Alpbach, 2006
Seminar 8

Scientific Rationality:
Bayesianism versus Reliabilism

Who We Are

- Stephan Hartmann
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- Clark Glymour
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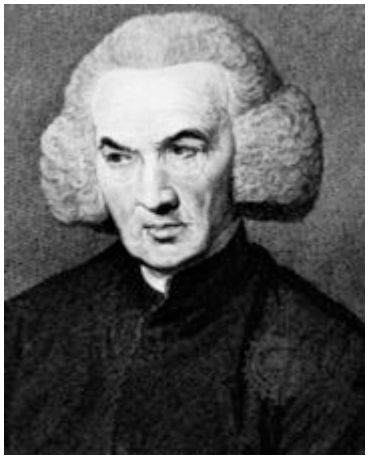
- And Who Are YOU (and why are you here)?

The Seminar Plan

- Today(18th): **Introduction** to the two views of inquiry, knowledge, belief, and science: Bayesian (Stephan) and Reliabilist (Clark). Questions for you. Reading for you: "How Did You Guess That, Watson?"
- 19th: **Bayesian epistemology** in detail (Stephan), with objections (Clark) and discussion from all of you.
- 20th: **Reliabilism** in detail (Clark), with objections (Stephan) and discussion from all of you.
- 21st: (Flexible) **Reliabilist Fruits**: From Sherlock Holmes to Real Science (Clark). Discussion and objections from everyone.
- 22nd: (Flexible) **Bayesian Fruits**: From Textbook Bayesianism to Naturalized Bayesianism (Stephan). Discussion and objections from everyone.
- 23rd: **Final comparisons and open issues**: scientific revolutions and rationality; rational inquiry in law, society and religion, etc.



A Brief History of Bayesianism

- 18th Century: **David Hume** argues that inferences to causes and prediction of the future cannot be founded on "reason."
- Late 18th Century: **Thomas Bayes'** unpublished "Essay on the Doctrine of Chances" argues for a method for computing *the probability* that *a chance* (e.g., the chance of a coin coming up heads on a flip) is between any two specified values (and two numbers between 0 and 1).
- **Richard Price** argues that Bayes' refutes Hume.

A Brief History of Bayesianism (cont'd)

- 1924: **Frank Ramsey** gives a systematic interpretation of probability as "degree of belief" measured by betting odds.
- Ramsey introduces "Dutch book" arguments that rational degrees of belief must satisfy the axioms of probability. Huge influence in statistics and economics.
- 1940s: **Rudolf Carnap** and others develop the idea of a "rational agent" with degrees of belief that are changed as new facts are acquired by using *conditional probabilities.*
- 1960s: Bayesian epistemology and philosophy of science becomes a major movement.
- 1970s: Bayesian statistics blossoms with the availability of cheap digital computation.

Bayesian Epistemology: The Basic Ideas

- Consider a *set of propositions*, including:
  - For every proposition in the set, its denial
  - For propositions A, B in the set, also the propositions A and B, A or B.
- Consider a *cognitive agent*, that has *attitudes* towards all of those propositions—in particular, she believes each of them to some degree (possibly 0), and where propositions can be bet upon, she is willing to bet according to her degrees of belief.
- Suppose now that she can acquire new certainties about some of these propositions, for example by observing the world.
- Then…

Bayesian Epistemology (cont'd)

1. Her degrees of belief should satisfy the axioms of probability:
   - If A and B are logically inconsistent, then

     $Pr(A \text{ or } B) = Pr(A) + Pr(B)$
   - $Pr(\text{non } A) = 1 - Pr(A)$.

2. If, having degrees of belief $Pr(A)$, $Pr(B)$ and $Pr(A \& B)$, she now comes to believe with certainty that A, her new degree of belief in B should be:

$$Pr_{learn(A)}(B) = Pr(A \& B)/ Pr(A)$$
$$=_{df.} Pr(B \mid A) \qquad \text{if } P(A) \neq 0$$

What's The Point?

- We have "intuitions" about relations between theory and evidence:
  - One theory better **explains** a body of evidence than does another.
  - One hypothesis is **simpler** than another.
  - One theory is more **coherent** than another.
  - One piece of testimony or evidence should be given more **weight** than another.
  - Some data is **relevant** to a theory and some is not relevant.
  - One theory is better **confirmed** by a body of data than another.

  (N.B., we use "hypothesis" for any proposition of scientific interest, and "theory" for any collection of hypotheses that are surmised to be true.)

Evidence for these “intuitions”

These intuitions are manifested in the practice of science, e.g.,

- Kepler claimed that the heliocentric model of the solar system better **explained** the apparent motions of the planets than did geocentric models.
- Dalton claimed his atomic hypothesis provided the **best explanation** of chemical regularities, e.g., the law of definite proportions.
- Most physicists and chemists thought experimental error was a **better explanation** of experimental results reported in Utah in the 1990s than was “cold fusion.”

More Evidence for these “intuitions”

- Lord Kelvin claimed that the heat generated from the combustion of a pound of coal was evidence **relevant** to—and against—the theory of evolution.
- After the 1919 eclipse expeditions to measure the deflection of starlight passing near the sun, many physicists concluded that (1) the measurements **confirmed** the general theory of relativity; and (2) previous measurements of the gravitational red shift contradicting GTR were **best explained** as experimental error.

And more…

- Biologists claim that various “intelligent design” theories are **incoherent.**
- Physicists claim that gravitation and quantum theory are not yet unified, and at present quantum theory and general relativity form an **incoherent** pair.
- …

In Addition

The history of science shows patterns of stability and instability, for example:

1) Certain theories, though now thought false, lasted a long time (e.g., Newtonian dynamics)

2) Nonetheless, they are sometimes rapidly overthrown (the quantum and relativity revolutions took only a quarter of a century, if that).

What’s the Point?

Bayesian epistemology provides a systematic, formal, clear reconstruction of many of these intuitions, and thus explains the principles behind the conduct of science, and helps to establish the rationality of the scientific process and of scientific degrees of belief.

That’s the claim…

Caveat

- Bayesian epistemology is not a done, finished thing. It is a framework, results, plus a *philosophical research program*.
- There are various difficulties (What if a new observation is less than certain? What if a brand new never before considered hypothesis is introduced? Can you really bet on the truth or falsity of scientific propositions? How can community degrees of belief rationally formed from individual degrees of belief? Who is the agent?) and philosophical research in Bayesian epistemology tries to expand and adapt the framework to account for them.

Reliabilism, in Simplest Terms

- **Rationality** in inquiry amounts to the adaptation of **methods** to **cognitive goals** or ends, subject to **constraints** on the inquirers abilities or prior beliefs.
- Philosophical methodology (and other methodology, e.g., in statistics and computer science) should investigate which goals can and cannot be achieved by which methods subject to which constraints.

Goals May Vary

- Finding the truth about a question of interest and knowing when it has been found.
- Eventually converging to the truth about a question of interest and being disposed to stick with it, even if one does not know when one has converged to the truth.
- Converging to the truth with high probability.
- Etc., etc.

Some goals are impossible to fulfill

- E.g., Socrates in Plato's Meno:

  Fill out "All and only virtues have the properties……." with a correct list of properties.
- And know when you have a solution that will survive all possible counterexamples.
- "How will we know the true answer if we hit upon it?" Meno asks Plato.

When some goals prove impossible to achieve, weaker goals may come to be substituted.

"All electrons have unit charge." cannot logically be guaranteed by any finite number of cases of electrons and their charge (pace Plato, Sextus, Hume).

So even if it is true, and we believe it, we cannot know (in Plato's sense of "know") that we are correct.

But we can be right about whether "All electrons have unit charge" for all but at most a finite number of trials—just conjecture the same so long as no electron with non-unit charge has been discovered.

So, reliabilism allows a range of cognitive goals, according to what is possible.

The Reliabilist Picture of a Discovery Problem

Space of allowed hypotheses

$H_1, H_2 \ldots\ldots H_{infinity}$

~~Excluded hypotheses $L_1 \ldots$~~

Possible data according to a hypothesis

$d_1, d_2, d_3, d_4, \ldots$

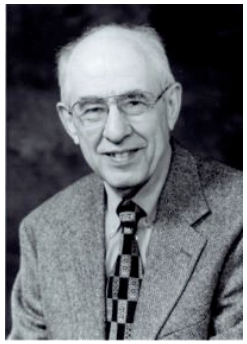
A method's conjectures:

$H_1, H_1, H_1, H_2 \ldots, H_2 \ldots, H_2, \ldots$

Confusions to Avoid

Reliabilist set up, but confuses

- Psychology of discovery with mathematical study of discovery procedures (Popper)
- Reliabilist program (which aims to analyze which goals are reachable by which methods under what constraints, and thus to improve inquiry) with reconstruction (as with Carnap or Bayesians, who aim to justify current and historical practices of inquiry.)



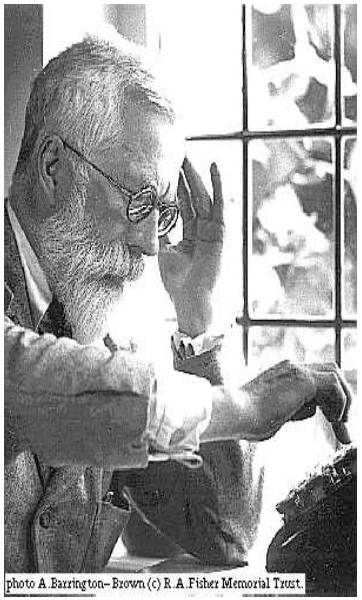
Range of Reliabilist Work

Highly idealized (e.g., learning propositions in a formalized language, or learning recursive functions)

Often to qualify or undermine various methodological slogans

Practical (e.g., learning causal relations from statistical data under various background assumptions)

To improve the conduct of science

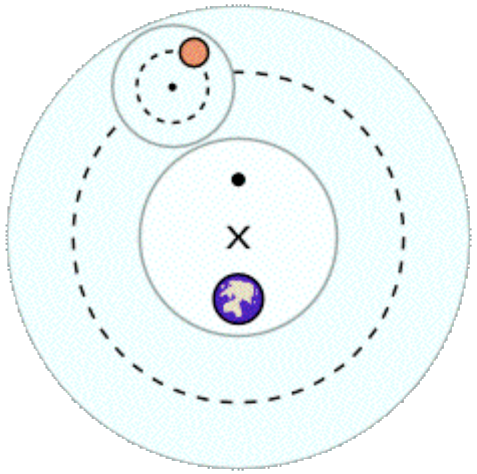


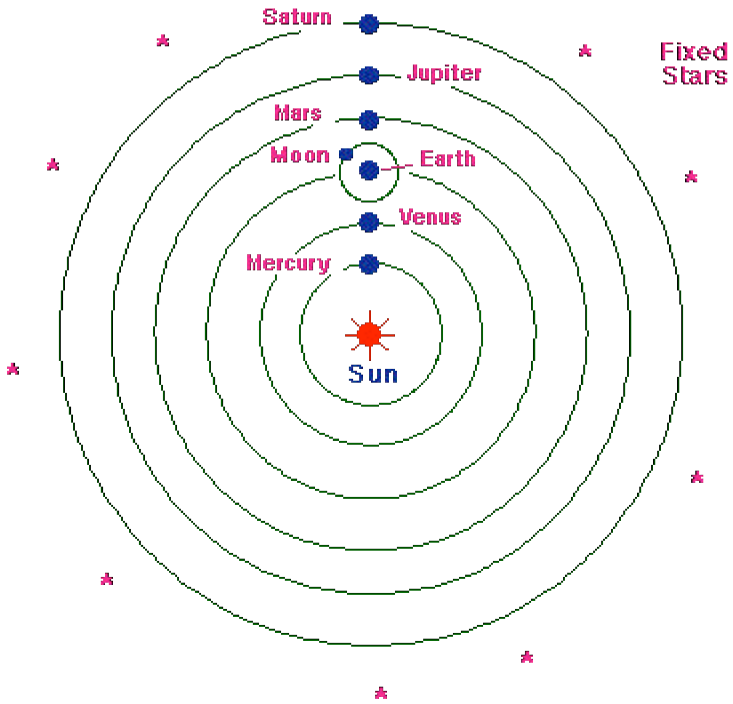
Critical Connections

- **Bayesian:**
  - reliabilism doesn't capture scientific intuitions about explanation, simplicity or confirmation, or help us understand the actual conduct of science present or science past.
  - Reliabilism relies on a God's eye view of the "truth."
  - Convergence theorems for probabilities provide all the "reliabiliy" one needs.
  - Reliabilism makes philosophy of science just part of science—and a not very interesting part.
- **Reliabilist**
  - Bayesianism doesn't "justify" most scientific intuitions (e.g., preference for simple theories); it just restates them.
  - Bayesian "reconstructions" just paste a gratuitous formalism over logical and semantical relations that are the basis of methodological intuitions.
  - Bayesian epistemology may be fine for Gods, but it is impossible for computationally bounded agents, except in trivial cases.
  - "Confirmation" is just a tool in methods of discovery, not a subject in itself disconnected from discovery problems.
  - Bayesian epistemology fails to make any contributions to science.

Things to Think About:

Why prefer Copernican theory to Ptolemaic?

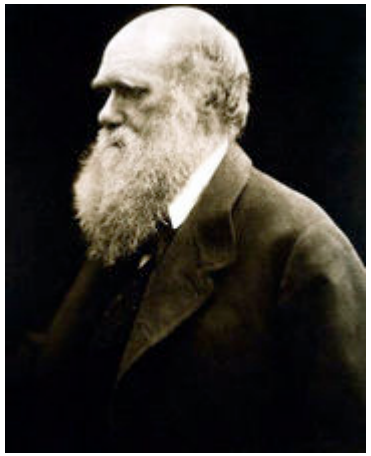




Why is Dalton's Explanation of the Law of Definite Proportions an Explanation?

- All samples of a compound substance consist of molecules, each molecule having the same number of atoms of any elementary kind.
- All atoms of the same elementary kind have the same weight.

- Law: Each sample of a compound substance is composed of the same elementary substances in the same proportions by weight.



Relevant and Irrelevant: Why?

- Kelvin argued that heat of burning coal is relevant negative evidence against Darwin's theory of evolution.
- Scientists (including Darwin) agreed with him.
- Kelvin did not claim that the fact that iron is heavier than oxygen is evidence relevant to Darwin's theory.
- Nor did any other scientists.

Relativity

- Einstein's 1915 General Theory implied, with approximations, an "anomaly" of 45" of arc per century in the perihelion of mercury.
- The anomaly had been known since 1858 and reconfirmed in 1900 and in 1912.
- So the anomaly was known to Einstein as he searched for a theory of gravitation, proposing at least five theories between 1907 and 1915.
- Does the anomaly "confirm" the general theory of relativity, or not, and whatever the answer, why?