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Three conceptions of explaining how possibly—and one reductive account

Philosophers of science have often favoured reductive approaches to how-possibly explanation. This article identifies three alternative conceptions making how-possibly explanation an interesting phenomenon in its own right.

The first variety approaches "how possibly X?" by showing that X is not epistemically impossible. This can sometimes be achieved by removing misunderstandings concerning the implications of one's current belief system but involves characteristically a modification of this belief system so that acceptance of X does not result in contradiction.

The second variety offers a potential how-explanation of X. It is usually followed by a range of further potential how-explanations of the same phenomenon. In recent literature the factual claims implied by the second variety have been downplayed whereas the heuristic role of mapping the space of conceptual possibilities has been emphasized. I will focus especially on this truth-bracketing sense of potentiality when looking closer at the second variety in the paper.

The third variety has attracted less interest. It presents a partial how-explanation of X. Typically it aims to establish the existence of a mechanism by which X could be and was generated. The third conception stands out as the natural alternative for the advocate of ontic how-possibly explanations.

This article transfers Salmon's (1984) view that explanation-concepts can be broadly divided into epistemic, modal, and ontic to the context of how-possibly explanations. Moreover, it is argued that each of the three above-mentioned varieties of how-possibly explanation occurs in science. To recognize this may be especially relevant for philosophers. We are often misled by the promises of various why-explanation accounts, and seem to have forgotten nearly everything about the diversity of how-possibly explanations.

1. The Dray-Hempel variety: from epistemic conflict to consistency

Hempel (1970) offers an account of how-possibly explanation in two steps. These can preferably be distinguished.[1] The first step builds on Dray (1957) and his observation about in which contexts we require how-possibly explanations:

[1] Already the first step captures a distinct notion whereas the second step is reductive

> [T]he demand for explanation is, in some contexts, satisfactorily met if what happened is merely shown to have been *possible*; there is no need to go on to show that it was necessary as well. To put the point another way, I shall argue that although, as Professor Toulmin puts it, to explain a thing is often to "show that it might have been expected", the appropriate criterion for [how-possibly explanations] is broader than this; for to explain a thing is sometimes merely to show that it need not have caused surprise. (Dray 1957, 157)

Dray emphasizes the element of surprise. He even claims that the essential feature of a how-possibly explanation is that it is given "in the face of a certain sort of puzzlement" (Dray 1957, 165).

But this first variety can be characterised independently of its psychological features. The need for how-possibly explanations arises when the explanandum, X, is (or at least seems to be) ruled out by the corpus of theories and empirical assumptions relied on in the explanans context (or "the system" as I will occasionally refer to it from now on). Many explanations—even why-explanations—are prompted by the belief that X should not have happened, but in this case it is (or seems) impossible to add X to the system, and this is what is characteristic about how-possibly explanations:

> […] some of the beliefs we hold concerning relevant matters of fact seem to us to make it impossible or at least highly improbable that X should have occurred (Hempel 1970, 428).

As a consequence the process of finding explanans stops before it has started.

With the exception of the belief in X itself, this variety of how-possibly explanation does not require evidence gathering in favour of any new explanatory pieces of belief about the world. What is needed is either a correction of one's perceptions of what the system is in fact consistent with or, more characteristically, a withdrawal of those elements in the system that would make a contradiction appear were a belief in the explanandum phenomenon to be added. Note that it is the only of the varieties to be discussed here that is about the acceptability of the *explanandum* itself.

As already advertised Hempel goes on to add a second step to his account of how-possibly explanation. But what we have, already, is in line with Hempel's idea that a successful explanation shows that the explanandum phenomenon was in fact to be expected. After removal of conflicting beliefs, the non-occurrence of X is no longer to be expected, at least not to the previous degree.

1.1 Illustration: The paradox of the plankton

The Dray-Hempel variety of how-possibly explanation seems to be operative in relevant scientific contexts. One case in point is what Hutchinson (1961) labelled *the paradox of the plankton*. Findings indicated that, particularly in summer times, natural waters present an environment with "striking" nutrient deficiency. According to the principle of competitive exclusion (Hardin 1960), we should expect that under such conditions

one species would outcompete the others "so that in a final equilibrium situation the assemblage would reduce to a population of a single species" (Hutchinson 1961, 137). However, in summer times a number of species of plankton are known to coexist.

The paradoxical character of this situation is evident. On the one hand the principle of competitive exclusion was supposed not only to be strongly corroborated but even analytically true; on the other hand it seemed to be an empirical fact that the principle came to the wrong prediction in this case:

> The problem that is presented by the phytoplankton is essentially how it is possible for a number of species to coexist in relatively isotropic or unstructured environment all competing for the same sorts of materials. (Hutchinson 1961, 137)

The primary explanatory ambition in such a case is to make the picture consistent—to decide on what in our explanatory belief system has to go when the explanandum is added (or, in simpler cases, to remove certain misconceptions we have about what this system implies). This is exactly the kind of situation Hempel centres on in the first step of his account of how-possibly explanation. By implication any attempt to adjust an explanatory theory so that it avoids falsification in light of new evidence is a possible instance in case. At least sometimes the scientist thinks of such an enterprise in terms of explaining how-possibly. Hutchinson apparently did.

2. The reductive response: From how-possibly questions to why-answers

What happens in step one above is normally not the end of the explanatory process triggered by a how-possibly question of Hempel's variety. The explanatory-seeking agent usually moves on beyond the first stage of restored consistency. Hempel (1970, 429) claims that a why-explanation attempt naturally follows. The guiding idea seems to be that the *explanatory* features of how-possibly explanations reduce to this second step involving why-explanation:

> Someone who asks how X could possibly have happened will not, as a rule, be satisfied to be told simply that he was mistaken in some of his empirical assumptions, which he thought precluded the occurrence of X; he will also want to be given a set of alternative, and presumably true, assumptions which, in conjunction with the rest of his background beliefs explain to him why X occurred. (Hempel 1970, 429)

There is an obvious problem with reductive attempts along Hempel's lines. It cannot be ruled out that enquiry starts with one type of explanatory-seeking question but continues with another. It does not take more than that there is an intermediary explanatory step of the kind described in the Dray-Hempel variety for us to have every reason to be sceptical about the reductive approach. A developmental account, where both of the two stages may be recognized as explanatory, would be a more modest position. Hempel clearly offers an interesting sketch of a developmental account of how-possibly

explanation; whether it is, also, intended to be reductive we leave as an open question. It cannot be motivated from the context of the Dray-Hempel variety unless the agent always moves directly from conflict and inconsistency to a new potential why-explanation.[2]

Going back somewhat in philosophical history, however, a frequent claim is precisely that every satisfactory explanation has to be an answer to a why-question. On this view, how-possibly explanation can—to the extent that it is an *explanation*—be nothing but why-explanation (see Salmon 1989, 136-137).[3] This view more clearly exemplifies the reductive position.

However, the above *prima facie* objection still stands. In order to merit attention the reductive account has to be promising as a descriptive account. Therefore, it is of interest whether there is an intermediary and explanatory first step in Dray-Hempel cases. In order to evaluate the position it is useful to know whether yet other varieties of how-possibly explanation exist. If so that would further complicate the relations between how-possibly explanation and why-explanation. The reductive account presupposed by some why-explanationists would be rather unattractive if, as I shall now argue, there are several distinct varieties of how-possibly explanation.

3. Potential how-explanation: bracketing truth-claims and mapping the space of possibilities

An alternative view of how-possibly explanation can be generated rather swiftly. The "possibly" in "how possibly" may qualify a how-explanation in a similar way that Hempel's term "potential" in "potential explanation" qualifies a why-explanation. On

[2] It may well be that Hempel thinks that this is the case, and that we can simply rephrase a how-possibly question as "Why did this event (which I initially regarded as impossible or highly improbable) occur?" (Salmon 1989, 137), but his following observation that many why-question can be rephrased as how-possibly questions clearly does not prove as much:

"[…] questions of the form 'why is not the case that p?' […] might well be rephrased as 'how-possibly' questions: 'How could it possibly be the case that not-p?'. Questions such as 'Why doesn't the Leaning Tower of Pisa topple over?' or 'Why don't the antipodes fall off the earth?', 'If reflection in a plane mirror interchanges right and left, why not also top and bottom?' will normally be raised only if the questioner entertains certain assumptions concerning relevant empirical matters which seem to him to make it certain or, at any rate, highly probable that the specified phenomenon should occur. A pragmatically adequate answer again will have to clear up the empirical or logical misapprehensions underlying this belief." (Hempel 1970, 429)

What such examples can show, I think, is that some why-questions are complex and that some how-possibly expressions are why-questions in disguise. If the observations in this talk are correct, both are very different from showing that every how-possibly explanation without residue can be rephrased as a why-explanation.

[3] However, the reductive perspective is often formulated and motivated rather casually: Cohen (1950, 259) requires of any explanation that it be an "appropriate answer to the question 'why' the explicandum is the case"; Braithwaite (1947, ii) states that an explanation is simply "any answer to a 'why' question which in any way answers the question, and thereby gives some degree of intellectual satisfaction to the questioner" (see Dray 1957, 156); van Fraassen (1980) echoes his forerunners. Given the sweeping formulations of Cohen and his contemporaries, it is perhaps misleading to understand these positions as serious reductive attempts at all.

this understanding a particular how-possibly explanation is almost like a how-explanation. The difference is that claims about how the world is, that the explanans of the how-explanation involves, are bracketed in the how-*possibly* explanation.

I want to separate two possible ways of interpreting bracketing. The reason is that we seem to have accounts of how-possibly explanation along both lines. I want to talk of a literal, metaphysical sense of bracketing. But I also want to acknowledge its epistemic counterpart. In the metaphysical sense bracketing stands for an intervention where a how-explanation is robbed of its implications about how the world is. On this reading, a how-possibly explanation does not *make the kind of claim* about the world that the how-explanation does. In the epistemic sense (to turn to its counterpart), bracketing reflects the fact that when we are dealing with how-possibly explanations we do not *know* whether the explanation is true. (This may be expressed in terms of the lack of adequate justification for how-possibly explanations.) On this reading, how-explanations are known to be true (or are adequately justified) whereas how-possibly explanations are not.

There are many possibly reasons why one might be interested in potential how-explanations – whether conceived of as making no claims about how the world is or not being known to be true (or adequately justified). There is a spill over effect from differences in explanatory interest to how, more precisely, one's conception of how-possibly explanation of this variety is crafted. Before restricting the discussion to potential how-possibly explanations in the metaphysical sense[4] I want briefly to introduce two explanatory interests that may result in potential how-possibly explanations.

The first example I select is discussed by Resnik (1991). In biology, he claims, certain explanations make scientific service despite their lack of adequate justification. Resnik (1991, 144) cites Darwin's explanations of the origin of biological adaptations as an influential instance in case. When discussing the evolution of bird wings, Darwin suggests that these could have developed in a series of evolutionary steps from appendages that were not capable of flight. This how-possibly explanation had many explanatory virtues. But the empirical evidence at the time was fragmentary, at best. And the same goes for many of today's evolutionary explanations in biology as well as in other disciplines.

Now, the concept Resnik develops clearly concerns epistemic bracketing, and will not be discussed further at this point.[5] In contrast, the conception I am concerned with here is the related phenomenon of bracketing of truth-claims concerning any particular how-possibly explanation. However, the motivation behind Resnik's conception – it seems to me – fits nicely with the understanding of how-possibly explanations as potential how-explanations of this variety.

[4] Its epistemic counterpart will be dealt with, briefly, in the end of the paper.
[5] According to him, the lack of adequate empirical support is definitive of how-possibly explanation. How-possibly explanations may become how-actually explanations as science progresses. It is a position reminiscent of Levi's (2003) understanding of dispositions. His dispsitions can become real as science progresses. See also Persson (2006). Machamer et al. (2000) seems attracted to a similar idea.

Maybe the second example is even more to the point. Neurath (1916) suggests that in order not to have to rely on 'insight' historiography should proceed in two steps. First, in a particular field, the elements out of which any particular theory could be reconstructed are to be identified. For instance, the optical theories of Huygens, Newton, Malebranche and others can be identified with the field of possible optical theories at a certain time. This first stage relies exclusively on 'a purely logical point of view.' It sees every possible theory as having equal value. "A special pleading is needed if one of them is preferred (Neurath 1916, 16; see also Reisch 1994, 168). Differentiating values are not introduced until the second stage. How-possibly explanations, on this understanding, span the space of possible options at a certain time:

> For a best possible mastery of historical development it is desirable to make a preparatory survey of all groupings of individual views that are possible in principle. Maybe the start can be made from the theory of greatest power, if there is one of this character. (Neurath 1916, 30)

Several philosophers have advocated views such as Neurath's. I will soon return to the role of how-possibly explanations in spanning the space of possibilities. But first two exemplifications of the basic conception of how-possibly explanation I am identifying.

Salmon (1989, 137) is one example of an advocate of how-possibly explanations of the second variety. He holds the view that: "a how-possibly question does not require an actual explanation; any potential explanation not ruled out by known facts is a suitable answer." There is an epistemic residue in this characterization but it is not farfetched to suggest that for Salmon we are not only warranted in claiming that a how-possibly explanation without adequate justification may be acceptable. A stronger claim is motivated. It is of no relevance per se whether the how-possibly explanation is (or parallels) an ontic explanation. In other words, the explanation *qua* how-possibly explanation does not involve any truth-claims concerning the explanans. These are bracketed in the metaphysical sense introduced earlier. The following, somewhat lengthy, quotation should make this clear:

> […] a DC-9 jet airplane recently crashed upon takeoff at Denver's Stapleton Airport during a snowstorm. One peculiar feature of this accident is that the plane flipped over onto its back. There are many explanations of a crash under the circumstances, but I wondered how it could have flipped over. Two how-possibly explanations were mentioned in the news reports. One is that it encountered wing-tip turbulence from another airplane just after it became airborne. Another was suggested by the report of a survivor, who claimed that the plane was de-iced three times during its wait for departure, but that on the latter two of these occasions one wing, but not the other was treated. If one wing had an accumulation of ice on its leading edge while the other did not, the difference in lift provided by the two wings might have been sufficient cause for the plane to flip over. As I write this paragraph I have not yet heard the final determination regarding the cause of this crash. *Both potential explanations I have mentioned are satisfactory answers to the how-possibly question, but we do not know the correct answer to the why-question*. (Salmon 1989, 137, my emphasis)

Other recent examples of the second variety are the views of Machamer et al. (2000), Craver and Darden (2005), and Craver (2007). However, looking at their suggestions through the lenses I have suggested above reveals some differences that may lead to uncertainty about their position within the two dimensions I examine. First, Machamer et al. (2000) invites us to think about "how-possibly, how-plausibly, and how-actually." This contextualization of how-possibly inspires the epistemic interpretation. Second, Craver and Darden (2005, 236) seems to suggest a metaphysical "error theory" interpretation of how-possibly explanations. Or at least that is one way of reading the following passage:

> The observable phenomena of the natural world are to be explained in terms of hidden mechanisms, and these mechanisms are to be inferred using well controlled experiments to sort how-actually from how-possibly descriptions of mechanisms.

The need for, as well as the nature of, the business of sorting out implies that how-possibly explanations make claims about the world – claims which are in fact false (!). The following quote from Craver (2007, 112) can be interpreted in both ways:

> How-possibly models are often heuristically useful in constructing and exploring the space of possible mechanisms, but they are not adequate explanations.

In agreement with Neurath and Salmon, Craver claims that when explaining how-possibly one does not need to presuppose that the explanans elements exist and – if so – whether they are organized in reality the way they are in the model. *Prima facie* no truth-claim concerning the particular how-possibly explanans needs to be involved in this characterisation. But the final verdict depends on what it is that makes how-possibly explanations inadequate. Is it – *pace* Craver and Darden (2005) – that they bracket claims about truth (metaphysical interpretation)? Is it that they are false? (metaphysical error theory)? Is it that they lack justification (epistemic interpretation)? Well, it is safe to conclude that it is one of these three. How-actually models, by contrast, (claim to) describe real features of the mechanism that in fact produces the explanandum phenomenon.

One of the examples Craver (2007) deploys is from neuroscience. It concerns the history of the discovery of the action potential. More specifically it concerns the possibility that ions are conveyed across the membrane by active transport. Bertil Hille developed a model, which is now textbook material. According to it, changes in action potentials are explained by opening and closing of transmembrane channels. To begin with, Hille (1992) presented a range of different how-possibly models. The models differed in their parts, in the activities the parts took part, as well as in how the mechanisms were organized:

> There are swinging gates, sliding gates, free-floating blockers, tethered balls and chains, rotating cylinders, and assembling components. Hille intended these as merely how-possibly models because he had no idea whether the channels would turn out to have parts of the requisite sort, or whether the parts could act as the model requires, or whether their activities were organized in the way that the model suggests. (Craver 2007, 117-118)

This final illustration combines the two features we have been concerned with in this section on how-possibly explanation as potential how-explanation. First, according to Craver's description Hille's model is a how-possibly explanation since it brackets claims about how the world is (metaphysical interpretation). This decision is grounded in lack of knowledge. Second, it utilizes these how-possibly explanations to map the space of possible explanations. Most of these possible explanations, it later turned out, could be ruled out in the face of known constraints and plausibility arguments (see Craver 2007, 118).

More could be said about this family of relatively common interpretations of how-possibly explanations. However, the cluster of conceptions offered so far make the need for yet another complementary understanding of how-possibly explanation obvious. This complementary conception constitutes this article's primary addition to our knowledge of how-possibly explanations.

Before we move on, however, it should be noted that the second variety (potential how-explanations) and the first variety (the Dray-Hempel variety) differ in several ways. The Dray-Hempel variety need not constitute substantial explanations, let alone substantial how-explanations. It is not really concerned with the *explanans* side of the explanation. In contrast, the second variety (potential how-explanation) requires many of the explanatory virtues of actual how-explanations. Exactly what virtue, if any, they *cannot* have may differ. According to Resnik (1990) and Craver (2007) they should not be backed up by adequate empirical evidence.[6] Neurath (1916) and Salmon (1989), as I read them, suggest instead that in how-possibly explanations truth-claims regarding the explanans are bracketed. That is, the potential explanation may be an actual – i.e. ontic or true – or adequately backed up explanation but whether or not it is is of no relevance in the context of how-possibly explanation.

Let us now ponder in which scientific contexts the two varieties appear. The Dray-Hempel variety occurs in an environment of conflicting beliefs and a certain sort of puzzlement. The context of the present variety, by contrast, is typically one of discovery, hypothesis generation, or exploration of a range of possible explanations in a research environment where the explanandum phenomenon is accepted as a fact and now needs to be integrated with the system.

4. Partial how-explanation: claiming the existence of an ontically explanatory mechanism

It is time to introduce yet another conception of how-possibly explanation. Inevitably, that the first and second conceptions of how-possibly explanation make no claims concerning the truth of the explanans in the actual world—or lacks adequate empirical support in favour of the explanans—provides room for independent conceptions. The absence of these features implies that the previous conceptions will not generalize to certain, apparently important, cases. Some how-possibly explanations entail more

[6] And, as already noted, in some places Craver and Darden might add the further restriction that the how-possibly explanation is actually false.

factual and/or empirically justified claims than the how-explanation conceptions of the previous sections can harbour. Below follows just a few examples that testify to this fact:

> A fundamental question is how it is possible for the shuttling transport receptors to carry their cargo in only one direction. (Kutay et al. 2007)
>
> By studying the biology of coral reproduction and recruitment, we gain an understanding of how it is possible to slowly degrade a reef. (Richmond 1997, 175)
>
> By starvation and by oxygenation and by a combination of starvation and oxygenation we have seen how it is possible to shift the protozoa about almost any way we wish. (Cleveland 1925, 317)

Apparently, in these cases the desired answers are not merely possible ways the world *could be* in order to produce the explanandum phenomena. *Pace* Salmon (1989, 138), far from "any potential explanation not ruled out by known facts is a suitable answer" to these three problems. The reason is that it matters a lot to the explanations on offer if they depict facts or not. For instance, the passage in Richmond (1997) continues: "This understanding is of central importance to coral-reef management and preservation". It matters even more – to the researchers themselves, that is – whether the how-possibly explanations on offer are empirically justified. This group of how-possibly explanations clearly makes claims about the world. It is usually mandatory that they are supported by adequate evidence. Hence there is disagreement between the third variety and the second variety regardless of our interpretation of potential explanations. Conflict appears whether potential how-explanations are interpreted metaphysically or epistemically.

However, the primary interpretation of the group of how-possibly explanations we are concerned with now is metaphysical or – as I shall prefer – *ontic*. What is needed as explanans are facts that make the explanandum phenomenon physically (or, in these cases, biologically) possible by providing a partial mechanism that in fact had the explanandum as outcome.

Let us expand briefly on the latest example. L. R. Cleveland is interested in the symbiosis between termites and their intestinal protozoa. With protozoa the termites seem to be able to feed only on wood, but without protozoa such a diet kills them within a few weeks. In this particular study, Cleveland wanted to find out how (i.e. in what ways) it is possible that the presence of protozoa in termites varies. He conjectured that oxygen could be one key. High levels of oxygen are toxic to many species. In his experiments, whereas protozoa quickly died from oxygen exposure, termites proved to be unaffected by even high levels of oxygen. "They easily live eight to ten days in an oxygen atmosphere which kills their intestinal protozoa in three days" (Cleveland 1925, 316). Similarly, starvation proved effective. Protozoa died well before their hosts did in circumstances of starvation.

These experimental results help Cleveland to the claim that he has found the answer to his how-possibly question. This immediately proves that the how-possibly question

posed in this context is neither one of epistemic inconsistency nor of mere potentiality in Neurath's or Salmon's sense. Indirectly, it also implies that Resnik's (1991) analysis of how-possibly explanations in biology does not cover this case.[7] As we remember, Resnik explicitly attempted to characterize how-possibly explanations in biology exactly by their lack of adequate empirical evidence:

> An explanation is a how-possibly explanation if and only if it 1) lacks adequate empirical support, but 2) still satisfies other explanatory virtues. (Resnik 1991, 143)

The kind of support Cleveland and others provide in favour of their conclusions that they have found part of the ontic explanation is normally rather impressive experimental data.

One conceptual question remains. Why then are these "possibly"-explanations? It may seem that they are too "actual" for that. My basic claim is that they deserve the epithet "possible" by claiming the existence of a mechanism without which the explanandum phenomenon would not have been produced (in the actual way this happened), but this part of the story is not sufficient to account for the truth of the explanandum.[8] These explanations are about a mechanistic or – broadly speaking – ontic sense of this-worldly possibility. This possibility is established by providing the mechanistic truth-maker needed for claims about how the phenomenon could – and in fact did – come about. However, such explanations amount to less than a complete how-explanation in that they may not include all the mechanistic facts we may need in order to see more precisely how the explanandum phenomenon was produced.

In this sense the third variety of how-possibly explanation identified here is doubly interesting to compare with potential how-explanations. It seems that the present variety can be formulated like this:

> An explanation is a how-possibly explanation if and only if it 1) is an ontic explanation, but 2) lacks certain other explanatory features of how-explanations.

5. How and how possibly

According to several conceptions of how-explanations causal or mechanistic detail is crucial for how-explanations. Dray, for instance, acknowledges this feature in historical how-explanations:

> 'Explaining how' may also mean making clear the detailed steps by which something came about. Thus Chester Wilmot states the theme of his recent book, *The Struggle for Europe*, as: "Not only how Hitler was overthrown but how Stalin

[7] It is trivial that this how-possibly explanation does not imply that the explanans are not adequate or – worse still – false.
[8] There are of course a number of complications that should be contemplated at this point and which have to do with the possibility of the existence of several mechanisms that might yield the same outcome. But they do not matter in this context, where the only thing I want to point out is the distinctness of this variety in comparison with the other varieties I have identified.

> emerged victorious, how Russia came to replace Germany as the dominant power in Europe, and how Stalin succeeded in obtaining from Roosevelt and Churchill what he failed to obtain from Hitler." This sense of 'explaining how' is a very common one in history, but it is quite different from explaining how something could be so. (Dray 1957, 166-167)

As this paper shows, I do not necessarily agree with Dray on what it is to explain how something could be so. What I do agree with Dray in is that it is rather easy to maintain a difference between typical how-possibly explanations and how-explanations by the amount of causal detail. How-possibly explanations diverge from and overlap with how-explanations by being partial how-explanations. This possibility, however, is absent in the second variety. Potential how-explanations are just like complete how-explanations in this respect.

6. In favour of how-possibly explanations of the third variety

Mechanisms are seldom causally isolated. There is causal interaction beyond the boundaries of mechanisms and between mechanisms. In order to be able to fill in the causal details of one how-explanation one sometimes needs to establish the existence of the surrounding mechanisms. And often, in biology at least, one is expected to back up a how-explanation by something more than an evolutionary just so story. How-possibly explanations of the third variety are just what we need.

I feel less convinced that Resnik's variety, let alone Salmon and Craver's, stands the test. Even when viewed as a heuristic it is probably generally to ask for too much and too little to present potential how-explanations without adequate empirical support. And it is normally never satisfactory to present a potential how-explanation that involves no existence claims concerning the explanans (not to mention the one which implicitly denies that the explanans does not exist).

It is often to ask for too much since one partial mechanistic framework would be enough. We seldom move forward by first conjecturing about all details of all potential how-explanations. Moreover, if we are partially ignorant about how the world really is it is painful—and useless—to engage in such an activity.

It is often to ask for too little since at least parts of the proposed potential how-explanations should enjoy empirical support. It is more in accordance with "good" biological science to secure support in favour of the crucial elements of the how-possibly explanation and leave the rest of the potential how-explanation sketchy or blank for the purpose of other studies. But the varieties of potential how-explanation we have pondered seem to require lack of support or even lack of existential claims, both of which make them unsuitable for the job.

I am speculating somewhat here in the very end. But an odd thing this exercise uncovers is that had it been performed on why-explanations little time would probably have been spent on the issue of potential why-explanation. Lipton (2004) acknowledges that inference to the best explanation should be interpreted as inference to the best *potential* explanation for the obvious reason that our "inductive" scientific inferences are fallible.

The implication is that the divide between actual and potential is not terribly interesting for sorting explanations in actual science.

This seems to lead to a dilemma for advocates of the second variety. First, unless the requirement on the second variety is that the empirical support should be next to nil or that no existential claims are involved it is difficult to uphold the difference between how-possibly explanations and ordinary how-explanations we meet with in scientific practice. Second, if this requirement is met how-possibly explanations are rather uncommon whereas so the potential how-explanations that frequently occur in science must be of another variety. For instance, the category of *potential* partial how-explanation, i.e., potential how-possibly explanations of the third variety should be more common if the observations in this section are right. This, too, seems to make how-possibly explanations of the third variety more practically important than other varieties that we sometimes also report by expressions such as "How possibly X."

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