A Brief History of Scientific Thoughts
Lecture 4

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David Hume (1711–1776) on Induction

- Deduction cannot justify rules for induction.
- Circularity: The principles for induction are justified by induction.
- So, induction cannot be justified.
- No certainty that the future will resemble the past.
  - Inductive reasoning cannot conclusively establish that the Sun will continue to rise in the East.
- Practical skepticism: we have to rely on induction even if it cannot be justified.



John Stuart Mill on Induction

- Mathematical truths are highly confirmed generalisations from experience.
- Knowledge of any kind is not from direct experience, but, an inductive experience from direct experience.
- An extreme position on the “competitive” roles of inductive and deductive inferences.
- Syllogistic logic adds nothing to our knowledge.
  - Its rules merely reflect our determination to reason consistently with the ways in which we have reasoned in the past.
- All ampliative (i.e., which increase knowledge) inferences are inductive.



Charles Sanders Peirce (1839–1914)

`http://en.wikipedia.org/wiki/Charles_Sanders_Peirce`

Contributions.

- Abductive reasoning (as a logic of pragmatism).
  - Placed inductive reasoning and deductive reasoning in a complementary rather than competitive mode.
- Doctrine of fallibilism.
- Approach to the scientific method.
  - The objects of knowledge are real things.
  - The properties of real things do not depend on our perceptions of them.
  - Everyone who has sufficient experience of real things will agree on the truth about them.



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Abductive Inference/Reasoning

Observation: the lawn is wet in the morning.
Inference: it rained during the night.

- The surprising fact, C, is observed;
  - But if A were true, C would be a matter of course,
  - Hence, there is reason to suspect that A is true.

The hypothesis A is an abduction/presumption/retroduction from the observation C.

- A kind of logical inference described by Peirce as ‘guessing’.

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Abductive Inference/Reasoning (contd.)

- The hypothesis is framed, but not asserted, in a premise.
- The hypothesis is asserted as rationally suspectable in the conclusion.
- Thus, the conclusion is based on premise(s).
- But, the hypothesis is a new or outside idea beyond what is known or observed.

Peirce argues that abduction is a ubiquitous aspect of thought.

> *"Not the smallest advance can be made in knowledge beyond the stage of vacant staring, without making an abduction at every step."*



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Abductive Inference/Reasoning (contd.)

- Formally, abductive reasoning appears to be as follows:
  - C;
  - A implies C;
  - Inference: A
- The above is a fallacious deduction!
- There are many possible explanations $A_1, A_2, \ldots$ for C; i.e., one may have:
  A_1 implies C;
  A_2 implies C;
  $\ldots$;
- The actual A is chosen based on other factors.
  - Simplicity, most economical (Occam's razor).
  - Elegance.
  - Prior probability.
  - Best explainability.



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Deduction, Induction and Abduction

Deduction.

- From A infer B.
- B is a formal consequence of A: whenever A is true, B must also be true.

Induction.

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- A gives us a good reason to accept B.

Abduction.

- Infer A as an explanation of B.
- There could be many possible explanations of B, and A is chosen based on some rule.
- Induction seeks facts to test a hypothesis; abduction seeks a hypothesis to account for facts.



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Mathematical Treatment of Abduction

- Formal logic: In a theory T, E is an explanation of an observation O, if
  - O follows from T and E;
  - E is consistent with T.

  Some method (such as Occam's razor) is required to pick E from the many possible explanations of O.
- Set theoretic: Let f be a function from the set of possible hypothesis to the set of possible observations.
  - Let M be a subset of observations.
  - A set H is abduced by M if $f(H)$ contains M.



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Probabilistic Abduction

- Let X: event that the test result is positive;
  Y: event that an individual is infected.
- Known.
  - Sensitivity: $p(X|Y)$; (and false positive rate $p(X|\overline{Y})$).
  - $p(Y)$: base rate of infection;
  - $p(X)$: test result is positive on a 'random' person.
- Required by the medical practitioner: $p(Y|X)$.
- This probability is abduced using Baye's theorem:

$$p(Y|X) = \frac{p(X|Y)p(Y)}{p(X)}.$$



Abduction and Pragmatism

- Pragmatism: the meaning of a proposition is to be found in the practical consequences of accepting it.
- Pragmatism has been called the logic of abductive inference.

A formulation of the pragmatic maxim by Peirce:

> *"In order to ascertain the meaning of an intellectual conception one should consider what practical consequences might conceivably result by necessity from the truth of that conception; and the sum of these consequences will constitute the entire meaning of the conception."*



Fallibilism

Principles.

- The conclusions of science are always tentative.
- The rationality of the scientific method does not depend on the certainty of its conclusions, but on its self-corrective character.
- By continued application of the method, science can detect and correct its own mistakes, and thus eventually lead to the discovery of truth.

Other proponents.

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- Ancient Greek philosophers, Karl Popper, Richard Feynman.



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Fallibilism: Criticism

- Self-contradictory: fallibilism in itself is an absolute knowledge claim.
- “This much is certain: nothing is certain.”
  - Self-contradictory (also self-referential) and cannot be true.
- Popper: accept as tentative, unless proved otherwise.
  - Amounts to skepticism.



Karl Popper (1902–1994)

(From the Stanford Encyclopedia on Philosophy.)

On observation and induction.

- Accepts the Humean criticism of induction.
- Rejects the Baconian view that ‘pure’ observation is the initial step in the formation of theories.
- All observation is selective and theory-laden – there are no theory-free observations.



Popper on Induction and Science

- Induction is not the method which characterises science.
- There is no unique methodology specific to science.
- Science, like every other human (or organic) activity, largely consists of problem solving.
- Science starts with problems rather than observation.
  - It is in the context of grappling with a problem that a scientist makes observations.
  - The observations are designed to test the efficacy of a theory to solve a given problem.



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Science and Falsifiability

- The feature which characterises a scientific theory is *falsifiability*.
- A theory is scientific only if it is refutable by a conceivable event.
- Every scientific theory is *prohibitive*, in the sense that it forbids, by implication, particular events or occurrences.

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Science and Non-Science

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  - It is easy to obtain evidence in favour of virtually any theory.
  - If a theory is vague, then it is easy to explain any observation within the theory.
- Falsifiability acts as the demarcating feature between scientific and non-scientific theories.
  - Science: physics, chemistry.
  - Pre-science: psycho-analysis. It is useful, but does not yet contain falsifiable statements.
  - Pseudo-science: astrology, phrenology.



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Science and Verifiability

- Verifiability is not the key feature of a scientific theory.
  - Growing corroboration does not make the theory more acceptable.
- By rejecting verifiability, he rejects the logical positivist view of science.
- There is an asymmetry between verification and falsification.
  - It is logically impossible to conclusively verify a universal proposition by reference to experience (Humean view).
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Falsifiability and Corroboration

A theory is scientific if and only if it divides the class of basic statements into the following two non-empty sub-classes:

- Statements with which it is inconsistent, or which it prohibits – these are potential falsifiers.
- Statements with which it is consistent, or which it permits – these bear out the theory.



Falsification and Practical Methodology

- No observation is free from the possibility of error in experimentation.
- In practice, a single counter-example is never methodologically sufficient to falsify a theory.
- Scientific theories are often retained even though much of the available evidence conflicts with them, or is anomalous with respect to them.

