Lecture 17: Scientific Methods and Approaches

What is the scientific method?

The methods we usually think of as scientific are three: inductive, hypothetical-deductive and abductive method. But each of these methods has some strengths and some limitations and will be better fit for certain situations rather than others.

Bacon's inductive method

In 1620, Francis Bacon introduced a scientific method that is supposed to take us directly from data to theories. This has influenced contemporary scientific methods, especially those that emphasise large data sets (quantitative methods). The inductive method has 4 steps:

Observation: We start with a set of single observations, without any expectations about what to find.

Hypothesis: Use the data to form a general hypothesis of what is going on.

Test/experiment: Now that we have expectations of what to find (hypothesis), we set up the test and decide which tools to use.

Result: If the results confirm the hypothesis, the hypothesis is confirmed (verified). If not, it's rejected (falsified).

Example: Side effect of Thalidomide: This drug was introduced on the market in 1957. One of the therapeutic uses was against morning sickness in pregnancy.

Observation: in 1961, a gynaecologist published the cases of malformations she observed in babies born from women who had used Thalidomide in pregnancy (limb and ear impairment). *Hypothesis*: Thalidomide was the cause of foetal malformations. *Testing:* a survey was made with mothers of babies born with that or similar malformation. *Verification:* a correlation was found between the use of the drug and the malformation. The drug was withdrawn from the market.

Some problems with the inductive method

Biases: Bacon recognised a number of biases that we ought to avoid when collecting the data:

- To impose order and regularity where there is none;
- To defend our current position and believe arguments supporting it more than those against;
- To confuse others/ourselves with imprecise language;
- To dogmatically follow orthodoxy and truth by authority.

Underdetermination: A data set can be consistent with many different theories and hypotheses. Aristotle and Copernicus had the same data, but presented radically different theories.

Raw data: Bacon wants data to be collected without biases. But Norwood Russell Hanson argues that all observations must be made with some expectations, including theoretical ones. When observing, we consider things relevant or irrelevant. Furthermore, Sabina Leonelli emphasises that data will be gathered for a certain purpose, with methods suitable for that particular purpose. We cannot then use the data for any given purpose. That would be to assume that data will remain unaffected by the methods by which they were generated.

Induction: Any universal theory will be an inductive inference, assuming that what holds in the observed instances also holds for unobserved ones. E.g. that all swans are white; all humans are mortal; all iron bars that are heated expand.

The hypothetical-deductive method

While the inductive method starts from observations and then lead to hypothesis and testing, Karl Popper's hypothetical-deductive method starts from a problem and a hypothesis of what the source of the problem is. This method has 5 steps:

Problem: What we wish to find out.

Hypothesis: Our idea of what could be going on.

Test implication (observable outcome): A way to check empirically whether the hypothesis is true.

Test/Experiment: Performing the test.

Result: the hypothesis is rejected (falsification) or supported (but never verified).

Example: The first vaccination (Edward Jenner 1797): *Problem*: Smallpox was a sickness that for many centuries devastated mankind. It was known that if a person survived sickness he was immune for the rest of his life. *Hypothesis*: There is a bodily mechanism that allows us to "remember", recognize and destroy the parasite after the first infection. *Test implication*: It is possible to immunize the body by introducing a parasite that is similar to smallpox, but not as dangerous. *Experiment*: Jenner took the infected liquid from cowpox lesions (the same illness that killed the cows but did not affect humans) and injected it into a boy. The boy was slightly sick for a couple of day. After 2 months, the boy was vaccinated with smallpox. No disease developed. *Conclusion*: the hypothesis was supported: a milder version of the virus could immunise the human body against smallpox, suggesting that there is a mechanism by which the body remembers and destroys a parasite after the first "meeting".

Abductive method

A problem with both the previous methods is that they can only test one hypothesis at the time and often the results, if negative, don't generate new hypotheses. What we need, then, is a way to make sure we have the best hypothesis to test. Abduction is one such method, the term coined by Charles Sanders Peirce.

This method is called "inference to the best explanation". It consists in looking at the available information and decide which conclusion that *best explains* it.

In medicine, one might have a symptom that fits different diagnoses. A headache can be a sign of dehydration, stress, hormonal imbalance, a tumour in the brain, or many other things. The doctor must consider which is most likely or serious, and test for it. In a criminal case, the available evidence can fit different explanations. Still, we might miss relevant information and draw the wrong conclusion.

Example: The discovery of penicillin: Returning from holiday in 1928, Fleming began to sort through petri dishes containing colonies of Staphylococcus, bacteria that cause boils, sore throats and abscesses. Observation: He noticed something unusual on one dish. It was dotted with colonies, except for one area where a blob of mould was growing. The zone immediately around the mould was clear. Fleming thought that the *best explanation* for this was that the mould had secreted something that inhibited bacterial growth. *Test*: He did a series of experiments that led to the isolation of penicillin from the mould. Penicillin was the first antibiotic.

Discussion questions

What are the main differences between Bacon's inductive method, the hypothetical-deductive method and abduction?

Which method do you think is best? Why?

Do you think that different types of sciences would prefer different types of methods? If so, what could help us choose the best method for our research?

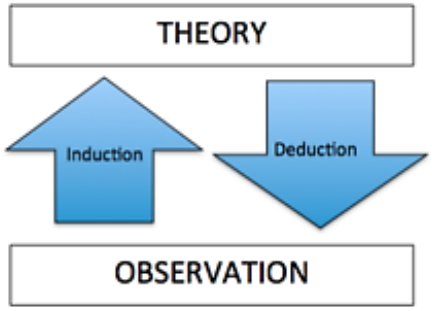
What are, according to Bacon, the 4 biases that we need to be aware of and avoid when we perform research?

Problems for the inductive method were underdetermination, raw data and induction. What are these?

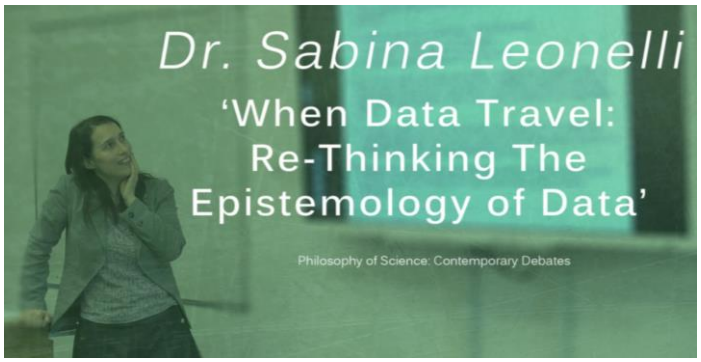
Do these problems apply only to Bacon's method, or do they also apply to other methods? Or do they apply more to Bacon's method than the others? Discuss.

The UN sustainability goals: do they follow the inductive ideal, the hypothetical-deductive, or the abductive, do you think?

Induction vs. deduction:

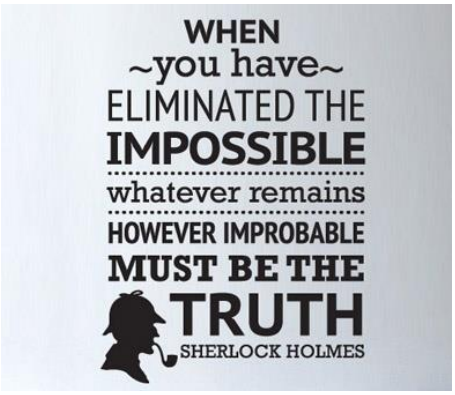


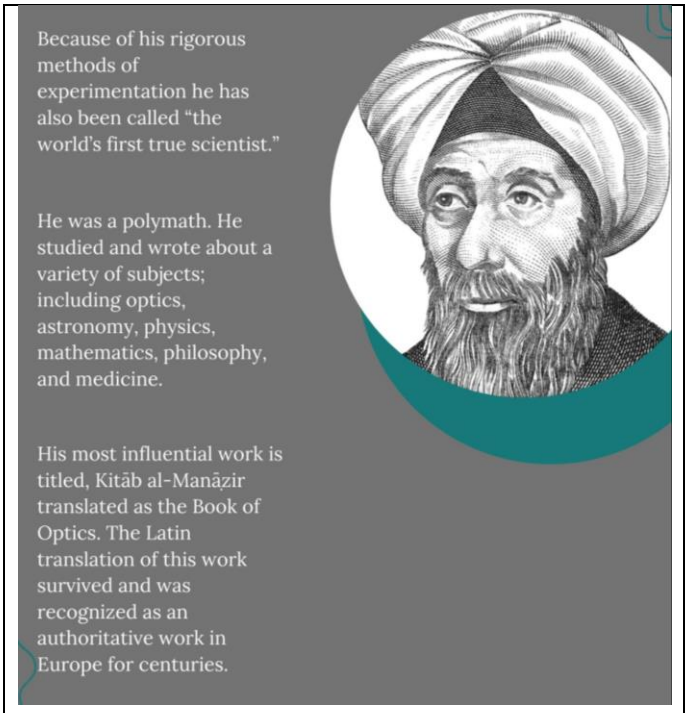
Abductive reasoning in practice:



Sabina Leonelli engages scientists in debates on whether data can be re-used for different purposes than what they were collected for. You can follow her on Twitter: [@sabinaleonelli](https://twitter.com/sabinaleonelli).

A Sherlock principle of abduction:





Ibn al-Haytham

(born in Iraq 965- died in Egypt 1040)

Pioneering Arab scientist, father of the experimental method and modern optics

- developed his own scientific methodology: experimentation as a mode of testing and proving a hypothesis or premise

- celebrated at UNESCO as a pioneer of modern optics

- wrote 25 works on mathematical sciences, and 44 works on Aristotelian physics & metaphysics, plus meteorology & psychology

- his discoveries predate many European discoveries of the same type by 600 years

- his experiments and discoveries laid the foundation for the development lens technology, and led to the development of microscopes, telescopes, and eyeglasses.

https://en.unesco.org/courier/news-views-online/ibn-al-haytham-s-scientific-method

https://historyofyesterday.com/alhazen-the-father-of-modern-optics-d81439ced26a