

# Underdetermination and holism

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# Newtonian method: inductivism

Newtonian method: direct demonstration of every proposition of a theory by drawing from phenomena and generalizing by induction

Example: according to Newton, his law of universal gravitation

$$F_{12} = G \frac{m_1 m_2}{r^2}$$

is directly inductively inferred from Kepler's laws; **but...**

“The principle of universal gravity, very far from being derivable by generalization and induction from the observational laws of Kepler, formally contradicts these laws. If Newton's theory is correct, Kepler's laws are necessarily false.” (Duhem, p. 268)

[Kepler's laws assume e.g. that Earth is attracted to the sun, but not vice versa]

“[I]f the certainty of Newton’s theory does not emanate from Kepler’s laws, how will this theory prove its validity? It will calculate, with all the high degree of approximation that the constantly perfected methods of algebra involve, the perturbations which at each instant remove every heavenly body from the orbit assigned to it by Kepler’s laws; then it will compare the calculated perturbations with the perturbations observed by means of the most precise instruments and the most scrupulous methods.

“Such a comparison will not only bear on this or that part of the Newtonian principle, but will involve all its parts at the same time; with those it will also involve all the principles of dynamics; besides, it will call in the aid of all propositions of optics, the statics of gases, and the theory of heat, which are necessary to justify the properties of telescopes in their construction, regulation, and correction, and in the elimination of the errors caused by diurnal or annual aberration and by atmospheric refraction. It is no longer a matter of taking, one by one, laws justified by observation, and raising each of them by induction and generalization to the rank of principle; it is a matter of comparing the corollaries of a whole group of hypotheses to a whole group of facts.” (Duhem, p. 269)

“[In an applied science such as physiology,] so long as the experiment lasts, the theory should remain waiting, under strict orders to stay outside the doors of the laboratory; it should keep silent and leave the scientist without disturbing him while he faces the facts directly; the facts must be observed without a preconceived idea and gathered with the same scrupulous impartiality, whether they confirm or contradict the predictions of the theory...” (p. 258)

“[But in a fundamental science such as physics,] it is impossible to leave outside the laboratory door the theory that we wish to test, for without theory it is impossible to regulate a single instrument or to interpret a single reading.” (p. 259)



### Thesis (Holism)

*When a physical theory is put to test, it is an entire collection of theories and auxiliary hypotheses, rather than that single theory alone, which are tested.*

# Duhem's theses of holism

$T$ : theory to be tested  
 $A_1, \dots, A_n$ : auxiliary hypotheses and assumptions  
 $O_1$ : testable prediction, observational statement

## Thesis (D1)

*It is not the case that  $T$  alone implies  $O_1$ .*

## Thesis (D2)

*The conjunction of  $T$  with  $A_1$  and... and  $A_n$  implies  $O_1$ .*

# Ambiguity of falsification

It follows quite directly from (D1) and (D2) that falsification is **ambiguous**:

## Thesis (D3)

*It is not the case that if  $O_1$  is false, then  $T$  is false.*

## Thesis (D4)

*If  $O_1$  is false, then the conjunction of  $T$  with  $A_1$  and... and  $A_n$  is false.*

# Remarks on the ambiguity of falsification

- example: Newton's law of universal gravitation as discussed above
- nothing is implied about which conjunct should be given up
- (D3) and (D4) do not imply that it is always possible to modify the auxiliaries such as to retain belief in a theory no matter what the evidence
- “good sense” and mature scientific judgment demand that ailing theory should not be maintained obstinately at any cost (example of Biot who finally gave up his emission theory of light in the light of Foucault's experiment showing that light travelled more slowly in water than in air)
- needed: general argument for holism; Duhem: theory-ladenness of observation

# Theory-ladenness of observation

“An experiment in physics is not simply the observation of a phenomenon; it is, besides, the theoretical interpretation of this phenomenon... An experiment in physics is the precise observation of the phenomena accompanied by an *interpretation* of these phenomena; this interpretation substitutes for the concrete data really gathered by observation abstract and symbolic representations which correspond to them by virtue of the theories admitted by the observer.”  
(p. 358)

- physical theories use theoretical terms such as **voltage, force, pressure, entropy, current, temperature** etc in order to formulate their laws
- in order to connect theoretical predictions with direct observation, physicist must translate from everyday language of untrained observer to theoretical language of physicist
- theory thus plays an indispensable role in experiment
- this theory-ladenness of observation offers a general argument for holism

## Definition (Crucial experiment)

*A crucial experiment is an experiment that conclusively falsifies one of two competing hypotheses (or theories), thereby establishing its rival as confirmed.*

- candidates: Wiener's experiment on the direction of oscillation of polarized light; Foucault's measurement of the velocity of light in air and water
- Duhem: none of these are crucial experiment as defined above
- his holism implies (by (D3) and (D4)) that no experiment or observation can conclusively falsify a physical theory, and that therefore there cannot be crucial experiments in physics

- not possible to perform a variant of Mill's method of difference because the alternative to a theory  $T$  is not its logical contrary  $\text{not-}T$ , but a rival, call it  $T^*$
- truth of  $T^*$  does not follow from the falsity of  $T$ :

### Thesis (D5)

*It is not the case that if  $T$  is false, then  $T^*$  is true.*

- example: wave theory and particle theory of light do not exhaust range of possibilities
- there are no crucial experiment in physics because
  - 1 ambiguity of falsification (D3) and (D4)
  - 2 rival theories not logically exhaustive (D5)

## Thesis (conventionalism)

*Many fundamental postulates of physics (e.g. Newton's laws of motion, conservation principles, law of multiple proportions in chemistry, law of rational indices in crystallography) are not empirical hypotheses but conventional definitions, unrefutable by experiment.*

Duhem maintained that no hypothesis or postulate was completely immune from refutation:

“[H]ypotheses which by themselves have no physical meaning undergo experimental testing in exactly the same manner as other hypotheses. Whatever the nature of the hypothesis is, ... it is never in isolation contradicted by experiment...” (p. 277)