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Wissenschaftstheorie & Einführung in das wissenschaftliche Arbeiten

Wissenschaftstheorie & Erkenntnistheorie II: Scientific inquiry (method & explanation)

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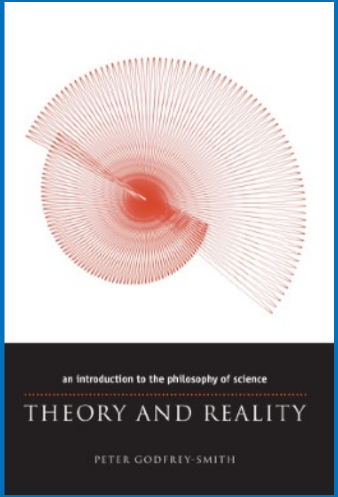
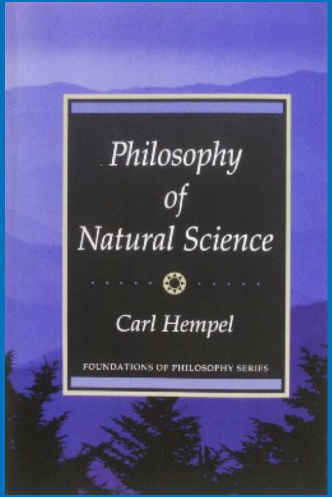




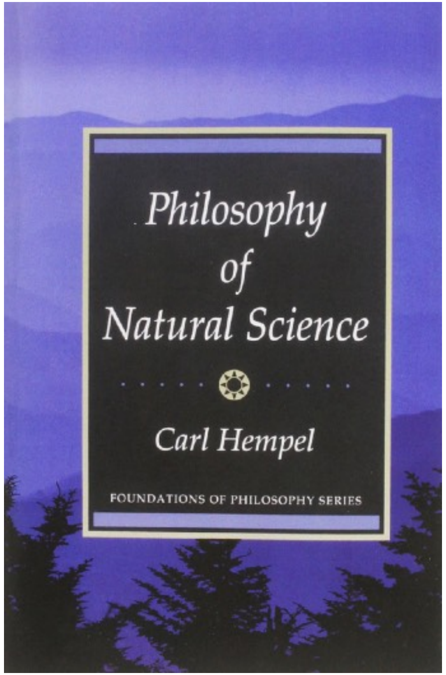
Scientific method

Scientific inquiry

scientific inquiry

- empirical
  - natural sciences (physics, chemistry, biology)
  - social sciences (sociology, anthropology economics)
- non-empirical (logic & pure-maths)

psychology



Ideal scientific inquiry?
— from data to general principles

"If we try to imagine how a mind of superhuman power and reach, but normal so far as the logical processes of its thought are concerned (…) would use the scientific method, the process would be as follows: First, all facts would be observed and recorded, *without selection* or *a priori* guess as to their relative importance. Secondly, the observed and recorded facts would be analysed, compared, and classified, without hypothesis or postulates other than those necessarily involved in the logic of thought. Third, from this analysis of the facts generalisations would be inductively drawn as to the relations, classificatory or causal, between them. Fourth, further research would be deductive as well as inductive, employing inferences from previously established generalisations."

Wolfe (1924). "Functional Economics" in Hempel (1966)

Naive inductivism (Induktivismus) — un-biased collection of observations

1. Observe and record all facts
2. Analyse and classify all these facts
3. Draw inductive generalisations
4. Derive testable predictions and test them

   Objectivity requires a neutral collection of facts without any pre-conceived ideas.

Objections

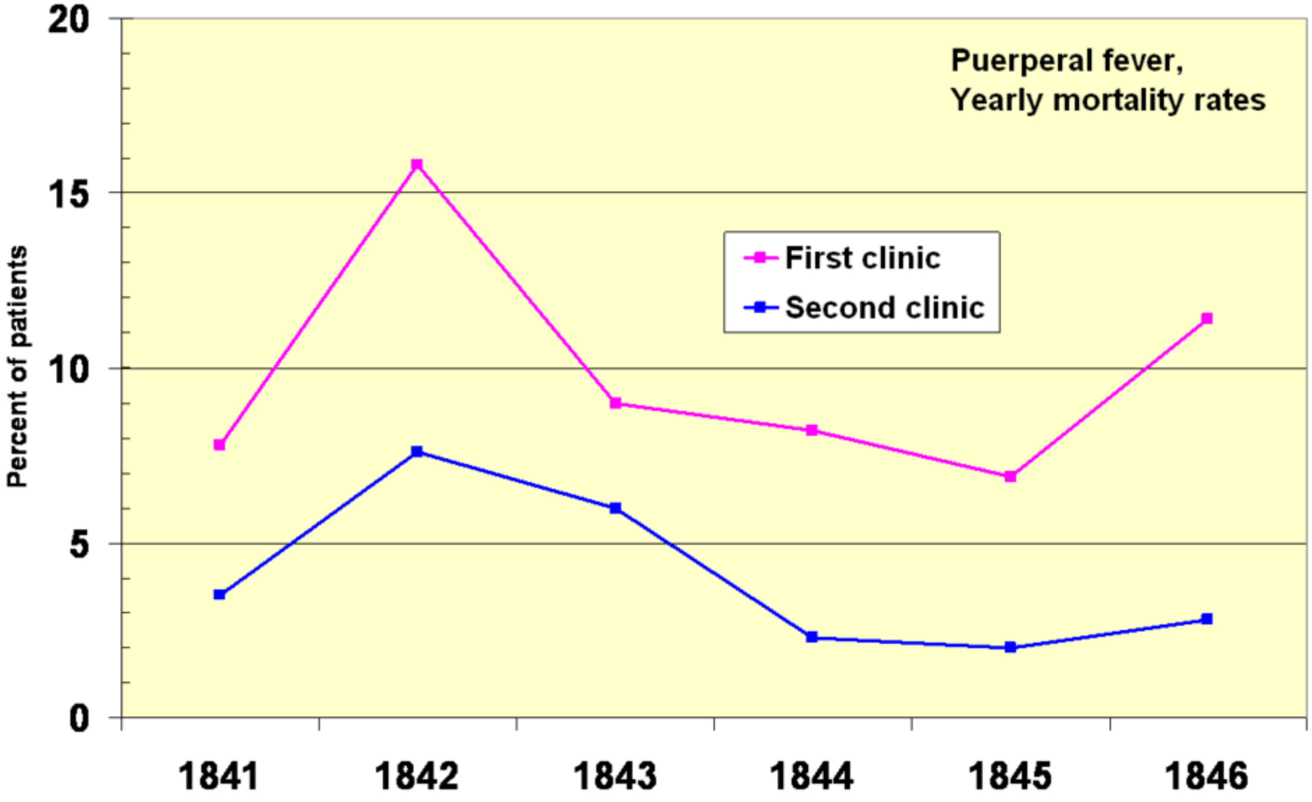
- How to start? How to collect *all* facts? If *relevant* facts ought to be collected, then *relevant to what*?
    - we need first a specified problem and collect all *available* data relevant to that problem, which is determined not by that problem but by a tentative answer.
- Facts / data can be classified / analysed in many different ways some of which will shed no light on the given problem and some may be un-trustworthy
    - meaningful analysis pre-supposes an idea how facts are connected
- How are we supposed to mechanistically derive theories from observations?
    - Theories are formulated in theoretical (not observational, immediate) terms (e.g., atom, working memory) to go beyond simple description of the data
    - “Theories are not *derived* from observed facts, but *invented* to account for them.” (Hempel)
- Objectivity is safe-guarded not by a pure and un-biased collection of facts but by critical scrutiny of subjectively invented ideas that requires suitable tests of their implications with careful observations or experiments.

Scientific inquiry
— invention and test

- A Hungarian physician ("saviour of mothers”) who was an early pioneer of antiseptic procedures.
- Puerperal fever ("childbed fever” / bacterial infection of the female reproductive tract following childbirth) was common in mid-19th-century hospitals and often fatal.
- Proposed hand-washing to reduce the mortality (down to 1% from ~10-14%)
- Rejected by the medical community because of no theoretical explanation.
- Years after his death (in mental asylum), L. Pasteur would offer the germ theory providing the theoretical explanation.

Ignaz Semmelweis (1818 - 1865)

Two clinics…


Puerperal fever,
Yearly mortality rates
First clinic
Second clinic
Percent of patients
20
15
10
5
0
1841
1842
1843
1844
1845
1846

Considering various hypotheses and testing…

- “epidemic influences”
    - why so selective? (First vs Second clinic)
    - childbed fever lower in “street birth” than in the First clinic
- “overcrowding”
    - but crowding was heavier in Second clinic
- “injuries due to rough examination by the medical students”
    - injuries from birth are much more extensive than from examination
    - the midwives in Second clinic do it the same way
    - number of students was reduced but the mortality after brief decline increased
- “position” (in First Clinic on the back, in Second on a side)
    - mortality remained unaffected after introducing the lateral position
- accident in 1874: a colleague, Kolletschka died after a puncture wound when performing an autopsy displaying similar course of symptoms to “childbed fever”
    - idea: medical student were carries of the infectious material when coming directly from performing the autopsy
    - washing hands in a solution of chlorinated lime before making an examination
    - mortality promptly began to decrease

The hypothetico-deductive method — the procedure

1. Specify a problem of inquiry.
2. Invent a hypothesis (by any means you like).
3. Assume the hypothesis is true and deduce test implications.
   If conditions of kind C are realised, then an event of kind E will occur.
   Example:
   - If the temperature of a body of gas is T1 and its pressure is P1, then its volume is: c x T1 / P1.
   - If the birth is delivered in lateral position, then the mortality of patients in the First Clinic from childbed fever will decrease.
4. Make relevant observations.
5. Evaluate the hypothesis given the observations:
   if they are true, go to step 3; if they are false, go to step 2.

The hypothetico-deductive method
— deductive predictions and inductive inference

Deduce implications from a hypothesis: If H, then I.

Observe test implications: I

———————————————————————————-

Evaluate H.

From a general principle to a particular observation

From a particular observation to a general principle. In other words, the inductive inference from the observed to the unobserved.

Structure of reasoning
— the fallacy of affirming the consequent

Example: If childbed fever is blood poisoning produced by cadaveric matter, then antiseptic measures will reduce the fatalities from the disease. But cadaveric matter was not the only source of infection (it could be also transmitted by living organisms)

If H is true, then so is I.

(As the evidence shows) I is true.

———————————

Therefore, H is true.

H for a hypothesis (a statement under test)

I for a test implication

What reason do we have for expecting patterns observed in our past experience to hold also in the future? — the problem of induction (see also the Raven paradox)

Example of a strong claim (certainty):

(P1) Experiment X has given the result Y till now.

(P2) The future will resemble the past.

———————————-

(C) Therefore, the experiment X will give the result Y.

Premise 2 is required to make a valid argument.

What reason do we have for thinking that the future will resemble the past?

(P1) The future so far has resembled the past.

(P2) The future will resemble the past.

————————————

(C) Therefore, the future will resemble the past.

The problem is whether anything about the past gives us good information about what will happen in the future.
To bridge the past and future, one needs a premise that is the conclusion one wants to make… It's a fallacy.

David Hume (1711 - 1776)

Example of a weak claim (likelihood):

It is likely that experiment X will give result Y. (see the new riddle of induction by N. Goodman)

Nature of scientific testing — confirmation

- Hypotheses in science are *confirmed* when their logical consequences turn out to be true (i.e., a hypothesis is confirmed when a true statement about observables can be derived from it.)
- Confirmation is a relationship of support between a body of evidence and a hypothesis.
- If the predictions come out as the hypothesis says, then the hypothesis is supported. If the predictions do not come out as the hypothesis says, the hypothesis is not supported and should be rejected. Evidence can support one hypothesis over another.
- Confirmation is not the same as proof; a hypothesis can be highly confirmed and yet to be false.

Confirmation is not the end of inquiry…

When prediction derived from a hypothesis is confirmed, then it does not show that the hypothesis is true. One can “always” find another hypothesis that leads to the same prediction (*the problem of underdetermination* — many hypotheses may be consistent with the evidence).

Prediction 1: If childbed fever is blood poisoning produced by bacteria, then antiseptic measures will reduce the fatalities from the disease.

Prediction 2: If childbed fever is blood poisoning produced by male sweat, then antiseptic measures will reduce the fatalities from the disease. (Credit to Kane B)

Hypothetico-deductive confirmation — the role / problem of auxiliary assumptions

Problem: a hypothesis will only have consequences of a testable kind when it is combined with other assumptions. Consider Semmelweis’ hypothesis about “washing hands in a solution of chlorinated lime.”

If both H and A are true, then so is I.

(As evidence shows) I is true.

———————————————-

H and A are both true.

A for auxiliary assumption

Hypothetico-deductive confirmation: A test implication (I) confirms a hypothesis (H) relative to initial conditions and auxiliary assumptions (A) if and only if the conjunction of H and A implies I.

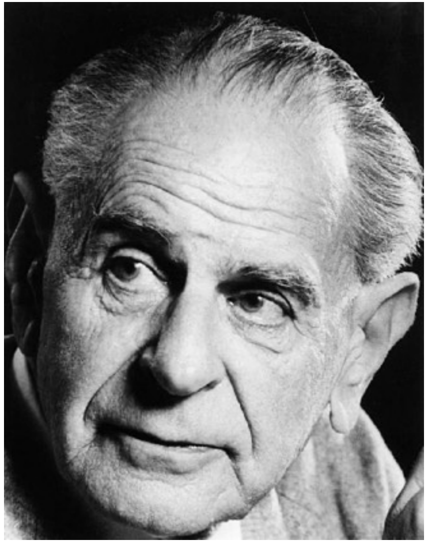
Objection of irrelevant conjunctions

If (H & H*), then so is I.
I
______________-
Therefore, H & H* is true. (Therefore, not only H, but also H* is true).

If H implies I, then the H & H* implies I as well. So H & H* is confirmed by I, and H* here could be anything at all.

Solving the induction problem — falsificationism (Falsifizierbarkeit)

- “Problem of demarcation” — what is the difference between science (Einstein’s theory) and non-science (marxism and Freud’s psychoanalysis)?
- Falsificationism — a hypothesis is scientific if and only if it has the potential to be refuted by some possible observation.
  - A hypothesis has to “stick its neck out”
- Induction is a myth, but science does not need it anyways.



Karl Popper (1902 - 1994)

Structure of reasoning — modus tollens

The only thing an observational test can do is to show that a hypothesis is false. Example: If the birth is delivered in lateral position, then the mortality of patients in the First Clinic from childbed fever will decrease.

If H is true, then so is I.

But (as the evidence shows) I is not true.

———————-

Therefore, H is not true.

H for a hypothesis (a statement under test)

I for a test implication

The nature of hypothesis evaluation (Popper)

- We can never be completely sure that a hypothesis is true.
  - The position that we can never be completely certain about our claims is often known as *fallibilism* (a term due to C. S. Peirce); the claims are always tentative but have some probability of being true.
  - But can we *increase* our confidence that a hypothesis is true when it passes observational tests?
- If the prediction does come out as predicted, then all we should say is that *we have not yet falsified the theory.*
  - The theory *might* be true is all we can say.
  - A theory that has survived many attempts to falsify it is "*corroborated*."
    - it performed well in the past, but we can say nothing about its future.
    - greater corroboration does not imply greater probability of truth

Objections to Popper's falsification

- Whenever we try to test a theory by comparing it with observations, we must make a large number of additional assumptions. An unexpected result can be always explained by inaccurate assumptions rather than a hypothesis.

  If (H & A), then so is I.
  But (as evidence shows) I is not true.
  ———————————
  Therefore, either H or A is false.

  - Response: test assumptions separately
    - but there is always an assumption
    - this describes a behaviour of a scientist, not a theory
- What if a hypothesis does not claim that observation O is forbidden, but very *unlikely*? Is it unfalsifiable and hence unscientific?
- Consider a choice between (a) a theory that has been tested many times and has passed all the tests, and (b) a brand new theory that has never been tested. We would think that it is rational to prefer theory a?

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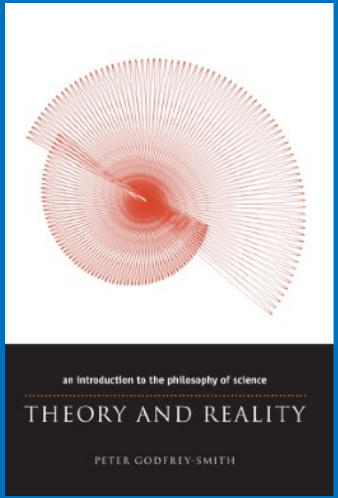
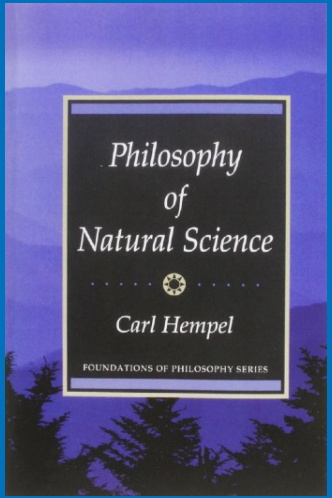


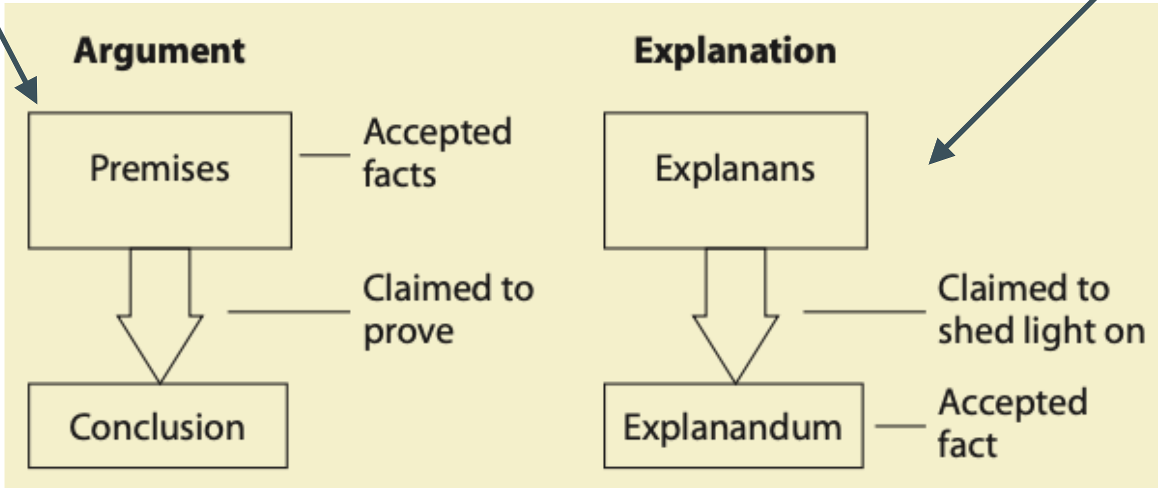


Scientific explanation

Explanations vs arguments

The purpose of premises is to prove **that** something is the case

The purpose of explanans is
to show **why** something is the case



Hurley (2012)

The Deductive-Nomological (DN) model (Hempel) — you can explain something if you can show it is to be expected

- To give an explanation of X is to show how to derive X from a logical argument:
  (P1) Statement of explanans consisting of general laws L1, L2, …, Ln.
  (P2) Statement of explanans asserting initial conditions C1, C2, …, Cn.
  ____
  (C) Statement of explanandum.
- Example (why does a sample of mercury, i.e., quicksilver, placed in hot water expand?):
  (P1) All metals expand when heated. [law of nature]
  (P2) The cool sample of mercury was placed in hot water. [initial condition]
  (P3) Mercury is a metal. [initial condition]
  ____
  The sample of mercury expanded in hot water.

The Deductive-Nomological (DN) model (Hempel) — you can explain something if you can show it is to be expected

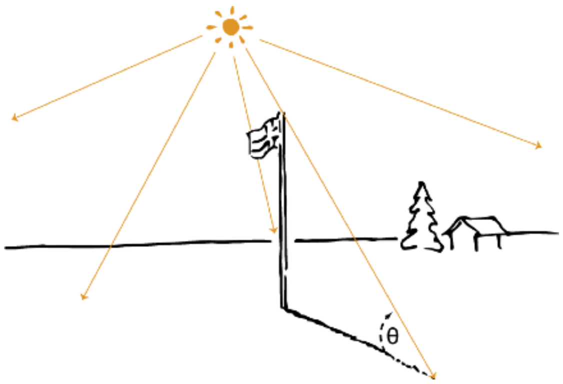
- What is a law of nature? Laws involve universal regularity (basic pattern in the flow of events) and support counterfactual conditionals: if X had happened, then Y would have happened.
- All premises must be empirically testable and true.
- We can make the deduction either before or after the explanandum event occurs. When done before, this is a *prediction*. Explanation and prediction differ only in terms when they are given ("symmetry thesis").

The Inductive-Statistical (IS) model (Hempel) — something is to be expected based on high probability

- Some regularities are probabilistic (e.g., smoking increase a chance of lung cancer).
- The Inductive-Statistical model works the same way as the DN, but appeals to probabilistic (statistical) laws.
- The relation between explanans and explanandum is inductive; an IS explanation will be good or successful to the extent that its explanans confers high probability on its explanandum.
- Example (Why does John recover from a bacterial infection after taking penicillin?):
  (P1) Most bacterial infections are cured by taking penicillin. [statistical law]
  (P2) John has a bacterial infection. [initial condition]
  (P3) John has taken penicillin. [initial condition]
  ———————————
  John has recovered.
- Note: if the probability of recovery is low, given that John has taken penicillin, then, even if John recovers, we cannot use this information to provide an IS explanation of his recovery. \
- Objection: What if John's infection is penicillin resistant?

Objection: asymmetry problem

- A flagpole is casting shadow on a sunny day. Why is the shadow X meters long?
- Based on the laws of optics, trigonometry, and position of the sun, and the height of the pole, we can deduce the length of the shadow.
- But using the same laws, we can deduce the height of the pole from the length of the shadow.
- Problem: we cannot run an equally good *explanation* in both directions (unless the flagpole can regulate its length to maintain a particular shadow)
- Likewise, symptoms of a disease can be used to predict, but they cannot be used to explain the disease (explanation runs only from disease to symptoms).



Why the flagpole objection is so powerful?
— DN appears insensitive to asymmetric features of explanations

- The flagpole case shows that a good explanation is provided by the answer that the shadow is caused by the interaction between sunlight and the flagpole. To explain something is to describe what caused it. The height of the flagpole causes the length of its shadow. (DN structure illustrates at best a necessary and not sufficient conditions.)
- Why did dinosaurs go extinct? Because an astroid hit the Earth. The asteroid impact caused the extinction of the dinosaurs.
- Due to D. Hume, empiricists have been very sceptical about causal claims. Causation — constant conjunction between two events (X regularly followed by Y) and a necessary connection (hidden, metaphysical connection between X and Y). The necessary connection can never be observed, we only observe regularity. Response: causation is analysed in terms of the *arrangement* of things rather than some extra *connection* between things.

The Statistical-Relevance (SR) Model (Salmon) — explanans increases the probability of explanandum

- Features of causal relevance are captured by the notion of *statistical relevance* (or conditional dependence relations) — the explanans should increase the probability of the explanandum than otherwise it would be, and can be still highly unlikely (in the DN model, explanandum must be highly probable given the explanans).
- Given some class or population A, an attribute C will be statistically relevant to another attribute B if and only if P(B | A & C) different from P(B | A), i.e., if and only if the probability of B conditional on A and C is different from the probability of B conditional on A alone.
- Consider an example that satisfies the DN criteria and yet it is a defective explanation due to irrelevancies
  (P1) All males who take birth control pill regularly fail to get pregnant. [law of nature]
  (P2) John Jones is a male who has been taking birth control pills regularly. [initial conditions]
  ——————————
  John Jones fails to get pregnant.
- SR explanation
  P(pregnancy | male & birth control) = P(pregnancy | male) = 0
  Being male "screens off" taking birth control from failing to get pregnant
  — A "screens off" B from C when P(C | A & B) = P(C|A)
  Likewise, P(pregnancy | female & birth control) < P(pregnancy | female)
  B is statistically relevant to C when P(C|A & B) is higher than P(C|A).

The Statistical-Relevance (SR) Model (Salmon) — explanans increases the probability of explanandum

- The SR model assumes that causal relationships are fully captured by statistical relevance. This is clearly false.
- Example: A structure in which B is a common cause of the joint effects A and C implies the same statistical relevance relations as a chain structure in which A causes B which causes C.
  - Unprotected sex (A) causes HIV infection (B) which causes AIDS (C)
  - A drop in the level of mercury in a barometer (A) is frequently followed by a storm (C). Since storms are not so frequent, these events are probabilistically correlated. A & C have a common cause B: a drop in atmospheric pressure.
  - Both have the same statistical relevance relations:
    $P(C \mid A \& B) = P(C \mid B)$, i.e., B “screens off” A

Other models of explanation

- The causal mechanical model (Salmon)
    - purely statistical relevance (empirical regularities) is not enough
    - add ontological aspect (metaphysical causality)
- A unificationist account of explanation
    - explanation is to provide a unified account of a range of different phenomena, e.g., Maxwell’s unification of electricity and magnetism; consider Bowlby’s attachment theory (unification of fear, development, self-regulation, and psychopathology)
- Pragmatic theories of explanation (Bas van Frassen)
    - the aim of science is the construction of theories that are “empirically adequate” (correct description of observables) and not, as scientific realists suppose, theories that aim to tell literally true stories about unobservables
    - explanation is use of information that is grounded in a theory
- Invariant explanations (David Deutsch)
    - the truth consists of hard-to-vary assertions about reality
    - a good explanation is hard to vary

Schlüsselwörter

- der naive Induktivismus / naive inductivism
- die hypothetisch-deduktive Methode / hypothetico-deductive method
- der Fehlschluss: Bejahung des Nachsatzes / the fallacy of affirming the consequent
- das Induktionsproblem / the problem of induction (Hume)
- die Verifizierbarkeit und Falsifizierbarkeit einer Theorie / verification and falsification of a theory (Popper)
- modus tollens
- die deduktiv-nomologische Erklärung / deductive-nomological model of explanation (Hempel)
- die induktiv-statistische Erklärung / inductive-statistical model of explanation (Hempel)

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