and substance use disorders | 122.76 million |
| Other NCDs | 121.89 million |
| Respiratory diseases | 112.32 million |
| Neurological disorders | 111.17 million |
| Unintentional injuries | 105.94 million |
| Digestive diseases | 85.29 million |
| Transport injuries | 75.33 million |
| Malaria & neglected tropical diseases | 62.28 million |
| Nutritional deficiencies | 58.03 million |
| Liver diseases | 41.4 million |
| Self-harm | 34.01 million |
| Interpersonal violence | 26 million |
| Maternal disorders | 11.8 million |
| Conflict and terrorism | 10.1 million |
| Natural disasters | 1.2 million |

0    50 million    150 million    250 million    350 million

# Is the burden of disease expected to decline?

(Mathers and Loncar 2006)

**Table 1.** Projected Average Annual Rates of Change in Age-Standardized Death Rates for Selec

| Group | Cause | Average Annual Change (Percent) in Age-S |
| --- | --- | --- |
| | | **Males** |
| **All Causes** | | −0.8 |
| **Group I** | | −1.4 |
| | Tuberculosis | −5.4 |
| | HIV/AIDS | 3.0 |
| | Malaria | −1.3 |
| | Other infectious diseases | −3.4 |
| | Respiratory infections | −2.7 |
| | Perinatal conditions[a] | −1.7 |
| | Other Group I | −3.0 |
| **Group II** | | 0.0 |
| | Cancer | −0.2 |
| | Lung cancer | 0.1 |
| | Diabetes mellitus | 1.1 |
| | Cardiovascular diseases | −1.1 |
| | Respiratory diseases | 0.3 |
| | Digestive diseases | −1.3 |
| | Other Group II | −0.7 |
| **Group III** | | 0.0 |
| | Unintentional injuries | −0.2 |
| | Road traffic accidents | 1.1 |
| | Intentional injuries | 0.2 |

# Communicable disease and age: HIV still affects children

(Naghavi and Abajobir 2017)

# Are the numbers affected by communicable diseases falling?

- ► Falling trend prior to the pandemic
- ► Expected to continue to fall



Disease burden from communicable, maternal, neonatal and nutritional diseases, World, 1990 to 2016

Total disease burden from communicable, maternal, neonatal and nutritional diseases, measured in DALYs (Disability-Adjusted Life Years) per year. DALYs are used to measure total burden of disease - both from years of life lost and years lived with a disability. One DALY equals one lost year of healthy life.
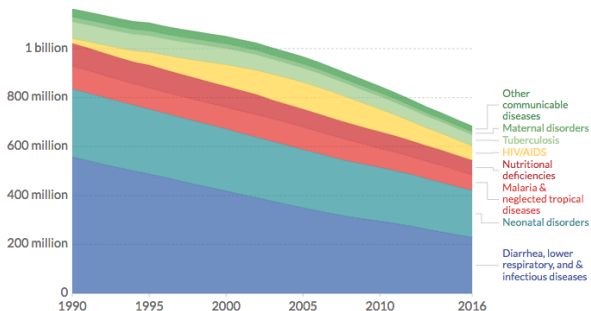
# Why study communicable diseases?

- ▶ Still a major cause of death, particularly HIV in sub-Saharan Africa
- ▶ Many communicable diseases cause morbidity (symptoms) and greatly reduced quality of life, even if they do not lead to mortality
- ▶ Epidemics have major societal impacts
- ▶ Developing vaccines provides insights into key aspects of biology
    - ▶ Oncology (relevant for cancer studies)
    - ▶ Immunology
    - ▶ Genetics

# What are the key terms to know?

- ▶ Outbreak: Spread of a contagious agent that is limited to a defined local population at risk
- ▶ Epidemic: An outbreak that extends to a wider geographical area
- ▶ Pandemic: An epidemic that potentially impacts the entire global population
- ▶ Endemic: Continuous presence of the contagious agent in a population or reservoir species

# More key terms

- ▶ Population at risk : number of potential infections
- ▶ Exposure: contact with disease causing agent
- ▶ Incidence : number of new cases
- ▶ Prevalence : Proportion of population affected
- ▶ Morbidity: Effects falling short of death
- ▶ Mortality: Death
- ▶ Virulence: Pathogenicity of the infectious agent
- ▶ Transmissibility: Infectiousness of the agent

# What are the origins of epidemiology as a science?

- ▶ The underlying cause of disease were not well understood until the 20th century
- ▶ Early epidemiologists aimed to understand the cause of incidence, prevalence and spread, rather than to study the agent
- ▶ The classic text book example: Cholera in London

# Who was John Snow?

- ▶ Founding father of epidemiology
- ▶ Discovered how cholera spread between people.

# How did Snow identify the source?

- Cholera first thought to be caused by a "miasma" in the air
- "The result of my inquiry is, that there has been no particular outbreak or prevalence of cholera in this part of London except among the persons who were in the habit of drinking the water of the Broad street pump"
- Cholera was eliminated in the UK through provision of sewage treatment.
- Finding the source and the route of transmission was the key.
- However the **cause** of cholera was still not known

# *Vibrio cholerae*

Now known to be a bacteria
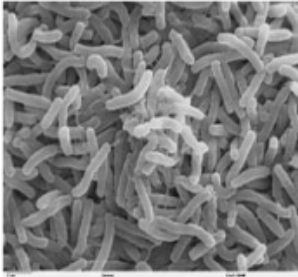
# How have epidemics changed history?

- Black Death: May have led to the end of the feudal system?
- "Guns germs and steel": Diseases (particularly smallpox) introduced to the new world led to the collapse of the Mayan, Aztec and Inca empires. J Diamond as reviewed by (Brooks 1999)
- Spanish flu: Could have produced some of the social conditions that led to the second world war?
- SARS-CoV-2 (Covid-19): Clearly had a major impact on many lives throughout the world

# *Yersinia pestis*: Bacteria

# Smallpox: Variola virus

# H1N1: Flu viral strain

# H1N1 1918: Impact on life expectancy

▶ Median age of death 28
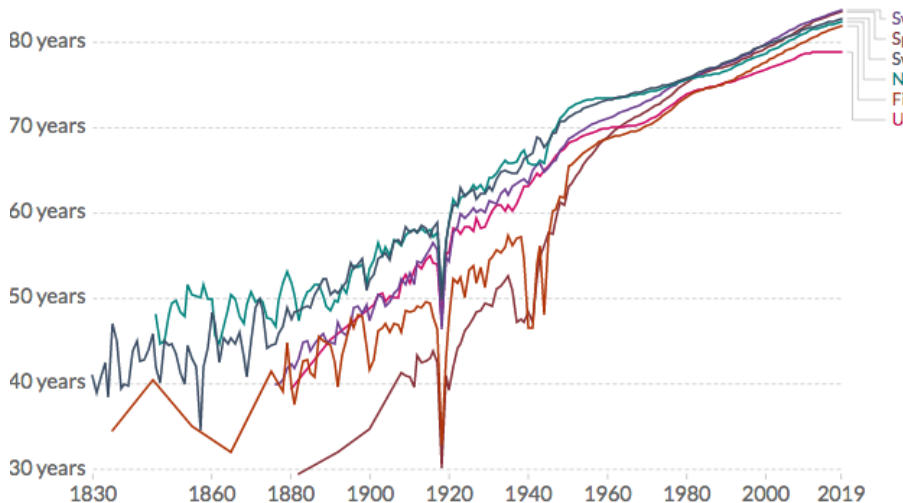
# H1NI 1918

- Flu typically results in 500,000 deaths per year throughout the world (Mills, Robins, and Lipsitch 2004)
- 1918 deaths. (Spreeuwenberg, Kroneman, and Paget 2018) 17.4 million deaths(?)
- Patterson and Pyle (1991) 24.7 to 39.3 million
- Other estimates even higher
- However, viral agent may have been confounded with other pathogens

# "Spanish flu"

- ▶ Epidemics often mistakenly named after country of supposed origin.
- ▶ Spanish flu may actually have begun in New York (Olson et al. 2005)
- ▶ Young people were at greater risk than the older population (not the usual pattern.)
- ▶ This could have been due to acquired immunity of the older population exposed to the "Russian" flu
- ▶ May also have bee exacerbated by poor health of returnees from the war

# Influenza pandemics (Krammer et al. 2018)
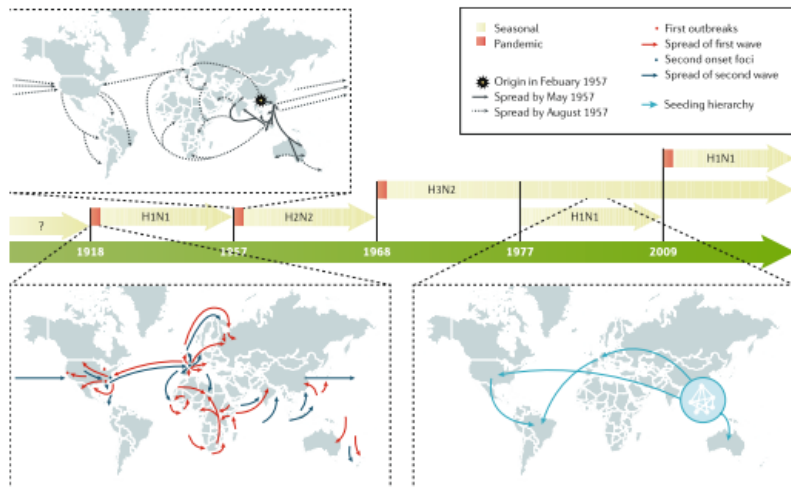


Fig. 2 | **Influenza pandemics.** In the past 100 years, four pandemics of human influenza have occurred, with the 1918 pandemic caused by an influenza A H1N1 virus being the most devastating, as it was associated with >40 million deaths.

# Mortality patterns in 1918
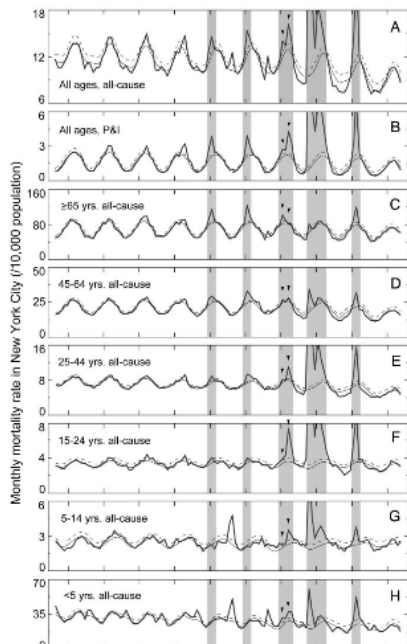
# 2020 SARS-CoV-2 pandemic

- ▶ Current estimate
- ▶ 483 million cases worldwide
- ▶ Perhaps around 6 million deaths worldwide (around 10% of global annual mortality, over 2 years)
- ▶ Economic impact unquantified.

# Worldwide mortality



## Number of deaths per year, World
The dotted line shows the medium variant of the UN population projections.

⇄ Change country
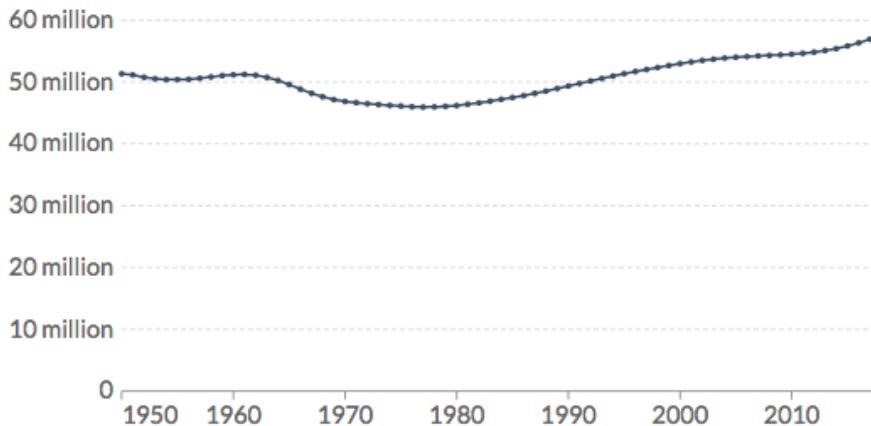
# Will the SARS-CoV-2 pandemic change global demographic parameters?

- ▶ Very minor increase in overall mortality ($<5\%$)
- ▶ Very little noticeable change in the overall life expectancy
- ▶ Most deaths in 2020 to 2022 were still from all the other typical causes, particularly in the young
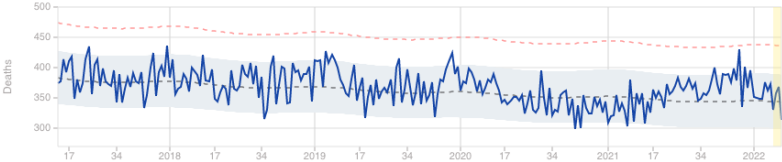- ▶ This contrasts with the 1918 flu, which did reduce life expectancy

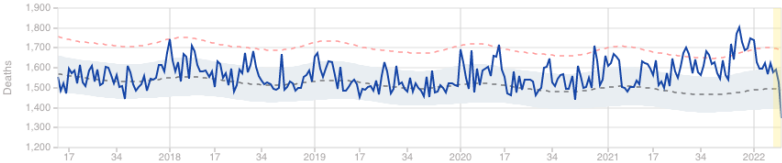# Excess deaths in Europe during SARS-CoV-2 epidemic
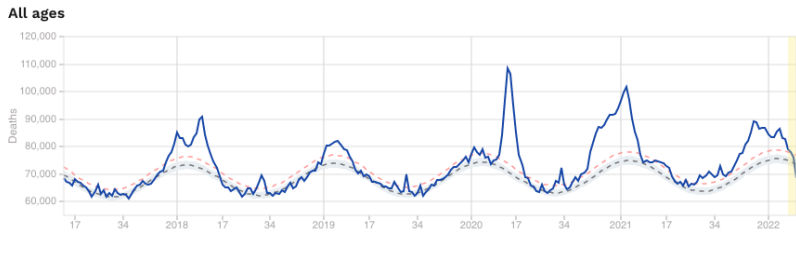


https://www.euromomo.eu/graphs-and-maps/
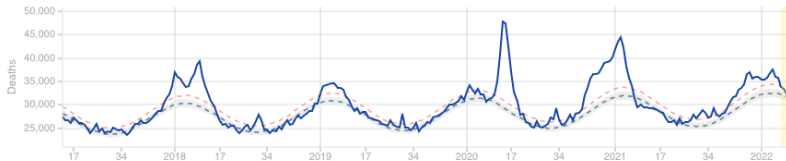
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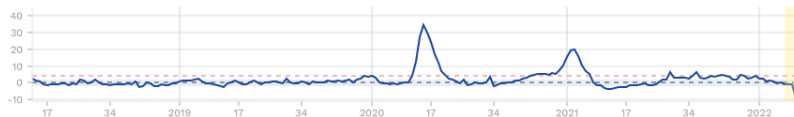
# Excess deaths in Europe during SARS-CoV-2 epidemic

# Excess deaths in England during SARS-CoV-2 epidemic



UK (England)

# Conclusions

- Epidemics can have dramatic impacts on human society (as we are too well aware of)
- Understanding source and transmission extremely important
- Patterns of epidemic development in space and time can be mapped and modelled
- We also need to understand the disease causing agent (the "epi" in epidemiology)

# Links

https://ourworldindata.org/spanish-flu-largest-influenza-pandemic-in-history

https://ourworldindata.org/child-mortality

https://www.worldometers.info/coronavirus/ (And multiple dashboards and data sources)

## References and further reading

Bloom, David E., and Daniel Cadarette. 2019. "Infectious disease threats in the twenty-first century: Strengthening the global response." *Frontiers in Immunology* 10 (MAR): 1–12. https://doi.org/10.3389/fimmu.2019.00549.

Brooks, Alex. 1999. "Guns, Germs and Steel: A Short History of Everybody for the Last 13,000 Years." *BMJ* 318 (7193): 1294. https://doi.org/10.1136/bmj.318.7193.1294a.

Krammer, Florian, Gavin J. D. Smith, Ron A. M. Fouchier, Malik Peiris, Katherine Kedzierska, Peter C. Doherty, Peter Palese, et al. 2018. "Influenza." *Nature Reviews Disease Primers* 4 (1): 1–21. https://doi.org/10.1038/s41572-018-0002-y.

Mathers, Colin D., and Dejan Loncar. 2006. "Projections of global mortality and burden of disease from 2002 to 2030." *PLoS Medicine* 3 (11): 2011–30. https://doi.org/10.1371/journal.pmed.0030442.

Mills, Christina E., James M. Robins, and Marc Lipsitch. 2004. "Transmissibility of 1918 pandemic influenza." *Nature* 432