

# What even is ‘science?’

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# Today:

- ▶ What is ‘science’;
- ▶ Theory, hypothesis, implication, test;
- ▶ The underlying logic of science.

## What science is NOT...

- ▶ Just a collection of facts;
- ▶ A mechanistic process;
- ▶ A single technical method (e.g. hypothesis testing);
- ▶ A topic (e.g. physics);
- ▶ Technology or engineering;
- ▶ A framework for making moral, aesthetic, or normative judgements;
- ▶ Truth.

Ok, then so what is science? Lots of views...

- ▶ **Rationalism:** theory generated deductively via reason ⇒ knowledge;
  
- ▶ **Empiricism:** observation ⇒ knowledge ⇒ general theory;
  
- ▶ **Critical rationalism:** theory ⇒ **falsifiable** hypotheses and tests ⇒ knowledge.



Ok, then so what is science? My perspective:

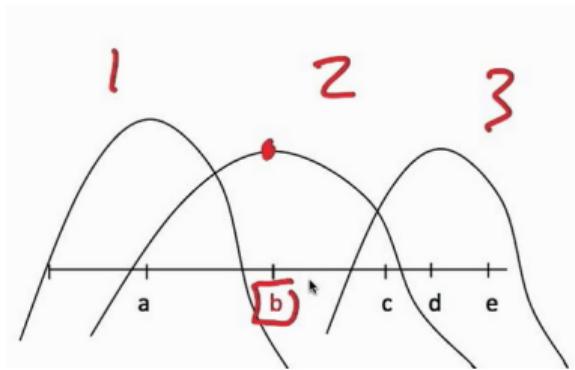
**Science = the iterative interplay between theory and empirical observation with the goal to produce an ever-better approximation of the world.**

# Expanding this...

- ▶ **Theory;**
  - ▶ Characteristics:
    - ▶ Explains;
    - ▶ Characterizes empirical phenomena as generated by underlying processes governed by theoretical first principles; predicts new empirical regularities;
    - ▶ Contains 'bridge principles' that connect unobservable processes to observables;
  - ▶ Example: The Theory of Relativity, Spatial Voting;
- ▶ **Empirical Observation;**
  - ▶ Characteristics:
    - ▶ Information accessible to observation, e.g. sense experience or measurement procedure;
    - ▶ Adjudicates between competing potential theories;
  - ▶ Example: Data on legislative roll calls in the US congress;
- ▶ **Law;**
  - ▶ Characteristics:
    - ▶ Describes;
    - ▶ Asserts a uniform connection between empirical phenomena without explanation;
  - ▶ Example: Democratic peace, Duverger's Law;

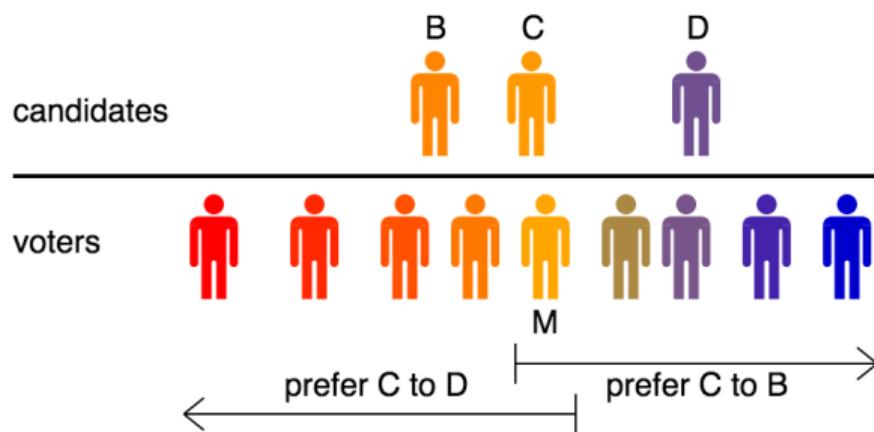
## Example of a Theory: Spatial Voting

- ▶ A spectrum of policy outcomes (e.g. a line with each point a policy);
- ▶ A group of actors, each with an ‘ideal’ policy (single peaked);
- ▶ For each actor, utility that describes their ‘happiness’ as we move away from their ideal policy;



## Example of a Theory: Spatial Voting

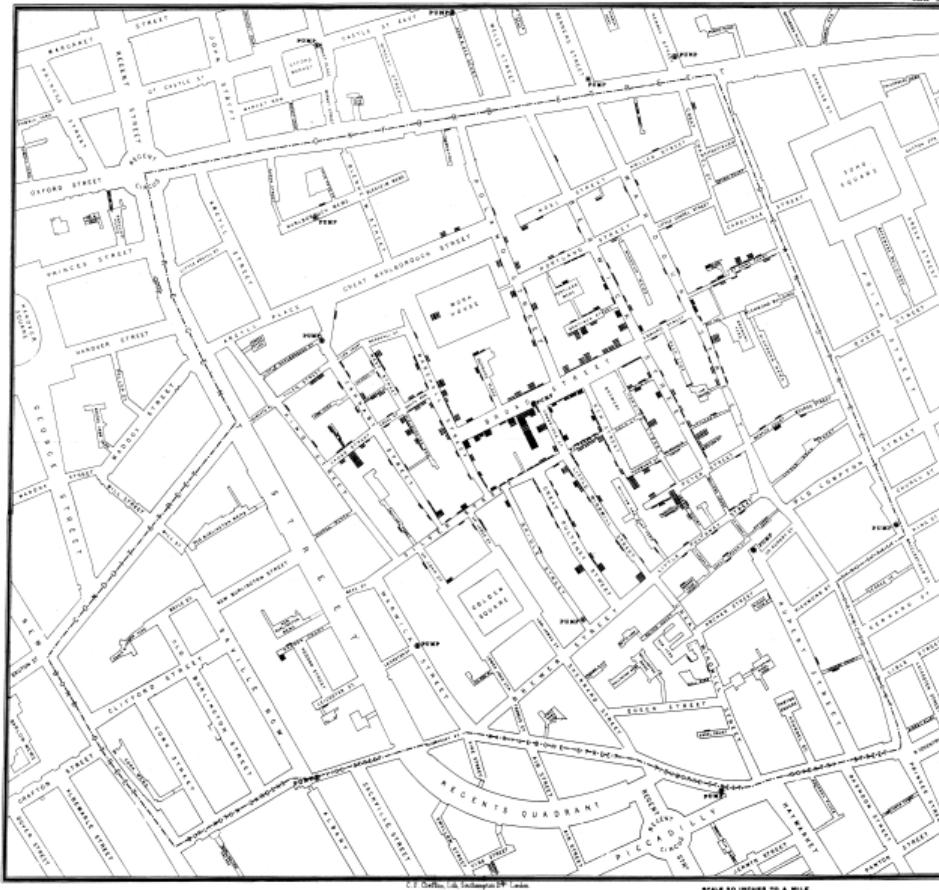
- ▶ Can we offer predictions about what policy a group of rational actors will choose?
- ▶ Median Voter Theorem: if preferences are single peaked and voting is by majority rule then there is a median voter and the winning alternative will be that preferred by the median voter.



# The Logic of Science

- ▶ If theory  $T$  is true then hypotheses  $H_1, H_2, \dots$  are true (implication);
- ▶ If hypothesis  $H_1$  is true then test implications  $I_1, I_2, \dots$  are true (implication);
- ▶ Example: 1854 London Cholera Outbreak;
  - ▶ Severe cholera epidemic broke out in 1854 in London's Soho district – 616 deaths;
  - ▶ Germ theory of disease: illness is caused by an unknown waterborne cell;
  - ▶ **IF germ theory is true THEN use of impure water spreads cholera;**
  - ▶ **IF use of impure water spreads cholera THEN removing access will reduce cholera sickness/death rates;**

MAP 2.



# The Logic of Science

## ► **Test 1 – The Broad Street Pump:**

*On proceeding to the spot, I found that nearly all the deaths had taken place within a short distance of the [Broad Street] pump...I had an interview with the Board of Guardians of St. James's parish, on the evening of Thursday, the 7th September, and represented the above circumstances to them. In consequence of what I said, the handle of the pump was removed on the following day.*

## ► **Test 2 – Who provides the water?**

- ▶ Southwark and Vauxhall, and Lambeth Waterworks drew from Thames – poorly filtered/yucky!
- ▶ New River and Chelsea Companies drew from Thames – much better filtration;
- ▶ Significant variation in water supplier = natural experiment with 300k subjects;

## ► **Results:** cholera generally ceased a few days after switching to cleaner water sources.

## So what can we learn?

- ▶ Removing access reduced cholera/death rates – what does this mean? More generally, what if are **test implications** are true? And what does 'true' mean?
- ▶ Propositional logic – the fallacy of ***affirming the consequent***:
  - ▶ If  $P$  is true then  $Q$  is true;
  - ▶  $Q$  is true;
  - ▶ Therefore  $P$  is true.

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- ▶ Propositional logic – the fallacy of ***affirming the consequent***:
  - ▶ If I fall off a cliff then I will be dead;
  - ▶ I am dead;
  - ▶ Therefore I fell off a cliff.
  - ▶ **THIS IS WRONG!**

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- ▶ Propositional logic – the fallacy of ***affirming the consequent***:
  - ▶ If an animal is a great white shark then it is a carnivore;
  - ▶ This animal is a carnivore;
  - ▶ Therefore it is a great white shark.
  - ▶ **THIS IS WRONG!**

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- ▶ Propositional logic – the fallacy of ***affirming the consequent***:
  - ▶ If germ theory is true then removing access to impure water will reduce cholera sickness/death rates;
  - ▶ Removing access to impure water DID reduce cholera sickness/death rates;
  - ▶ Therefore germ theory is true.
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- ▶ Propositional logic – ***modus tollens***:
  - ▶ If P then Q;
  - ▶ Not Q;
  - ▶ Therefore, not P.

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  - ▶ **THIS IS WRONG!**
- ▶ Propositional logic – ***modus tollens***:
  - ▶ If Watson is a miniature schnauzer then Watson is a dog;
  - ▶ Watson is not a dog;
  - ▶ Therefore, Watson is not a miniature schnauzer.

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  - ▶ **THIS IS WRONG!**
- ▶ Propositional logic – ***modus tollens***:
  - ▶ IF theory  $T$  is true THEN hypothesis  $H_1$  is true;
  - ▶ IF hypothesis  $H_1$  is true THEN test implication  $I_1$  is true;
  - ▶ Test implication  $I_1$  is not true;
  - ▶ Therefore hypothesis  $H_1$  is not true;
  - ▶ Therefore Theory  $T$  is not true.

# Doctrine of Falsification

- ▶ So what do we have?
  1. Scientific theory is linked to the observable world by logical implication...
  2. Affirming the consequent is a logical fallacy...
  3. and *modus tollens* allows us to show theories are false...
- ▶ We can never show theories to be true via empirical tests – we can only show that either:
  1. they are not inconsistent with the observable world or...
  2. ...they are false.
- ▶ This is known as the **Falsifiability criterion** – a cornerstone of science.

# Why should we care?

Everything else that follows is constrained by this logic – we need to understand the limitations of the models we build and the things we can derive from them to use them properly.