Types of Models

Modern Techniques in Modelling

Many models, so little time

- **Model** is a generic term used to refer to a representation of reality, often (but not always) quantitative in nature.

- We use the term **mathematical models** to refer to a class of (quantitative) models that are **mechanistic** in nature.

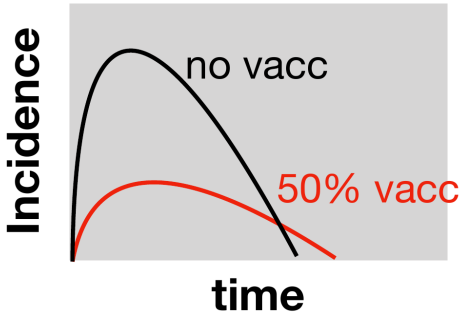
- The opposite of mechanistic is **phenomenological**. Phenomenological models can be called **statistical** models to differentiate them from mathematical (mechanistic) models.

Many models, so little time

Mechanistic

Variables are tracked through causal routes

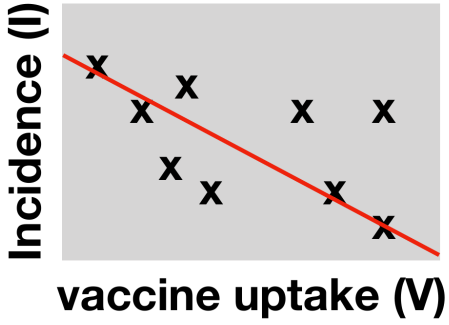
To understand how parameters and variables impact other variables



Phenomenological

Variables are tracked through association relationships

To understand how variables behave, not why they behave that way.



$I = aV + b$

Which models will we see in the course?

Difference equations

Tracks the number of individuals in each epidemiological "compartment" (e.g. Infected or Susceptible) at each e.g. day or week timestep

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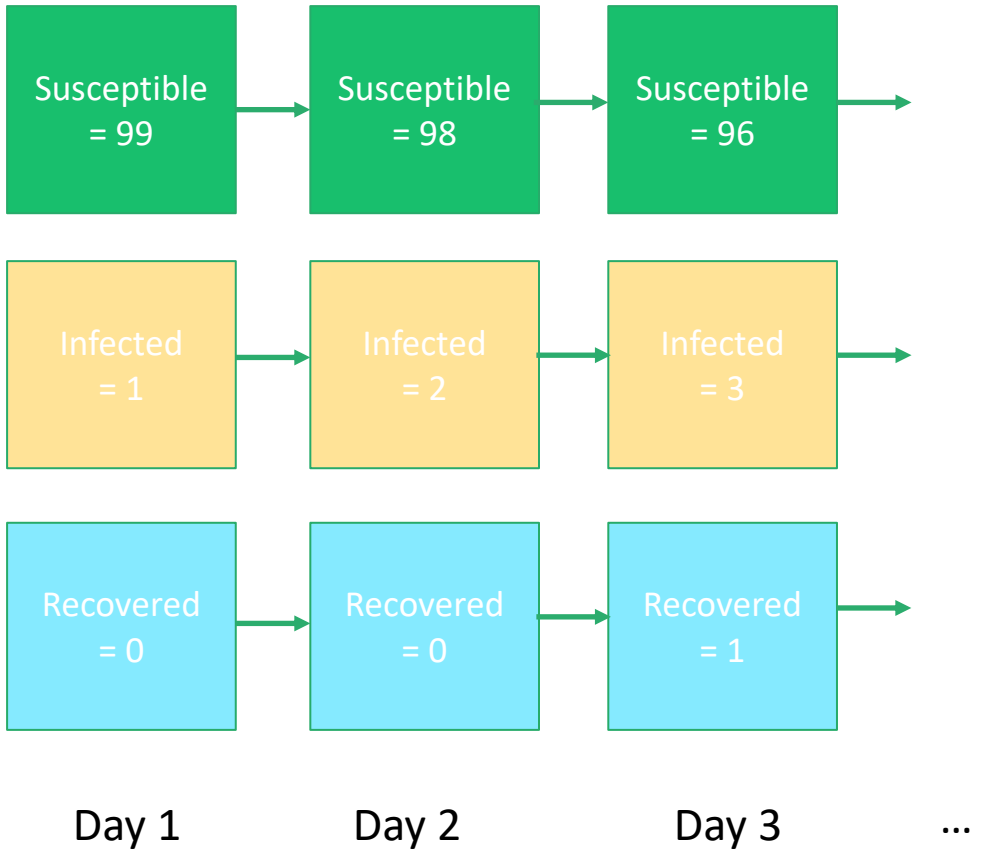

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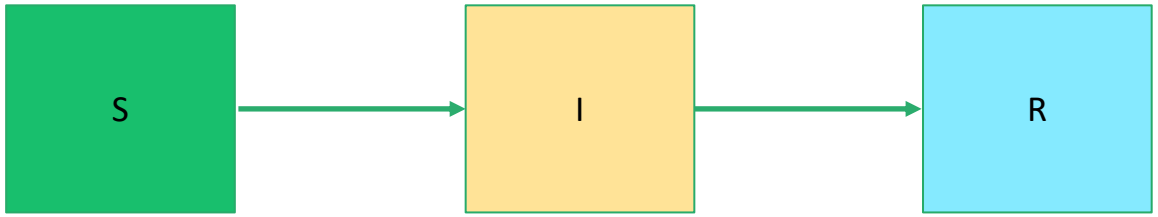
Ordinary Differential Equations (ODEs)

Same as 'difference equations' but instead of calculating at each timestep, we move to continuous time



Defined by change in the number of people in each compartment

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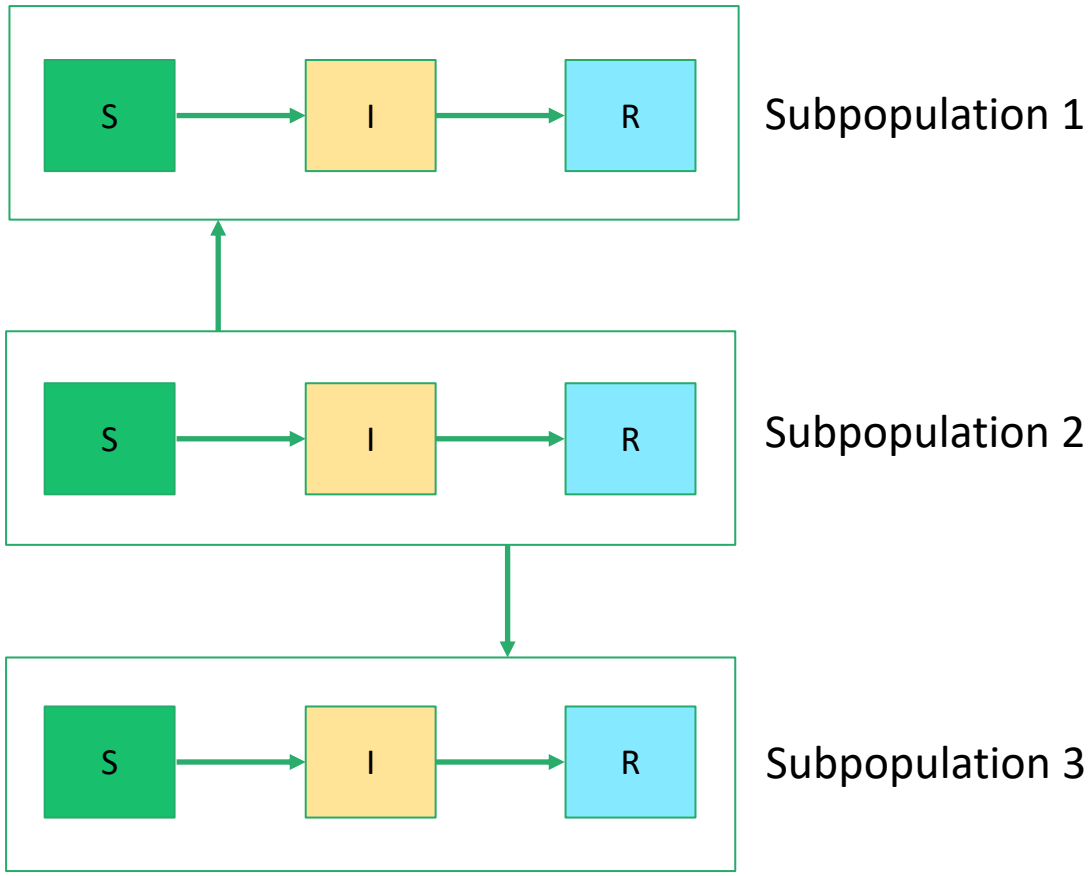

Metapopulation

Add in structure to ODE model by creating multiple subpopulations that can transmit infections within and between each subpopulation

Which models will we see in the course?

1. F 48.3y; became infected on day 16; has an incubation period of 5.2 days, will have mild symptoms and lose infectiousness after 8.6 days.

2. M 15.9y; became infected on day 102; has an incubation period of 3.0 days, will be hospitalized in North London on day 106, discharged on day 108 and lose infectiousness 10.6 days later.

Individual-based model

Tracks each individual, each with their own epidemiological characteristics; this model class also introduces the idea of randomness

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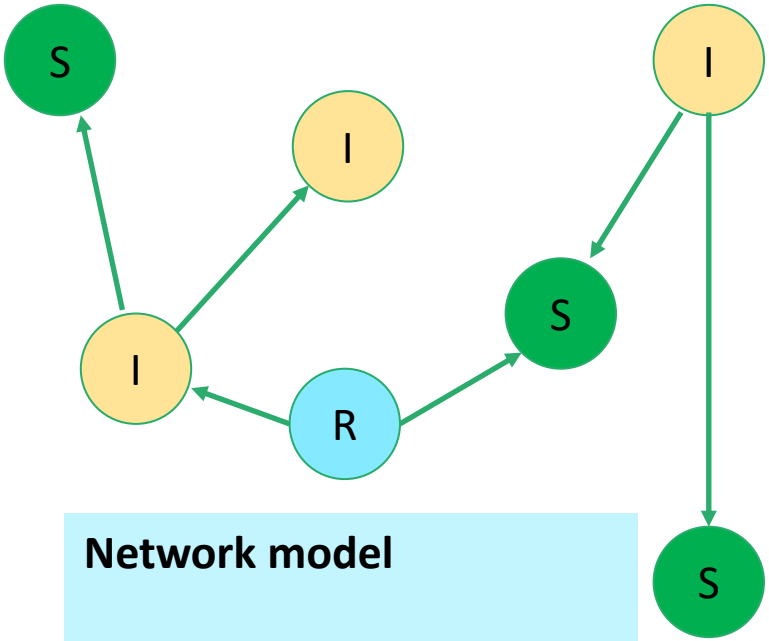
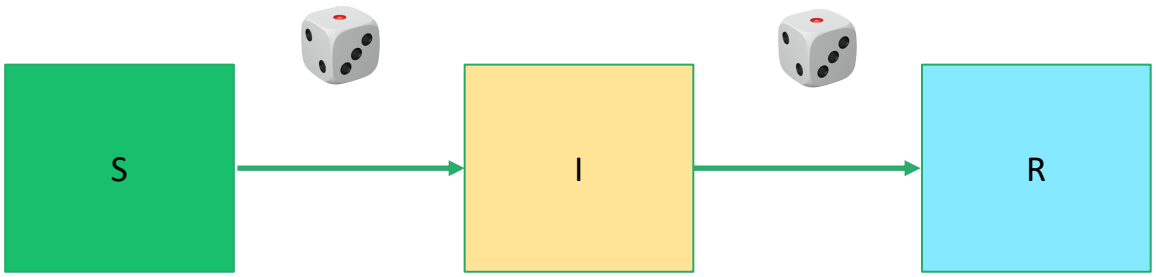


Network model

Adds structure to the individual-based model, where each individual is constrained by who they can transmit to

Which models will we see in the course?



Still defined by change in the number of people in each compartment.

But events (e.g. infections, recoveries etc.) happen stochastically.

Because we are still tracking total number of people and not individuals, it's quicker.

Stochastic compartment model

A stochastic implementation of our compartment ODE model but there is randomness in events happening

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LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

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Main Question: how do we choose a model type and a model structure?

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- What is the research question?
- How big is the population?
- Are there stochastic fluctuations in the data that cannot be mechanistically accounted for?
- Do we need to track every individual?
- What type of events are we modelling and how do we parameterise them?
- What type of data do we have?

Terminology clarification

- **Model Variable**: A quantity that is tracked through time and changes as a function of the other variables/parameters (e.g. number of infected people)
- **Model Parameter**: Will stay constant through a whole iteration of a model (e.g. vaccine coverage, mortality rate)
- Note that in R parameters and variables are both sometimes called "variables”

Reminder: Course website

All of the practical exercises will use R scripts that you will create yourself following instructions at the course website:

1. Navigate to **cmmid.github.io/mtm** in your internet browser;
   use the “Practicals” menu at the top to access the relevant practical

2. Open RStudio on your computer, start a new R script
   (File > New File > R Script) and follow the instructions in the practical

3. Solutions are also available from the course website

Model type examples used in papers

- Ordinary differential equations
  - Hethcote (2000) SIAM 42(2): Review on constructions of SIR-type models
  - Perelson et al. (1996) Science 271(5255): First description of within-host HIV dynamics spread
- Networks
  - Meyers, LA (2005) J Theor Biology 232: Using networks to understand outbreak heterogeneity
- Individual-based models
  - Halloran, ME (2008) PNAS 105(12): Pandemic flu containment in the US
- Stochastic 'event-driven' model
  - Legrand et al. (2007) Epi & Infection 135: Modelling Ebola epidemics