Scientific Explanation

Terminology

- A scientific explanation will be trying to explain why some fact is true or some phenomenon occurred. Call that thing—the *thing to be explained*—the *explanandum*.
- The explanation will appeal to some other facts in order to explain *why* the explanandum is true/occurred. Call those things—the things that *do* the explaining—the *explanans*.

Aspects of Scientific Explanation

- Consider some scientific explanations:
  - Semmelweis's explanation of the higher rate of childbed fever in the first division.
  - Torricelli's explanation of the reason why a vacuum could not raise water higher than 34 feet.
  - The explanation of why a figure skater spins faster when they bring their arms in.
- All of these explanations seem to make their explanandum *to be expected*. Hempel calls this aspect of scientific explanations their *explanatory relevance*—the explanans are explanatorily relevant to their explanandum.
- Consider some poor explanations:
  - Francesco Sizi's explanation of why there are seven planets in terms of the number of "windows" in the human head.
- According to Hempel, this explanation does not serve to make its explanandum *to be expected*. Its explanans are not *explanatorily relevant* to its explanandum.
- What makes for the difference? What makes a scientific explanation a *good* one? What separates the explanations of Semelweis and Torricelli from that of Sizi?
- This is the question that a philosophical account of explanation sets out to answer.

The Deductive-Nomological (DN) Account of Scientific Explanation

- According to Hemple, in general, an explanation of explanandum E is an argument which has as its premises some claims about particular matters of fact $C_1, C_2, ..., C_N$ and some universal generalizations (claims of the form 'all Fs are Gs') $L_1, L_2, ..., L_M$ and has as its conclusion the explanandum E.

$$\begin{array}{c} C_1, C_2, ..., C_N \\ L_1, L_2, ..., L_M \\ \hline E \end{array} \quad \begin{array}{l} \left.\begin{array}{c} \\ \\ \end{array}\right\} \textit{Explanans} \\ \left.\right\} \textit{Explanandum} \end{array} \tag{DN}$$

- Hempel says that an explanation like this is adequate only if the argument is *deductively valid*. That is, only if the explanandum E deductively follows from the claims $C_1, C_2, ..., C_N$ and $L_1, L_2, ..., L_M$.
- He additionally requires that the premises of the explanation be *true*.
- This account says that the relation of explanatory relevance is just the relation of *deductive entailment*. The explanations of Torricelli and Semmelweis make their explanandum *to be expected* by simply *entailing* them.
- However, further restrictions must be placed on the argument before we can have an adequate account of explanation.
  - As Hempel stresses, it is important that the universal generalizations $L_1, L_2, ..., L_M$ be *laws of nature*, and not mere accidentally true generalizations. Otherwise, we would have to count the following as an adequate explanation

    1. Every rock in this box contains iron.
    2. This rock is inside this box.

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    3. This rock contains iron.

    However, the fact that the rock is inside the box, together with the universally true generalization that every rock in the box contains iron does not adequately explain *why* this rock contains iron.
- So, we have to add the following restriction to the basic account offered above: *the universal generalizations must be* laws of nature.
  - We need not require that the argument include some particular matters of fact. There are good explanations which subsume some particular phenomenon under a general law without the need to mention any other matters of fact. For instance, the following argument

    1. Nothing can travel faster than the speed of light.

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    3. The signal from your cell phone does not travel faster than the speed of light.

provides an adequate explanation of why the signal from your cell phone does not travel faster than the speed of light.

- However, we *do* have to require that the argument include some laws of nature. Otherwise, we'll be able to explain why Jim has measles as follows:

  1. Sam's son has measles.
  2. Jim is Sam's son.

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  3. Jim has measles.

  But this isn't a good scientific explanation of why Jim has measles.

- So we'll have to add the following restriction to the basic account offered above: *the explanans must include at least one law of nature.*

  - However, it turns out to not be enough to require that the explanans *include* a law of nature, since we can just take the poor explanation above and add to it Newton's 2nd law of motion to get:

    1. $F = ma$
    2. Sam's son has measles.
    3. Jim is Sam's son.

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    4. Jim has measles.

    This argument is deductively valid, and it contains a law of nature. But it is not a good explanation of why Jim has measles.

- Hempel adds the following restriction to the account: *the law of nature must be required for the deductive validity of the argument.* If you remove the law of nature from the argument, the argument must become deductively *invalid*. The explanation of Jim's measles fails this test.

  - Hempel also worries about explanations like this:

    1. Massive bodies love one another.
    2. Bodies which love each other attract one another.
    3. Both the moon and the earth's oceans are massive.

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    4. The moon will attract the earth's oceans.

    He thinks that this is a poor explanation of the tides. So he requires that the explanans "have empirical content"—that is, that they be empirically testable. Since 1 above is not empirically testable, it is an inadequate explanation.

- So, Hempel adds this requirement to the account: *the explanans must have empirical content—i.e., must be empirically testable.*

- In sum, then, the DN account claims that a scientific explanation is a deductively valid argument with the explanans as premises and the explanandum as conclusion, whose premises are all true and have empirical content and which contains at least one general law without which the argument would not go through.

Problems with the DN Account

- The following explanation meets the criteria laid down above:

1.	Either Jim has measles or $F \neq ma$
2.	$F = ma$
3.	Jim has measles.

  However, this is not a good scientific explanation of why Jim has measles.

- The following is a good DN explanation of why Mary didn't get pregnant (suppose, for the sake of argument, that birth control pills are 100% reliable):

1.	No one who takes birth control pills gets pregnant.
2.	Mary takes birth control pills.
3.	Mary didn't get pregnant.

  However, it seems that whether this is an adequate explanation of Mary's failure to get pregnant depends not only upon the truth of 1 and 2, and the fact that 3 follows from 1 and 2, but additionally upon whether Mary *had sex*. If Mary is a virgin, then the above argument is a poor explanation of why she didn't get pregnant.

  – To make the point vivid, suppose that Jim accidentally starts taking his wife's birth control pills. Then, the following DN explanation meets all the criteria laid down above:

1.	No one who takes birth control pills gets pregnant.
2.	Jim takes birth control pills.
3.	Jim didn't get pregnant.

  But *this* isn't the explanation for why Jim didn't get pregnant. The explanation for why Jim didn't get pregnant is that Jim is male, and male's can't get pregnant (*Junior* notwithstanding).

- Suppose that in Sally's office there is an ink stain on the floor. And suppose that we are interested in explaining why it is there. Michael Scriven argues that the following offers an adequate explanation of why there is an ink stain on the floor of Sally's office:

  > Yesterday, there was an ink bottle sitting on Sally's desk. Sally bumped the desk with her elbow, causing the ink bottle to tip over, causing ink to spill on the floor.

  However, Scriven notes that this argument does not contain any laws of nature. It merely mentions the *cause* of the ink stain—Sally's bumping her desk. However, it is not in general a law of nature that when one bumps their desk, an ink stain shows up on the floor. Nor is it in general a law of nature that when one bumps their desk when an ink bottle is sitting on it, it will spill over.

- Hempel thinks that, in general, any causal relation requires some background law of nature (see page 53). This is called the 'covering law' for a causal relation. So he thinks that, in Scriven's example, there will be *some* true and lawlike universal generalization saying that if one bumps ones desk in such-and-such conditions with an ink bottle in such-and-such location and condition, then the ink bottle will spill over.
- Scriven needn't deny that the explanation *could* be filled out in this way. He need only insist that the explanation is fine *without* being filled out in this way. It is fine *on its own*, without any corresponding generalization.
  - Hempel accepts an account of causation according to which causal claims are only true if there is some covering law, so he will think that to make the causal claim is to presuppose that there *is* some corresponding true law of nature governing desk bumps and ink spills.
  - We'll think more about causation later on.

- Suppose that the sun is at an elevation of $\alpha°$ in the sky. There is a flagpole which is h meters tall. The flagpole casts a shadow l meters long. Suppose that we want to explain the length of the flagpole's shadow. On Hempel's model, the following explanation is sufficient.

  1. The sun is at an elevation of $\alpha°$ in the sky.
  2. Light propagates linearly.
  3. The flagpole is h meters high.

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  4. The length of the shadow is $l = h/\tan\alpha$

  So far, so good.

- Suppose, however, that we're interested in explain how tall the flagpole is. Then, the DN models tells us that the following explanation should be perfectly good.

  1. The sun is at an elevation of $\alpha°$ in the sky.
  2. Light propagates linearly.
  3. The shadow cast by the flagpole is l meters long.

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  4. The height of the flagpole is $h = l \cdot \tan\alpha$

  But this explanation is *not* good. The length of the shadow cannot be used to explain the height of the flagpole.

- Things get worse. Suppose that we're interested in explaining why the sun is at an elevation of $\alpha°$ in the sky. The DN account will smile on the following explanation:

  1. The flagpole is h meters high.
  2. The shadow is l meters long.
  3. Light propagates linearly.

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  4. The sun is at an elevation of $\alpha = \arctan(h/l)$ in the sky.

  But the flagpole and its shadow cannot explain the elevation of the sun in the sky.

- All of these problems appear to be pointing in the same direction: *deductive entailment* is not sufficient for *explanatory relevance*. Salmon argues that *causal relevance* is also required.