Scientific Explanation: From the Deductive-Nomological to the Causal Model

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Outline

What Is a Scientific Explanation?

Distinguish two types of scientific knowledge:

1. descriptive knowledge ("knowledge *that*");
   e.g.: The density of ice is smaller than the density of water.
2. explanatory knowledge ("knowledge *why*");
   e.g.: The ice cube stays on the surface *because* its density is smaller than the density of water.

The central question

What exactly is the difference between these two kinds of knowledge?

First idea: someone who has explanatory knowledge does not only know some facts about ice and water, but also what these facts imply about a specific phenomenon.

The Deductive-Nomological Model of Explanation

Basic idea of the D-N model

To explain X is to give an argument in which X is deduced from laws of nature and some specific conditions.

The premises of this arguments are called explanans,
X is called explanandum.

Simple example

Laws:

- The density of ice is smaller than the density of water.
- (some laws of fluid mechanics)

Specific conditions (also called *antecedent* conditions):

- An ice cube is placed into water (on earth).
- (information about the earth's gravitational field)

The ice cube stays on the surface of the water.

Generalizations of the D-N Model

- The D-N model does not only apply to explanations of *particular facts* (such as the floating of our ice cube). It also applies to explanations of *general regularities*. (Example: the derivation of Kepler's laws from Newton's laws of motion and gravitation)
- However, the D-N model does not apply when laws are *probabilistic*. For this case, two related models have been introduced (see Hempel 1965*):
  1. the inductive-statistical (I-S) model for explanations of particular facts by probabilistic laws;
     (example: explaining a patient's recovery from an infection by his taking of penicillin)
  2. the deductive-statistical (D-S) model for explanations of probabilistic regularities by more general probabilistic laws.
     (Example: the derivation of the half-life of uranium-238 from the laws of nuclear physics)

* All references can be found on pp. 16–17 of the course booklet.

What Is a Law of Nature?

Since D-N explanations are characterized by the fact that the explanans contains at least one law of nature, we need to know how to distinguish laws from other general statements. Consider the two statements (from Salmon 2006, 15):

1. No gold sphere has a mass greater than 100'000 kg.
2. No enriched uranium sphere has a mass greater than 100'000 kg.

Both statements are completely general and (most probably) true. What is the difference between them?

- Statement 2 is a *lawful* generalization, while 1 is an *accidental* generalization. But what is lawfulness?
- Statement 2 supports counterfactuals, while 1 does not. But the notion of counterfactual depends on the notion of law.

Explanations without Laws

Example (Woodward 2009, subsection 2.4)

"The impact of my knee on the desk caused the tipping over of the inkwell."

This statement seems perfectly explanatory, but it does not have a D-N structure.

Possible reply by the proponent of the D-N model:

The hidden structure strategy

"cause" needs to be analyzed in terms of regularities (and, ultimately, laws), so the example really has a hidden D-N structure.

However, it is not clear whether the hidden structure strategy can be made to work.

Explanatory Asymmetries and Irrelevancies

Example 1 (Woodward 2009, subsection 2.5)

One can explain the length s of the shadow cast by a flagpole by deriving it from the height h of the pole, the angle θ of the sun above the horizon and laws about the propagation of light. But in the same way, one could "explain" the height of the pole by deriving it from s and θ and the same laws.

Example 2 (ibid.)

All males who take birth control pills fail to get pregnant.

John Jones is a male who has been taking birth control pills.

John Jones fails to get pregnant.

Explanatory Asymmetries and Irrelevancies

Consequence of the examples

The D-N model does not state sufficient conditions for what it is to be an explanation; something can conform to the D-N scheme without being an explanation.

Possible reactions:

1. Try to find *additional conditions*, which, together with the D-N-conditions are sufficient ($\rightarrow$ unificationist model of explanation). Note that this approach still relies on the hidden structure strategy.
   (For more on the unificationist model, see Woodward 2009, section 5; Friedman 1974 and Kitcher 1981)
2. Abandon the D-N model and focus on the causal aspects of explanation.

General Remarks about Causal Explanation

A causal model's advantages over the D-N model:

inkwell example: No appeal to “hidden structure” is needed, the statement can be seen as explanatory as it stands.

flagpole example: The height of the pole h explains the length of the shadow s (and not vice versa), because h causes s (and not vice versa).

pregnancy example: Taking the pills does not cause Jones' failure to get pregnant, so it is not an acceptable explanation.

However, there is a challenge. . .

For the causal model to be informative, we need to explicate what we mean by “cause”!

The Statistical Relevance (S-R) Model

See Woodward 2009, section 3

The basic idea

C is statistically relevant for E if and only if $P(E \mid C) \neq P(E)$

Applied to the pregnancy example: Let

C = taking of birth control pills,

E = pregnancy.

If we consider a male population, then the irrelevancy of C is clear from $P(E \mid C) = P(E) = 0$.

By contrast, in a female population, $P(E \mid C) < P(E)$, thus C is statistically (and therefore explanatorily) relevant.

Contrast between the I-S and the S-R model (Salmon 2006, 67)

An I-S explanation implies that the explanandum occurs *with high probability*. An S-R explanation only requires the explanans to be statistically relevant to the explanandum, *regardless of the degree of probability that results*.

Causal Relevance $\neq$ Statistical Relevance

A real life example (from Cartwright 1983, 37–38):

- The graduate school at Berkeley was accused of discriminating against women, because it was found that $P(A \mid W) < P(A)$ (where A = acceptance to the program and W = being a woman).
- However, if one looks at each department separately, it turns out that $P(A \mid W) \approx P(A)$. The difference in total acceptance comes from the fact that women tended to apply to departments with high rejection rates.
- Therefore, being a woman is statistically, but not causally relevant for acceptance at Berkeley.

According to Cartwright (and Woodward), causal relevance differs from statistical relevance in that it grounds effective strategies. By contrast, Salmon tries to locate the difference in the analysis of causal processes.

The Causal-Mechanical (C-M) Model

See Woodward 2009, section 4; Salmon 1998 and Dowe 2008

The basic idea

To explain X is to describe the causal processes and interactions that lead up to X and those that constitute X.

- A process is something which displays consistency of structure over time.
- A causal process is a process able to transmit a mark in a continuous way.

Some problems of the C-M model:

- Causal processes have several properties, not all of which are causally (and explanatorily) relevant to the explanandum.
- For many explanations (e.g. in thermodynamics, biology, economics), the tracing of causal processes is irrelevant.