Scientific Explanation- Causation and Unification
By Wesley Salmon

Analysis by Margarita Georgieva,
PSTS student, number 0102458
Van Lochemstraat 9-17
7511 EG Enschede

Final Paper for “Philosophy of Science” course
February 2005

The Problem
In his paper W. Salmon analyses the question what is scientific explanation. He compares two leading theories about scientific explanation – the unification theory and the causation theory.

Philosophical context
The concept of scientific explanation is very important in philosophy of science because of several reasons:

• Most people and most scientist intuitively believe, that one of the goals of the science is to explain the phenomena in the world. Some people even believe that explanation is the main goal of science. Whether this intuitive belief is accepted by philosophers is not so important – just the fact that there is such belief is a good reason to analyze the concept of explanation and in particular scientific explanation.

One further indication that such belief exists is that even empiricist, who think that prediction of phenomena is the goal of science, still explain why they don’t accept explanation as goal of science.

• Scientific realists use the “inference of best explanation” (IBE) principle to solve the strong under-determination problem and this way to prove that science can create true knowledge even about non-observable (non-empirical) entities. The IBE principle, in short, says that between strongly empirically equivalent hypotheses we should “infer the truth of the hypothesis which gives us the best explanation of the phenomena”1. This brings us the question what is “best explanation”, but before we can analyze what is best explanation, we have to analyze what is explanation in general.

According to Balashov and Rosenberg2, there have been four main philosophical streams about the definition scientific explanation:

• Covering law model, proposed by Hempel3. Hempel tries to give an explicit definition of scientific explanation, based on deductive or probabilistic relation between some laws of nature together with some initial conditions (called together explanants) and what has to be explained (called the explanandum)

---

1 Ladyman, p.209
2 Balashov, Rosenberg, pp. 40-41 (Part II, introduction)
3 Balashov, Rosenberg, pp. 45-55 (Hempel)
• Pragmatic model, defended by Van Fraassen, who says that explanation is a relation between explanants, explanandum and a pragmatic context, depending on the situation and person requesting explanation. And because science is context-neutral, science can't provide explanation

• Unification model, by Kitcher. It says that “explanation is scientific if it unifies disparate phenomena under a small number of principles”

• Causal model, defended by Salmon. According to him to explain something is to say what are the causes of this thing.

Scientific context
At first look it may seem that the strong under-determination problem is only a philosophical construction, which is not so important for actual science. But as Ladyman points out, the work of Poincare shows that “we can’t decide by experiment whether or not the world is Euclidean or non-Euclidean”, so the strong under-determination problem becomes a real problem for modern physics and cosmology. So, the IBE principle becomes practically important and as a result the conceptual analysis of explanation also becomes practically important.

Quantum-mechanics is another scientific area that makes the definition of explanation practically important. It seems, that in quantum mechanics there are laws which are really non-deterministic. In other words, there are only probabilistic dependencies – we can predict that something will happen with certain probability, but we can't say what determines if it will actually happen in any particular case or not. Furthermore, there are phenomena in quantum-mechanics that suggest that something can cause another thing at a distance, with no intermediate chain of causes. All this creates problems for both covering law model and causal model of explanation. But quantum-mechanics deals with elementary particles and in this way it is basis of physics. So if quantum-mechanics can't explain, how can physics explain anything?

So, this is the philosophical and scientific background on which Salmon tries to solve the problem of what is scientific explanation.

The Solution
It is important to say, that Salmon has defended for long time the causal theory of explanation. But in this paper his solution is to combine two models of explanation - the unification model and the causal model - and to argue that they both give valid scientific explanations. Furthermore, he states that the unification model is a successor and an extension of the covering law model. The covering law model Salmon calls “the received view”.

Salmon’s main point in this paper is that “the successors of the received view [e.g. unification theory] and its causal opponent are actually compatible and complimentary.” This is based on that “it is not plausible to expect a successful characterization of scientific explanation in terms of any simple formal schema or linguistic formulation”. He argues, that the concept of explanation is dual in its nature and that it has a unification component and a causal-mechanical component.

---

4 Balashov, Rosenberg, p. 41 (part II, introduction)
5 Ladyman, p. 173
6 Balashov, Rosenberg, p. 98 (Salmon)
At the end of his paper, Salmon goes even further. He suggests, that “it may be futile to try to explicate the concept of scientific explanation in a comprehensive manner. It might be better to list various explanatory virtues that scientific theories might possess and to evaluate scientific theories in terms of them.”

**The reasoning**

Salmon builds his argument in several steps. First, he defines what unification and causal concept of explanation are.

Unification concept of explanation is about “showing that apparently disparate phenomena can be shown to be fundamentally similar”. Phenomena in this context means regularities in the nature.

Causal concept of explanation is based on Salmon’s definition of causality as causal interaction. Causal interaction is “an intersection of two processes …[in which] both processes are modified in the intersection in ways that persist beyond the point of intersection.” He admits that causal interactions are not necessarily deterministic; but they are always local, so there is no “cause at a distance”. But when defining explanation, Salmon does not take into account all causes. He focuses on causal interconnections between parts of an object or a system, in order to explain how the whole object or system behaves. That’s why he calls this approach a *causal-mechanistic* concept of explanation.

After defining the two concepts or approaches, Salmon states that these approaches are often seen as rival. But he gives three examples, which show that both approaches generate different, but equally legitimate explanations. These examples provide evidence, that both approaches are compatible. Salmon also mentions that pragmatic factors can determine which explanation is more useful in a particular context. It is shown, that in some contexts causal-mechanical explanation is more useful and in some other contexts the unification explanation is more useful. This fact suggests that the two approaches are actually complimentary.

Then Salmon lists some areas, where causal-mechanical explanation would be very complex and impractical (although theoretically possible), while unification explanations are simpler and more practical. These areas are biology (especially evolution theory), social sciences and psychology. He also says, that in quantum-mechanics a causal-mechanical explanation is seems impossible, because of “cause at a distance” issue, but a unification explanation is possible. So quantum-mechanics “in some sense can explain things, but in another sense it cannot”. These examples give further evidence that the two approaches are different and complimentary (where the causal-mechanical explanation is impossible or impractical, unification explanation may be possible and practical).

After the examples Salmon analyses the concept of scientific explanation, in order to provide more general evidence of his position that the two approaches are compatible and complimentary. This analysis consists of two parts.

---

7 Balashov, Rosenberg, p. 104
8 Balashov, Rosenberg, p. 94
9 Balashov, Rosenberg, p. 95
10 Balashov, Rosenberg, p. 102
First, he analyses the concept of “understanding”, based on the assumption that “one of the chief aims [...] of the science is to enhance our understanding of the world.”\textsuperscript{11} Because of this, the purpose of scientific explanation should be to increase our understanding, so in order to analyze what is (scientific) explanation, we have to analyze what is (scientific) understanding. Salmon distinguishes two component of scientific understanding – “fitting phenomena into a comprehensive scientific world picture” and “achieving a knowledge how things actually work.”\textsuperscript{12} He illustrates these two components with examples from Physics. The “fitting phenomena” component, according to him, corresponds to the unification approach of explanation. The “how things work” component corresponds to the causal-mechanistic approach. Salmon admits, that he makes his analysis from a position of scientific realism, in two senses – he accepts explanation as primary goal of science and he accepts that science can generate true knowledge about un-observable. So the science can explain how things work even when we can’t directly perceive the parts of the things – e.g. electrons.

Finally, Salmon looks into our intuitive concept of explanation in general. He tries to see how explanation is expressed in language. He concludes, that explanations are usually answers to the question “why” and “how”. In his view, the unification approach more-or-less corresponds to the why question and the causal-mechanical approach corresponds to the how question. So again, the two approaches seem both valid and complimentary. Salmon here makes an explicit remark, that in scientific explanation the “why” question should not be taken as question about human purposes and wishes, but it means why things in the world behave is certain way.

**Internal Critique**

In this section I will analyze the reasoning in Salmon’s article in terms of is it valid, consistent and complete.

Salmons main point is, that the unification and causal-mechanical theory of explanation are compatible and complimentary. This means that:

1. Both theories can produce explanations; these explanations can be different (distinction)
2. When both theories produce explanations, these explanation are equally valid (compatibility)
3. In some cases, only one of the theories may produce an explanation (complementariness)
4. When both theories produce explanations, one explanation may be more useful then the other (complementariness)

There is a very important point here. Salmon speaks several times about the “two explanations” that are provided by the two theories. These different explanations “need not conflict with another” and that they “both are perfectly legitimate”\textsuperscript{13}. He does not say, that the two theories together produce one explanation. In other words, the unification (the sum) of explanations provided by either theory is part of all explanations in the world.

\textsuperscript{11} Balashov, Rosenberg, p. 102
\textsuperscript{12} Balashov, Rosenberg, p. 103
\textsuperscript{13} Balashov, Rosenberg, p. 99
From this point of view, it seems that Salmon’s reasoning is based on the following propositions:

1. Unification and causal-mechanical theories of scientific explanation are different. If they were the same, or one is reducible to the other, there is no point to talk about compatibility and complementariness.
2. There can be more than one explanation of a phenomenon. Otherwise there can’t be different explanations provided by different theories. Different explanation may be more useful or less useful, depending on the context, but they are all valid explanations.
3. Explanation is context-independent, it does not depend on who is asking the explanation.
4. The goal of explanation is to increase understanding.
5. Scientific understanding has two components – fitting things into world picture (unification) and seeing how things work (mechanical causes)
6. Our intuitive concept of “explanation” is an answer of “why” or “how” question in English.

Propositions 3 and 4 are actually presuppositions – they are taken as granted. For proposition 1 and 2 there is evidence provided in the paper. Propositions 1, 2 and 3 they are not used directly in the reasoning, but they are necessary conditions for the conclusions. If any of them is broken, the conclusions can’t be true. That’s why it is important to mention them and to check if they are analyzed in the paper.

But before I analyze the propositions further, I would like to mention, that from 4 and 5 deductively follows that unification and causal-mechanical explanations are both legitimate and needed. The same conclusion probably follows from 6, if we take the semantics of English language into account. Salmon does not try to make this semantics explicit, but he gives some very illustrative examples. This reasoning makes the complementariness clear from a logical perspective.

For propositions 5 and 6 there is inductive evidence – for 5 it is taken from science and for 6 there are examples from everyday explanations that answer both questions.

Now I will consider the evidence in support of propositions 1 and 2. It is inductive evidence. It includes 3 main examples from Physics and several brief examples from biology, psychology and social sciences. It is clear from these examples, that:

- both theories generate explanations,
- these explanation are different
- they have different pragmatic value.

Salmon does not try to bring a formal definition of “explanation”. He appeals to our intuition, helped by his proposition 4 and 6. Indeed, explanations shown in his example seem intuitively legitimate. They do increase our understanding and they do answer “why” or “how” questions. This is sufficient reasoning to accept that more than one explanation of a phenomena can exist (proposition 2). This is also strong evidence to support 1, because if two theories generate different results, they are probably different theories. But Salmon gives further evidence in support of 1. He explains his concept of causation and says that it is different that Hume’s concept of causation. Hume described causation as contiguous regularity. Unification theory of

---

14 Note that both causation and unification theory take scientific explanation as context-independent.
explanation is based on natural laws and regularities. If Salmon’s concept of causality is not reducible to regularity, then the causal-mechanical theory of explanation is not reducible to unification theory. So propositions 1 and 2 seem sufficiently well defended.

But there is one thing, which does not follow from Salmons reasoning. He does not argue, that the unification theory and causal theories are always true. He proves that such two types of explanations must exists, that the two theories in many diverse cases generate valid explanations, but he does not analyze if each theory formulates necessary and sufficient conditions for defining explanation of “its own” kind. This is important to say, because we know that there are objections to each of the theories – that’s why they were rivals. Simply unifying them (taking the sum of their results) will not solve these objections. If we assume that Salmon defends both theories are true, then his paper will be open for serious external criticism. But in my opinion Salmon does not go that far. He only suggests that the current theories work in most cases and that it is possible to have two different, true theories for scientific explanation – one based on unification and another one based on (mechanical) causality.

**External Critique**

**Definition of explanation**

Intuitively, Salmon says, explanation is answer to “why” and “how” questions (if we don’t interpret the “why” in anthropocentric way). But most other authors see explanation as answer to “why” question only. Maybe they think that most “how” questions can be replaced with “why” questions like “How clock works?” with “Why the hands of the clock move?” But this replacement means that we already know what means the clock “to work”. So I think Salmon is right to consider both questions.

The other direction defining explanation is “something which increases our understanding”. If we take Kant’s concepts of understanding, we see that “cause” and “community” (similar to unification?) are both present in the “Relation” category. This can be taken as support the dualism of scientific understanding. But then why other concepts of understanding don’t bring more “explanatory virtues”? Or is there something special about scientific understanding, that relates only to understanding of relations? Or is Kant’s model of understanding not applicable?

**Compatibility and complementariness of the theories**

First I will take the “narrow” interpretation of Salmon’s paper and consider only the compatibility and complementariness of the theories, without the discussion if they are always valid. From this point of view, there are two main points of discussion – Hume’s theory of causality and the possibility to have more than one explanation of a phenomenon.

Empiricists have attacked the causal theory of explanation with the argument, that causality is just regularity of contingent phenomena, without a necessary connection between them. “External objects, as they appear to the senses, give us no idea of power of necessary connection”\(^{15}\)

\(^{15}\) Hume, Part 1
Since laws of nature describe regularities of phenomena and theoretically any regularity can be described by (or deduced from) a law of nature, then causal theory of explanation is reducible to the covering law model. This reasoning is based on Mill and Ramsey definition of laws of nature as “the axioms [which we should take], if we knew everything and organized it as simply as possible in a deductive system”.\(^{16}\)

Of course there are different views of causality, than Hume’s. Kant, for example, names the causality “an a-priory concept of understanding”\(^ {17}\) and sees it as condition of possibility to experience in general. According to Kant, the external world exists (metaphysical realism), but we can’t know anything about it, we can know things only about the worlds as it appears to us (epistemological antirealism) and causality is part of this world. This is not enough for Salmon. Salmon is scientific realist and he needs both metaphysical and epistemological realism, in order to be able to claim the “inference of best explanation” principle. Salmon’s theory of causality is based on interference of causal processes in which one process puts a “mark” on the other and the mark persists after the moment of interference. So in Salmon’s view the causality is objective. Unfortunately, from this article it is not very clear how Salmon’s theory of causality relates to Hume’s regularity-based theory. Salmon probably assumes that the reader is familiar with his theory. An interesting subject for further study would be to compare the two theories in more detail.

The second point in this section – the possibility to have more than one explanation – seems indirectly supported by other authors. For example, Kitcher\(^ {18}\) says that “successful explanations … belong to a set of explanation, the explanatory store, and the fundamental task of theory of explanation is to set conditions on the explanatory store”. If we interpret Salmon’s point in such a way, that both unification and causal-mechanical theory can contribute to the explanatory store, and then pragmatic factors determine which possible explanation is the successful explanation, we have an alignment.

**Truthfulness of the theories**

In this section I will review some objections to the truthfulness of both theories of explanation. The first criticism I would like to mention is Van Fraassen’s idea that explanation is always pragmatic, i.e. “we wish explanation why P is true in contrast to members X of a set of propositions”. Unification and causal-mechanical theory does not take pragmatics into account, so they can’t provide explanations. For example, says Van Fraassen, when we ask for causal explanation, we don’t know which of the 4 Aristotelian types of causes we mean. Only pragmatics (the context of the request for explanation) can determine that. But Salmon apparently looks for (combination of) efficient and material causes only. But even in this case, argues Van Fraassen, how back in the chain of causes should you look, in order to generate an explanation. If Salmon believes that matter is not endlessly dividable, he may answer that causal-mechanical explanations always reduce the whole to its parts, so there is natural end of the chain (the smallest particle of the matter). But this answer would depend on certain metaphysical belief about matter.

---


\(^{17}\) Kant, pp. 302-304

\(^{18}\) Balashov, Rosenberg, p. 80 (Kitcher)
But there is another, more general way to look into this disagreement. We may again interpret Salmon’s position that theories generate possible explanations and the context of request determines the successful (or the useful) one. In this case I can imagine that their positions are compatible – Van Fraassen’s theory then focuses on how we choose one useful explanation from a set of valid possible explanations.

Now let’s take a closer look what means that a theory of explanation is true. The strongest definition is, that the theory contains necessary and sufficient conditions for a story to be an explanation. If we take this definition, that Salmon’s statement in this paper has a problem. If the two theories are different then they specify different necessary conditions (non-reducible to one another) so then there will be cases in which an explanation acceptable in one theory will not be acceptable in the other. But I interpret Salmon’s position that it sees both theories providing only sufficient conditions for explanation.

But even in this case, there is criticism possible. According to Ladyman “Most of the objections to the covering law model of explanation are designed to show that Hempel’s conditions are not sufficient”\(^\text{19}\). Ladyman mentions 5 problems with Hempel’s theory:

- Irrelevance, Preemption, Over-determination – I put these 3 together, because in all cases the suggested explanation is possible, but not relevant in the given situation.
- Asymmetry – scientific laws treat variables symmetrically, but our explanations are not symmetrical. We explain the length of a tree’s shadow with the height of the tree and position of the sun, but we don’t explain the height of the tree with its shadow.
- Difference between prediction and explanation. Not everything that predicts something else can also explain that something else. For example, fall of barometer predicts a storm, but does not explain it.

According to Salmon, Hempel’s theory explains “particular facts, but … could not explain general laws”\(^\text{20}\). Salmon mentions that Friedmann and Kircher solve this problem with the unification theory. Kircher claims that the unification theory solves also the irrelevance and the asymmetry problem, because the most unified explanation is relevant and it takes the asymmetry into account. But there are counter-arguments, especially about the asymmetry problem. For example, Woodward argues that in many cases there is more than one explanation, so even “a bit less unified” explanations are valid. But in this case, the asymmetry problem is not solved.

The main objections against the causal theory – impossibility to derive necessity from experience and that it is not clear what type of cause we look for and how back in causal chain we have to look for explanation – were already discussed and I will not repeat them here.

**Conclusion**

The main point of Salmon in this paper – about the compatibility and complementariness of unification and causal-mechanical theories – is well defended. I

---

\(^{19}\) Ladyman, p. 202

\(^{20}\) Balashov, Rosenberg, p. 93 (Salmon)
agree that both types of explanations are possible and valid. But I think that we can go even further and say that no one of the theories can alone be sufficient. This is in line with Salmon’s idea about different explanatory virtues, but I think that these virtues are interlinked, not independent.

For example, the covering law model (and maybe also unification model) can’t solve the asymmetry problem. The causal approach naturally solves it. On the other hand, the “endless cause chain” problem of the causal model can be solved by the covering law model, if we see laws of nature as axioms – we naturally don’t require explanations for axioms.

So I think that maybe the two explanatory virtues can be even more meaningfully combined, then simply by unification. This is interesting point for further research.

**Literature**

- **Balashow, Yury, Rosenberg Andrew**, “Philosophy of Science, Contemporary Readings”, Routledge 2002
  - Wesley *Salmon*, “Scientific explanation: Causation and Unification”
  - Carl *Hempel*, “Two models of scientific explanation”
  - Bas van Fraassen, “The pragmatics of explanation”
  - Philip Kitcher, “Explanatory unification and the Causal structure of the World”
  - John *Earman*, “Laws of nature”
- **Kant, Immanuel**, “Prolegomena”
- **Ladyman, James**, “Understanding Philosophy of Science”, Routledge 2002