Modelling infectious disease outbreaks
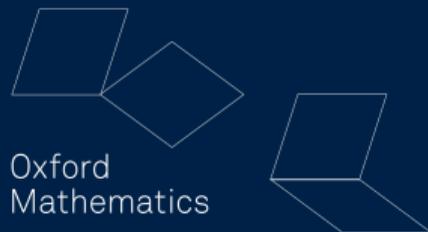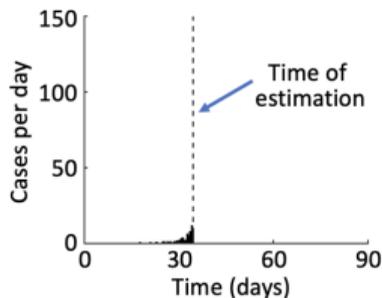
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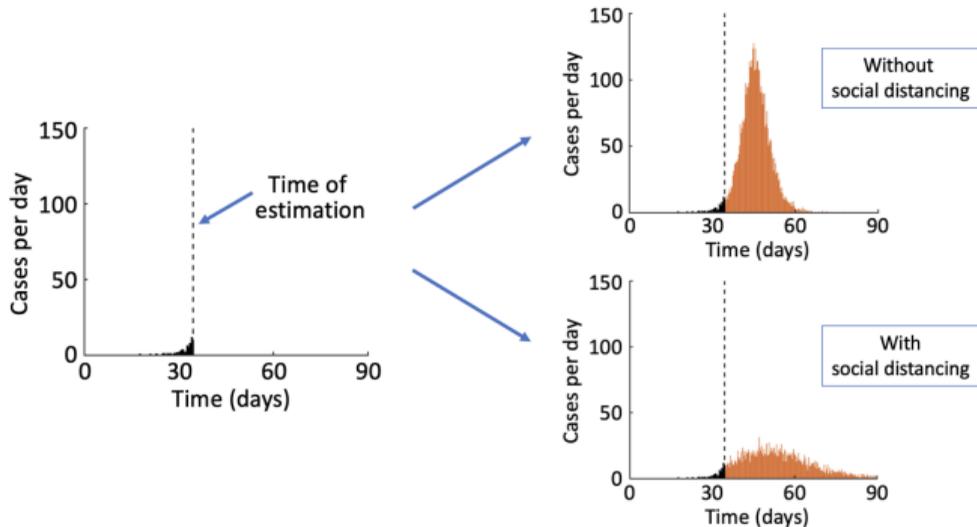
Mathematical modelling project, Hillary term 2026

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- ▶ Emerging infections require rapid and robust modelling tools.
- ▶ You will develop and analyse models to support policy decisions.

▶ Emerging infections require rapid and robust modelling tools.
▶ You will develop and analyse models to support policy decisions.

You will:

► Formulate deterministic and stochastic epidemic models.

► Fit models to outbreak data.

► Evaluate intervention strategies.

The SIR epidemic model divides the population into three compartments or classes:

▶ S: **susceptible** individuals who may get infected,

▶ I: **infectious** individuals who are infected and can infect susceptible individuals,

▶ R: **recovered** individuals who have been infected, but do no longer transmit the disease and are now immune.
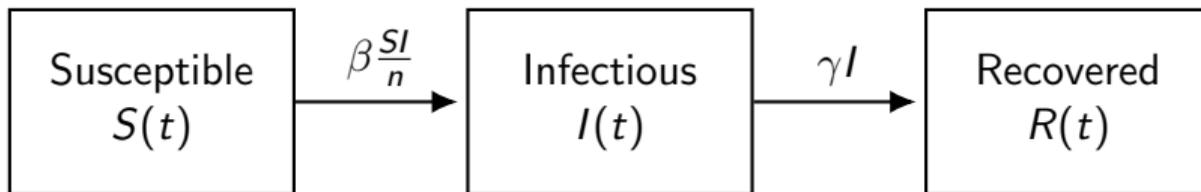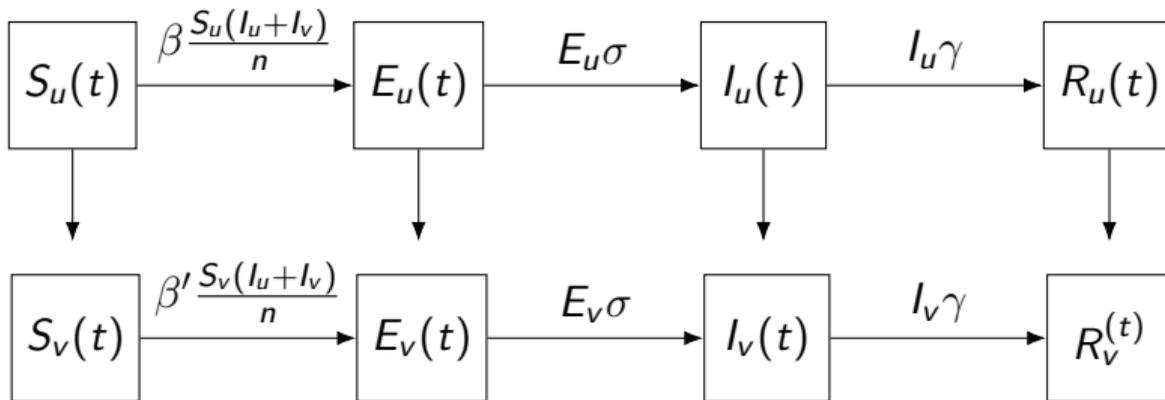
SIR model can be defined by ODEs

$$\frac{dS}{dt} = -\beta \frac{SI}{n}$$

$$\frac{dI}{dt} = \beta \frac{SI}{n} - \gamma I$$
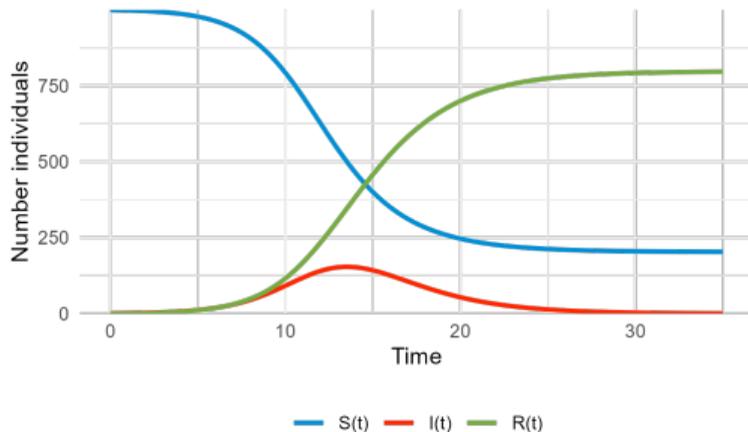
$$\frac{dR}{dt} = \gamma I$$

Many possible extensions including latent periods, waning immunity, or heterogeneities as age structure, vaccination status etc.
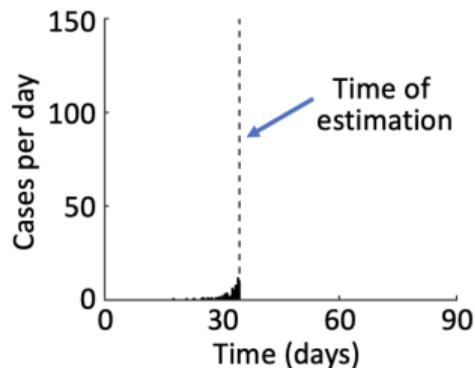
A hypothetical respiratory virus:

- ▶ Latent period: $\sim$ 3 days
- ▶ Infectious period: $\sim$ 5 days
- ▶ Asymptomatic transmission possible
- ▶ 50 initial cases, 30 days of incidence data

Part A: Model formulation

Core requirements:

▶ Deterministic SEIR model

▶ Stochastic model (e.g., Gillespie)

Possible extensions:

▶ Age structure or asymptomatic compartments

▶ Vaccination dynamics

▶ Behaviour-dependent contact rates

▶ Spatial or network modelling

You may estimate:
- ▶ Transmission rate β
- ▶ Latent and infectious periods
- ▶ Initial conditions
- ▶ R_0 and R_t

You may evaluate:

- ▶ Vaccination (efficacy, rollout speed, waning immunity)
- ▶ Testing and isolation (delays, sensitivity)
- ▶ Non-pharmaceutical interventions (mask use, distancing)
- ▶ Combinations of interventions

Goal: Identify conditions for epidemic control.

Questions that could be addressed

- How do the conditions/interventions that achieve epidemic control depend on the chosen definition of "under control"?
- How does the time point at which an intervention is put into place affect its outcome?
- How do the modelling choices for any particular intervention affect the conditions for epidemic control?

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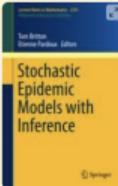
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Optimal Intervention Strategies for Minimizing Total Incidence During an Epidemic

Authors: Tom Britton and Lasse Leskelä

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https://doi.org/10.1137/22M1504433

Article | Open access | Published: 26 July 2021

A modified age-structured SIR model for COVID-19 type viruses

Vishaal Ram & Laura P. Schaposnik ✉

Scientific Reports 11, Article number: 15194 (2021) | Cite this article

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Journal of Theoretical Biology 562 (2023) 111417

Contents lists available at ScienceDirect

Journal of Theoretical Biology

ELSEVIER journal homepage: www.elsevier.com/locate/yjtbi

A practical guide to mathematical methods for estimating infectious disease outbreak risks

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