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
Background - demarcation

- Aristotle and Plato – no distinction between science and philosophy
- Greeks to the Age of Enlightenment – mysticism, religion, ideology
Background - demarcation

- 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
Science and Mathematics

- Similarities: search for truth and proof
- Science relies on mathematics
Science and 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
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

Al-Kwarizimi (ca 830) : Source of words algebra and word algorithm

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Philosophy of Mathematics

- Mathematics: Analytical statements: true by virtue of the meanings of words
- Science: Synthetic statements: true by virtue of the way things are

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Milestones in the Philosophy of Mathematics

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


calepiopress.it/mandelbrot_large/
mikecane2008.wordpress.com/edward-lorenz
Other Popular Science

Simon Singh: Fermat’s Last Theorem, 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
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
Karl Popper

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
Falsifiability?

Freud  Marx  Einstein
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: “Bats use ultrasound, not their eyes, to navigate”
Hypothesis: “All vowel cards have an even number on their back”

Which two cards should one turn to test the theory?

A B 2 3

Goldacre, 2006
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?
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.
- James L. Gould – "blindfolded" the dancing bee
Does Popper work for you?

- Yes, in my own research
- Not in my own research, but in my field of research
- Not in my own field, but I can see why it applies in other areas
- Not at all
Problems with Falsification

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

1. Observe natural phenomena
2. Formulate Hypothesis
3. Test hypothesis via rigorous Experiment
4. Establish Theory based on repeated validation of results

**THE ACTUAL METHOD**

1. Make up Theory based on what Funding Agency Manager *wants* to be true
2. Design minimum experiments that will prove *show* suggest Theory is true
3. Publish Paper: rename Theory a "Hypothesis" and pretend you used the Scientific Method
4. Defend Theory despite all evidence to the contrary
Problems with Falsification

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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 hypothesis 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
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
Popper’s response

“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 this type of scientific validity as compared to physics?
Monday 29\textsuperscript{th}

- Demarcation of science from pseudoscience
  
  \textbullet\ Recommended Literature: Feyerabend paper