Philosophy of Science Survey

Week 4

PHIL 2160. Ohio University. Spring 2021.

Chapter 5: The Quine-Duhem Thesis and Scientific Method

Review: Confirmation and Disconfirmation Reasoning

Confirmation (Inductive)	Disconfirmation (Deductive)
If T, then O	If T, then O
O	Not O
So, probably T	So, not T

Review: Disconfirmation Reasoning (Refined)

1. If **T** and $A_1, \ldots, A_n$, then **O**.
2. Not **O**.
3. So, not **T**, or not $A_1, \ldots$, or not A_n.

- Note that the conclusion does not say that **T** is definitively false.
- It only says, "T is false, and/or any one or more of the auxiliary hypotheses are false."

The Quine-Duhem Thesis

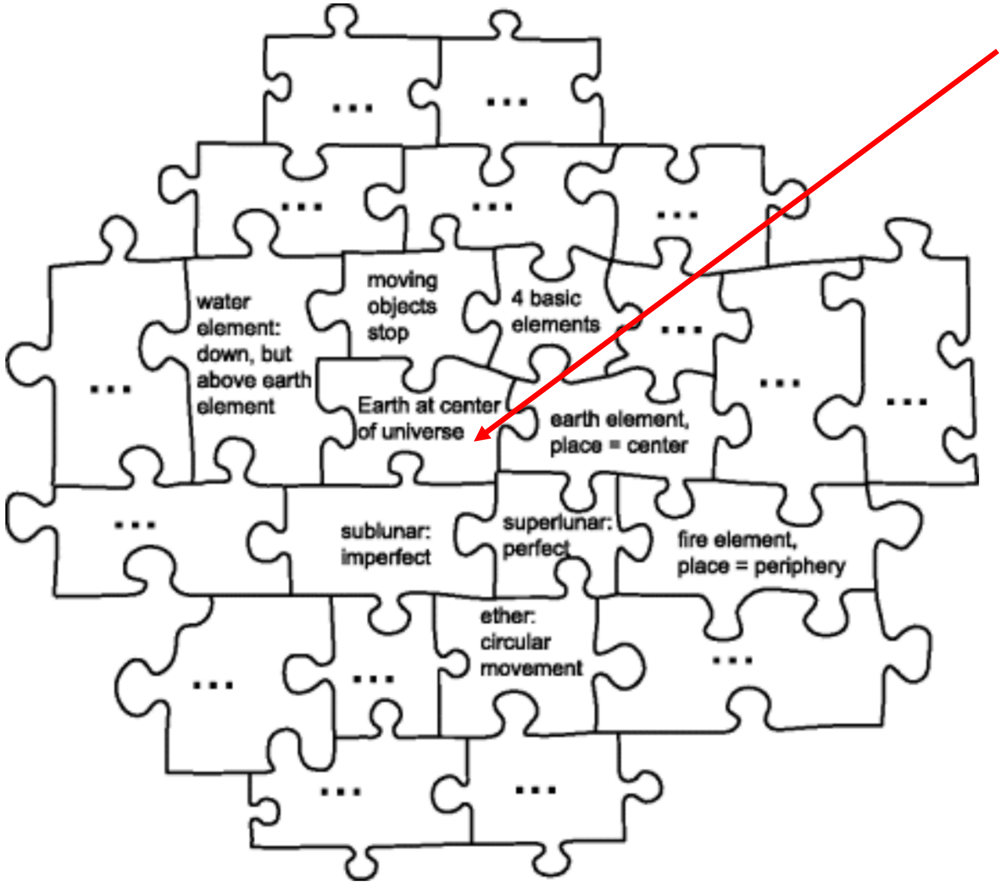
- A set of claims about the relationship between theory (or worldview) and evidence in the confirmation and disconfirmation reasoning.

1. What is confirmed or disconfirmed is an entire body of beliefs (an entire theory) rather than an isolated belief or hypothesis.
2. Crucial experiments are nearly impossible.
3. Theories are underdetermined by evidence.

The Quine-Duhem Thesis (I)

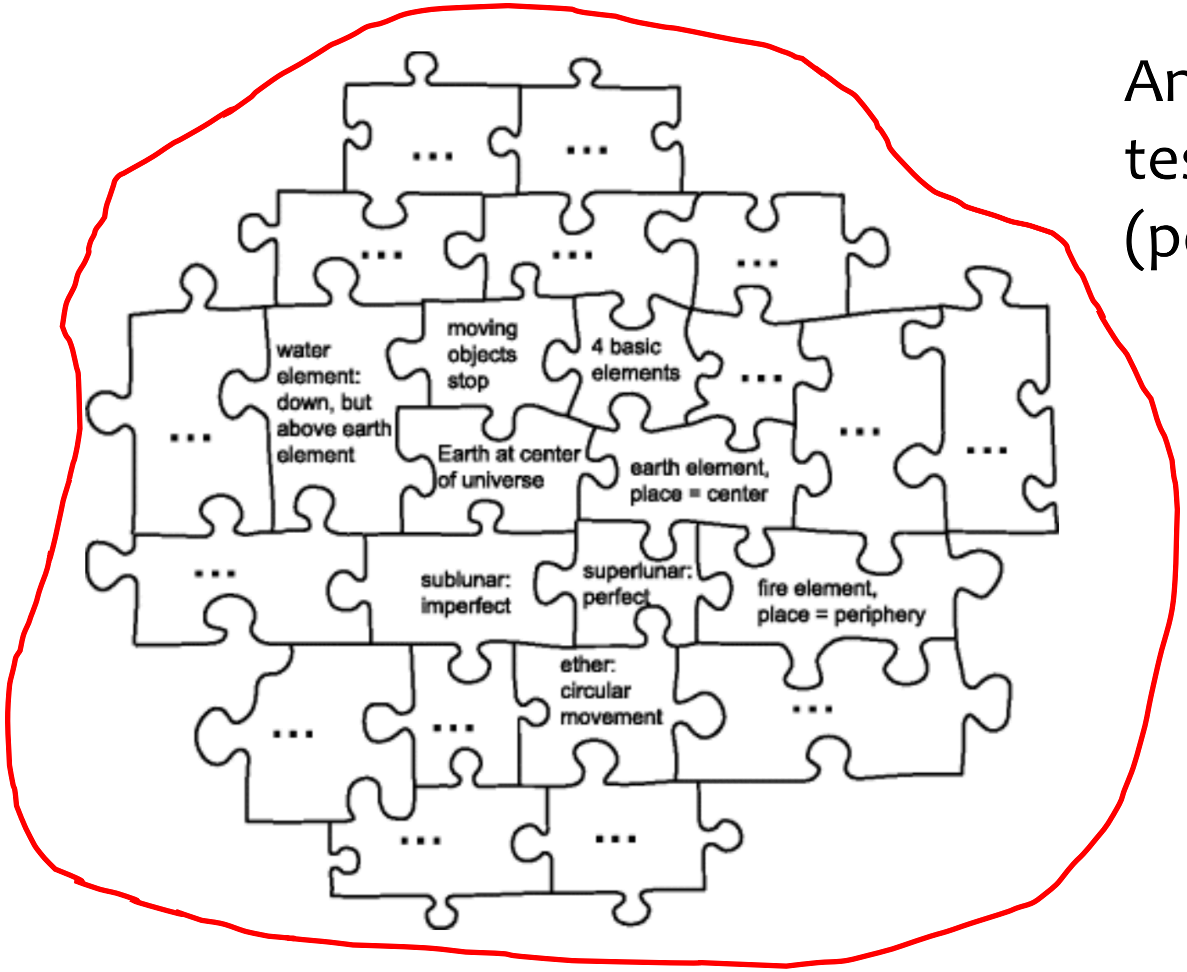
- *What is confirmed or disconfirmed is an entire body of beliefs (an entire theory) rather than an isolated belief or hypothesis.*
- This claim has positive and negative parts:
    a. An entire theory is what is tested against evidence.
    b. A single belief of a theory is *not* what is tested against evidence.
- See the jigsaw puzzle model (next)

The Quine-Duhem Thesis (I)



A single puzzle piece is not what is tested against evidence.
(Negative part of the thesis)

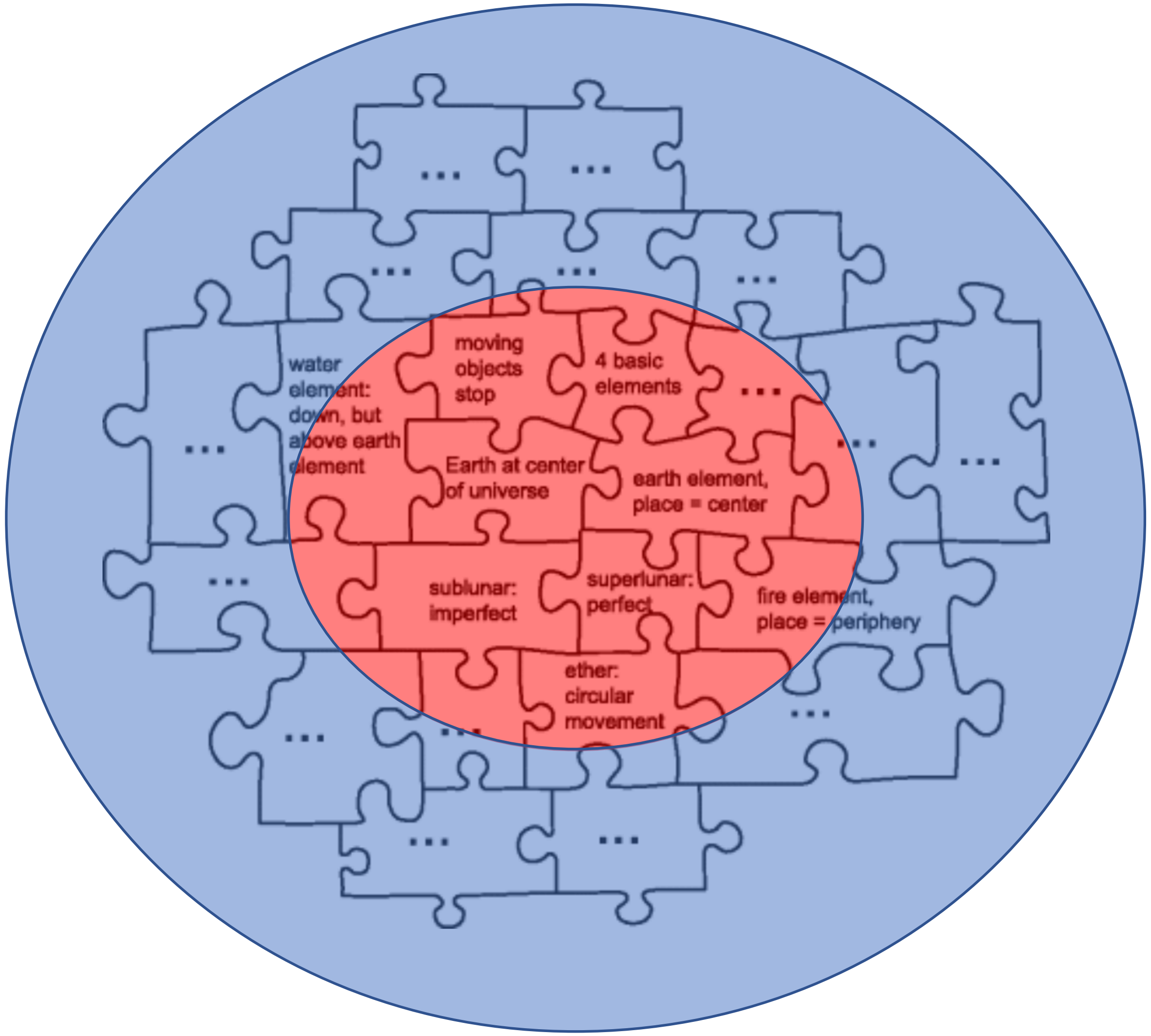
The Quine-Duhem Thesis (I)



An entire puzzle is what is tested against evidence. (positive part of the thesis)

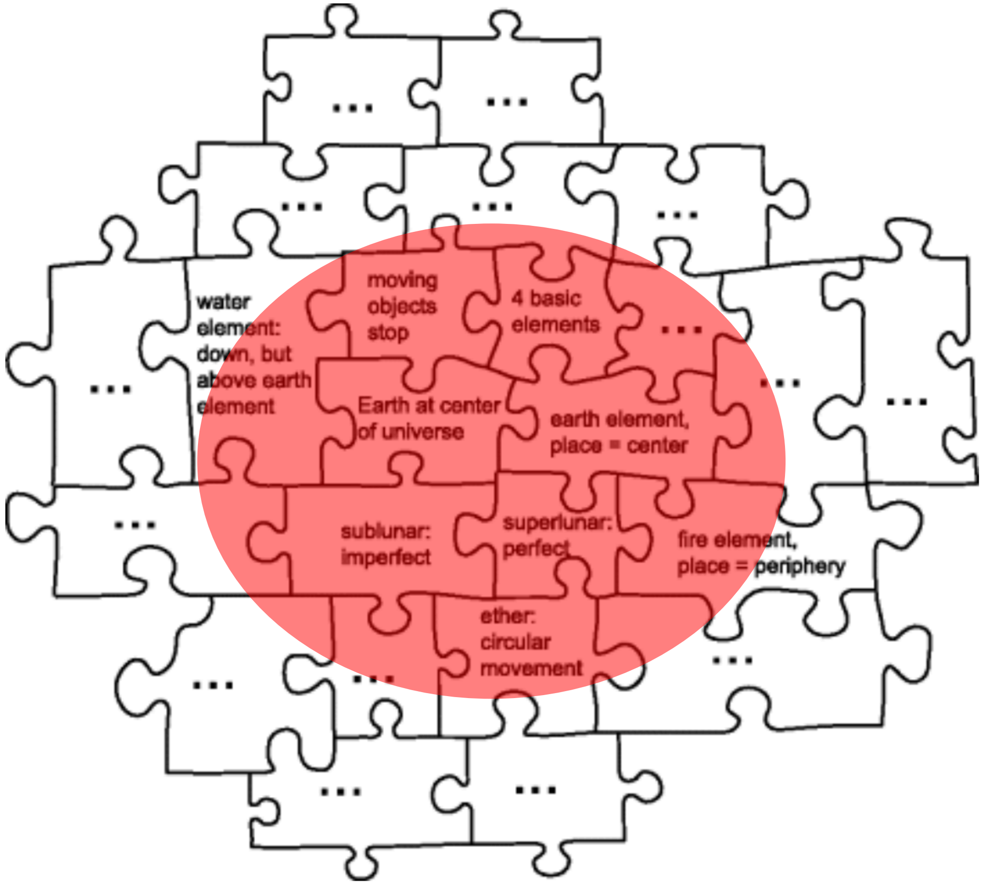
But why is it that a single belief is not what is tested?

The Quine-Duhem Thesis (I)



Recall our discussion of the core and peripheral beliefs.

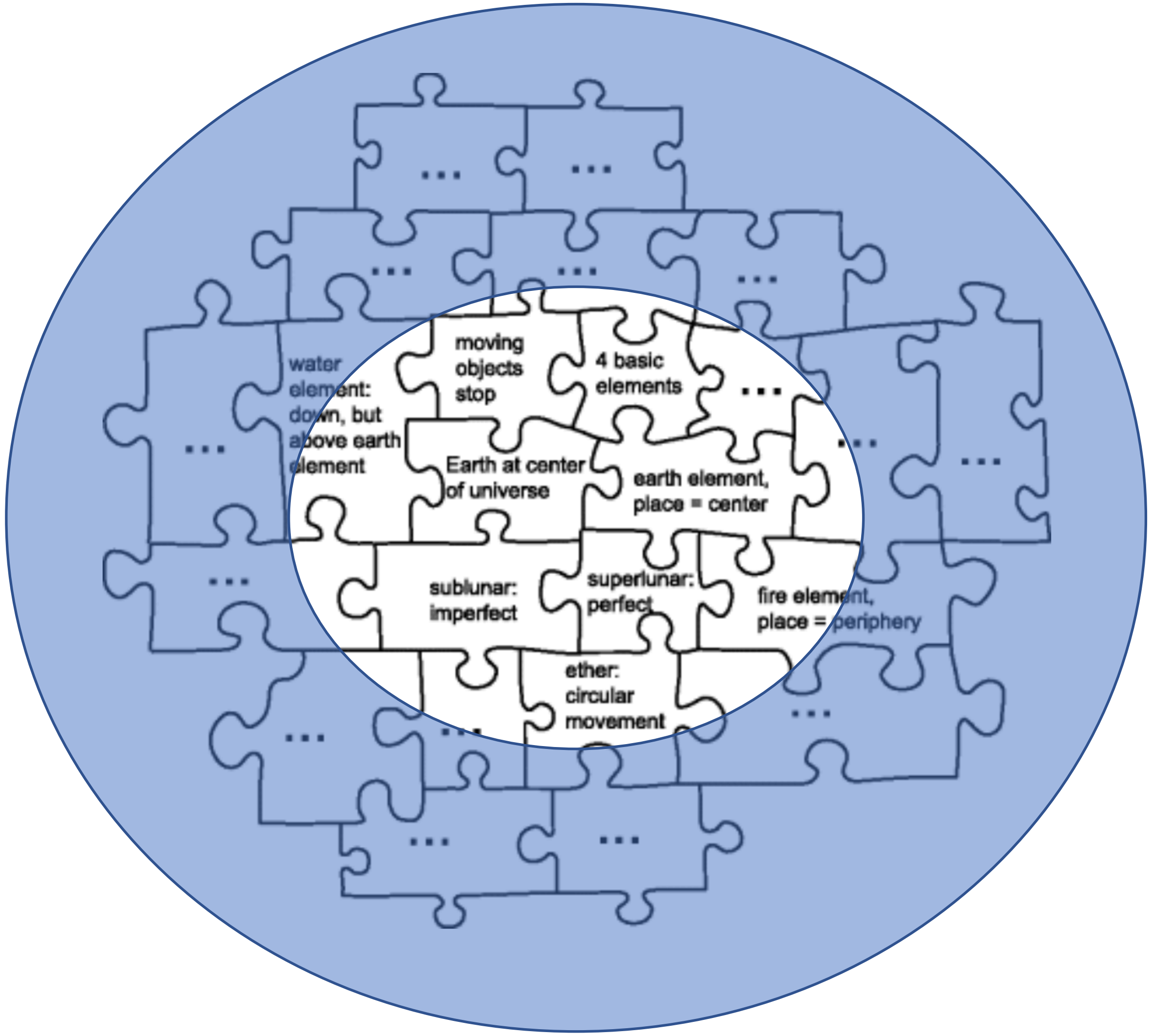
The Quine-Duhem Thesis (I)



Imagine one of the core beliefs is T in the scheme below, and it is challenged by evidence.

If T, then O.
Not O.
So, not T.

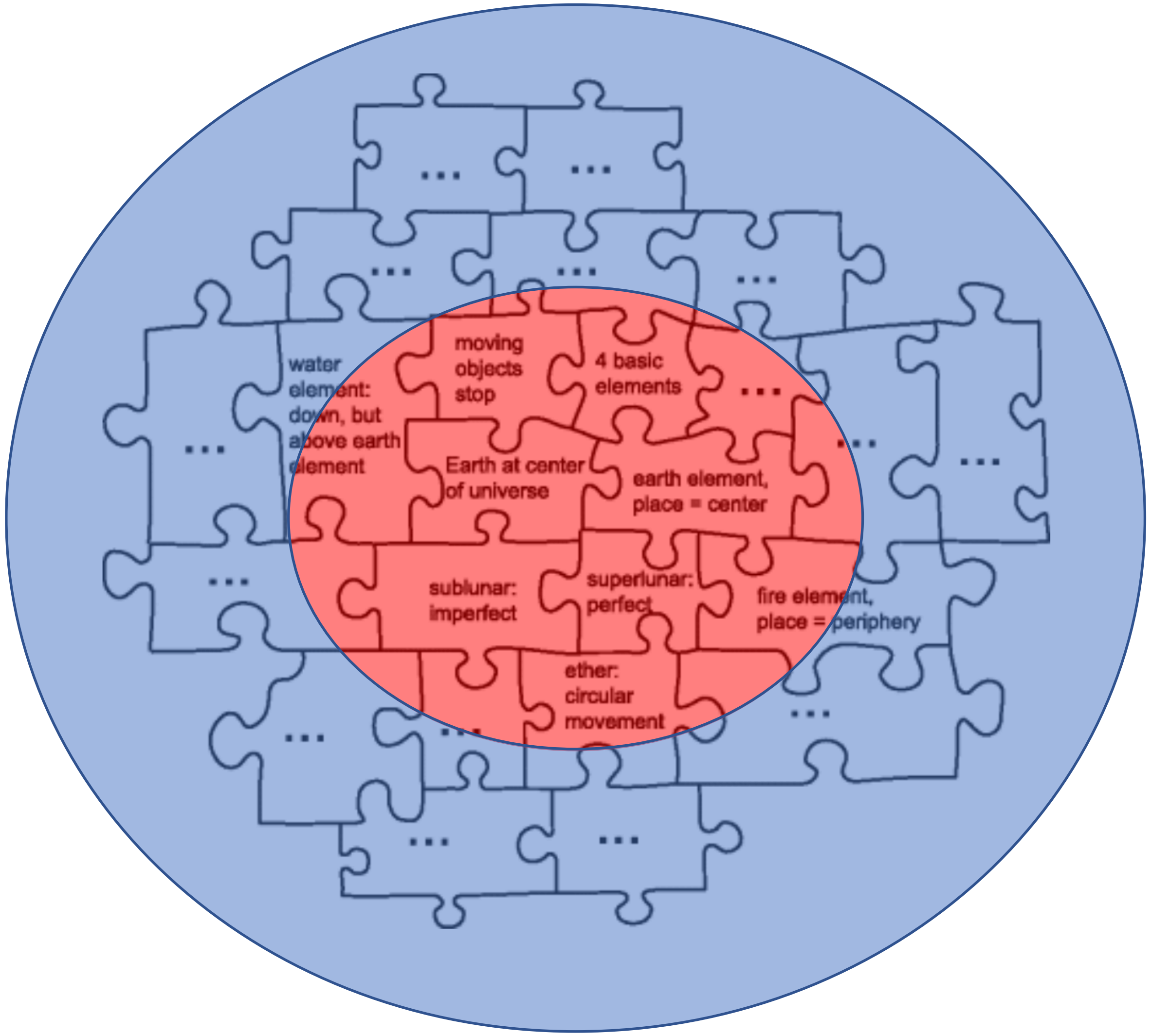
The Quine-Duhem Thesis (I)



But it's possible to adjust peripheral beliefs to explain the discrepancy between the theory and evidence.

This adjustment allows us to keep the core belief in question.

The Quine-Duhem Thesis (I)



When a core belief of a theory is challenged by evidence, scientists generally look for possible adjustments in the peripheral beliefs.

The peripheral beliefs here include auxiliary hypotheses.

The Quine-Duhem Thesis

- A set of claims about the relationship between theory (or worldview) and evidence in the confirmation and disconfirmation reasoning.

1. What is confirmed or disconfirmed is an entire body of beliefs (an entire theory) rather than an isolated belief or hypothesis.
    - It's possible to keep the core beliefs and adjust peripheral beliefs.
2. *Crucial experiments are nearly impossible.*
3. *Theories are underdetermined by evidence.*

- (2) and (3) are the consequences of (1).

The Quine-Duhem Thesis (II)

- *Crucial experiments are nearly impossible.*
- A crucial experiment:
  - Involves two (or more) theories.
  - The theories make conflicting predictions about a possible observation.
    - If T1, then O
    - If T2, then not O
  - The observation is then used to decide which theory is mistaken.
- But as we saw, it is possible to save the challenged theory by adjusting auxiliary hypotheses.
- So it's hard to design crucial experiments.

The Quine-Duhem Thesis (III)

- *Theories are underdetermined by evidence.*
- When we say that available evidence *determines* a theory, we mean that the evidence *uniquely supports a particular theory among competing alternatives*.
- The history of science shows that evidence rarely, if ever, determines a theory.
- Rather, evidence usually ***underdetermines*** theories: *Evidence supports multiple theories equally or nearly equally*.
    - In fact, scientists routinely work with alternative theories or try to formulate alternatives that are supported as well as the current theories.

The Quine-Duhem Thesis (III)

- Some of you noticed an important question raised by underdetermination of theories by evidence.
- Why do we rely on our current scientific theories if they are underdetermined by evidence?
- The topic of reliability and public trust in science is an active area of research (see next).

WHY TRUST SCIENCE ?

NAOMI ORESKES

The Quine-Duhem Thesis (III)

- One way to think about reliability is to think about what reasons you appeal to when you rely on a tool (e.g., car).
- Your reasons probably don’t include anything like a “proof” (in the strong sense) that a tool will do what you want it to do.
    - In fact, you probably can’t ever have such a proof.
- Your reasons are more likely to be the tool’s past track-record.

The Quine-Duhem Thesis (III)

- Scientific theories that are accepted at a given time have good past track-record (e.g., they have confirming evidence, enabled progress in many areas, made technological advance possible, etc.).
- So one way to understand why we rely on these theories is to see that we can appeal to the same sorts of reasons that we would appeal to in the case of tools.

Implications for Scientific Method

- More properly, “implications for our common, textbook view of *the* scientific method”

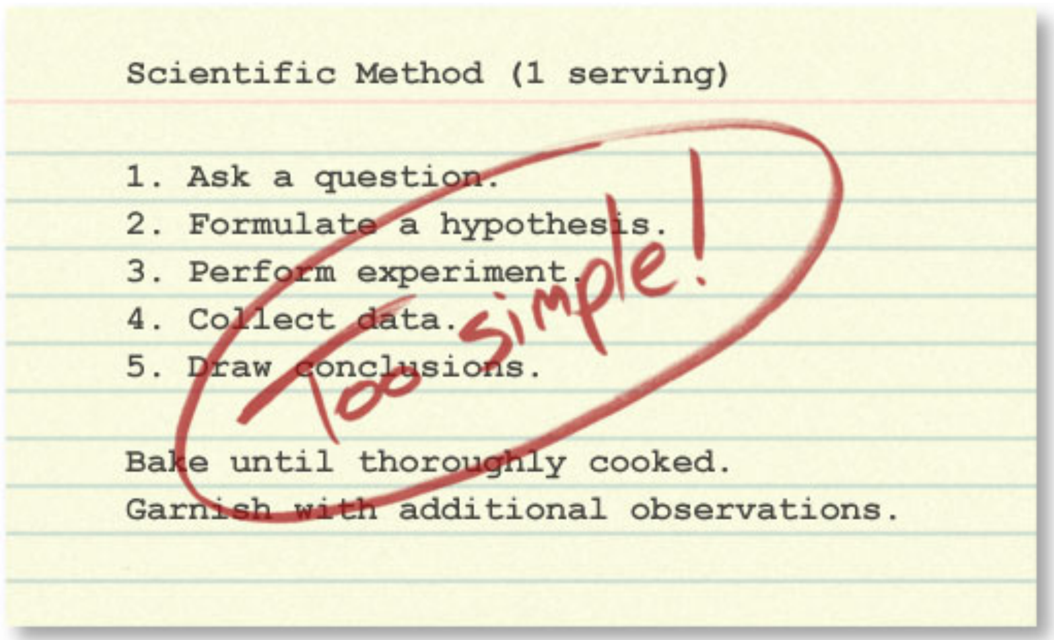
The Scientific Method

- Science education and science textbooks typically present *the* scientific method (note, “the”) as a step-by-step process:

1. Observe and gather data
2. Generate a hypothesis
3. Test the hypothesis by experiments to confirm or disconfirm it

- This observe-hypothesize-test method and its variants are typically taught as what defines the scientific method and as a recipe for doing science.

The Scientific Method as a Recipe



The Scientific Method

- The textbook recipe for science implies:

1. There is one grand method (*the* method) for doing science.
2. A hypothesis is tested in isolation.
3. Confirmation and disconfirmation are straightforward processes.

- Many of you noted how (2) is commonly taught in schools.
- But by now, you know (2) and (3) are not quite correct. Can you explain why they are not correct?
- DeWitt's section on "implications for scientific method" in Chapter 5 challenges (1).

The Scientific Method

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How Science Textbooks Treat Scientific Method: A Philosopher's Perspective

James Blachowicz

ABSTRACT

This paper examines, from the point of view of a philosopher of science, what it is that introductory science textbooks say and do not say about 'scientific method'. Seventy introductory texts in a variety of natural and social sciences provided the material for this study. The inadequacy of these textbook accounts is apparent in three general areas: (a) the simple empiricist view of science that tends to predominate; (b) the demarcation between scientific and non-scientific inquiry and (c) the avoidance of controversy—in part the consequence of the tendency toward textbook standardization. Most importantly, this study provides some evidence of the gulf that separates philosophy of science from science instruction, and examines some important aspects of the demarcation between science and non-science—an important issue for philosophers, scientists, and science educators.

Epistemology for the Masses: The Origins of "The Scientific Method" in American Schools

John L. Rudolph

Introduction

In the widely disseminated Harvard report *General Education in a Free Society* (1945), the authors of the section on science teaching in the schools made passing reference to the portrayal of the scientific method in the existing curriculum. Rather than simply noting its inadequacy in representing the process of scientific research, they could not resist the urge to deliver a more scathing commentary. "Nothing could be more stultifying, and, perhaps more important, nothing is further from the procedure of the scientist," they insisted, "than a rigorous tabular progression through the supposed 'steps' of the scientific method, with perhaps the further requirement that the student not only memorize but follow this sequence in his attempt to understand natural phenomena." This indictment was followed in 1951 by similar comments from Harvard president James B. Conant in his book *Science and Common Sense*. Conant's criticism of what he called the "alleged scientific method," seemed to resonate with interested readers of the time. The eminent wartime research director Vannevar Bush, writing in the *Saturday Review*, praised him for making it "crystal clear that there is no such thing as the scientific method." "The elegant definition of *the* scientific method that we have read for years," he noted approvingly, "comes in for the dissection it has long needed." Another reviewer hailed Conant's "service to the community [in] briefing the busy citizen on the way in which science

The Scientific Method

- For those interested, both papers are posted in the library on Perusall.
- Rudolph traces the origins of the "observe-hypothesize-test" method in the history of American school education. The recipe-like method goes back to the early 20th century.
- Blachowicz finds the "observe-hypothesize-test" method as a common feature of contemporary science textbooks. He also discusses discrepancies between science instruction and the more sophisticated understanding of science developed by historians and philosophers of science.

Implications for Scientific Method

- There are many scientific methods. There is no "*the*" scientific method that is followed by every scientist everywhere.
- DeWitt's examples:
  - Axiomatic method
  - Falsificationism
  - Hypothetico-deductive method
- These methods are still quite general, and different fields of science have developed their own local methods. And different methods were favored at different times.

Axiomatic Method

- The scientific inquiry focuses on the search for *first principles*, which will serve as necessarily true premises for subsequent deductive reasoning.
- The acceptable scientific reasoning is only deduction from first principles.
- This method is similar to the geometric method (hence called "axiomatic"; see next).

Axiomatic Method

- For example, Euclid's *Elements* postulates five axioms (necessarily true statements) and proceeds to develop knowledge of geometry by deducing results (theorems) from the axioms.
- The distinguishing feature of axiomatic methods is the certainty of conclusions.
  - If the first principles (axioms) are true, then all conclusions deduced from them must also be true.
- The problem of axiomatic methods is to find first principles (axioms), which turned out to be quite difficult.
  - Even Euclidean geometry is not the only geometry!

Falsificationism

- Defended by Karl Popper.
- Falsificationist methods emphasize (1) developing theories that make precise, testable predictions and (2) disconfirming theories.
  - In short, the methods look for falsifiable theories.
- Falsificationist methods don’t consider confirmation to be important.
  - This is related to Popper’s skepticism toward inductive reasoning. He preferred the certainty of deductive reasoning.
  - But of course working scientists do consider confirmation to be important, so there is a discrepancy between Popper’s prescription and actual scientific practice.

Falsificationism

- Popper also argued that a theory is more scientific if it's falsifiable.
- His own motivation is summarized in the second and third paragraphs of DeWitt's section on falsificationism.
- And we'll talk more about this point when we discuss Ch. 7, which is on falsifiability.

Hypothetico-deductive method

Confirmation (Inductive)	Disconfirmation (Deductive)
If T, then O	If T, then O
O	Not O
So, probably T	So, not T

- HD method is another name for confirmation and disconfirmation reasoning. Unlike, axiomatic methods and falsificationism, HD method acknowledges confirmation (induction) to be an important part of scientific methods.

Hypothetico-deductive method

- The simple schema of confirmation and disconfirmation reasoning resemble the "observe-hypothesize-test" method.
- But the simple schema hide:
  - The role of auxiliary hypotheses.
  - The body of beliefs that is tested.
- Once we recognize these things, we can see that the HD method, even in general terms, is more complicated than the "observe-hypothesize-test" method.

Implications for Scientific Method (Summary)

- The textbook recipe for science implies:

1. There is one grand method (*the* method) for doing science.
2. A hypothesis is tested in isolation.
3. Confirmation and disconfirmation are straightforward processes.

- (1)-(3) are all not quite correct!

Chapter 6: Problem of Induction

Problems of Induction

- These problems are *foundational* (or “philosophical”) problems.
  - They have to do with the nature of and justifications for our everyday or scientific practice.
- We use inductive reasoning in both ordinary and scientific contexts.
- To study the foundations of inductive reasoning is to study the nature of inductive reasoning and its justifications.

Problems of Induction

- Like many foundational studies, the foundational study of induction has uncovered puzzling problems, problems that resist solutions, etc.
- And like many foundational studies, the foundational study of induction is not meant to suggest that we stop using induction.

Problems of Induction

- Rather, what the foundational study of induction shows is that we need more work to improve inductive reasoning.
- For example, the problems of induction have no counterparts in deductive reasoning, suggesting that induction is fundamentally different from deduction.
- So philosophers and later statisticians have been working on the theories of inductive logic, statistical inference (a kind of inductive reasoning), probabilistic reasoning, forecast, etc.
- All this work is based on the belief that induction is central to our everyday and scientific practice.

Problems of Induction (General)

- In general, the problems of induction concern these questions:
- How can experience (observation) justify beliefs about things we have not seen? Or equivalently:
- How can our observations make it rational for us to form beliefs about the unobserved?
- Note that future is a kind of *the unobserved*, but the unobserved includes many other things.
    - Prehistoric past; contemporary things that you have not yet observed

Hume’s Problem of Induction

- For Hume’s problem, the unobserved is the future. Consider:

The Sunrise Case 1 (see also in DeWitt)

1. The sun has risen everyday up to now.
2. So the sun will rise tomorrow.

- This is our ordinary reasoning to our belief that the sun will rise tomorrow. Hume and others are *not* questioning the legitimacy of reasoning.

Hume’s Problem of Induction

The Sunrise Case 1 (see also in DeWitt)

1. The sun has risen everyday up to now.
2. So the sun will rise tomorrow.

- We know this reasoning is not deductive, because the conclusion can turn out to be false even if the premise is true.
- Hume’s problem concerns *the kind of justification* our reasoning has for our belief in the conclusion.

Hume’s Problem of Induction

- Consider:

1. All cats are mammals.
2. Gatto is a cat.
3. So Gatto is a mammal.

- This is deductive: if the premises are true, the conclusion must also be true.
- When we have a deductive argument like this, we are justified in believing the conclusion because it is guaranteed to be true, as long as the premises are true.

Hume's Problem of Induction

The Sunrise Case 1 (see also in DeWitt)

1. The sun has risen everyday up to now.
2. So the sun will rise tomorrow.

- Inductive arguments don't offer the same kind of justification as deductive arguments.
- So what justifies us to believe the conclusion of an inductive argument?
  - This is Hume's problem.

Hume's Problem of Induction

- One possible solution, as Hume considers, is to turn induction into deduction. Consider:

The Sunrise Case 2 (see also in DeWitt)

1. The sun has risen everyday up to now.
2. [The future will resemble the past.] (Implied premise)
3. So the sun will rise tomorrow.

- This is now deductive: if the premises are true, the conclusion must also be true.

Hume’s Problem of Induction

- Note the implied premise: *The future will resemble the past*.
- This is a version of **the uniformity principle**.
  - Nature’s regularities operate uniformly.
  - The unobserved instances of the same kind must resemble the observed instances of that kind.
  - (These are equivalent statements of the principle.)
- Our past experience indicates a regularity about sunrise. The uniformity principle says that this regularity will hold in the future.
- The principle also says that the unobserved instances of sunrise (future ones) must resemble the observed ones.

Hume's Problem of Induction

The Sunrise Case 2 (see also in DeWitt)

1. The sun has risen everyday up to now.
2. [The future will resemble the past.] (Implied premise)
3. So the sun will rise tomorrow.

- This is now deductive: if the premises are true, the conclusion must also be true.
- Hume points out that for induction to give the same kind of justification as deduction, the uniformity principle must be justified.

Hume’s Problem of Induction

- But Hume famously argues that the uniformity principle is itself supported only by induction.

The Uniformity 1 (see also in DeWitt)

1. In the past, the future resembled the past.
2. So the future will resemble the past.

- This is inductive, and turning this argument into deduction leads to circularity (see next).

Hume's Problem of Induction

The Uniformity 2 (see also in DeWitt)

1. In the past, the future resembled the past.
2. [The future will resemble the past.]
3. So the future will resemble the past.

- This argument is circular in the sense that the conclusion is already assumed in the premises.

Hume's Problem of Induction

- Other statements of the uniformity principle face the same issue.
- Example
  1. All the regularities we found in nature so far have not been disrupted later.
  2. [Nature's regularities operate uniformly.]
  3. So nature's regularities operate uniformly.

Hume’s Problem of Induction

- Upshot:

1. The uniformity principle is needed to turn induction into deduction.
2. But the uniformity principle itself is supported only by induction.
3. So induction cannot be turned into deduction.

Hume’s Problem of Induction

- *Induction cannot be turned into deduction.*
  - This implies that ***whatever justification induction provides, it is not the same as the kind of justification deduction provides***.
  - Notice that it does not mean that induction does not provide any justification at all!
  - Rather, it means that induction is fundamentally different from deduction.

Hume’s Problem of Induction

- “No inference about the future can be **logically justified**, so no inference about the future provides any **logical reason** to believe its conclusion.” (DeWitt)
- “Logically justified” and “logical reason” refer to the kind of justification deduction provides.
- So **don’t** interpret this to mean:
  - No inference about the future can be *justified*.

  Or
  - No inference about the future provides *any reason* to believe its conclusion.

Hume’s Problem of Induction

- On the contrary, inductive reasoning is an excellent guide in our ordinary life as well as in science.
- Hume’s point was that inductive justification is fundamentally different from deductive (what DeWitt calls “logical”) justification.
- This calls for a separate study of induction (“inductive logic”).

Quiz 2

Hempel’s Raven Paradox

- The paradox has a different focus than Hume’s problem.
- The paradox is about the kind of evidence (premises) that goes into induction.

Hempel’s Raven Paradox

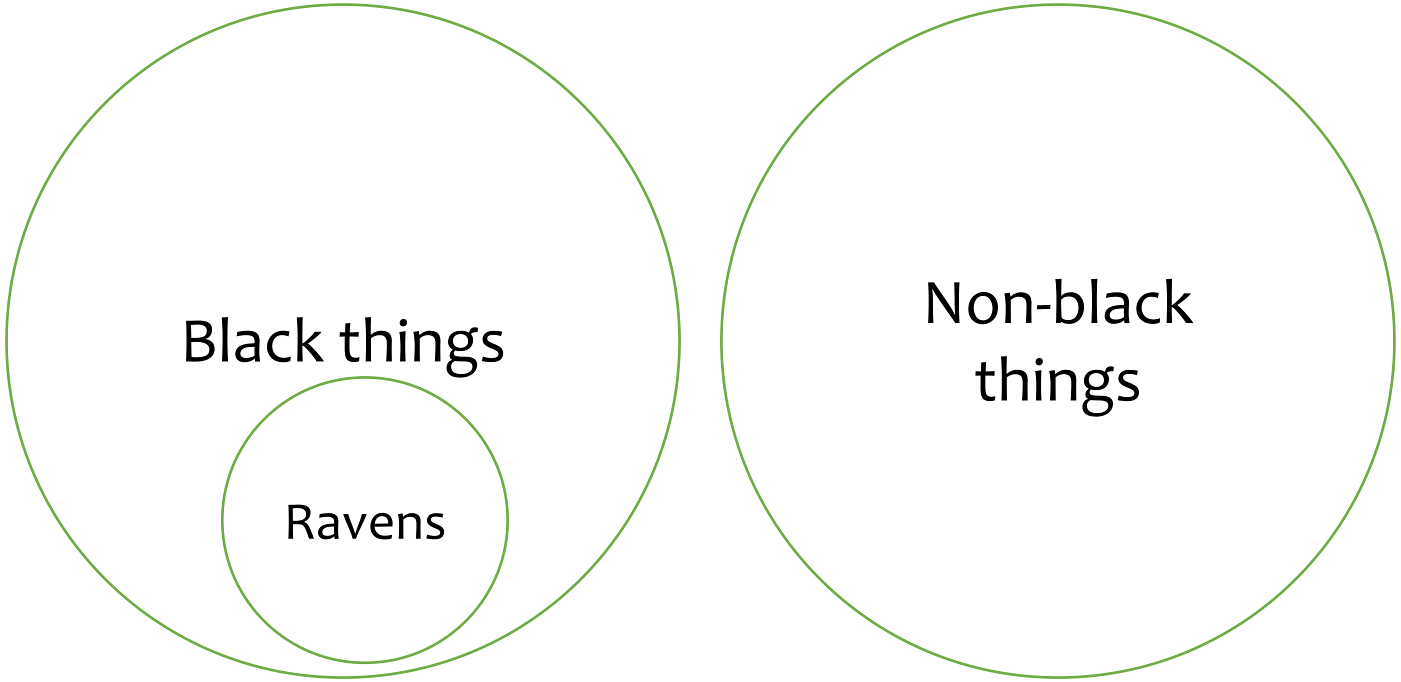
Raven 1

1. All ravens so far observed are black.
2. So all ravens are black.

- This is inductive, like **Sunrise Case 1**.
- Hempel considers the nature of the conclusion.

Hempel's Raven Paradox

All ravens are black. This describes the relation:



This relation can also be described as *All non-black things are not ravens*.

Hempel’s Raven Paradox

1. All ravens are black.
2. All non-black things are not ravens.

- These statements are *logically equivalent.*
  - Whenever (1) is true, (2) must also be true.
- So if we have reasons to believe (2) to be true, we also have reasons to believe (1) to be true.

Hempel’s Raven Paradox

- But consider:

1. All non-black things so far observed are not ravens.
   - E.g., snow is not black and is not ravens.
2. So all non-black things are not ravens.

- (1) supports the conclusion. So it should also support the logically equivalent conclusion that *all ravens are black*.
- But this sounds paradoxical: observing snow to learn about ravens!

Hempel’s Raven Paradox

- Of course, Hempel doesn’t think that observing snow tells us anything about ravens.
- That is, “All non-black things so far observed are not ravens.” is not evidence for “All ravens are black.”
- But then the paradox suggests that there must be some criteria for admissible evidence in inductive reasoning.

Hempel's Raven Paradox

- But then the paradox suggests that there must be some criteria for admissible evidence in inductive reasoning so that Raven 1 is legitimate induction, whereas Raven 2 is not.

Raven 1

1. All ravens so far observed are black.
2. So all ravens are black.

Raven 2

1. All non-black things so far observed are not ravens.
2. So all ravens are black.

Why Induction?

- Many of you have rightly wondered why induction is used in science at all, especially since induction cannot guarantee the truth of its conclusion.
- The foundational answer to this question—justifying induction—is an issue in philosophy of science.
- But we can appreciate why induction is *important* in science.
  - We know it is important. The question is why it is.

Why Induction?

- Recall the axiomatic method. It was the dominant method of science in the Western world until the 16th century.
- In the 16th century, some European philosophers and scientists (natural philosophers) advocated experimentation and aided observation (e.g., telescopes, microscopes).
  - Before then, Islamic scientists advocated experiments and observations.
- These methods are irrelevant to the axiomatic method.
  - Recall the axiomatic method is like the method of geometry.
  - Experiments and observations are irrelevant to deductive reasoning of geometry.

Why Induction?

- Of course, experiments and observations are heart of induction. They supply the premises for inductive reasoning.
- Now, what is important in the axiomatic method is first principles (necessarily true statements).
- In the Western science up to the 16^{th} century (and beyond), the Catholic Church decided what the first principles are.
  - They are usually Aristotelian beliefs that are also thought to be consistent with the Catholic view of the world.

Why Induction?

- Scientists who advocated induction (experiment, observation) used induction to challenge scientific authorities of their day (i.e., the Church).
- One way to do that was to develop a new worldview based on conclusions of inductive reasoning, which in turn used experiments and observations as evidence.
  - This procedure of course doesn't guarantee any certainty, unlike the axiomatic method.
  - But using induction to develop an alternative worldview was the only (and dangerous) way to challenge the Church's authorities.

Why Induction?

- Induction continues to be central to much of science today. Consider how we determine values of physical constants, such as the elementary charge:

1. Repeated experiments give the value of the elementary charge to be X.
2. So the elementary charge is X.

- This is induction, and the conclusion is a belief about *all* protons in the universe.