Holism and underdetermination

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Plan

1. Holism and crucial experiments
   - Duhem: holisme et expériences cruciales
   - Quine and confirmation holism
2. Logical and methodological underdetermination
   - (a) Logical underdetermination (LUD
   - (b) Methodological underdetermination (MUD)

Confirmation holism

- Pierre Duhem [*La théorie physique: son objet, sa structure*, 1906]
- Willard Van Orman Quine ['Two Dogmas of Empiricism', 1953]

Duhem and confirmation

- A experiment in physics is not simply the observation of a phenomenon; it is also the theoretical interpretation of that phenomenon.
- In order to obtain an interpretation, the physicist substitutes sensible qualities with symbolic and abstract representations which correspond to them by virtue of the theories accepted by the observer.

Examples of symbolic and abstract representations:

temperature, force, pressure,...

Duhem:

Pierre Duhem (1906). *La Théorie physique: Son objet, sa structure.*

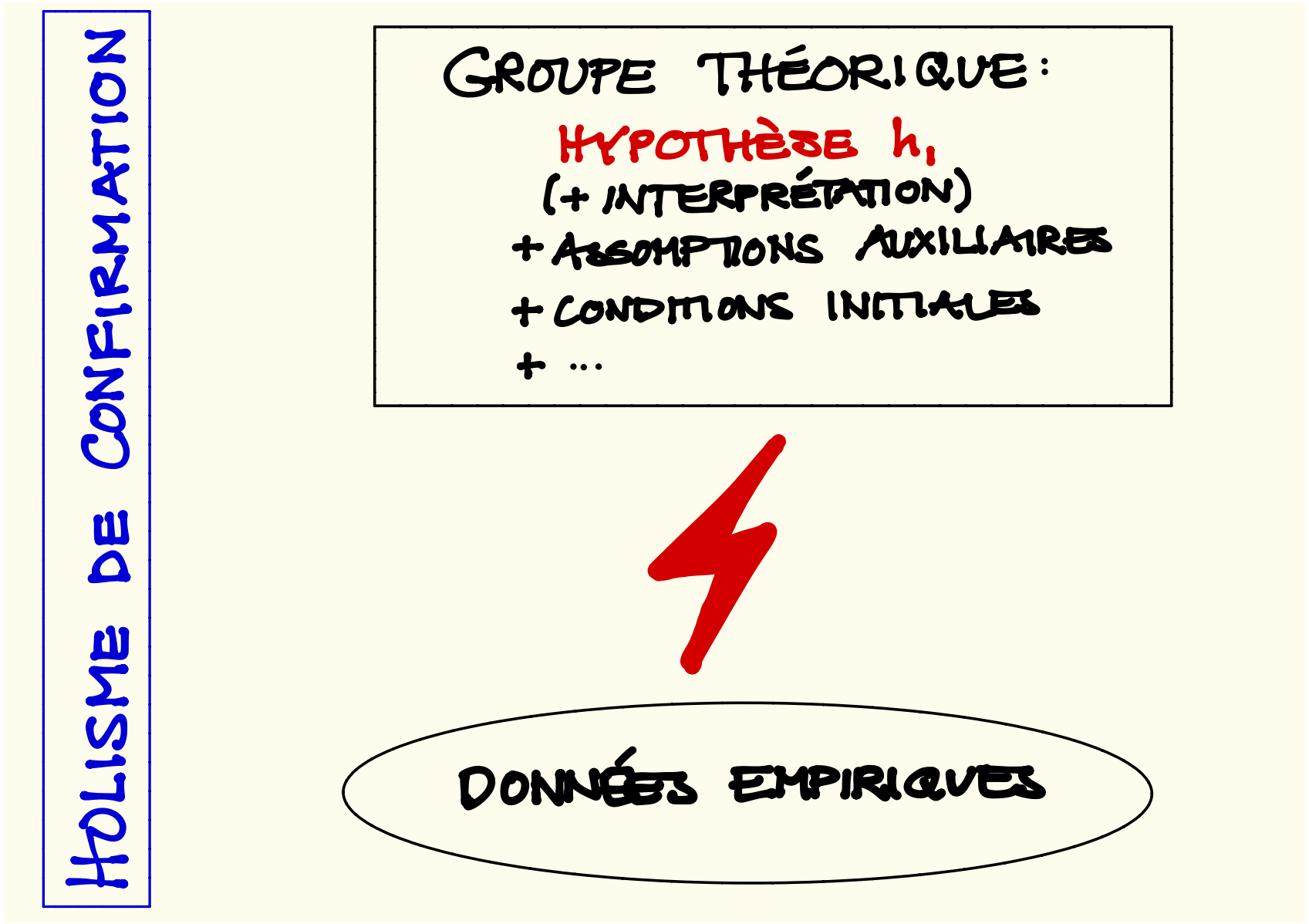
Duhem (1906, 281)

«La seule chose que nous apprenne l'expérience, c'est que, parmi toutes les propositions qui ont servi à prévoir ce phénomène et à constater qu'il ne se produisait pas, il y a au moins une erreur ; mais où gît cette erreur c'est ce qu'elle ne nous dit pas.»

Duhem (1906, 335)

«Mais il n'est point possible de comparer une conséquence isolée de la théorie à une loi expérimentale isolée. Ce sont les deux systèmes pris dans leur intégrité, le système entier des représentations théoriques, d'une part, le système entier des données d'observation d'autre part, qui doivent être comparés l'un à l'autre et dont la ressemblance doit être appréciée.»

The situation according to Duhem



Thesis (Holism)

An experiment in physics can never condemn an isolated physical hypothesis, but only an entire theoretical group.

An immediate consequence: the ambiguity of falsification, by modus tollens:

(p_1) $h\&a_1\&...\&a_n \rightarrow e$

(p_2) $\neg e$

(c) Thus, $\neg(h\&a_1\&...\&a_n)$

(c') Equivalently: $\neg h \vee \neg a_1 \vee ... \vee \neg a_n$

The OPERA experiment

Example: OPERA experiment

- Muon neutrinos produced at CERN and sent to Gran Sasso (Italy), where their time of flight was measured.
- In September 2011, the collaboration reported that these neutrinos reached their target about 60ns earlier than they would have, had they travelled at the speed of light. This difference is significantly larger than any that could be attributed to measurement errors.

Principle (Implication of special relativity)

No material body or signal can travel fast than the speed of light.

OPERA press release (Geneva, 23 September 2011)

`https://home.cern/news/press-release/cern/opera-experiment-reports-anomaly-flight-time-neutrinos-cern-gran-sasso`

Quoting from the press release

The OPERA measurement is at odds with well-established laws of nature, though science frequently progresses by overthrowing the established paradigms. For this reason, many searches have been made for deviations from Einstein's theory of relativity, so far not finding any such evidence. The strong constraints arising from these observations makes an interpretation of the OPERA measurement in terms of modification of Einstein's theory unlikely, and give further strong reason to seek new independent measurements.

"This result comes as a complete surprise," said OPERA spokesperson, Antonio Ereditato of the University of Bern. "After many months of studies and cross checks we have not found any instrumental effect that could explain the result of the measurement. While OPERA researchers will continue their studies, we are also looking forward to independent measurements to fully assess the nature of this observation."

"When an experiment finds an apparently unbelievable result and can find no artefact of the measurement to account for it, it's normal procedure to invite broader scrutiny, and this is exactly what the OPERA collaboration is doing, it's good scientific practice," said CERN Research Director Sergio Bertolucci. "If this measurement is confirmed, it might change our view of physics, but we need to be sure that there are no other, more mundane, explanations. That will require independent measurements."

OPERA: the resolution

- In February 2012, it was suspected that an optical fibre connection transferring the external GPS signal to the OPERA master clock in the computer was not properly connected and thus responsible for the result. This was confirmed later in 2012.
- Note that it took the large international collaboration half a year of busy work to identify and confirm the error.

$\Rightarrow$ In realistic and often complex scientific situations, it is often far from trivial to determine what exactly has been falsified.

Nota bene

Although Duhem talks about the refutation of hypotheses (by eliminative induction), his argument also concerns confirmation. A theoretical interpretation of the data is also necessary to confirm a hypothesis.

But a false interpretation can mask the falsity of a hypothesis. If the data can support a false hypothesis because of false theoretical interpretations, the experiment can only provide a reason to believe this hypothesis if we have a reason to believe that the theoretical interpretation is correct.

Crucial experiments in physics

Definition (Crucial experiment)

A crucial experiment is an experiment that conclusively falsifies one of the two competing hypotheses (or theories), and in so doing establishes its rival.

- candidates: Wiener's experiment on the orientation of the plane of oscillation of polarised light, Foucault's measurement of the speed of light in air and water

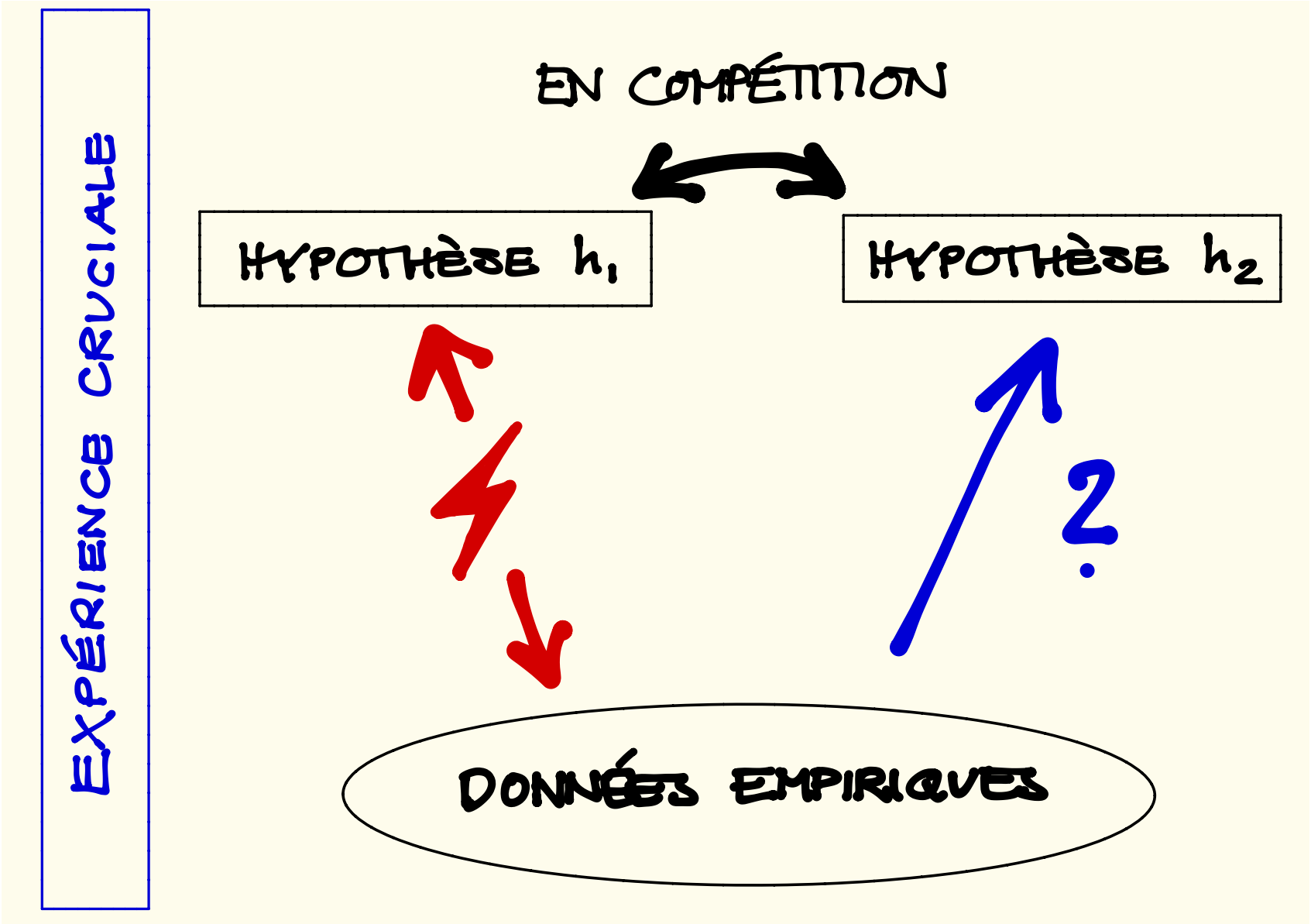
Thesis (Duhem)

None of these experiments is a crucial experiment as we have defined it.

Thesis (Crucial experiments in physics)

There are no crucial experiments in physics.

The situation according to Duhem



- Duhem's holism implies that no experiment or observation can conclusively falsify a physical theory, and that, consequently, there can be no crucial experiment in physics.
- In short, there are no crucial experiments in physics for two reasons:
  1. Because of the ambiguity of falsification, the incompatibility between h_1 and the empirical data (in red on the previous slide) is in question.
  2. Rival theories are not logically exhaustive: there are other logical possibilities and therefore, perhaps, other physical theories that are better.

Rival theories are not exhaustive

- It is impossible to practice a variant of Mill's method of difference because the alternative to a theory t is not its logical opposite $\neg t$, but a rival, say t^*.
- The truth of t does not follow from the falsity of t^*, and thus:

Thesis (Rival theories are not logically exhaustive)

It is not the case that: if t is false, then t^* is true.

Example

The wave and corpuscular theories of light do not exhaust the spectrum of possibilities.

Quine and confirmation holism

Thesis (Quine's confirmation holism)

Isolated propositions cannot be confirmed or refuted by experience. What is confronted by experience is always a system of propositions (an entire theory) and, in the final analysis, the totality of our knowledge.

[Summary by Michael Esfeld, Philosophie des sciences: une introduction, *2006]*

Quine's radical holism

W V Quine. Two dogmas of empiricism. *Philosophical Review* 60 (1951): 20-43.

Quine (1951)

[O]ur statements about the external world face the tribunal of sense experience not individually but only as a corporate body...

The totality of our so-called knowledge or beliefs, from the most casual matters of geography and history to the profoundest laws of atomic physics or even of pure mathematics and logic, is a man-made fabric which impinges on experience only along the edges. Or, to change the figure, total science is like a field of force whose boundary conditions are experience. A conflict with experience at the periphery occasions readjustments in the interior of the field. Truth values have to be redistributed over some of our statements. Re-evaluation of some statements entails re-evaluation of others, because of their logical interconnections—the logical laws being in turn simply certain further statements of the system, certain further elements of the field.

Quine's radical holism

Quine (1951)

Having re-evaluated one statement we must re-evaluate some others, whether they be statements logically connected with the first or whether they be the statements of logical connections themselves. But the total field is so underdetermined by its boundary conditions, experience, that there is much latitude of choice as to what statements to re-evaluate in the light of any single contrary experience. No particular experiences are linked with any particular statements in the interior of the field, except indirectly through considerations of equilibrium affecting the field as a whole.

Quine's radical holism

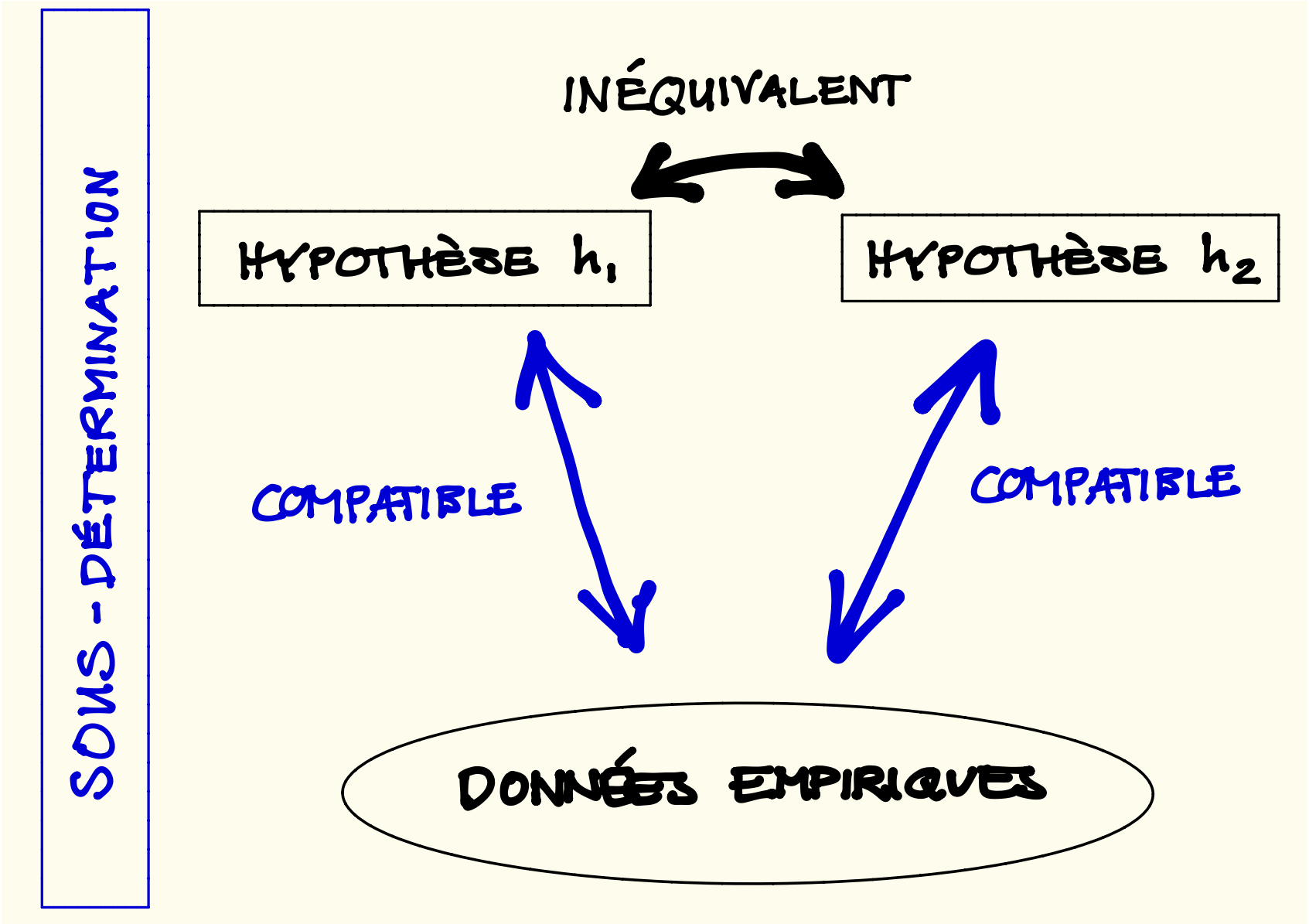
Quine (1951)

If this view is right, it is misleading to speak of the empirical content of an individual statement—especially if it be a statement at all remote from the experiential periphery of the field. Furthermore it becomes folly to seek a boundary between synthetic statements, which hold contingently on experience, and analytic statements which hold come what may. Any statement can be held true come what may, if we make drastic enough adjustments elsewhere in the system. Even a statement very close to the periphery can be held true in the face of recalcitrant experience by pleading hallucination or by amending certain statements of the kind called logical laws. Conversely, by the same token, no statement is immune to revision. Revision even of the logical law of the excluded middle has been proposed as a means of simplifying quantum mechanics; and what difference is there in principle between such a shift and the shift whereby Kepler superseded Ptolemy, or Einstein Newton, or Darwin Aristotle? (39f)

Underdetermination as a consequence of holism

- If it is an entire theoretical group, or even the totality of our knowledge, that is submitted to the tribunal of empirical confirmation, then in general, scientific hypotheses or theories are underdetermined by the empirical data.
- Let's study this idea...

Underdetermination: the situation



Underdetermination

Thesis (Underdetermination)

Empirical data are often compatible with more than one hypothesis.

Let us distinguish two forms of underdetermination:

1. Logical underdetermination (LUD)
2. Methodological underdetermination (MUD)
   - MUD: weak form and strong form

Example

The ideal gas law of Boyle(-Mariotte) (cf. lecture 4, pp. 21-22) is underdetermined by empirical data.

(a) Logical underdetermination (LUD)

Definition (LUD)

The underdetermination of a theory by empirical data is a logical underdetermination if it is logical reasoning that is at its origin.

(p) I have waken up every morning until now.

(c_1) Thus, I will always wake up

(c_2) Thus, I will wake up every morning until ...

- Both conclusions are compatible with the premise, but this is trivial; this fact arises from the inductive nature of this inference.
- In inductive inferences, there are always several conclusions compatible with the premises. Only in deductive inferences is the conclusion sometimes determined solely by the premises.

Logical underdetermination can consist in the logical compatibility of data with more than one hypothesis (absence of contradictions) or in the logical implication of the same data by different hypotheses:

$h_1 \rightarrow e$

$h_2 \rightarrow e$

$h_3 \rightarrow e$

(b) Methodological underdetermination (MUD)

Definition (MUD)

Theories (hypotheses) are underdetermined by empirical data augmented by rules of ampliative inference.

Example

Boyle's law is no longer underdetermined by the empirical data if we use standard regression methods (multilinear or polynomial) and adjust the curve.

LUD vs. MUD

Example: smoking and cancer

- LUD: The empirical data are logically compatible with these two hypotheses:

(1) Smoking causes lung cancer.

(2) There are genes that cause not only lung cancer but also addictive behaviour.

- Nevertheless, data augmented by causal inference methods (statistics) confirm hypothesis (1).

$\Rightarrow$ No MUD!

[Note the use of the word 'confirmation' in the methodology: 'e confirms h' = there is a 'good' inductive inference from e to h; no definitive proof is needed.]

Weak MUD

- In the weak form of the methodological underdetermination thesis: if the data are not sufficient, other data will arrive later which will break the underdetermination by favouring one of the hypothesis over the others.
- The existence of weak MUD is not disputed.

Examples: weak MUD

- Ptolemaic astronomy and Copernican astronomy between 1540 and 1620
- wave and corpuscular theories of light before 1900
- Atomism and anti-atomism between 1800 and 1905

In all these cases, at least for a time, the observational data did not allow a choice between one or the other, even if the most reliable methods of ampliative inference were employed.

But new data made it possible to choose a theory more recently, so the MUD had a temporary, transient character.

Strong MUD

Strong form of MUD

The MUD is of a strong form if a set of hypotheses can never be decided on the basis of data, because for any set of data that confirms a hypothesis h_1 there exists a hypothesis h_2 (and perhaps h_3, h_4...) that is also confirmed by the same data.

- This form of MUD is hotly debated in philosophy of science.
- Why?
- Because strong MUD prevents science from discovering a single reality, and is therefore in conflict with scientific realism!

Example

Standard quantum mechanics and Bohmian quantum mechanics are empirically equivalent and are thus an example of strong MUD.