Scientific Reasoning
Lecture-Seminar 1
‘Observation and Theory’

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Course Introduction
Aim: To cultivate a general understanding of science and, in particular, scientific reasoning.

Focus: Some key methodological ideas and tools in science.

A great deal of the material in this course is typically found in a philosophy of science course.

As always, please consult the corresponding Moodle page where you will find the syllabus and various readings.
week 01: observation and theory
week 02: induction and falsification
week 03: explanation and confirmation
week 04: thought experiments
week 05: the social science and humanities context
week 06: methods in psychology
week 07: READING WEEK
week 08: evidential standards in medicine
week 09: data science (part I)
week 10: data science (part II)
week 11: REVISION
week 12: EXAM
The aim of this lecture is threefold:

* What is a theory?

* What is an observation?

* How are the two related?
Theories
What is a theory?

- Arguably, the main aims of science are to describe, predict and explain the world. To do that, scientists utilise theories.

- As a first approximation, a theory can be thought of as a set of general claims about some domain of ‘phenomena’.

**Examples:**
* Maxwell’s theory of electromagnetism
* Lavoisier’s caloric theory of heat
* Darwin’s theory of evolution
* Neoclassical theory of economics
* Freud’s theory of the subconscious
* Marx’s theory of historical materialism
* Velikovsky’s theory of worlds in collision
* ...
Theories vs. hypotheses

• In scientific discussions they are often treated as distinct concepts. Hypotheses are thought of as (more) tentative.

• Should we call non-scientific, e.g. common-sense or religious, general claims about some domain of ‘phenomena’ theories?

• Following the above rationale, so long as they are not (so) tentative, they deserve to be classified as theories.

• We here take a more liberal approach and, unless otherwise noted, use the two concepts interchangeably.

• The question then becomes whether they’re good or bad at representing, predicting and explaining their phenomena.
What’s in a theory?

• A theory may be said to consist of or at least to be associated with one or more of the following:

  laws, principles, (statistical) regularities, models, axioms, invariances, symmetries, etc.

• Examples:

  * Law of diminishing returns (Production theory).


  * The Hardy–Weinberg principle (Population genetics).
What accompanies a theory?

• A theory is useless unless it’s also accompanied by some conditions of application:

  * initial, boundary or idealising conditions

• For convenience, and unless otherwise stated, we shall stick to the umbrella term ‘auxiliary assumptions’ to cover all of these.

• Examples of auxiliary assumptions:

  * the density of the universe at the Big Bang is $\rho_c$
  * the motion of membrane-embedded molecules is 2D.
  * market $m$ is in a state of perfect competition.
• In the natural sciences at least, the more mature a theory is the more likely it will be mathematically formulated.

Galileo: “... this grand book [of the universe]... is written in the language of mathematics” (quoted in Drake 1990, pp. 237-8).

• Why is mathematics so important?

Because it allows us to formulate more precise (and thus more easily refutable) claims.

• *Compare:*  
  Electrons have mass.  
  Electrons have a mass of $9.10938291(40) \times 10^{-31}$ kg.
Can you think of some other examples of theories?
Observations
Observing (broadly construed)

• Observation, as it is understood in this context, is not restricted to seeing, but refers also to the other forms of sensing.

• Moreover, our senses have been ‘extended’ by various instruments. These act to amplify certain signals.

Examples:
* a cell’s structure through an electron microscope.

* cognitive process complexity via response times.

* solar neutrinos through particle detectors.
Direct vs. indirect observation

- **Direct**: When our observations track the object we are targeting.

  *Example*: Observations of the Sikhote Alin meteorite.

- **Indirect**: When we observe something else that allows us to infer the existence and properties of the target object.

  *Example*: Meteorite inferences via observations of the Barringer crater.
The significance of observations

- Observation can help the construction/alteration of theories.

**Example**: Tycho Brahe’s meticulous observations helped Kepler postulate his three laws of planetary motion.

- Perhaps more importantly, observation seems to be the ultimate arbiter of disagreement between theories.

**Example**: The unexpected Poisson spot and other observations favoured Fresnel’s wave theory of light over the corpuscular theory.
Theories go beyond observations

• Theories have much more content than actual observations. After all, to generalise is to go beyond particular observations.

Compare (Case 1):
* When dropped, *this* object will move towards the ground with constant acceleration.
* When dropped, *all* objects will move towards the ground with constant acceleration.

Compare (Case 2):
* John and Jill are economists and have clear and ordered preferences when investing.
* All economists have clear and ordered preferences when investing.
Theories go beyond the observable

- Theories do not only generalise but sometimes go beyond what is directly observable and even beyond what is observable.

  * Positing entities that are only *indirectly observable*.

  **Example:**
  Higgs bosons produced in a particle accelerator.

  * Positing entities that are *not observable at all*.

  **Example:**
  Branching worlds (whose existence is presumably effected by the measurement of microscopic states).
Give an example of a thing that is only indirectly observed.
Theory-Ladenness of Observation
Theory-ladenness of observations

• Keeping in mind that theories go beyond actual observations, we should be cautious about this extra content.

• Indeed, there are reasons to be cautious about observations themselves. That’s because of the risk of theory-ladenness.

• Though the rough idea is arguably quite old, the modern conception owes much to N. R. Hanson (1958), among others.

Central Idea: ‘Theoretical’ factors influence and potentially distort perceptions, perceptual beliefs and observation reports.

• Why the inverted commas? Because many of these factors are not strictly speaking theoretical in character.
The multi-faceted nature of theory-ladenness

• That at least some **differences** in:
  
  • sensory physiology
  • linguistic choices
  • conceptual schemes
  • prior beliefs
  • theories
  • and/or environmental cues

**affect and potentially distort** what we perceive, believe and report.
• **Problem**: If individuals sponsoring rival hypotheses perceive and/or report the world in a genuinely rival manner, then those perceptions/reports cannot be neutral adjudicators between the said hypotheses.
No neutral adjudication?

- Implicit in this claim is that distinct theories distort the content of observation reports in distinct ways.
- On this view, the reports of observers with distinct theories cannot form a neutral adjudication basis.
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\[O_1 \rightarrow T_1 \rightarrow \cdots \rightarrow T_2 \rightarrow O_2\]
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Example: Free falling objects

- Gunstone & White (1981): College students asked to perceptually judge falling speed of 2 balls (iron, plastic).

- For all intents and purposes, the two balls reached the ground at the same time.

- A number of students whose initial hypothesis was that the heavier balls fall faster maintained that view.
In 1903, Prosper-René Blondot, a renowned French physicist, announced the discovery of N-rays.

Brewer & Lambert (2001: 180): “[s]oon over 300 papers by 100 different scientists were published on the properties of N-rays”.

But... within a few years, N-rays were rejected as unreal.
Fighting biased observations

• If the results cannot be reproduced (using the same or even different instruments) then the observations are suspicious.

• R.W. Wood visited Blondot’s lab only after the inability of other labs to reproduce those results.
What do you see?
The End