Data, models and science

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DAIDD 2020

Outline

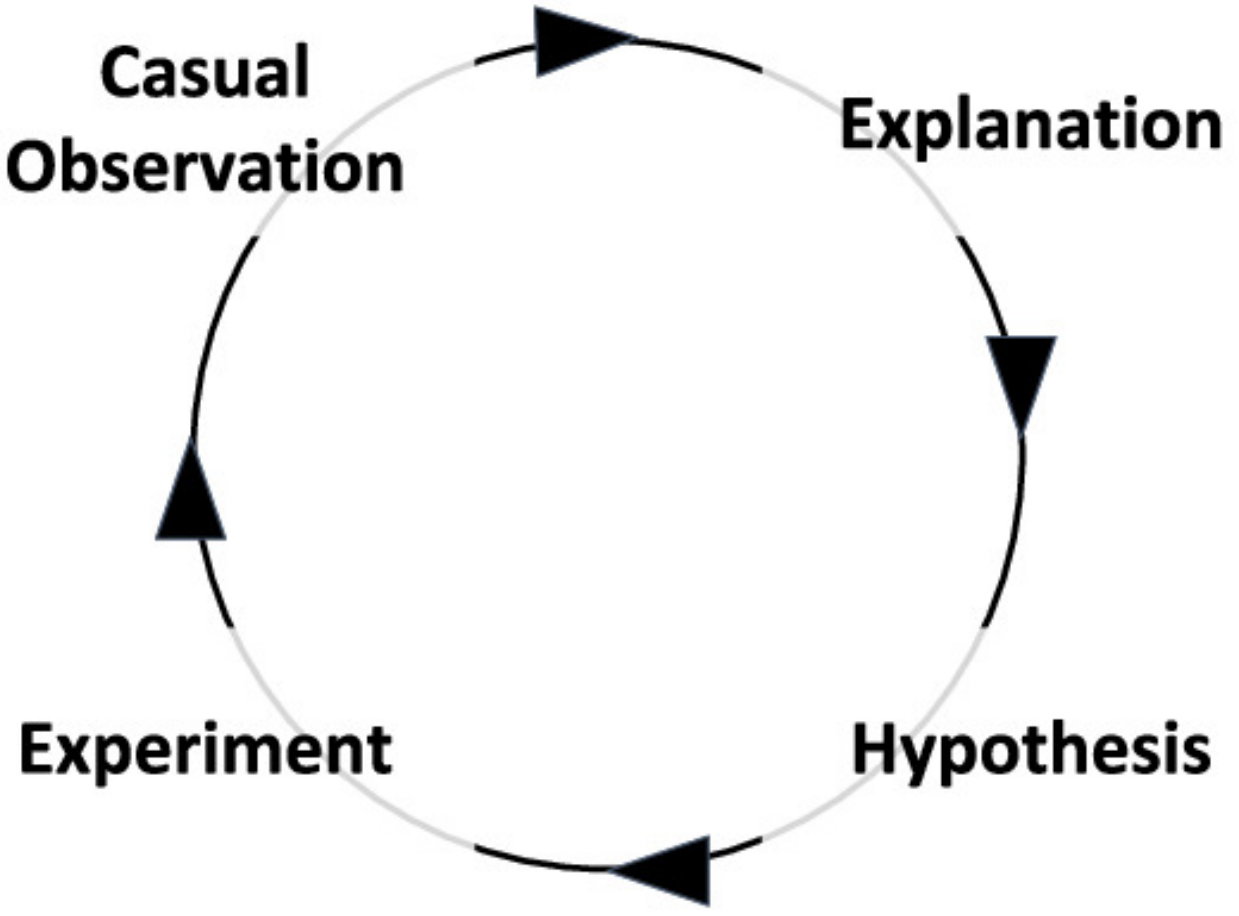
Goals

- Process of science
- How science informs public health
  - Specific examples
- Approaches to epidemiology

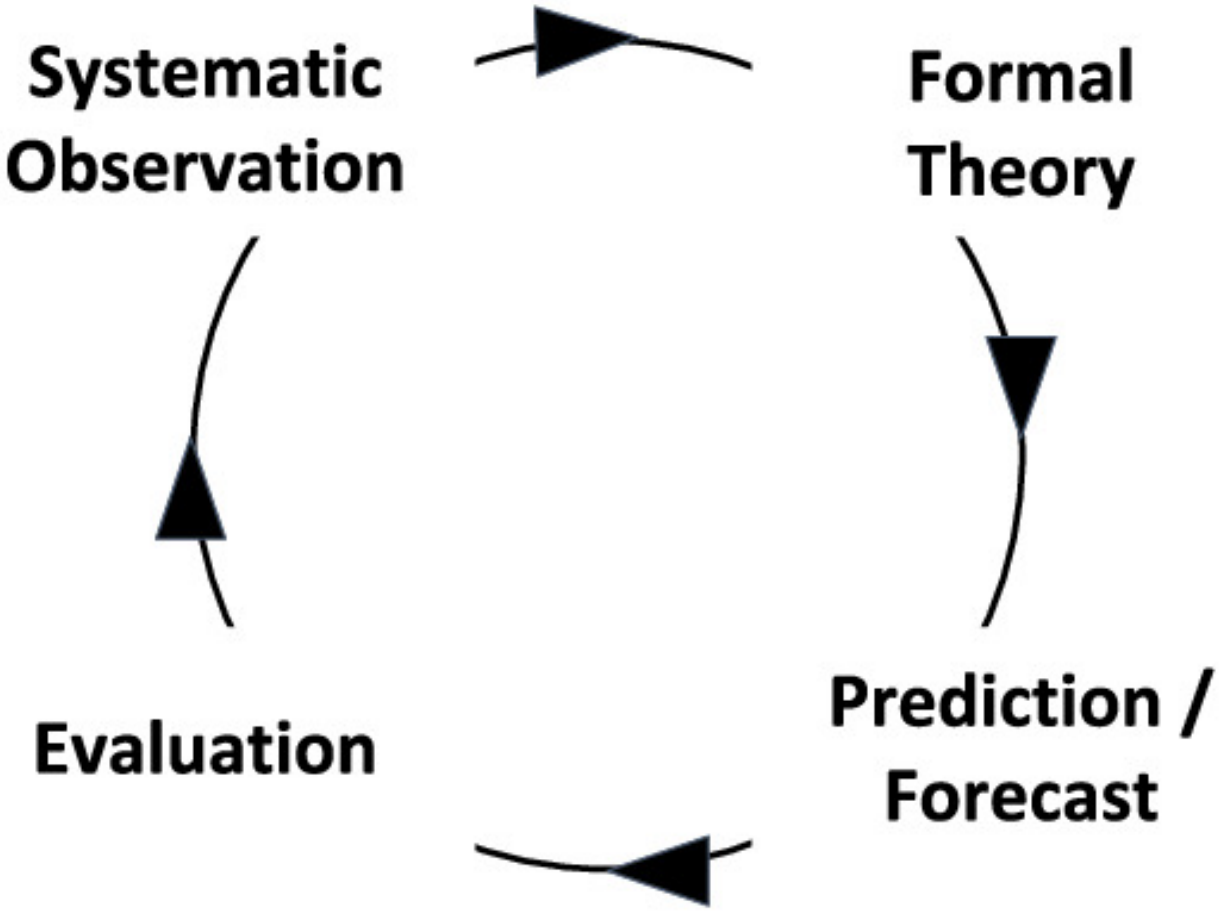
Science is a *process*

- Observe and experiment with reality to *discover* and *challenge* ideas about how it works
- A key to science is that everything is open to question
  - Science is the belief in the ignorance of experts – *Feynman*

The process of science



Science without experiments



Outline

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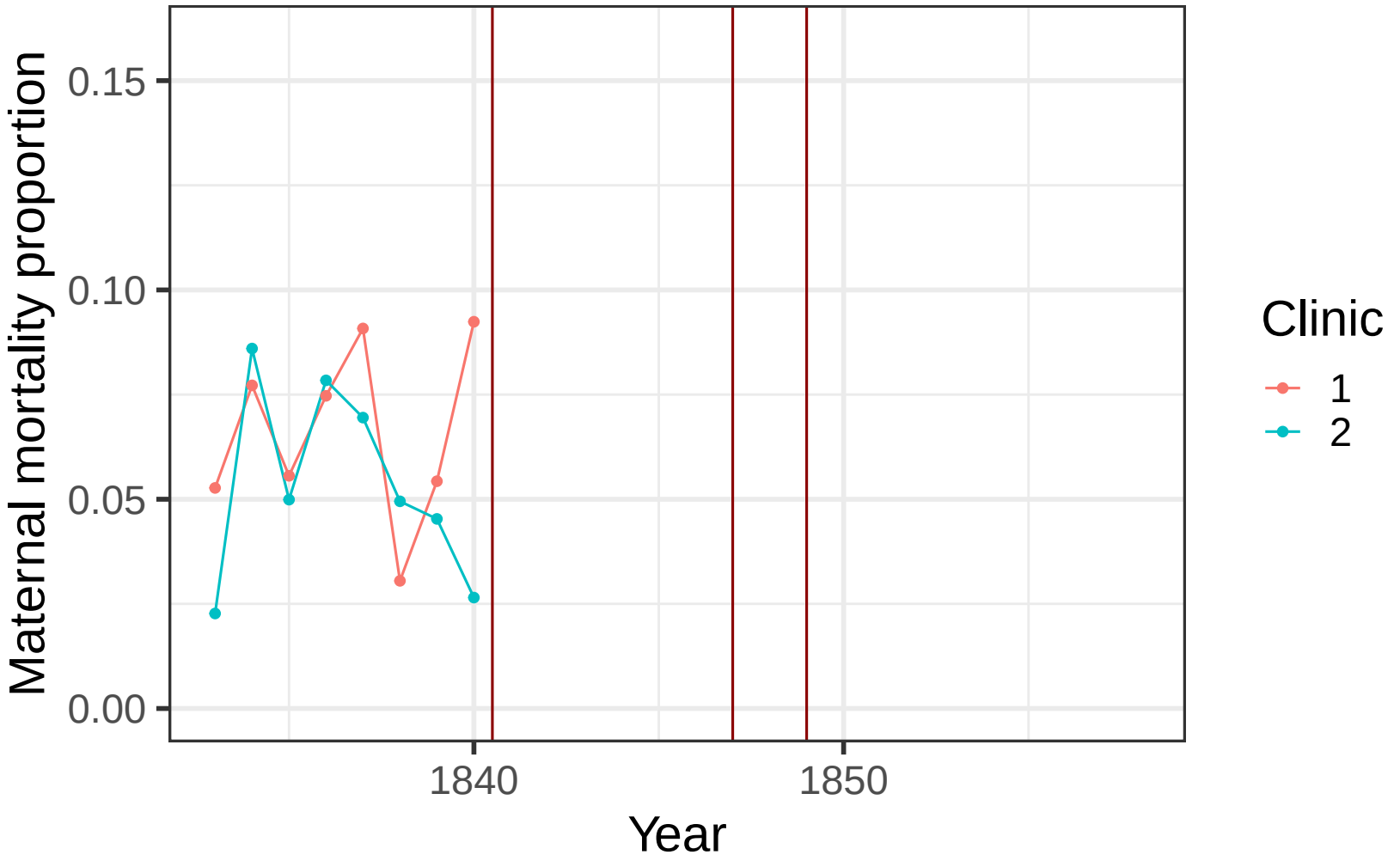
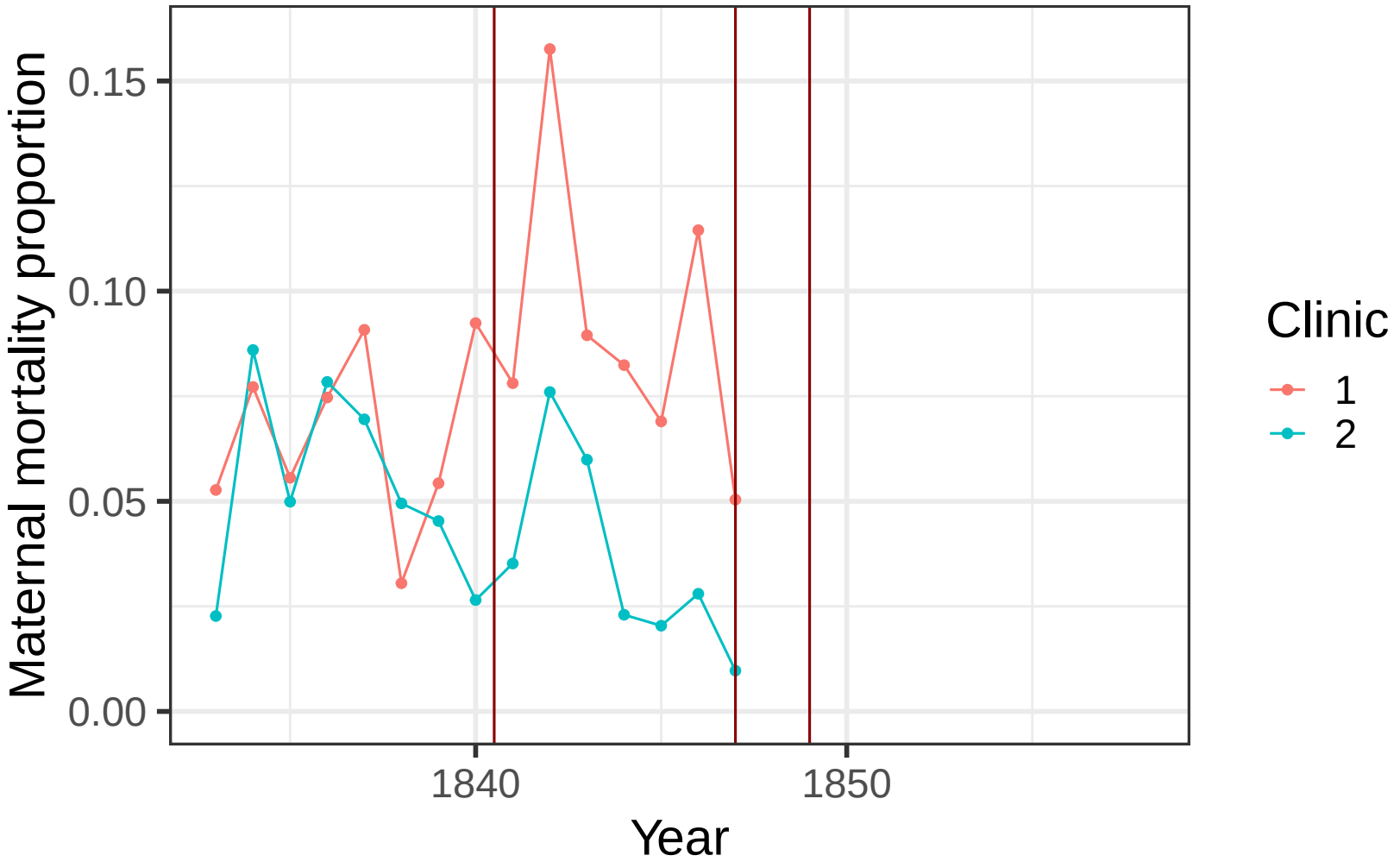
Maternal mortality


Maternal mortality proportion
0.15
0.10
0.05
0.00
1840
1850
Year
Clinic
1
2

Observation and action

- In 1840, medical students stopped visiting Clinic 1
- In 1847, a surgeon died from infection following a scalpel injury
  - Igor Semmelweiss made medical students wash their hands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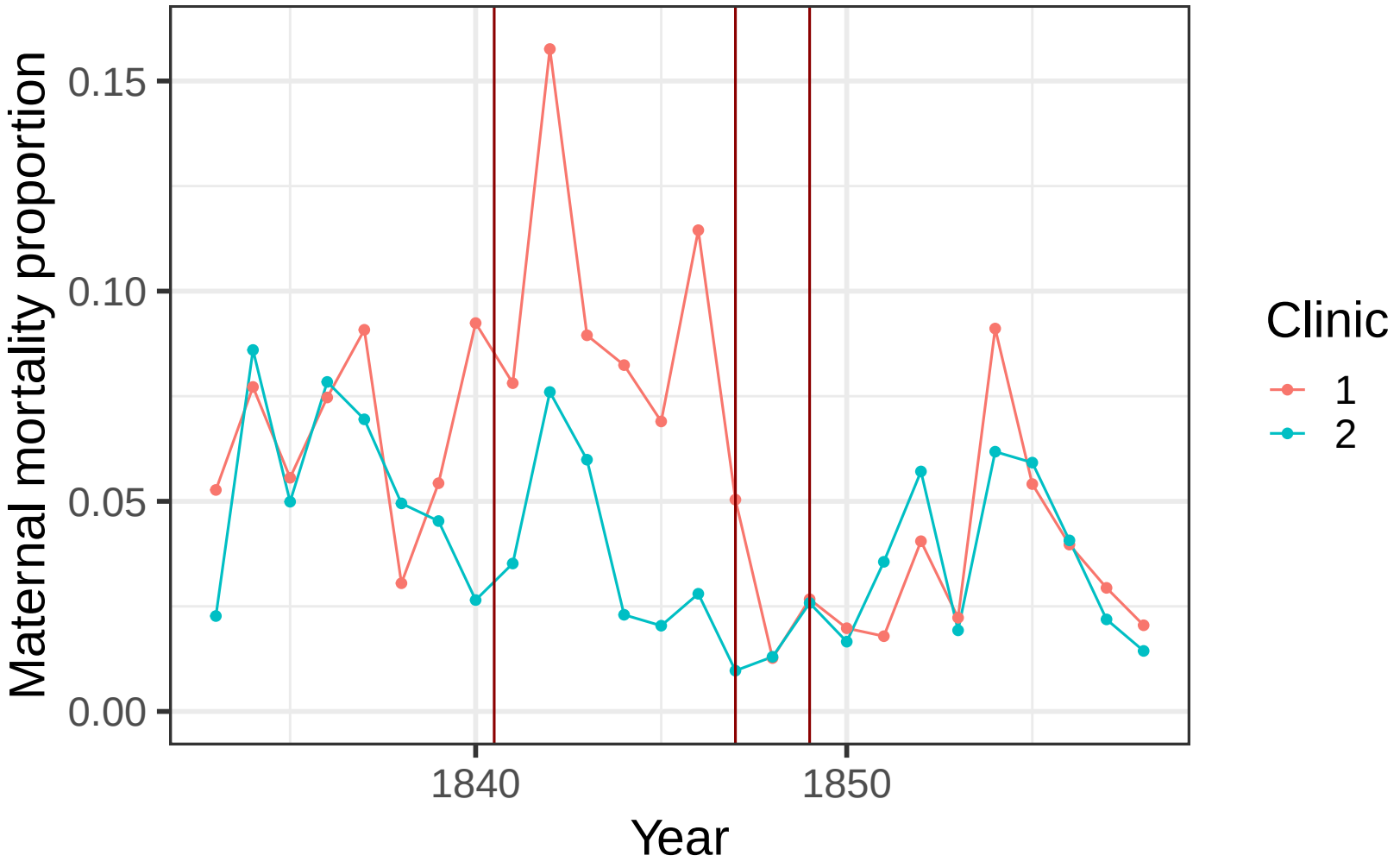
Maternal mortality proportion
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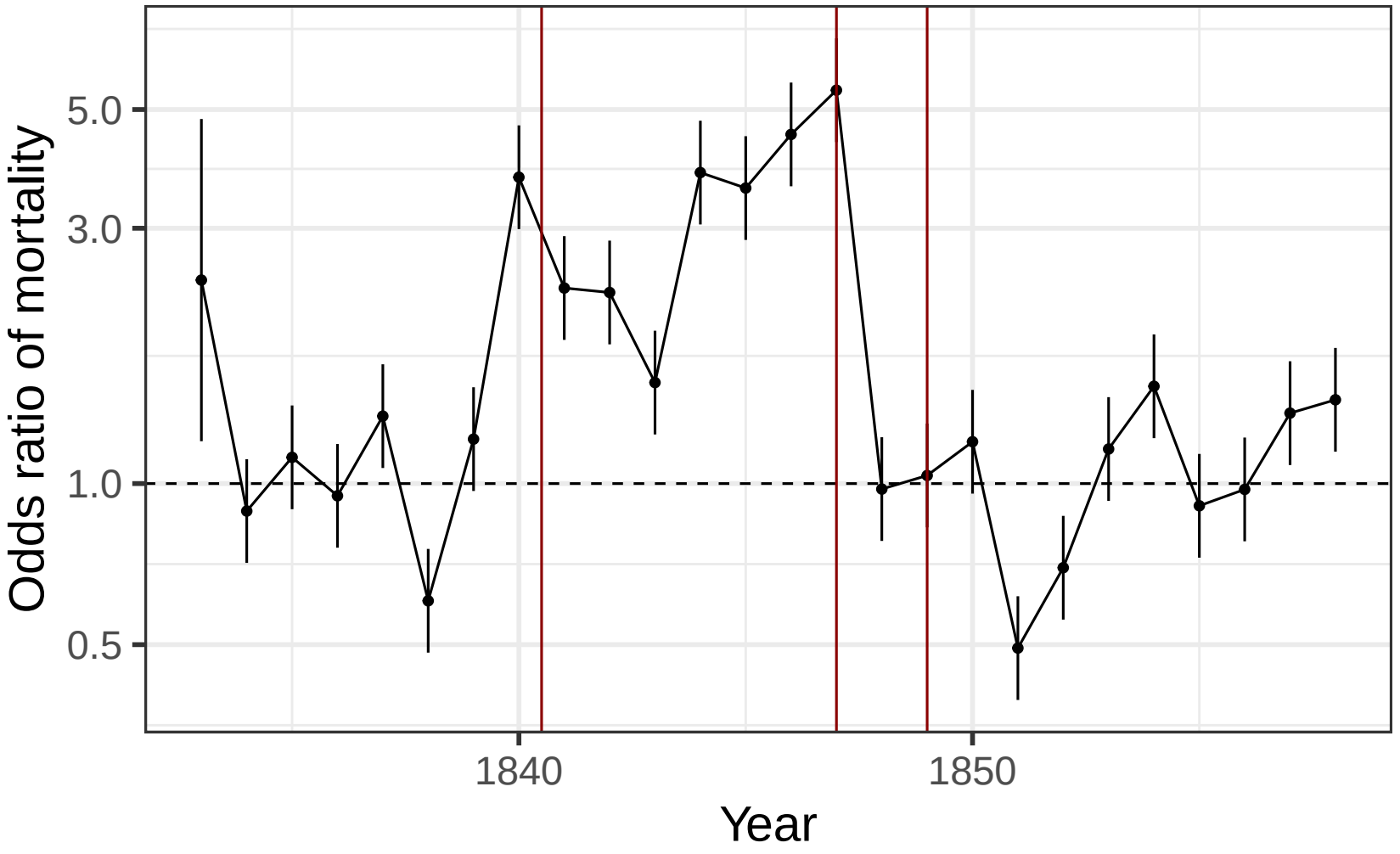
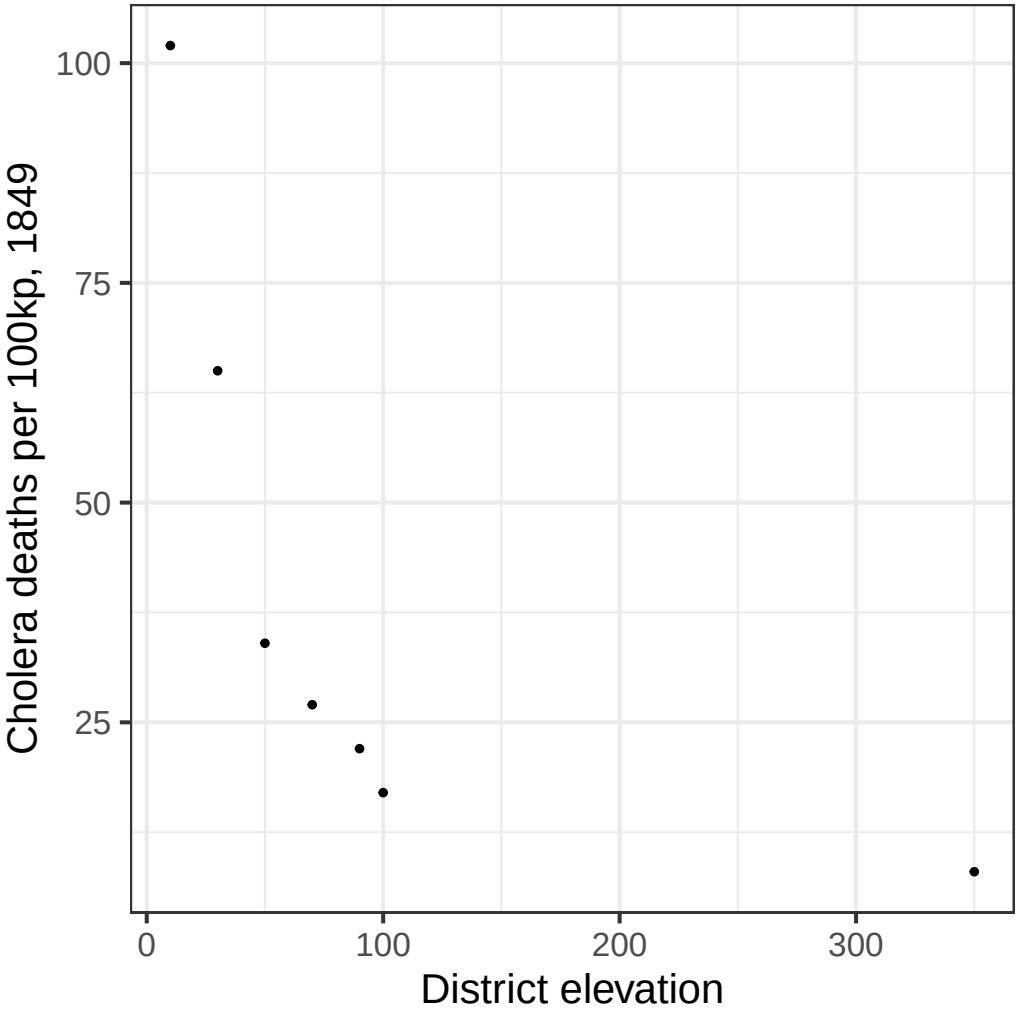

Odds ratio of mortality
5.0
3.0
1.0
0.5
1840
1850
Year

Outline

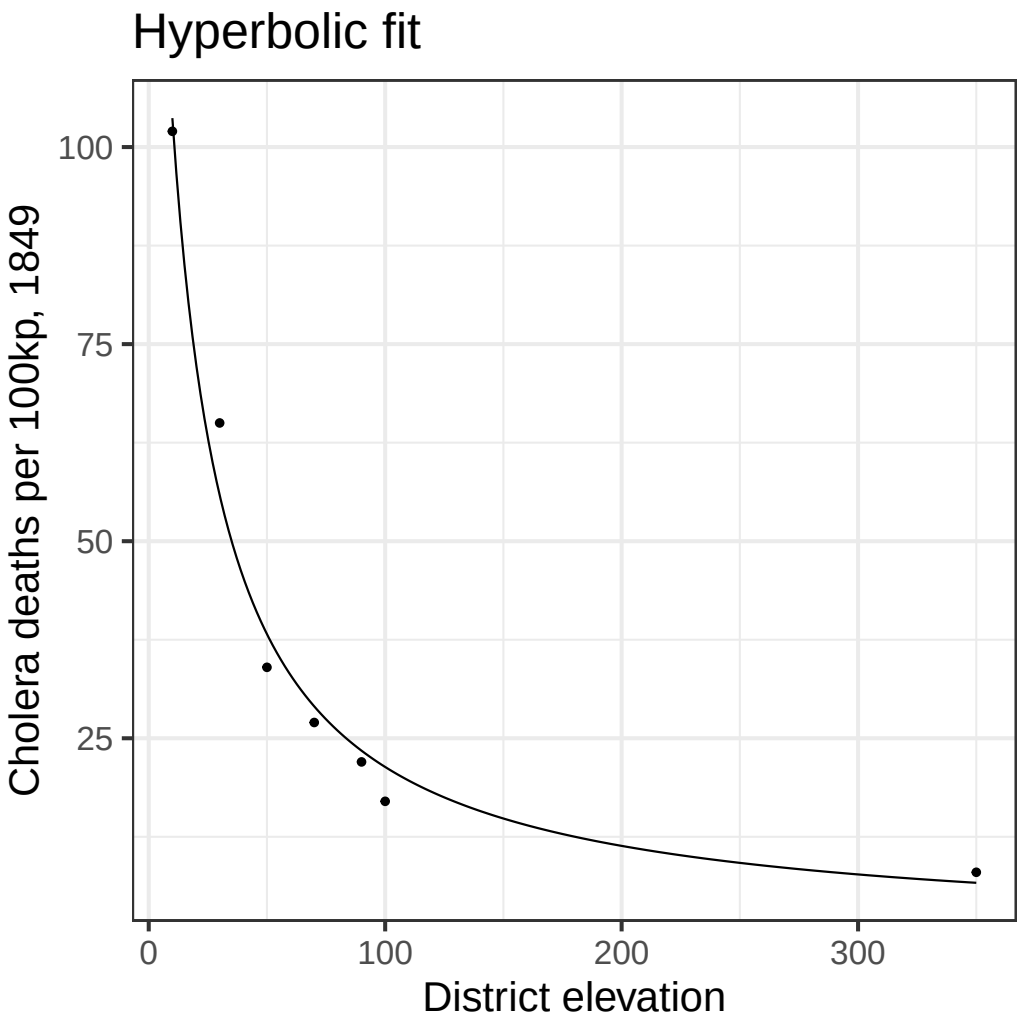
Cholera

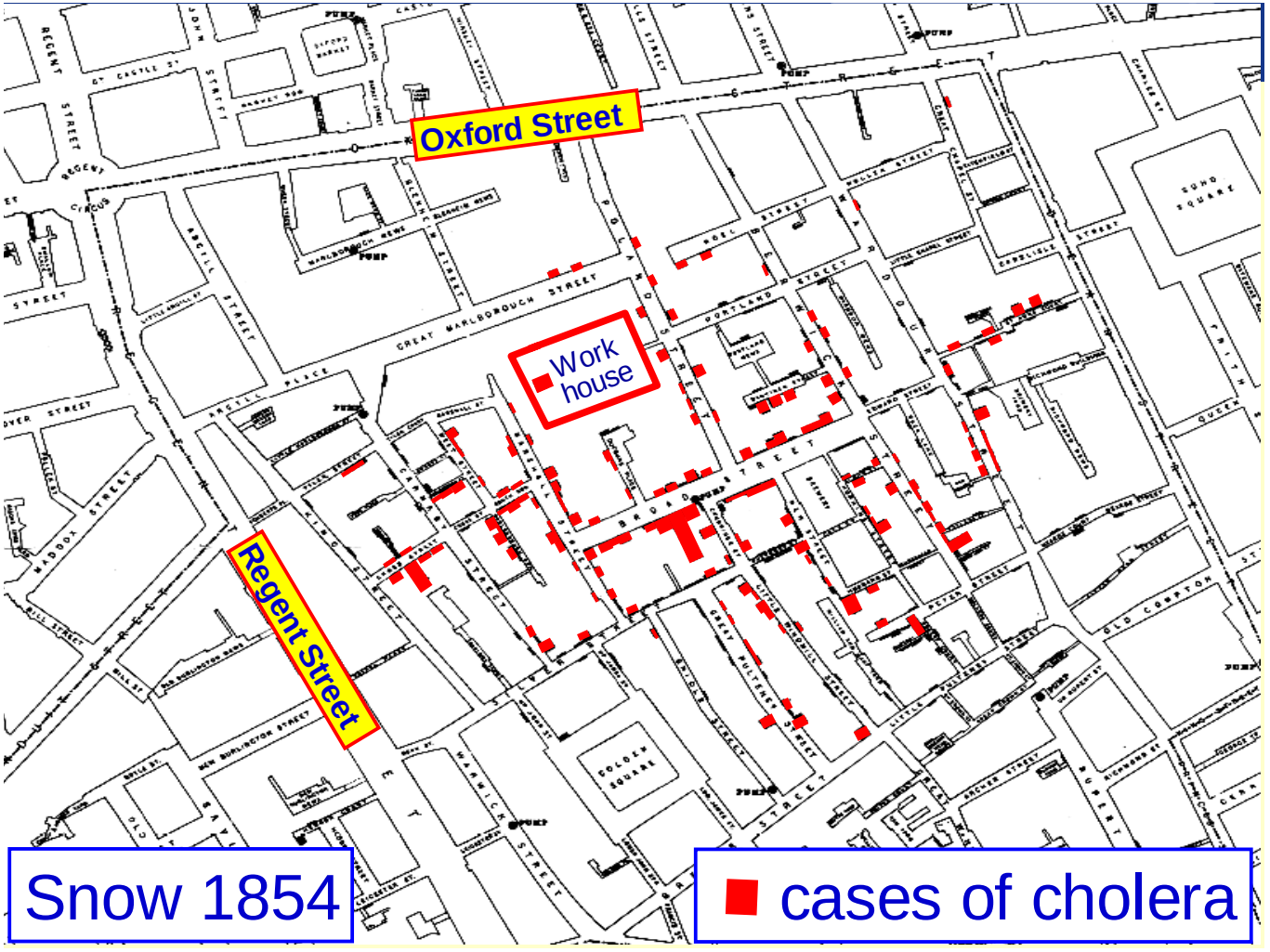
- Is it caused by bad air, or bad water?
- What's bad about it?

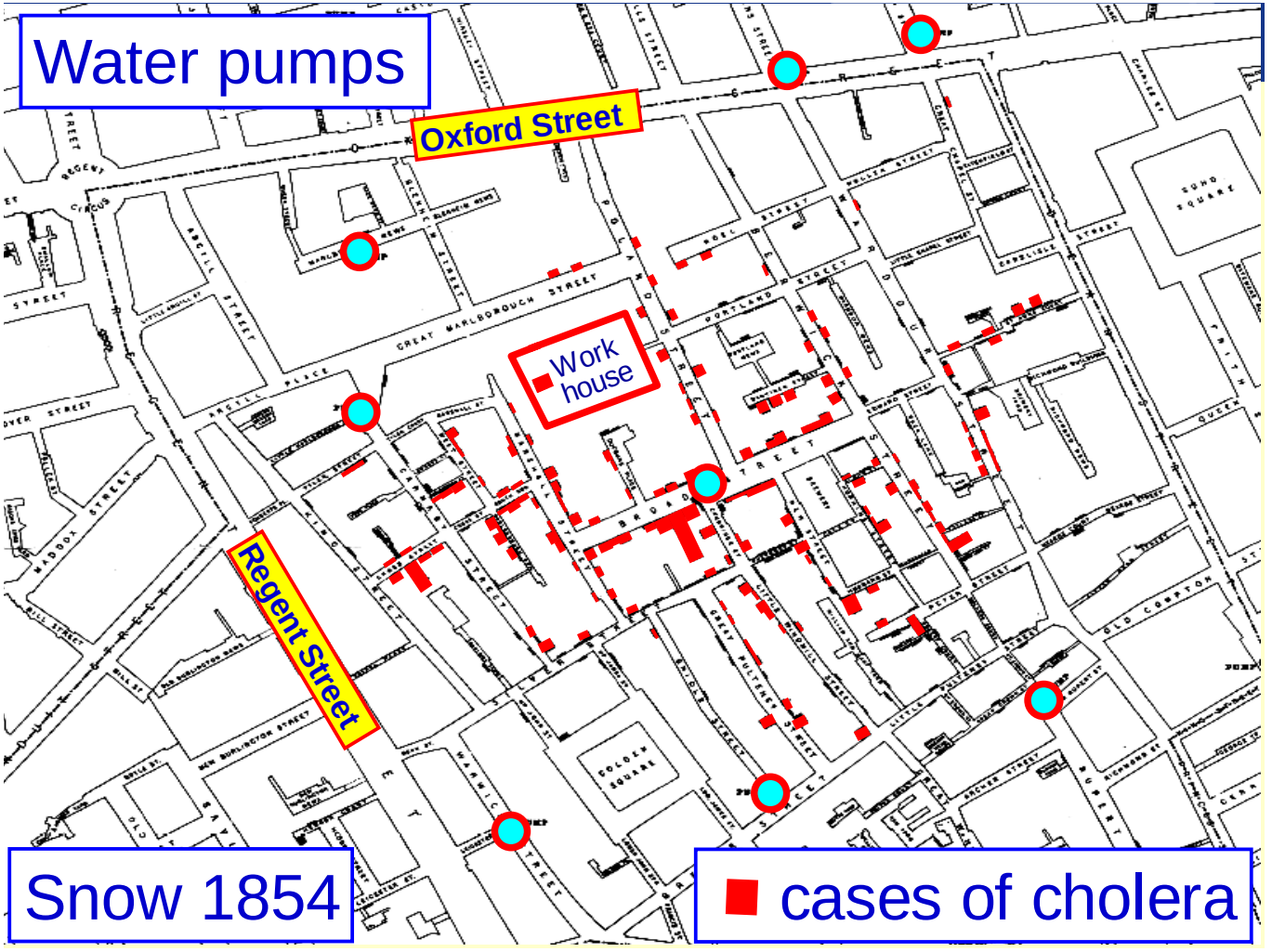
Cholera and air (present)



Cholera and air




Oxford Street
Work house
Regent Street
Snow 1854
cases of cholera


Water pumps
Oxford Street
Work house
Regent Street
Snow 1854
cases of cholera

Outline

Yellow fever and malaria

- Ross determined the cause of malaria primarily by experiments on mosquitoes
- Reed determined the cause of yellow fever primarily by experiments on human volunteers

Outline

Data, models and science

- We're never finished, we compare models to data over and over again
- Data is what we use to develop and understand models
- Models are what we use to interpret data
  - and they can suggest what data we need to collect
- Complicated or hard-to-test theories may require *dynamical* models

Classical epidemiology

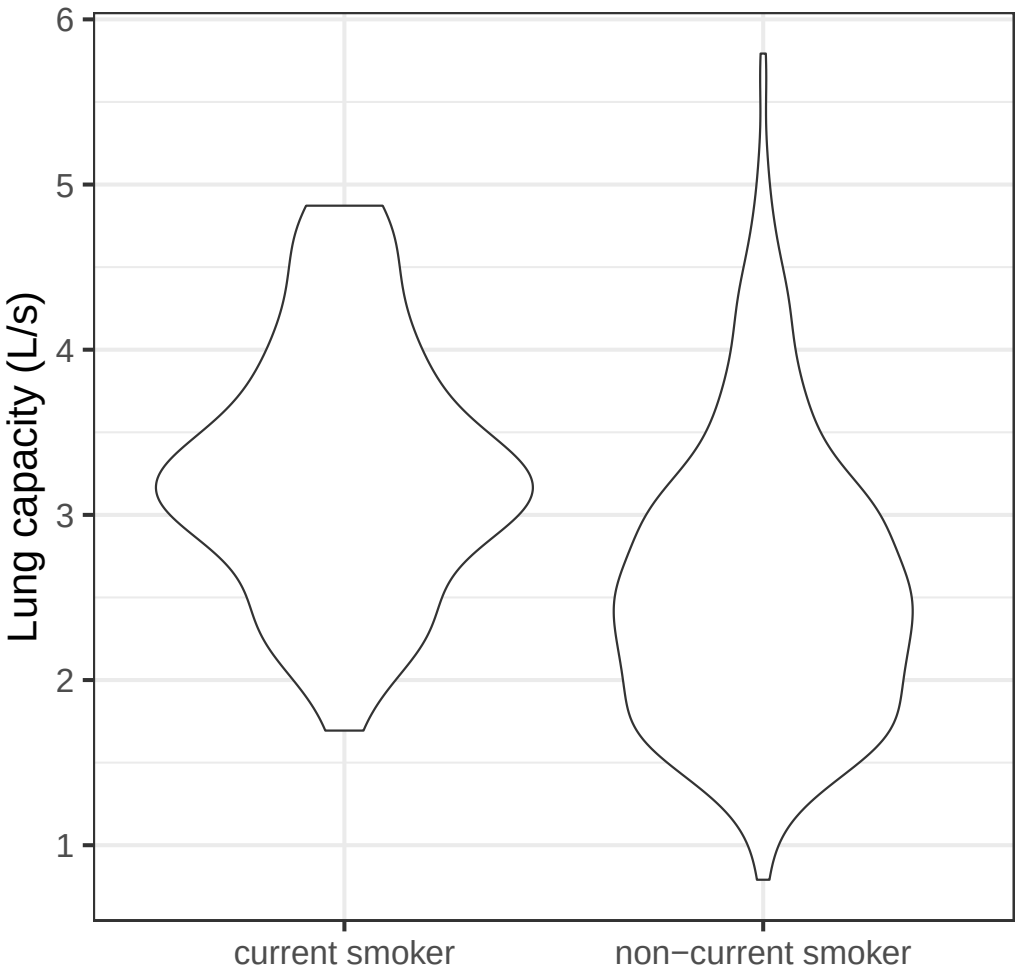
- Avoid mechanism
- Control for non-independence of "units"

Dynamical epidemiology

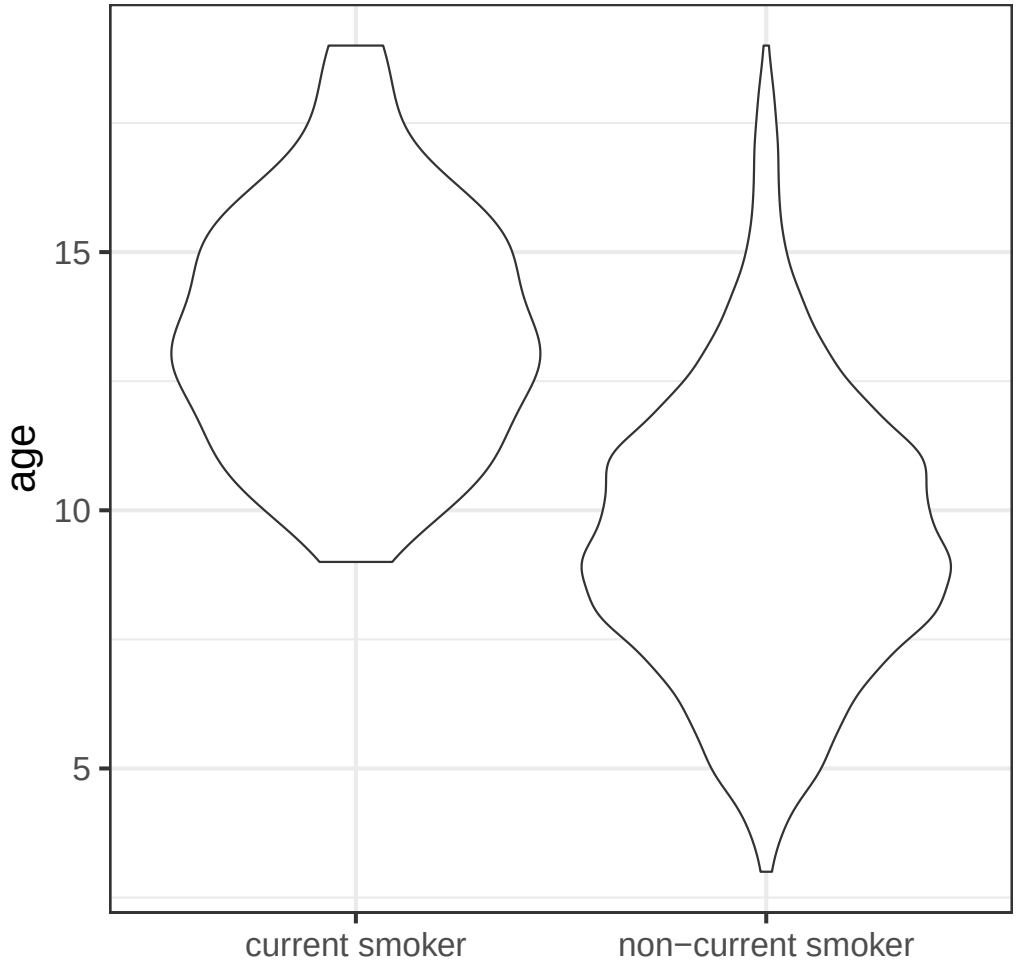
- Embrace mechanism
- Explicitly incorporate dependence between units
  - X is infected because Y infected them

Outline

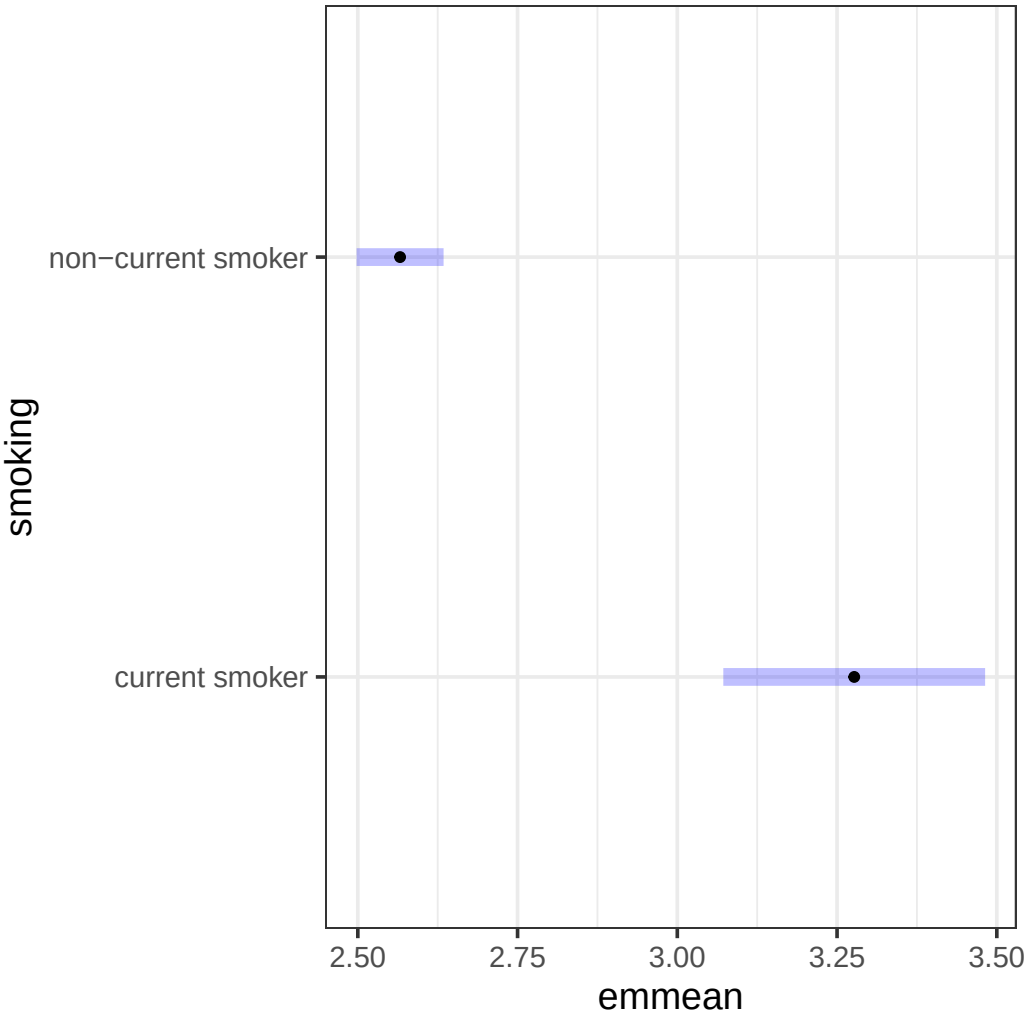
Classical example



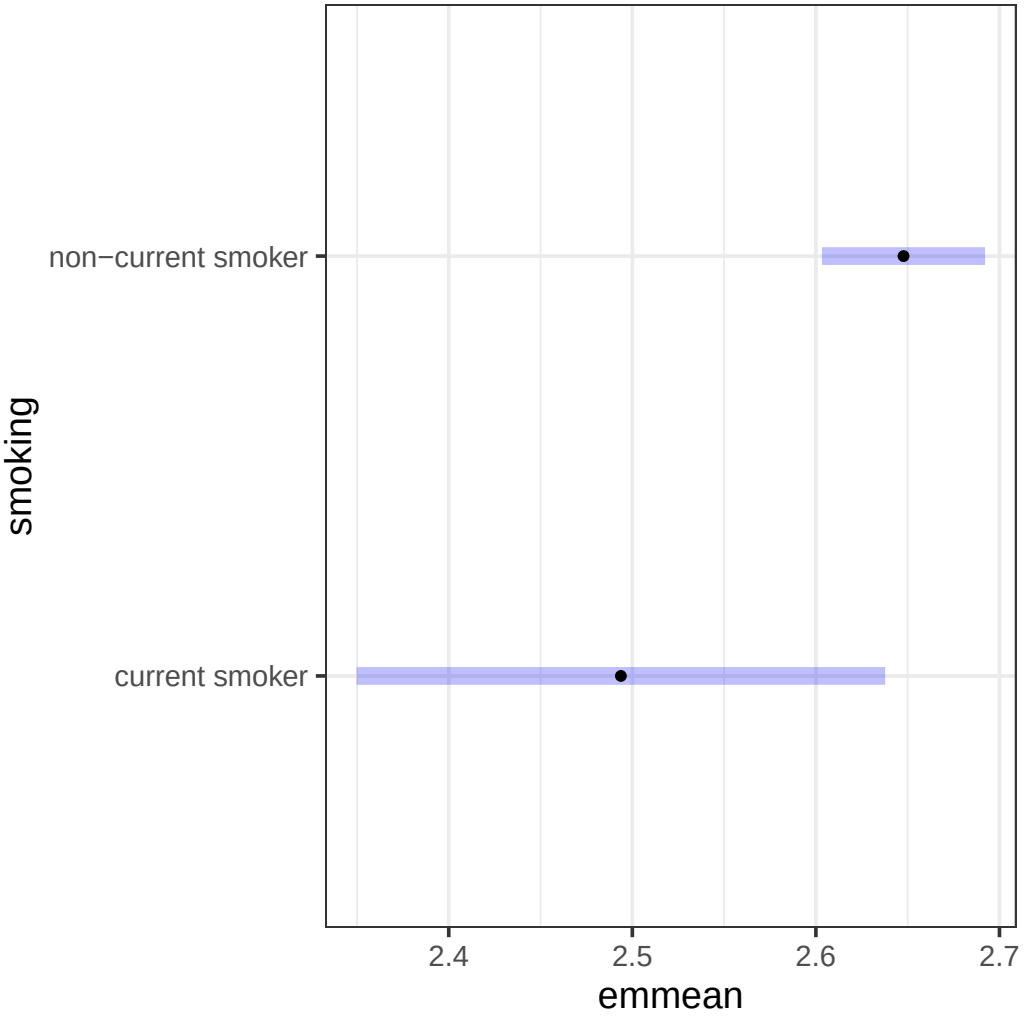
Classical example



Univariate means



Multivariate means



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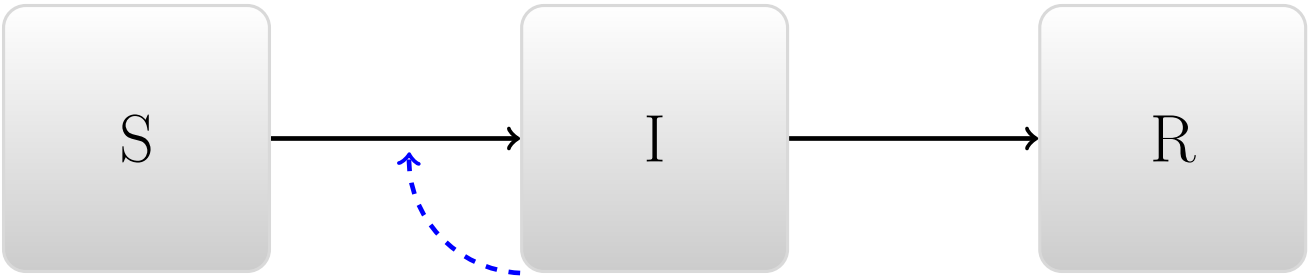
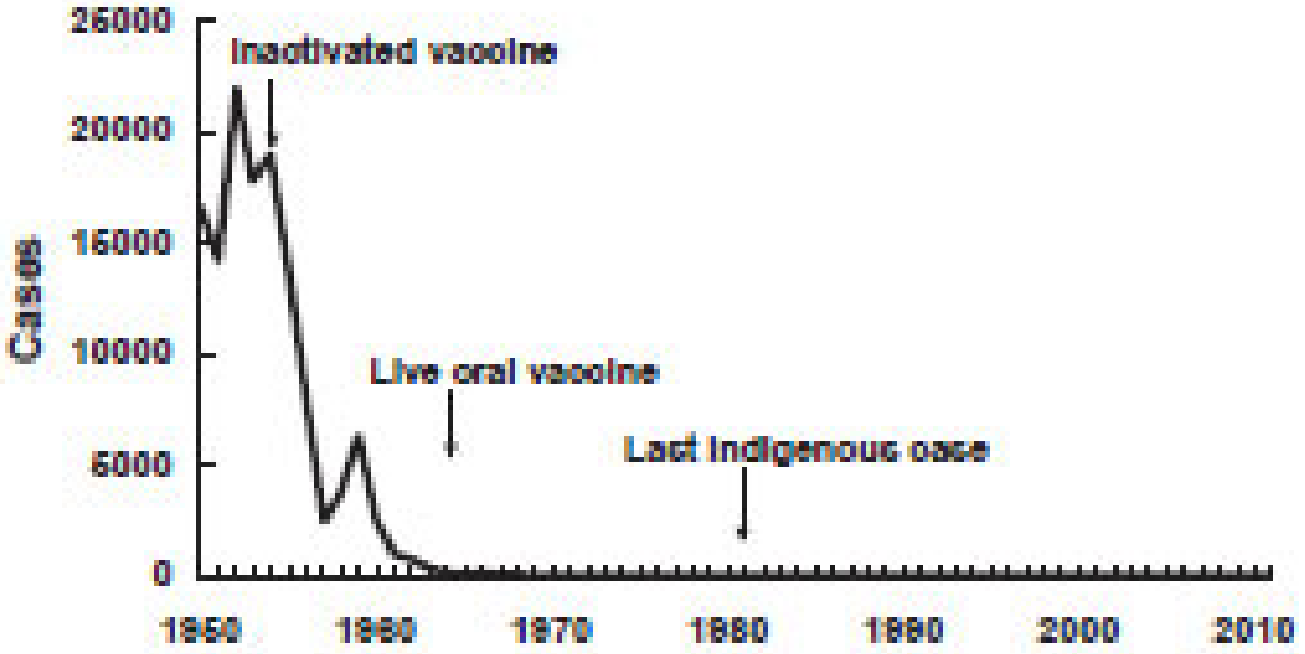
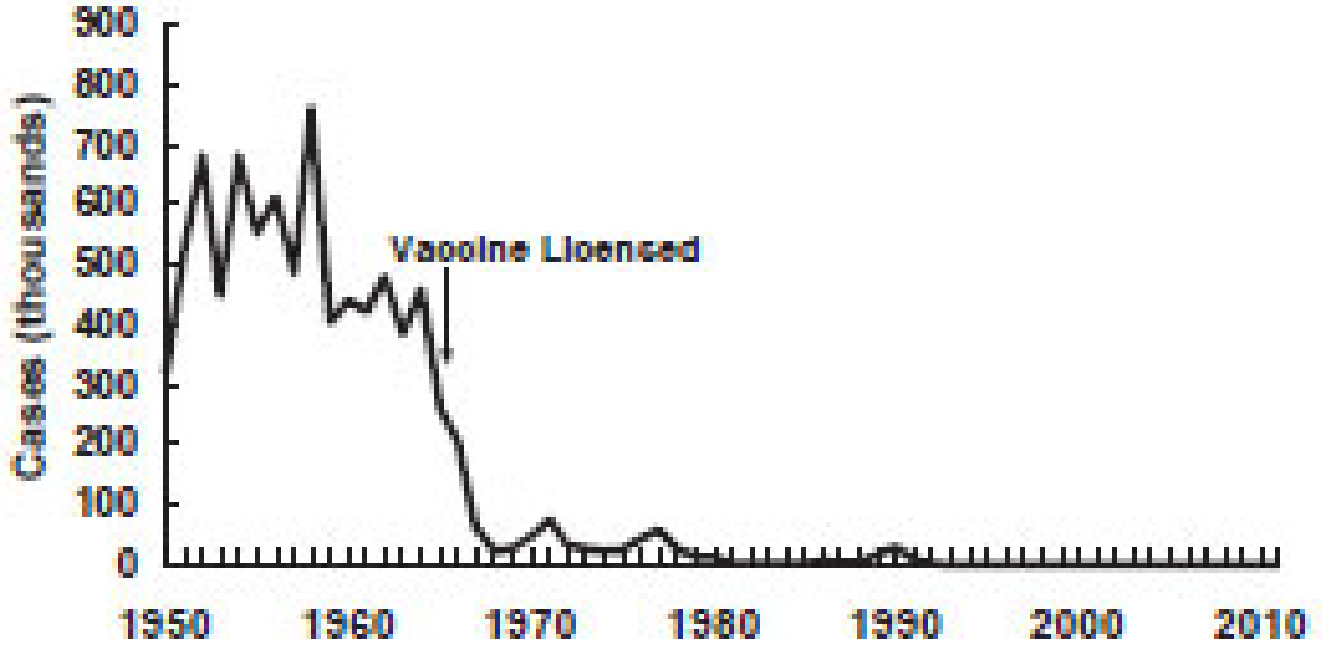
Dynamical epidemiology



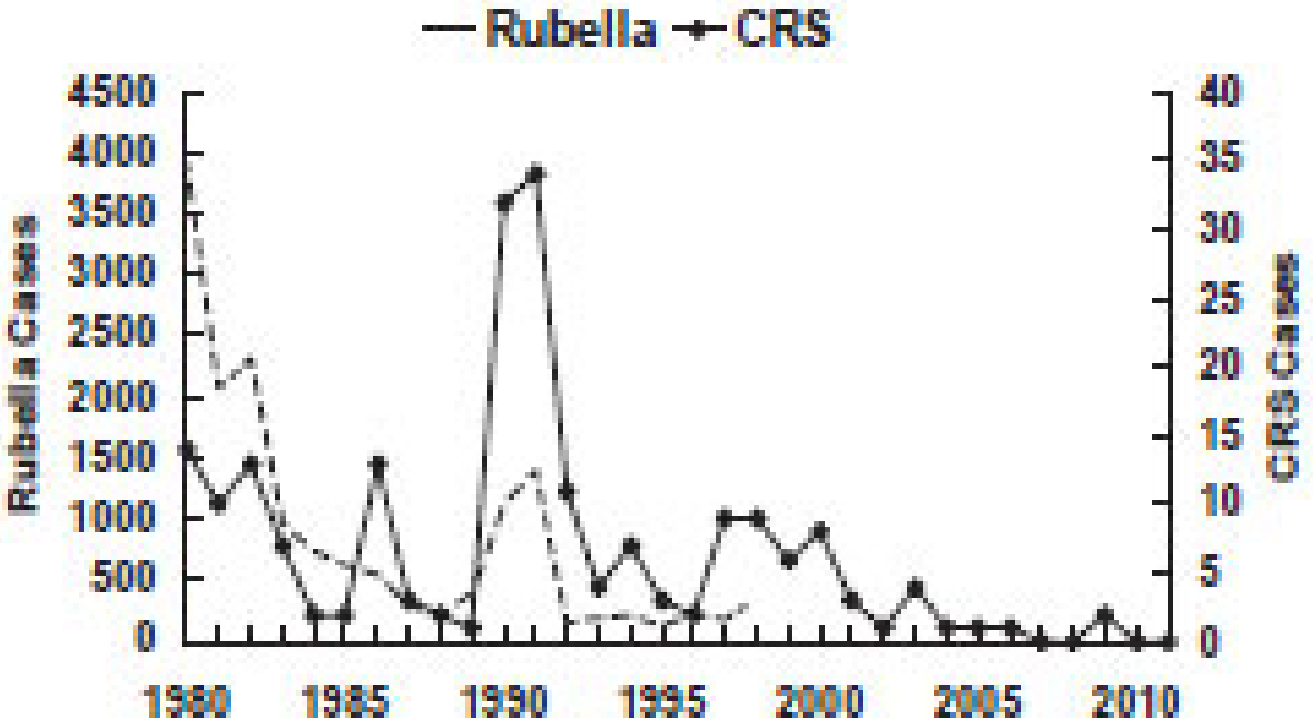
Polio (present)



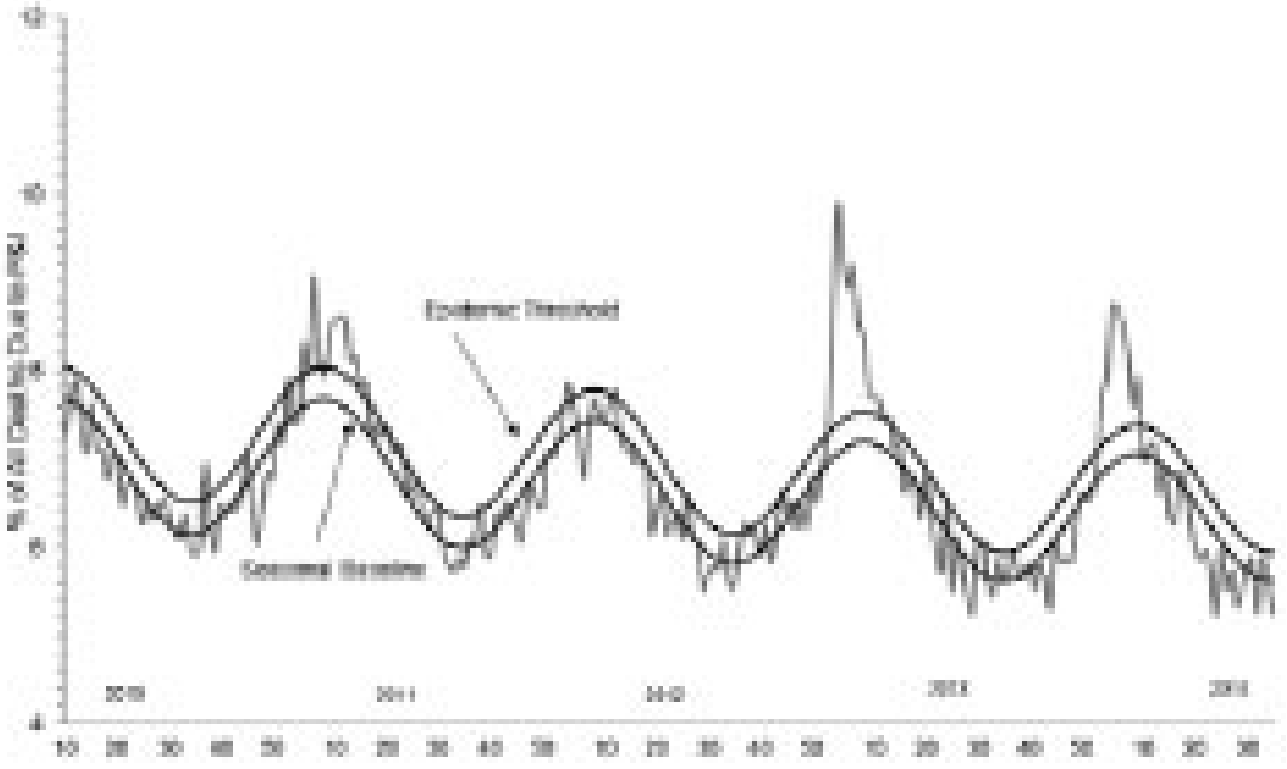
Measles (present)



Rubella (present)



Influenza (present)



Bridging

- Classical epidemiology relies on statistics, avoids mechanism
- Mathematical epidemiology (the traditional approach to dynamical epidemiology) explores mechanism, avoids statistics
- Much modern dynamical epidemiology seeks ways to put dynamical mechanisms into a statistical framework
  - This is hard

Outline

Summary

- Science is an ongoing process
- Models are the way that we bridge between theory and reality
- Dynamical models have a key role
  - When we can't do experiments
  - When mechanisms are complex
- We should work to combine dynamics with statistical approaches

Title: Data, models and science
Attribution: Jonathan Dushoff, McMaster University, DAIDD 2020