Microparasitic models II

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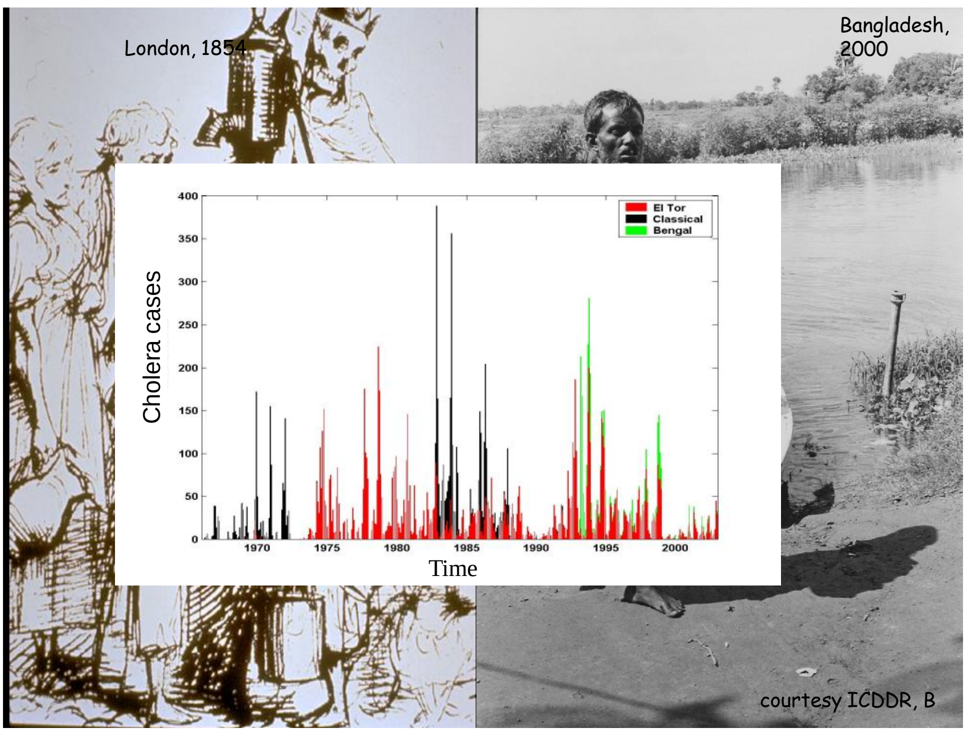
questions:

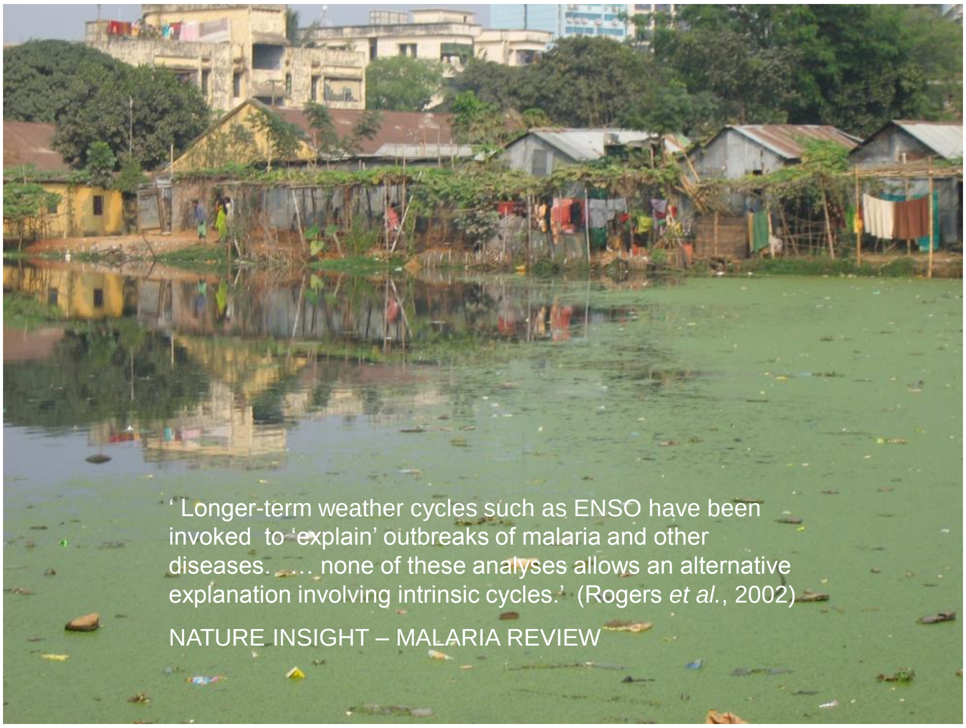
- ❖ why do some diseases persist and become endemic?
- ❖ why do some diseases cycle?
- ❖ what leads to complex temporal patterns?

Syphilis cycles in the US

(NATURE highlights)

Repeated epidemics of syphilis across the United States during the past 50 years have followed a roughly ten-year cycle. These fluctuations have been attributed to changes in sexual behavior, but a new analysis, based on case report data collected from 68 cities since 1941, suggests that they are natural oscillations in disease incidence linked to host immunity. (Science Photo Library).

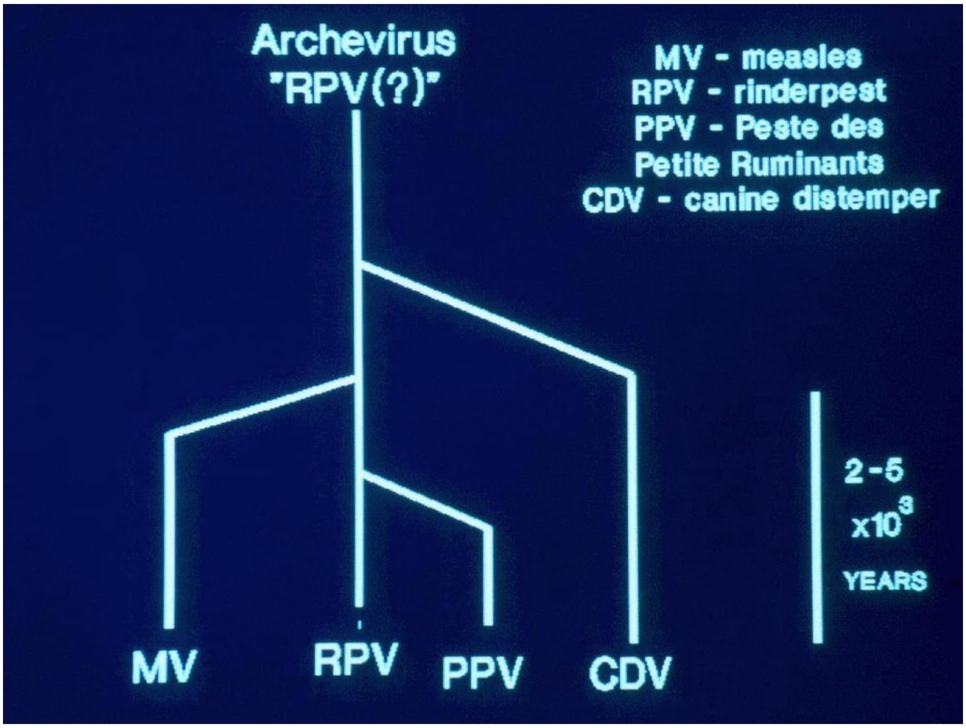




Measles

- Airborne RNA virus
- Respiratory infection
- Mean latent period: 8 days
- Mean infectious period: 5 days
- Lifelong immunity after recovery
- Easy to diagnose

Still kills ~ 1 million people/year



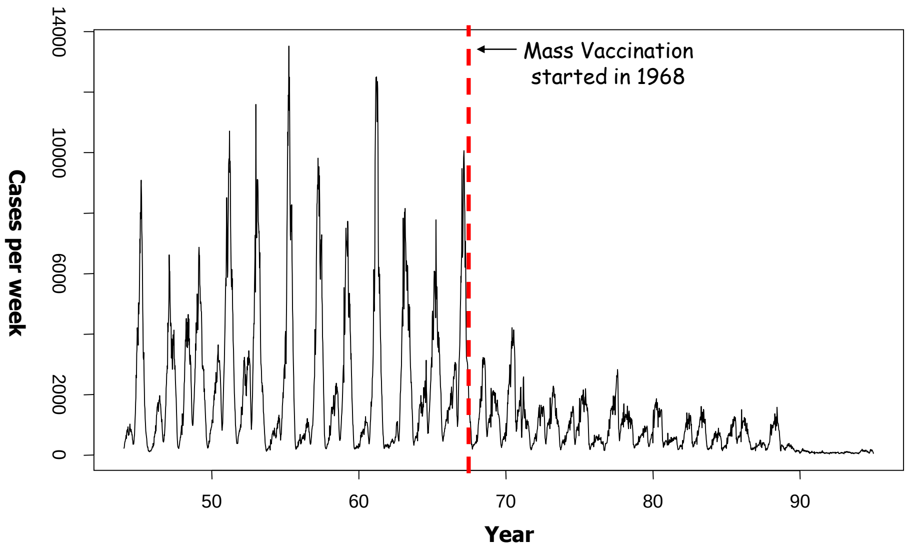
Harbour Seals & Phocine Distemper Virus (PDV)

- 1988: First Record- the best documented mass mortality event of sea mammals (18,000 killed)
- A morbillivirus, like measles
- Spreads through respiratory aerosol
- Started in the Wadden sea
- Spread through Baltic & North sea

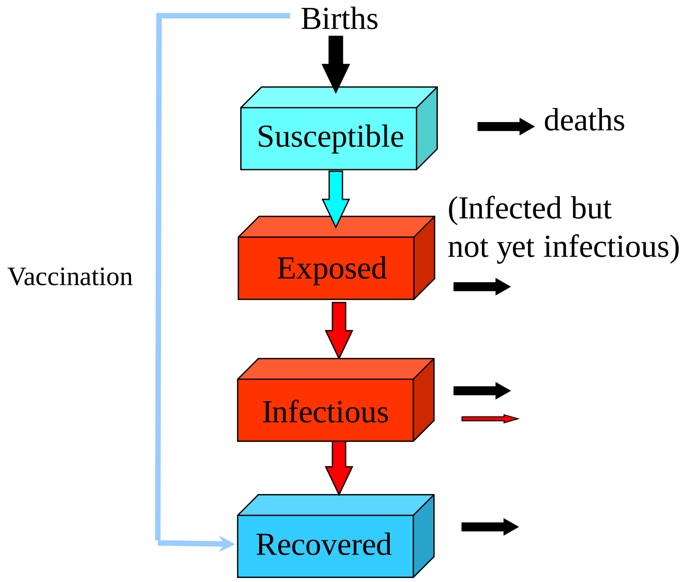
Why has measles become the 'poster-child' for the population dynamics of infectious diseases?

- >50 years of weekly abundance data
- Data are spatially structured (>1000 spatial locations in England and Wales; e.g. Grenfell et al. 2001, *Nature* 414:716)
- Vaccination campaigns = major manipulative experiments

Measles in England & Wales 1945-1995



SEIR Model: Flow Chart



SEIR Model: Equations

$$\frac{dS}{dt} = \vartheta(1-p) - \beta IS - \mu S$$

ϑ, μ = birth, death rates

p = proportion vaccinated

β = mean transmission rate

$$\frac{dE}{dt} = +\beta IS - \sigma E - \mu E$$

σ = 1/(mean latent period)

$$\frac{dI}{dt} = +\sigma E - \gamma I - \mu I$$

γ = 1/(mean infectious period)

$$\frac{dR}{dt} = \vartheta p + \gamma I - \mu R$$

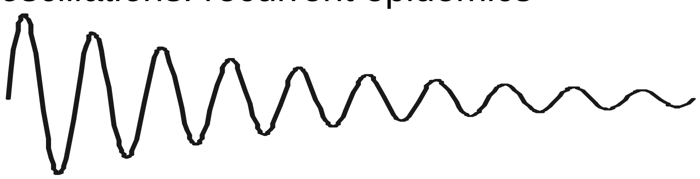
ϑ = μN , N=1

Assumptions:

- Background mortality balances births
- Transmission of infection follows a bilinear contact term βIS/N → 'mass-action transmission' in a homogeneously-mixed host population
- No disease-induced mortality, just morbidity
- An exponential distribution of incubation and infectious periods
- Recovered individuals are immune from infection for life

SEIR Model: behavior

- *Endemic equilibrium* when $R_0(1-p)>1$
- *Explains persistence* of diseases (via births)
- Equilibrium approached by *damped oscillations:* recurrent epidemics

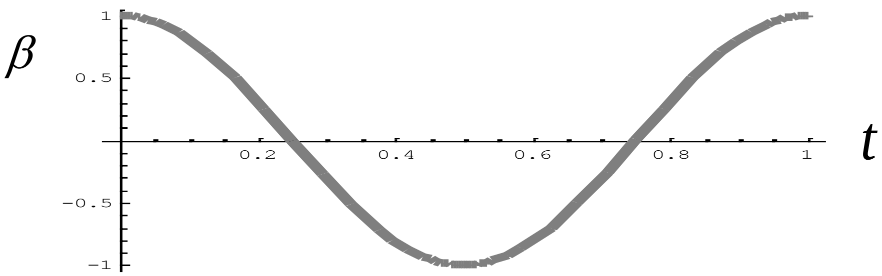


- Does not explain *persistent* oscillations

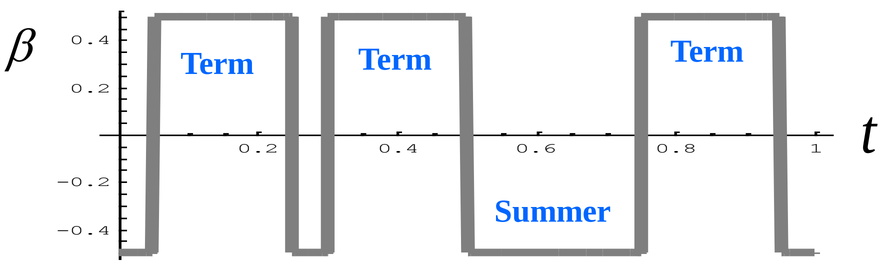
We need to add seasonal contact rates

- We now have a *forced* system
- Forcing frequency can *resonate* with the natural timescales of the disease (e.g., damping period)
- Very rich dynamical system…
  (analogy: *forced pendulum*)

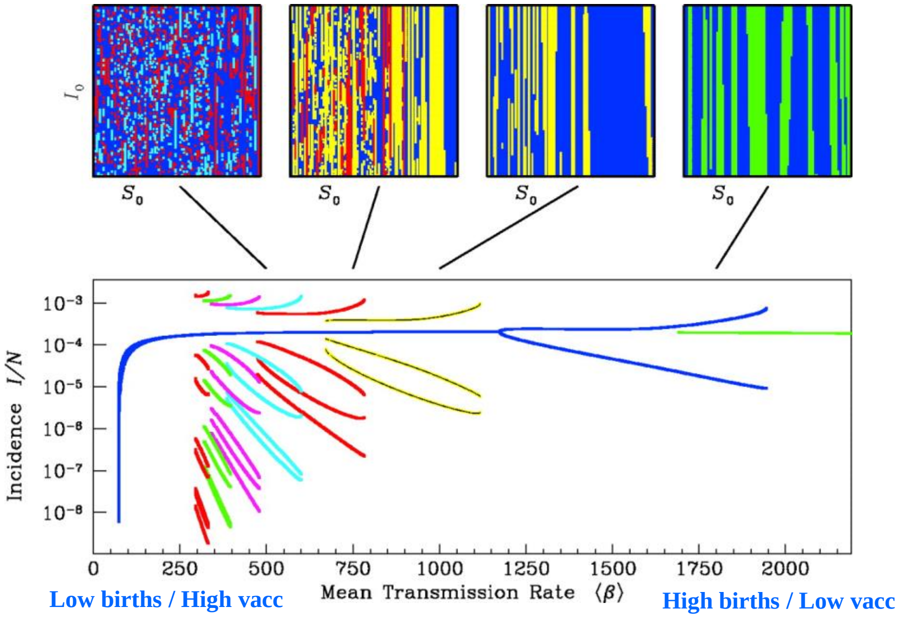
Sinusoidal Forcing



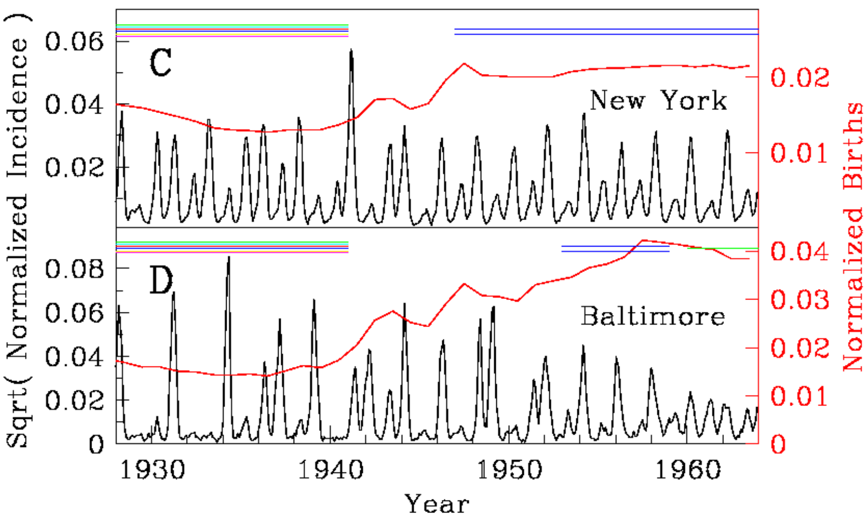
Term-Time Forcing

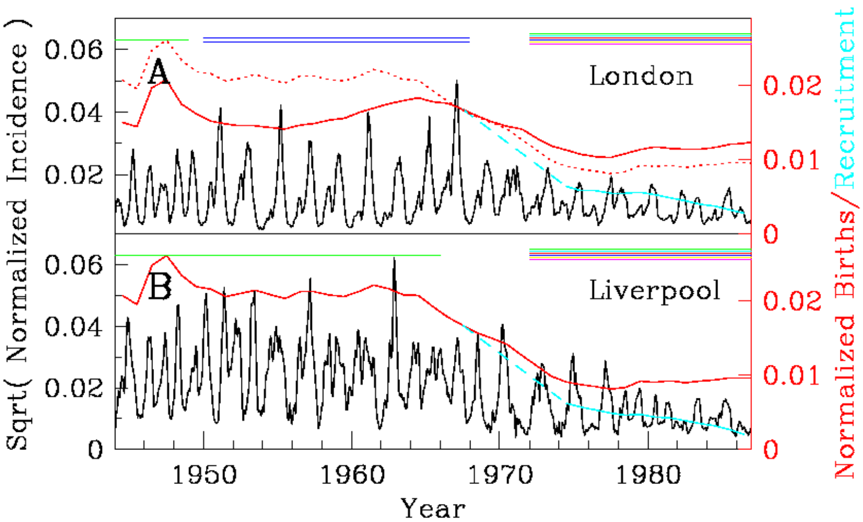


Earn, Rohani, Bolker, Grenfell, *Science* **287**, 667-670 (2000)



Comparison of data and model predictions





Measles The Movie

articles

Travelling waves and spatial hierarchies in measles epidemics

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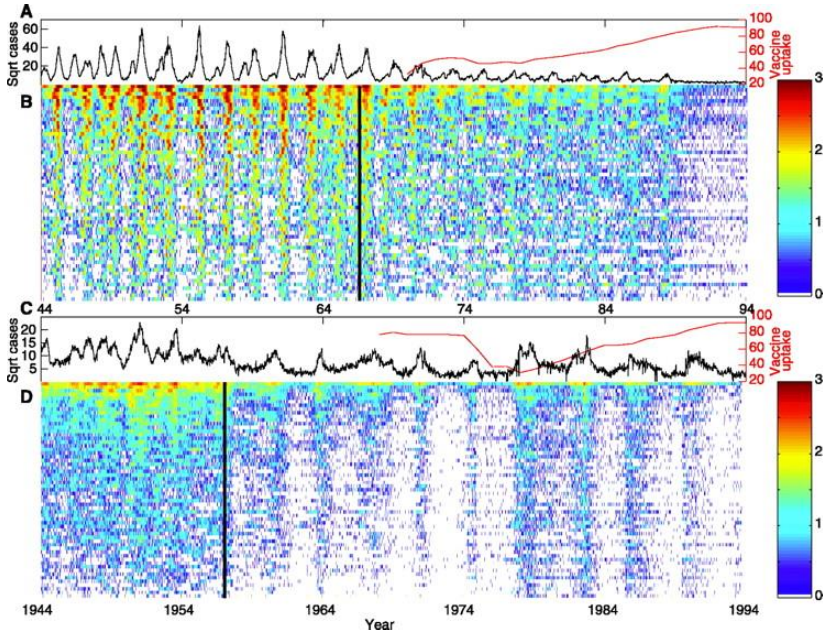
Rohani, Earn, Grenfell, *Science* **286**, 968-971 (1999)



References:

1) Earn, D.J.D., Rohani, P., Bolker, B.M., and Grenfell, B.T. 2000. A simple model of complex dynamical transitions in epidemics. Science 287: 667-670
2) Commentary by R. May in same issue