Demarcation of Science from other academic disciplines

- Demarcation of natural sciences from other academic disciplines
- Demarcation of science from technology, pure and applied science
- Demarcation of science from mathematics

Literature: Popper, Chalmers, Ziman, Kitcher
Definitions (OED)

- **Science** – systematic study through observation, experimentation, interpretation to the derivation of universal laws and theories
- **Natural Sciences** – the study of the nature of the material and physical universe (physics, chemistry, biology, geology, astronomy, etc.)
- **Social Sciences** – the study of society and the relationship of individual members within society (economics, history, political science, psychology, anthropology, sociology, etc.)
- **Technology** – the application of practical or mechanical sciences, usually to industry of commerce; the methods, theory and practice governing such applications

*(Vitenskap – science or branch of knowledge)*
Background - demarcation

- Aristotle and Plato – no distinction between science and philosophy
- Greeks to the Age of Enlightenment – mysticism, religion, ideology
- Bacon and Descartes – scientific methodology, logic, mathematics
- Russell and Wittgenstein – demarcation between metaphysics and science; and between science and mathematics
- Popper – demarcation between natural and social sciences

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Science and Mathematics

- Similarities: search for truth and proof
- Science relies on mathematics
- Differences:
  - Mathematics relies on logic rather than experiment and observation
  - Mathematics uses more sophisticated forms of proof: eg. Asserting a proposition by proving that its negation implies a contradiction

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Philosophy of Mathematics

- Origins of mathematics in China, India, Arabia, Middle East, Greece
- Philosophical questions concerned with the nature of mathematical truth. Are numbers mental constructs, facets of an idealised reality, rules
- Mathematics: Analytical statements: true by virtue of the meanings of words
- Science: Synthetic statements: true by virtue of the way things are

Al-Kwarizimi (ca 830) : Source of words algebra and word alogorithm
Milestones in the Philosophy of Mathematics

- Russell and Whitehead’s *Principia Mathematica*, 1910
- Gödels Incompleteness Theorum proved that there will always be unanswerable questions in mathematics. No logic system is capable of providing the firm foundations that Russel had hoped for.

Russell’s Paradox: Imagine there is a town with one barber, and where the law states that everyone who doesn’t shave himself is shaved by the barber. Who shaves the barber? (1901)
Milestones in the Philosophy of Mathematics

- Chaos Theory: Lorenz (1960) observations of effect of small variations in weather models: Non-linear systems

J. Gleick. Chaos (1987); Fermat’s Last Theorum, A. Doxiadis and C.H Papadatos: Logicomix; Uncle Petros
Science and Technology

Arguments for a difference

- Scientific thought has only one genesis (Greece-Europe)
- Technology developed all over the world
- The understanding of the world acquired through science is different than that obtained from technology

(Wolpert, 1992)
Counter-arguments

- Requires a theory of what science is
- The distinction between science and technology seems blurred in modern research
- The pragmatist/instrumentalist claims that science is only science when it is of practical use
Similarities between science and other academic studies

- Intellectual, reflectory
- Own technical language
- Informative “speaks to the mind”
- Explanatory power: once theories have been proposed it is possible to see confirming instances everywhere (inductively powerful)

Ziman
Aim: To compare and contrast the following contemporary Twentieth century theories

- Einstein’s theory of relativity
- Freud’s theory of psychoanalysis
- Alder’s theory of psychology
- Marx’s theory of economics

What made Einstein’s theory special?
Observation is guided by theory
Theories are intellectually constructed conjectures
Theories can be conclusively falsified in the light of suitable evidence, whereas they can never be established as true or even probably true whatever the evidence
Scientific hypothesis need to be falsifiable
Scientific knowledge grows, there is progress in science

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Falsifiability ?

Freud  Marx  Einstein

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Falsifiable Hypotheses

- Metals contract when heated
- Planets circle the sun in ellipses
- Large gravitational fields will bend light
- Diseases are transmitted by germs
Non-falsifiable hypothesis

- All ferric compounds contain iron
- You might meet a tall handsome man this evening
- Animals have evolved so as to best fulfil the function for what they were intended
- Human emotions are motivated by feelings of inferiority
Bold Conjectures and Experimental Hypothesis

- “Best” hypothesis: bold, falsifiable, testable
- “Best” experimental scientists: really try to test their hypothesis (not to verify them)

See also Nelson Goodman on simplicity, strength and safety of hypotheses
Hypothesis: “All vowel cards have an even number on their back”

Which two cards should one turn to test the theory?

Goldacre, 2006
Hypothesis: “Bats use radar and not sight to navigate”
Case study: Dancing bees

- Karl von Firsch
- Hypothesis: after finding a source of nectar, bees returning to the hive use a complex "dance" to communicate the location of the source to other bees

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The "waggle dance"
Wenner’s challenge

- No proof that the other bees understand the dance?
- Many other ways for the bees to find food – including odour-search. No proof of cause and effect.
- What kind of experiment would really test the hypothesis?
Problems with Falsification

- Scientists don’t reject their hypothesis
- All observation statements are fallible, including those purporting to reject a hypothesis

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Milikan’s Oil Drop Experiment (1916)
Auxiliary and *ad hoc* Hypothesis

- Scientists try to save their theories in the light of falsifying evidence.
- Hypotheses are usually built on a host of auxiliary hypotheses and subsidiary assumptions.

- Popper’s reply
  - Distinguish between interpretations of evidence that bring forth new, independently testable hypothesis and those resorting to *ad hoc* hypothesis.
THE SCIENTIFIC METHOD

Observe natural phenomena

Formulate Hypothesis

Modify Hypothesis

Test hypothesis via rigorous Experiment

Establish Theory based on repeated validation of results

THE ACTUAL METHOD

Make up Theory based on what Funding Agency Manager wants to be true

Design minimum experiments that will prove theory is true

Modify Theory to fit data

Publish Paper: rename Theory a “Hypothesis” and pretend you used the Scientific Method

Defend Theory despite all evidence to the contrary

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British Test Veterans – Darby et al., 1989

- Hypothesis: veterans exposed to radiation during weapons tests should not show increased leukaemia incidence because the doses were too small.
- Compared medical records of 22300 exposed veterans and military controls.
- By 1984, 20 of exposed group had died of leukaemia compared to 6 controls.
- Apparent increased risk dismissed by the authors as bias since the control cohort had a significantly low rate of leukaemia incidence compared to the general population.
Correct use of auxiliary hypotheses

- Independently testable
- Science should be unified
- Fecundity – opens up new areas of research
- Ad hoc hypothesis – no change in testability
- Example: The prediction of Neptune from Uranus’s movements
Mode of discovery and mode of justification

- Difference between what scientists do as individuals (fallible) and what they do as a scientific community – critical rationalism
- Progress can be measured by the significance of observations and confirmations
- Problem: all observation statements are fallible, including those purporting to reject a hypothesis

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“The empirical basis of objective science has nothing “absolute” about it. Science does not rest upon a bedrock. The bold structure of its theories rises, as it were above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or “given” base; and if we stop driving the piles deeper, it is not because we have reached firm ground. We simply stop when we are satisfied that the piles are firm enough to carry the structure, at least for the time being.”

Essay Topics

- Which do you think is the most rational grounding for scientific facts: observation or theory?
- Identify some key hypotheses from your own branch of science. How well do they meet Popper’s model?
- Do some areas have an inherently harder job in demonstrating scientific validity as compared to physics?
Group Discussions

- Get to know your group – short introduction round and PhD topic
- Are any PhD projects based on hypothesis testing?
- How well does your PhD project fit either Popper’s falsification model or the inductivist approach?
- Even if your own PhD is not focused on hypothesis testing, can you identify key hypotheses and theories from your field of research?
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Main Literature for tomorrow: Feyerabend