Scientific explanation

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Explanation as purpose of science

- some believe that science must deliver explanation of why something happens—over and above description of what happens or prediction of what will happen
- assume we have a theory
- problem of explanation may not be independent from problem of evidence (What is it to have evidence to believe in a theory?)
- explanatory inference: inference from set of data to hypothesis that would explain data
- general goal: give individually necessary and jointly sufficient conditions which a scientific explanation must satisfy
- logical empiricism: covering-law model of explanation

The logic of explanation

Question

What is a scientific explanation?

Carl G Hempel and Paul Oppenheim. Studies in the logic of explanation. *Philosophy of Science* 15 (1948): 135-175.

Hempel and Oppenheim (1948, 152)

> *By the explanandum, we understand the sentence describing the phenomenon to be explained (not that phenomenon itself); by the explanans, the class of those sentences which are adduced to account for the phenomenon.*

- *explanandum*: that which is to be explained
- *explanans*: what does the explaining
- explain = show how to derive by logical argument
- premises (= explanans), conclusion (= explanandum)

D-N ('deductive-nomological') model of explanation

(AKA 'H-O scheme of explanation')

'nomos' = (Greek) law

(1) $L_1, ..., L_n$ *(general laws of nature)*
(2) $C_1, ..., C_m$ *(particular facts)*

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(3) E (explanandum)

$\Rightarrow$ not much difference between explanation and prediction!

Conditions of adequacy

An argument of the form of the H-O scheme qualifies as scientific explanation if (among others) the following conditions are satisfied:

1. The explanandum follows deductively from the propositions in the explanans.
2. All propositions of the explanans are true.
3. The explanans contains at least one proposition expressing a general law of nature.
4. The explanandum does not follow from the non-nomological (= non-lawful) propositions of the explanans alone.
5. The laws in the explanans are not only true, but also in fact laws of nature according to our best science.

The first two conditions can be seen as the 'deductive' part, and conditions 3 through 5 as the 'nomological' part of the explanation.

Hempel 1962: 'Hierarchy of covering laws'

Carl G Hempel (1962). Explanation in science and in history. In Robert Garland Colodney (ed.), *Frontiers of Science and Philosophy*, University of Pittsburgh Press, pp. 9-33.

Central idea:

Explanation as subsumption under 'covering laws'.

particular fact [this stone dropped just now falls...]

$\Downarrow$

class of particular phenomena [stones dropped fall towards Earth's center]

$\Downarrow$

empirical generalization [Galileo's law of free fall]

$\Downarrow$

comprehensive theories [Newtonian mechanics]

$\Downarrow$

more comprehensive theories [general relativity]

$\Rightarrow$ increase in breadth and depth of scientific understanding

breadth: new principles cover broader range of phenomena

depth: original empirical laws seen as holding only approximately or within certain limits

Note:

- (Often) causal explanations are deductive-nomological in character, but there are D-N explanations which aren't causal (e.g. subsumption of Kepler's laws under Newtonian mechanics, temporal order may be different).

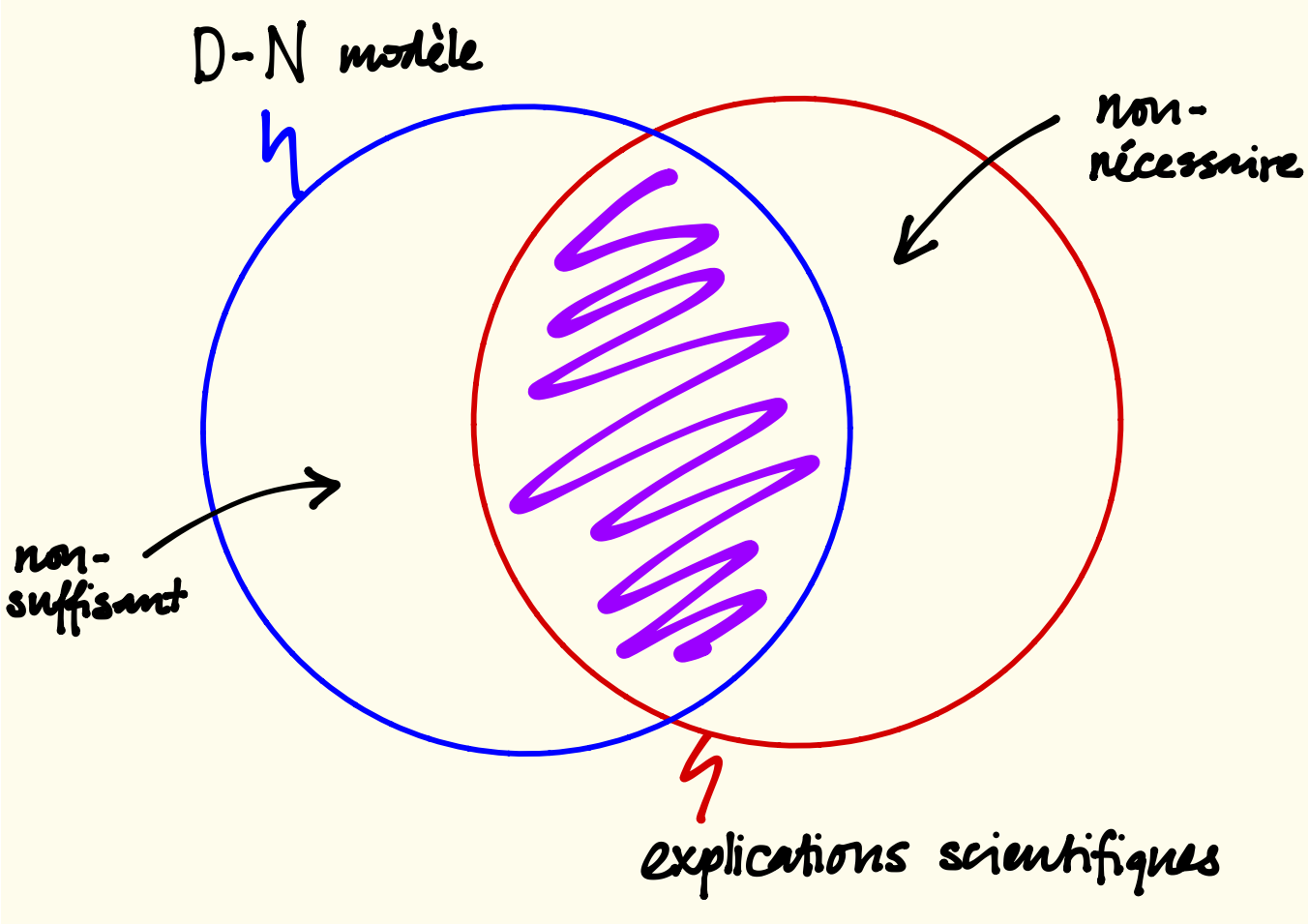
$\Rightarrow$ {Causal explanations} $\subset$ {D-N explanations}

Difficulties of the D-N model

The difficulties come in two broad categories:

- The D-N model is not necessary, i.e. there are sets of statements that clearly are explanations but do not qualify as explanations according to the D-N model $\Rightarrow$ conditions are too narrow.
- The D-N model is not sufficient, i.e. there are sets of statements that qualify as explanations according to the D-N model yet one would not normally think of them as explanatory $\Rightarrow$ conditions are too broad.

Difficulties of the D-N model



The D-N model as unnecessary

1. Probabilistic explanations seem important in medicine, genetics, quantum mechanics, statistical physics... yet D-N model can't account for them.
2. Michael Scriven (1962): statement 'The impact of my knee on the desk caused the tipping over of the inkwell' should count as explanatory although it does not involve a law

Michael Scriven (1962). Explanations, predictions, and laws. In H Feigl and G Maxwell (eds.), *Minnesota Studies in the Philosophy of Science*, vol. III. University of Minnesota Press, pp. 170-230.

(1) Probabilistic explanation (I-S model)

Probabilistic explanations: not deductively valid argument as demanded by D-N model (adequacy condition 1 violated)

$\Rightarrow$ inductive-statistical explanations (I-S model)

Two features:

1. The laws are of probabilistic-statistical form such as 'Smoking leads to lung cancer'.
2. The inference is not deductively valid, only 'inductive'.

(1) Fi (in case i, factors F were realized)
(2) $p(O, F)$ is very high (law of probabilistic form)

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(3) Oi (instance i under consideration has outcome of type O)

Important: (1) and (2) make (3) very likely rather than deductively certain (indicated by double line)

likelihood: relation (capable of gradation) between statements—not kinds of occurrences as in the probabilistic law; 'strength of inductive support', 'degree of rational credibility'

I-S model is natural extension of D-N model because of...

- nomic expectability: a phenomenon is explained if it is shown that it is to be rationally expected, given the particular circumstances and the relevant laws
- (deflationist account of causation: Humean regularity theory of causation)

(2) Self-admitted limitation of D-N model

- Many scientific explanations are incomplete (or elliptic): either they do not explicitly contain a law, or they do not list all the particular facts necessary to deduce the explanandum.
- Although gaps in explanations often can readily be filled in, this is generally not the case because particular events have an infinity of different aspects, they cannot all be accounted for by an finite number of explanatory statements.

Scriven's example reconstructed

(from Woodward, 2003, Section 2.4)

1. "Whenever knees impact tables on which an inkwell sits and further conditions K are met (where K specifies that the impact is sufficiently forceful, etc.), the inkwell will tip over. (Reference to K is necessary since the impact of knees on table with inkwells does not always result in tipping.)
2. "My knee impacted a tables on which an inkwell sits and further conditions K are met.

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3. "The inkwell tips over."

The D-N model as insufficient: causation

If explanans and explanandum don't stand in the relevant causal relation, insufficiency worries arise:

1. Retrodiction: position of planet today and the laws of celestial mechanics don't explain the plant's position yesterday
2. Common cause: the falling barometer and the laws of meteorology don't explain the incoming low-pressure front; neither do the yellow fingers and the 'laws of medicine' explain the lung cancer
3. Asymmetry (Sylvain Bromberger 1966): case of flagpole and shadow

- General: Problems concerning causal relations point to possibility that explanation and prediction may not be on a par
- Hempel's reply: if D-N model allows explanations to run in two directions, both directions must really be OK

Bromberger's flagpole problem

Sylvain Bromberger (1966). Why questions. In Robert Colodny (ed.), *Mind and Cosmos: Essays in Contemporary Science and Philosophy*. University of Pittsburgh Press.

A mast of height h casts a shadow of size r. We can give a perfectly satisfactory D-N explanation for the size of the shadow (the explanandum in this case):

(1) Law of rectilinear projection of light (general law)
(2) Specific circumstances: h, angle of incidence of the light α

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(3) $r = h/tan\alpha$

Bromberger's flagpole problem

But we can give a D-N explanation for the height of the mast in an analogous way:

- A mast of height h casts a shadow of size r. We can give a D-N explanation for the size of the mast (the explanandum in this case):

  (1) Law of rectilinear projection of light (general law)
  (2) Specific circumstances: r, angle of incidence of the light α

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  (3) $h = r\tan\alpha$

But...

... the size of the shadow does not explain the height of the mast!

Bromberger's flagpole problem

- The D-N model of explanation implies symmetry of explanation and prediction. But in fact, this symmetry does not exist in real explanations.
- On the contrary, causal explanations are typically not symmetrical; their asymmetry is a consequence of the asymmetry of the causal relationship.

The D-N model as insufficient: irrelevance

Wesley C Salmon (1971). Statistical explanation. In Robert Colodny (ed.), *The Nature and Function of Scientific Theories*. University of Pittsburgh Press, pp. 173-231.

(I) All persons who take birth control pills regularly fail to get pregnant.
(c_1) John Jones is a person.
(c_2) John Jones has been taking birth control pills regularly.

(e) John Jones fails to get pregnant.

These arguments indicate that we may need additional conditions, i.e. that the D-N model only offers necessary, but (jointly) insufficient conditions.

Recent directions in scientific explanation

1. (van Fraassen) pragmatic account of explanation
2. (Kitcher, Friedman) explanation in terms of unification: explanation is matter of connecting diverse set of facts by connecting them under a set of basic patterns and principles
3. (Nagel) explanation in terms of reduction: explaining a theory and the phenomena it addresses by 'reducing' it to a more fundamental theory
4. (Salmon) explanation in terms of causation: explaining a natural phenomenon is to state its (necessary and) sufficient causes
5. pluralism about explanation: all of these important types of explanatory relations, and possibly more
6. contextualism with respect to explanation: standards for good explanations depends on context, particularly on sci discipline and on historical period

General lessons of the modules on confirmation and explanation

- The project of logical empiricism to deal with meta-scientific concepts such as confirmation and explanation by employing only logical notions fails.
- It is not possible to completely avoid metaphysical notions, in particular causal concepts (unless one adopts a point of view such as that of Pierre Duhem according to which the sciences cannot provide explanations but only classifications of phenomena).
- The notions of confirmation, explanation, and also law of nature are much more richer and complicated than logical empiricists (initially) thought.