The Underdetermination of Theory by Evidence

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Today's Agenda

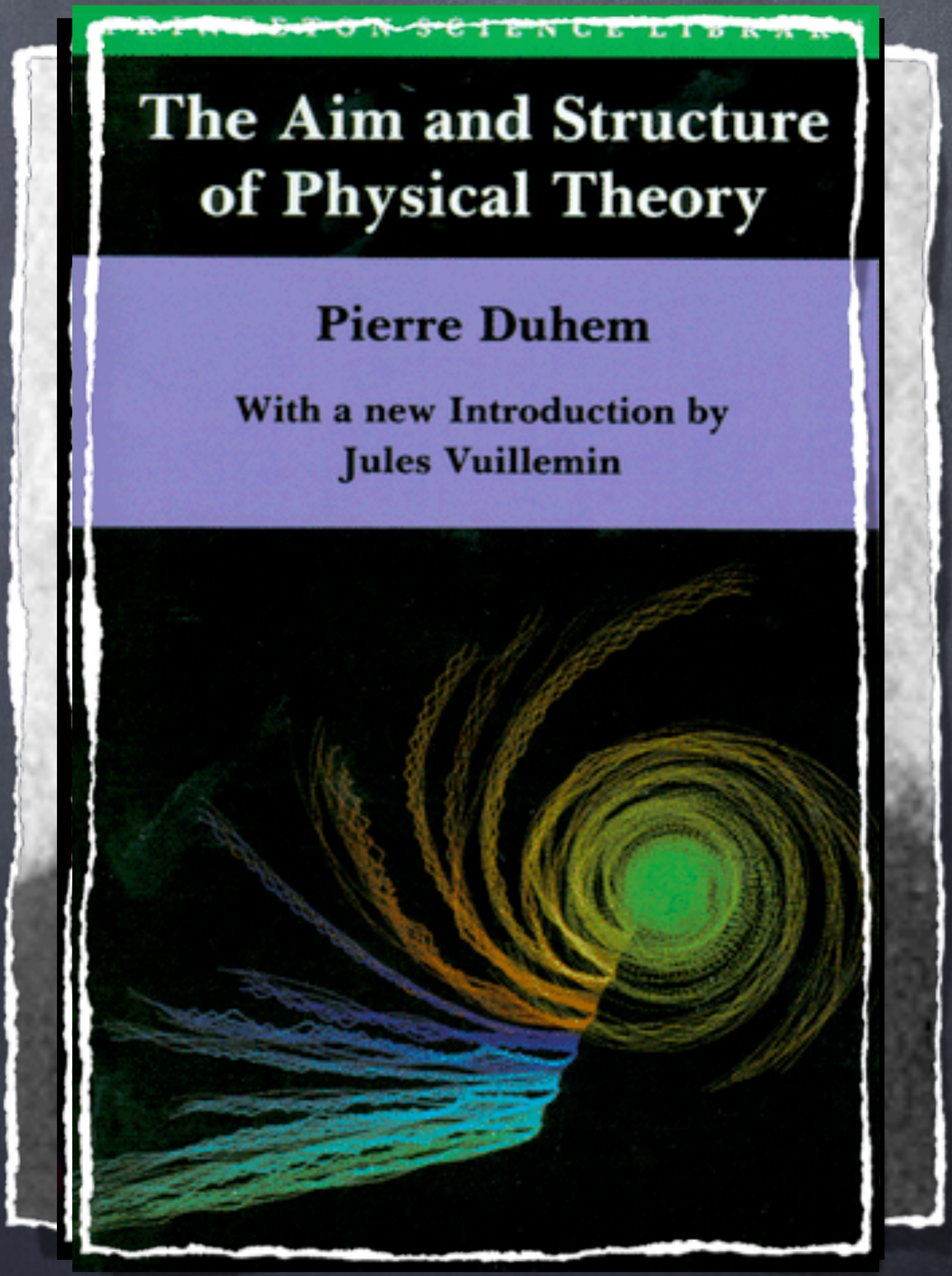
- We're discussing a challenge to attempts to reason from evidence to hypothesis: the underdetermination problem
- A hero in this story is the 19th century physicist Pierre Duhem
- He pointed to a problem in the confirmation of physical theories we now refer to as the Duhem problem or Duhem-Quine problem
- We'll then discuss another type of underdetermination and some responses to it

Background

- Yesterday we examined in some detail how William Whewell proposed to infer scientific hypotheses from the evidence
- He thought that this process led to a unique choice of hypotheses: 'discoverer's induction' plus tests using prediction, coherence and, in particular, consilience, guarantee the correctness of the hypothesis established in this way
- Today we'll examine a view according to which Whewell must be regarded as too optimistic: evidence never 'determines' scientific theory or 'speaks unambiguously'

Pierre Duhem

- 1861-1916
- French physicists, mathematician and historian/philosopher of science
- On the losing side of several disputes within science (e.g., relativity theory)
- But hugely insightful analyst of the logic of science



Duhem: We never test a hypothesis in isolation

- Duhem pointed out that scientific hypotheses by themselves do not make any interesting predictions
- For example, the hypothesis that planets travel in ellipses around the sun does not tell us whether or not we should see a bright spot in a certain location in the sky at a certain time tonight
- Scientific hypotheses make predictions only in conjunction with AUXILIARY HYPOTHESES

Auxiliary Hypotheses

- Auxiliary ('helping') hypotheses contain assumptions:
  - about the initial conditions (if we want to predict where a planet is tonight we must make an assumption about where it was some time in the past)
  - about additional laws of nature (how is light refracted by the atmosphere?)
  - about the workings of our experimental equipment (does our telescope work? does it introduce artefacts that need to be corrected?)
- Thus, in fact, predictions are derived from large bundles of assumptions

The logic of testing

- Is, consequently not a simple modus tollens:

  $h \rightarrow e$

  $\neg e$
  ___

  $\neg h$

- Or its positive counterpart (which is in fact a fallacy: the fallacy of affirming the consequent)

$h \rightarrow e$		$h \rightarrow e$
e	or	e
h		h is more likely

The logic of testing

- But rather a lot more complicated:

  $h \,\&\, a_1 \,\&\, a_2 \,\&\, \ldots \,\&\, a_n \rightarrow e$

  $\neg e$

  $\neg(h \vee a_1 \vee a_2 \vee \ldots \vee a_n)$

- And:

  $h \,\&\, a_1 \,\&\, a_2 \,\&\, \ldots \,\&\, a_n \rightarrow e$

  e

  $h \,\&\, a_1 \,\&\, a_2 \,\&\, \ldots \,\&\, a_n$

The Duhem Problem

- … is that we have no means to attribute praise or blame to a specific assumption/hypothesis
- Thus, what we learn in case of failure is that there is something wrong in the bundle of our assumptions; we don't know that this is due to the falsehood of the hypothesis or rather an auxiliary (e.g., contaminated equipment)
- Similarly, in case of success, we know only that the bundle has been successful; it is possible that two or more falsehoods conspire to produce a correct outcome

The Duhem Problem

- Recall Achinstein's example from the first reading group
- Hertz had argued that cathode rays are electrically neutral waves of some sort and thus wanted to rule out the hypothesis that they are charged particles (h)
- So Hertz arranged an experiment to test the hypothesis: in a set-up where cathode rays had to pass an electric field produced by charged plates, electrically neutral waves should not be affected whereas charged particles should be deflected

The Duhem Problem

- Let's call the evidence that was the be expected under the hypothesis h, 'Rays are deflected': e
- So, Hertz argued: h -> e; ¬e; therefore, ¬h; and therefore his preferred hypothesis received inductive support
- But he overlooked an important auxiliary assumption: the tube must not contain air, otherwise the air molecules can be ionised, thus neutralising the electric plates: a
- So in fact, he tested the bundle h & a:
  h & a -> e
  ¬e
  ———
  ¬(h v a)
- And we know that Thomson repeated the experiment using a different apparatus and e instead of ¬e obtained

The Duhem Problem

- Lesson: we never know for certain what we can learn from the evidence about the hypothesis of interest
- When things go right, this may be because the falseness of one assumption conspires with the falseness of the hypothesis so that the expected result occurs
- When things go wrong, we dont know whether to blame the hypothesis or an auxiliary

No crucial experiment

- Therefore, Duhem is sometimes credited with the phrase 'There is no crucial experiment'
- A crucial experiment is one that decides between two rivalling hypotheses - i.e., it proves one wrong and the other right
- The necessity of making auxiliary assumptions prevents this
- Duhem therefore argues that it is the physicist's good sense (bon sense) that decides how to interpret results

Aside: Quinean Holism

- Just to mention this: Willard van Orman Quine, one of the most important analytical philosophers of the 20th century took Duhem's point further and argued that each time we test a hypothesis, our entire 'web of belief' can be challenged
- Why? Even Duhem took logic, mathematics, meaning, causality etc. for granted. But why stop at auxiliaries?
- For example, Duhem accepted the principle of the excluded middle: $\vdash h \vee \neg h$
- Perhaps a better way to deal with conflicting experimental results is to challenge logic or mathematics?

A different kind of underdetermination

- The Duhem/Quine problem is called an 'underdetermination' problem because the evidence does not determine whether we should retain or eliminate a hypothesis
- There is another (related) kind of underdetermination: there may always be multiple hypotheses compatible with the same evidence
- These are so-called 'empirically equivalent' hypotheses

Empirically Equivalent Hypotheses

- Some famous fictional examples:
  - Brains in vats
  - Matrix
- Physics examples:
  - Is Newtonian absolute space at rest or moving?
  - Various interpretations of quantum mechanics
- Examples from the biomedical and social sciences:
  - 'Correlation is not causation'

Curve Fitting

- A mathematical analogy shows that it is indeed always possible that there are empirically equivalent hypotheses
- Hypotheses can only ever be tested against a finite number of data points
- As we collect more evidence, we can rule out some alternatives, but there always remain infinitely many...

Must hypotheses always be underdetermined?

- One argument that has been given against underdetermination is that there is no guarantee that, in scientific practice, there are always serious empirically equivalent contenders
- Over time experimental techniques improve, more things become observable/testable, we understand test equipment better etc. so that two theories, once indistinguishable, become distinguishable
- But perhaps it's enough that there is SOME empirical equivalent at each time? It doesn't have to be the same one
- Thus, even if we can rule out any alternative at some point in time, that doesn't mean that at each point, there isn't an alternative

Must hypotheses always be underdetermined?

- There might be other reasons to prefer one alternative over another:
    - Perhaps it's derivable from a more general theory and thus may receive indirect support?
    - Generally, some hypotheses may be more epistemically entrenched than others, more coherent with other beliefs that we hold

Must hypotheses always be underdetermined?

- Another possible response is to argue that the mere POSSIBILITY of an alternative isn't enough to show that for all our theories there always exists a serious alternative that cannot be eliminated on the basis of evidence
- It's very hard to come up with a good scientific theory that fits the evidence; much harder to come up with two or more!
- Until we are able to actually construct an empirically equivalent alternative to a given theory, the bare possibility that such equivalents exist is insufficient to justify suspending belief in the best theories we do have

A Final Challenge

- Perhaps it is indeed the case that present theories are not underdetermined by existing alternatives
- But this does not mean at all that there aren't alternatives that are presently unconceived by us
- And indeed, it seems that the history of science points in this direction
- In the progression from Aristotelian to Cartesian to Newtonian to contemporary mechanical theories, for instance, the evidence available at the time each earlier theory dominated the practice of its day also offered compelling support for each of the later alternatives (unconceived at the time) that would ultimately come to displace it
- Kyle Stanford's 'problem of unconceived alternatives'

In sum,

- There are two lines of argument showing that no matter how good our evidence, we cannot trust our hypotheses very much
- Duhemian 'holist' underdetermination: we don't know where to place praise or blame – in the hypothesis itself or rather in auxiliary assumptions needed to derive a prediction
- 'Contrastive' underdetermination: there may always be – actual or unconceived – alternatives that fit the evidence equally well but make different predictions about unobserved phenomena