Exploring the interaction between models and data

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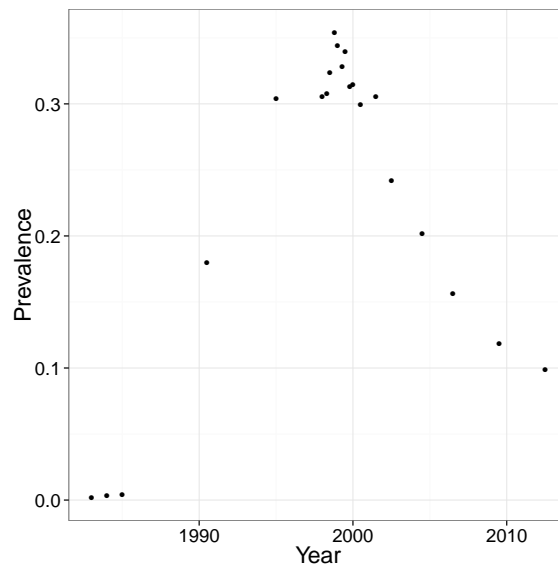`http://lalashan.mcmaster.ca/DushoffLab`

Goals

- Explore some ideas of using a model to explore disease data

- Use estimates of HIV prevalence from Zimbabwe as an example
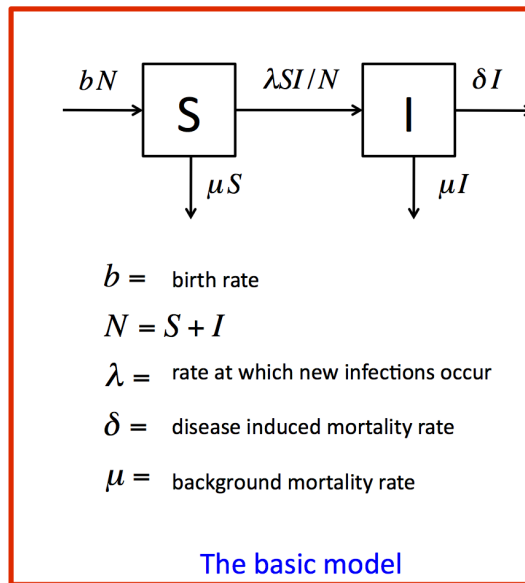
Bridging

- Models are the tool we use to bridge between data and mechanisms

- In both directions

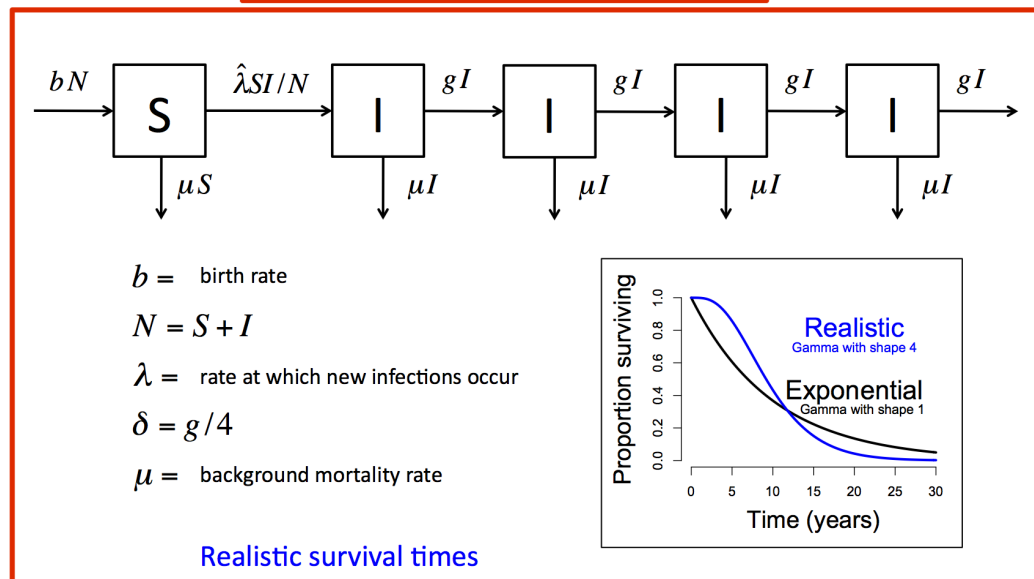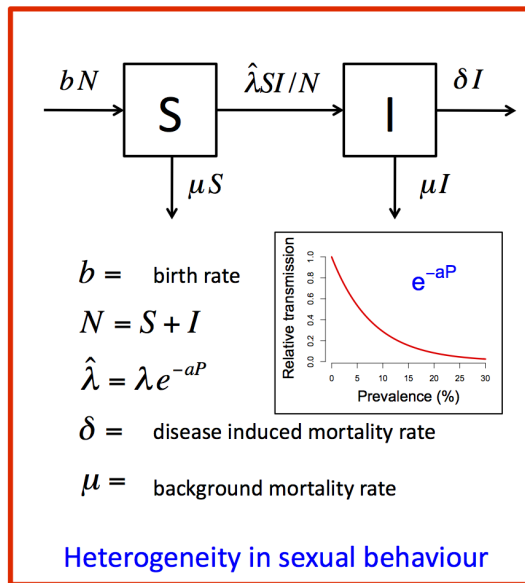## Estimated HIV prevalence in Zimbabwe

Experimental fitting

- We will fit by eye, for learning purpose only

- Later, we will talk about statistical frameworks

- Code online: `https://github.com/dushoff/SIR_simulations`

The basic model

$b =$ birth rate

$N = S + I$

$\lambda =$ rate at which new infections occur

$\delta =$ disease induced mortality rate

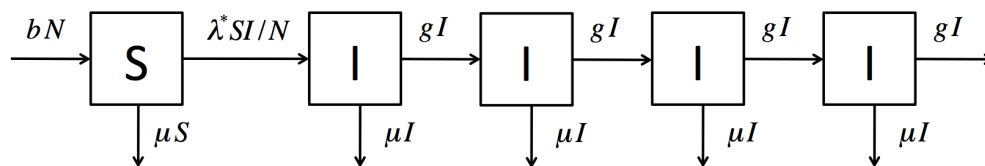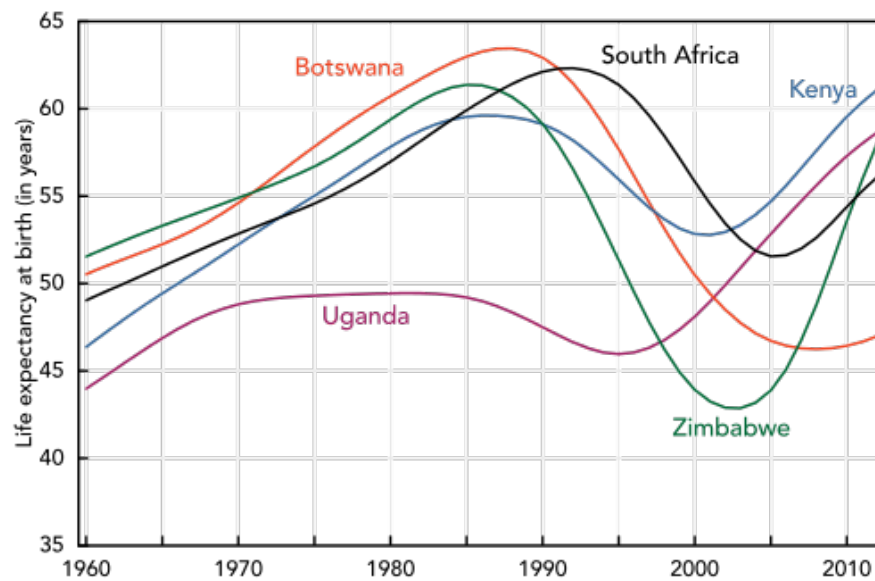$\mu =$ background mortality rate

Phenomenological heterogeneity

- Just *assume* that you can approximate this complicated phenomenon with a simple functional form, $\beta = f(P)$

    - Original study used $\beta = \beta_0 \exp(-\alpha P)$
    - We will use $\beta = \beta_0 (1 - P)^\kappa$

- Both forms start with $\beta = \beta_0$ and decline smoothly with prevalence

Top box

bN $\hat{\lambda}SI/N$ δI

| **S** | | **I** |

μS μI

$b =$ birth rate

$N = S + I$

$\hat{\lambda} = \lambda e^{-aP}$

$\delta =$ disease induced mortality rate

$\mu =$ background mortality rate

e^{-aP}

Relative transmission — Prevalence (%)

Heterogeneity in sexual behaviour

Bottom box

bN $\hat{\lambda}SI/N$ gI gI gI gI

| **S** | | **I** | | **I** | | **I** | | **I** |

μS μI μI μI μI

$b =$ birth rate

$N = S + I$

$\lambda =$ rate at which new infections occur

$\delta = g/4$

$\mu =$ background mortality rate

Proportion surviving — Time (years)

Realistic
Gamma with shape 4

Exponential
Gamma with shape 1

Realistic survival times

Are people *responding* to the epidemic?

Life expectancy at birth (in years) — Botswana, South Africa, Kenya, Uganda, Zimbabwe

$$b N \rightarrow \boxed{S} \xrightarrow{\lambda^* S I / N} \boxed{I} \xrightarrow{g I} \boxed{I} \xrightarrow{g I} \boxed{I} \xrightarrow{g I} \boxed{I} \xrightarrow{g I}$$

μS μI μI μI μI

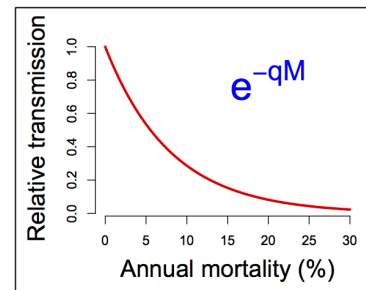$b =$ birth rate

$N = S + I$

$\lambda^* = \hat{\lambda} e^{-qM}$

$\delta = g / 4$

$\mu =$ background mortality rate

Relative transmission vs Annual mortality (%): e^{-qM}

Mortality leads to behaviour change