Two Explanatory Questions
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Abstract: When an event occurs by chance, there are at least two distinct questions that arise: (1) why did the event occur? and (2) why was the event’s chance of occurring equal to \( n \)? (where “\( n \)” is a particular real number along the unit interval). I argue that influential discussions of explanation in indeterministic contexts have confused these two questions by mistaking plausible answers to question (2) for plausible answers to question (1). When these two questions are appropriately distinguished, the following view of scientific explanation (surprisingly) emerges as among our best options: chances explain the occurrence of chance events, while other ingredients of scientific theorizing (such as laws of nature and/or causes) explain an event’s chance of occurring.

0. Introduction

When an event occurs by chance (as when some radioactive material decays, or when some ice cubes melt, or when someone’s latent untreated syphilis develops into paresis), there are two distinct explanatory questions that may arise: why did the event occur, and why was the event’s chance of occurring equal to \( n \) (where \( n \) is a real number along the unit interval). When we ask for an explanation of the occurrence of a particular chance event, we are requesting what I’ll call a “chance explanation”. When we ask for an explanation of a particular event’s chance of occurring, we are requesting what I’ll call an “explanation of chance”.

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1 Thanks to John Carriero, Jane Friedman, Pamela Hieronymi, Matthew Kotzen, Marc Lange, John Roberts, and Elanor Taylor for a great deal of help with this manuscript and its ancestors.
Plausibly, scientific theories provides answers to both kinds of question. For example, physics arguably tells us both why some portion of radioactive material decayed during a particular time interval and why the chance of that much decay during that interval was 50%, (non-equilibrium) statistical mechanics arguably tells us both why our ice cubes melted and why their chance of melting was so spectacularly high, and medical science arguably tells us both why someone contracted paresis and why their chance of contracting paresis was 30%.

If the chance of every occurrence were either 1 or 0, the distinction between chance explanation and explanation of chance would be of little philosophical interest. According to one influential line of thought (Hempel 1965), for example, scientific theories explain a given proposition by showing that it had to be true given the laws of nature and antecedent conditions. When an event had to occur given the laws and antecedent conditions, its chance of occurring had to be 1 given those very laws and conditions; and, when an event’s chance of occurring had to be 1 (prior to the event’s occurrence) given the laws and antecedent conditions, the event had to occur given those very laws and conditions. According to this line of thought, then, there seems to be no philosophically interesting distinction between explaining an event’s occurrence and explaining its chance 1 of occurring; every chance explanation doubles as an explanation of chance, and vice versa.

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2 If chance functions satisfy the standard axiomatization of probability, then events of chance 1 need not occur and events of chance 0 can nevertheless occur. For example, a random continuous variable’s taking any particular value has probability 0 according to the standard analysis. Perhaps this counterintuitive implication is reason to model chance functions with some non-standard analysis, but perhaps not. Either way, I take there to be an intuitive distinction between events that are the outcomes of chance processes and events that are not, and I assume that this distinction survives whether or not both kinds of events can have extremal chance values. If we decide to stick with the standard analysis, we should ultimately agree on some less potentially misleading way to mark the distinction between events with chance 1 that are the outcomes of chance processes and events with chance 1 that are not. For the time being, because it is an exegetically convenient way to track this distinction, I write as if an event’s chance 1 of occurring implies that it does and an event’s chance 0 of occurring implies that it does not occur.
However, we must be careful to not overgeneralize from the deterministic case. We should not in general expect that whatever philosophical account we give of chance explanation can just as satisfactorily be extended to explanation of chance or *vice versa*. The primary moral of this essay is that attending to the distinction between chance explanation and explanation of chance is crucial to developing a philosophical account of scientific explanation that works in contexts in which the chances of some occurrences fall between 0 and 1. I will argue that the kinds of relationships that have struck philosophers as plausibly underwriting scientific explanation are not, on reflection, relationships that both information about the occurrence of chance events and information about an event’s (non-extremal) chance of occurring can stand in. I consider non-causal accounts (on which causal notions play no role in explanation’s analysis, as exemplified by Kitcher 1989 and Salmon 1971), causal accounts (on which scientific explanations consist only in information about causes, as exemplified by Lewis 1986 and Woodward 2003) and what I’ll call “causes plus” accounts (on which both causal and additional nomic relations are essential ingredients of scientific explanations, as exemplified by Railton 1978). According to my analysis, many of these theories are promising accounts of explanation of chance but each has surprisingly little to say that is at once plausible and illuminating about the nature of chance explanation—a fact that has been obscured by the literature’s tendency to mistake plausible observations about explanation of chance for plausible observations about chance explanation.

Another result of this tendency to blur the distinction between chance explanation and explanation of chance is the widespread consensus that, when an event occurs by chance, its occurrence is explained by something other than, or something in addition to, its chance of occurring (such as information about laws, antecedent conditions, or causes). This consensus is
backed by plenty of intuitive appeal. After all, no scientist interested in understanding, say, atomic decay, would ever be satisfied to merely learn the chances of various decay events, and so a full understanding of atomic decay must involve something other than, or something in addition to, information about chance values.

However, while it is indisputable that our best indeterministic scientific theories contain a great deal of explanatory information apart from chance ascriptions, the distinction between chance explanation and explanation of chance allows us to ask whether this additional explanatory information helps to provide chance explanations or explanations of chance. For example, perhaps the additional information desired by our scientist who is interested in atomic decay (but already knows the chances of decay) is an explanation of why those chances obtain rather than additional explanatory information about why various decay events occur. The second moral I draw from the survey that follows is that, once we are careful to distinguish between chance explanation and explanation of chance, the view that chances explain the occurrence of chance events, while other ingredients of scientific theorizing explain an event’s chance of occurring, emerges as among our most attractive options.

1. Chance and Chance Events: Initial Assumptions

When I use the word “chance”, I mean to be referring to a mind-independent feature of the world that is appropriately modeled by probability theory and that at least sometimes takes values between 0 and 1. Philosophers disagree about which (if any) indeterministic scientific theories are best interpreted as modeling chance rather than as modeling, e.g., reasonable degree of belief or actual relative frequency. For example, our commonsense theory of coin flips assigns a 50% probability to the proposition that a quarter lands heads after a good flip, but it is
not obvious whether this probability ascription means that a quarter has a 50% chance of landing heads, or that even money is a fair bet on heads, or that half the coins flipped so far have landed heads, or something else entirely. For some philosophers, only fundamental physical theories such as quantum mechanics model chance. For others, chances feature in non-fundamental sciences such as thermodynamics, evolutionary biology, medicine, and meteorology.

Partly for the sake of having familiar examples with which to work, I’ll use chance ascriptions drawn from both fundamental and non-fundamental sciences. Our intuitions about explanation are most clear when we consider familiar cases, and explanations endorsed by commonsense and non-fundamental physical theories are those with which most of us are most familiar. That said, my appeal to non-fundamental chance is not merely an exegetical convenience; my own view is that at least some commonsense and non-fundamental physical theories do indeed model chance and that these theories provide genuine explanations of events that occur by chance in precisely the same way as do fundamental physical theories. Defending that view, however, is more than I’ll do here. All that is essential to the discussion that follows is that there are some events that occur by chance.³ Readers who believe examples of chance events are best drawn from fundamental physics may safely replace my non-fundamental cases with their own.⁴

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³ I take no stand on the metaphysics of events, except to assume that events are “Humean”, i.e., broadly non-nomic features of the world. For example, its being a law that all copper conducts electricity is not an event, but a particular piece of copper conducting electricity is an event. Similarly, an event’s chance of occurring is a nomic feature of the world and so is not itself an event.

⁴ In other words, I take the paradigmatic examples of chance events to be those drawn from diachronically indeterministic theories of the fundamental structure of the world (such as the standard interpretation of quantum mechanics) and this essay aims to explore what explains the occurrence of such events. Accordingly, I do not engage with philosophical accounts of explanation that are targeted at the explanatory value of probability ascriptions in non-fundamental theories but that are not meant to extend to the explanatory value of probability ascriptions in diachronically indeterministic theories of fundamental physics. Such accounts can be found in, for example, Schaffer’s (2007) account of the explanatory role of probability in classical statistical mechanics, Streven’s (2008) account of the explanatory role of probability in explanations involving coin flips and Skow’s (2014) account of “almost necessity” explanations.
I further assume that at least some objective chances are “single-case” chances: chances of a particular event occurring. For example, I assume that atomic physics reveals the chance that a particular sample of radioactive material will decay during some time interval rather than merely revealing the chance of decay among a collection of (actual or hypothetical) relevantly similar samples of radioactive material. Some philosophers are skeptical of single-case chances (e.g., von Mises 1957, Howson and Urbach 1993, Gillies 2000) and single-case chances open the door to further difficulties such as the reference class problem (discussed in, e.g., Ayer 1963, Hajek 2007), but I’ll ignore these complications in what follows.

Additionally, I assume that an essential feature of chance (perhaps the essential feature) lies in its unique relationship to the doxastic states of rational agents. The details of this relationship are much disputed, but the most famous codification of the relationship is David Lewis’s “Principal Principle” (Lewis 1980). Disagreement about details aside, most everyone agrees that if an agent is certain that some outcome has a particular chance of occurring then, ignoring extraordinary cases involving sources of evidence that (as a matter of fact) agents like us do not typically have, her degree of confidence in that outcome should (on pain of irrationality) be equal to the chance of that outcome. So, for example, if I am sure that there is a 70% chance of rain tomorrow then my degree of confidence that it will rain tomorrow should also be 70%.

The extraordinary cases are ones in which an agent has “inadmissible” information, which is information that somehow provides evidence about whether an outcome occurs that is even better evidence than is the outcome’s chance value. Offering non-circular characterizations of “inadmissible information” is difficult. As a first pass (and as a good heuristic), information about the state of the world prior to an event’s occurrence is admissible while information about
the state of the world at or after an event’s occurrence is inadmissible. This characterization, however, cannot be quite right. Were I to know that, long ago, a reliable crystal ball predicted that it will be dry this evening despite this morning’s high chance of evening rain, then I would have information about the state of the world prior to this evening that is nevertheless better evidence about whether it will rain this evening than is this evening’s high chance of rain. I return to the question of how best to characterize admissible information in section 3.2.

What is it for an event to occur by chance? I assume that chance values can differ between one proposition and another, between one world and another, and between one time and another. So characterized, chances define chance events as follows: an event $E$ occurs by chance (in world $W$) if and only if (i) there is some time $T$ such that the chance at $T$ (and at $W$) that $E$ occurs is between 0 and 1 and (ii) there is no time between $T$ and $E$’s occurrence such that the chance at that time (and at $W$) that $E$ occurs is 0 or 1. In other words, events that occur by chance are those events that have non-extremal chances of occurring right up until they occur.

2. Nomic Expectability: A Unified Account

I will be arguing that many influential theories of scientific explanation are best understood as theories of explanation of chance or as theories of chance explanation, but not as theories that provide a single unified account of both these kinds of explanation. However, the first major modern discussion of indeterministic explanation (due primarily to Carl Hempel) provides a helpful example of a theory that unifies chance explanation and explanation of chance.

Hempel’s account features three models of explanation. The “Deductive-Nomological” model accommodates explanations of events that occur in deterministic contexts. According to
the model, we have an explanation of an event’s occurrence if we have statements of particular fact and statements of general law that, when conjoined, deductively entail that the event to be explained occurs (provided that the statements of general law are essential to the validity of the argument). To use a standard example, the current position of the celestial bodies and the laws of planetary motion combine to explain the next lunar eclipse because the former imply that the latter occurs.

The D-N model, of course, cannot be extended as a model of chance explanation because the laws governing the occurrence of chance events are essentially probabilistic and so cannot be used to deduce that a particular chance event occurs. Nevertheless, Hempel argued that indeterministic physical theories also provide genuine scientific explanations, and he introduced two additional models to capture the explanations provided by indeterministic scientific theories: one for chance explanation and one for explanation of chance.

The “Inductive-Statistical” model accommodates chance explanation. According to the model, explanations of events that occur by chance take the form of strong inductive arguments. For example, the present thermodynamic features of the ice and water in my glass combine with the probabilistic laws of thermodynamics to explain the fact that my ice soon melts, since the former provides us with an inductively strong argument for the latter (provided that the thermodynamic laws are essential to the strength of the inductive argument and that an additional condition, “the requirement of maximal specificity” is met). Abstracting away from a multitude of details, the I-S explanation of my ice cube melting looks, structurally, something like this:

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5 The requirement of maximal specificity requires, roughly, that an argument fails to satisfy the I-S model if its premises leave out some information we have that, were that information included among the argument’s premises, would change the inductive strength of the argument. If we have only admissible information and if the premises of an inductive argument imply an event’s chance, then, by the Principal Principle, the requirement of maximal specificity is met.
P1. Whenever condition \( C \) obtains, the chance that the ice cubes will melt is equal to \( n \) (where \( n \) is some value extremely close to 1).

P2. Condition \( C \) obtains.

So,

C. The ice cubes melted.

The “Deductive-Statistical” model accommodates explanation of chance. Like D-N explanations, D-S explanations take the form of deductively valid arguments. Like I-S explanations, however, D-S explanations employ essentially probabilistic laws as premises and so their conclusions are also probabilistic, i.e., the explanandum of a D-S explanation is a statement that a proposition has a certain probability of being true. When these probabilistic conclusions model chance (as opposed to, say, relative frequencies), a D-S explanation is an explanation of chance. For example, the present thermodynamic features of the ice and water in my glass combine with the probabilistic laws of thermodynamics to explain the fact that my ice’s chance of melting is extremely high. Abstracting away from the details once again, the D-S explanation of my ice’s high chance of melting looks something like this:

P1. Whenever condition \( C \) obtains, the chance that the ice cubes melt is equal to \( n \) (where \( n \) is some value extremely close to 1).

P2. Condition \( C \) obtains.

So,
C*. The ice’s chance of melting is equal to $n$.

Though there are some interesting differences between the D-N, I-S, and D-S models (owing to the interesting differences between deduction and induction), a single unifying picture of scientific explanation motivates each one. Arguments that satisfy one of the models “show that, given the particular circumstances and laws in question, the occurrence of the phenomenon was to be expected; and it is in this sense that the explanation enables us to understand why the phenomenon occurred.” (Hempel 1965, pg. 337) On Hempel’s view, scientific theories explain by providing nomic grounds for expecting the truth of the explanandum sentence, whether that sentence is about the occurrence of a determined event, the occurrence of a chance event, or an event’s having a particular chance of occurring. Thus, Hempel provides a unified account of indeterministic explanation on which chance explanations and explanations of chance are fundamentally of the same sort: both essentially involve a display of the nomic grounds for expecting the truth of the sentence to be explained.

There is an additional sense in which the I-S and D-S models are “unified”: the I-S explanation of my ice melting and the D-S explanation of my ice’s high chance of melting exactly share a set of premises. This second sense of unification is importantly independent of the sense of unification discussed above. In particular, it does not follow from the fact that a single body of information provides both chance explanations and explanations of chance that it does so for the same reasons. For example, it could be (but happens not to be on Hempel’s account) that P1 and P2 explain both C and C*, but do so in virtue of standing in very different relationships to C on the one hand and C* on the other.
Despite being alive to the distinction between chance explanation and explanation of chance, Hempel’s account of scientific explanation is untenable. It is widely acknowledge that displaying the nomic grounds for expecting the truth of a proposition is insufficient for explaining that proposition. For example, the laws of planetary motion and the current positions of the celestial objects combine to deductively imply the date of past lunar eclipses, but the current positions of the celestial objects in no way contribute to an explanation of an eclipse that occurred in the past. So, though Hempel succeeded in identifying a relationship—nomic expectability—that both chance events and an event’s chance of occurring can stand in, that relationship does not plausibly underwrite either chance explanation or explanation of chance.

The contemporary literature on scientific explanation has benefited greatly from the lessons of Hempel’s success and failures. Each kind of view discussed below is meant to improve in one way or another on Hempel’s and each, I think, contains interesting ideas about either chance explanation or explanation of chance. However, I will argue that none of the following views adequately addresses both.

3. Non-Causal Accounts of Indeterministic Explanation

From the perspective of a certain kind of empiricist, one of the primary virtues of Hempel’s account of scientific explanation is that it makes no mention of causation. In this section, I consider two approaches to scientific explanation that were designed to capture the asymmetry of explanation (e.g., the fact that the present explains the future but not the past) without invoking the asymmetry of causation (e.g., the fact that the present causes the future but not the past).
3.1 Unificationism

I’ll use the term “unificationism” to refer to theories of scientific explanation on which explanatory theories are those that best balance the virtues of entailing a great deal of information and of being relatively simple. I take unificationism to be exemplified by Philip Kitcher, who writes that a scientific theory is explanatory to the extent that it “unifies” or “systematizes” the world by “showing us how to derive descriptions of many phenomena, using the same patterns of derivations again and again…” (Kitcher 1989, p. 432) On this picture, the fewer patterns of derivation a theory employs, the simpler it is. The best theory of a particular domain will allow one to derive the most information about the domain using the fewest number of derivation patterns. A scientific explanation, in turn, is a derivation that follows one of the patterns of such an ideally unified theory.

Kitcher hoped to capture the asymmetry of explanation by showing that derivation patterns that are intuitively not explanatory are also less efficient than are intuitively explanatory patterns. For example, while one can derive the height of a flagpole from information about its construction or from information about the shadow it casts, the pattern of derivation that uses facts about its construction is more efficient since it can be applied to derive information about objects whether or not they are casting a shadow. So, the theory that allows us to derive the most information with the fewest number of patterns will use the construction derivation pattern but not the shadow derivation pattern. Finally, the reason why a flagpole’s height is explained by being derived from facts about its construction rather than by being derived from facts the length of the shadow it casts is that the former derivation (but not the latter) follows a pattern employed by an ideally unified theory.
For unificationists like Kitcher, then, scientific explanations take the form of deductively valid arguments. However, as we saw in our discussion of Hempel, deductively valid arguments are well-suited to theories of explanation of chance but poorly suited to theories of chance explanation. When an event occurs by chance, there is no deductively valid argument for the occurrence of that event, provided that we restrict ourselves to premises that could at all plausibly be instances of an explanatory pattern of derivation (and so exclude, for example, sentences about the future.) So, unificationist views do not unify chance explanation and explanation of chance: the unificationist treatment of explanation of chance cannot be extended to accommodate chance explanation.

When a theory of scientific explanation fails to capture either chance explanation or explanation of chance, we have two options. One option is to view the theory as incomplete. We could, for example, think of unificationism as the correct theory of explanation of chance but combine it with some distinct theory of chance explanation. A second option is to reject whatever kind of scientific explanation our theory fails to accommodate.

Kitcher goes in for this second strategy. He rightly notes that unificationism cannot be extended to chance explanation, and he explicitly embraces and defends the view that, in indeterministic contexts, we only ever have explanations of chance. On Kitcher’s view, for example, medical science might tell us why someone had a 30% chance of contracting paresis but medical science cannot tell us why a particular individual contracted paresis. And, physics might tell us why some radioactive material had a 50% chance of decaying during a particular time interval, but it cannot tell us why the material decayed. In other words, Kitcher argues that chance occurrences are simply not the kinds of things that are explained by scientific theories.
However, denying that there are ever any chance explanations comes at a high cost. After all, it is currently a live (epistemic) possibility that our best physics will reveal that nearly every event happens by chance. If the standard interpretation of quantum mechanics is correct and if the indeterminism it describes at the level of fundamental physics “percolates up” into the non-fundamental world in such a way that most happenings turn out to be chance events, Kitcher’s view has the breathtaking consequence that almost no occurrence is explicable. For those who think that one of the primary aims of scientific theorizing is to explain what happens in our world, denying that there are every any explanations of chance occurrences is a last resort.

From here on out, then, I’ll focus on the first strategy, i.e., I’ll assume that theories of scientific explanation that fail to accommodate either chance explanation or explanation of chance are at best incomplete. That said, those who are skeptical of either chance explanation or explanation of chance should still read on. In the spirit of the second strategy, the following observations about our dearth of unified accounts of indeterministic explanation might be repurposed as a new reason for skepticism about either chance explanation or explanation of chance.

3.2 Best Admissible Grounds

Hempel posited a very tight connection between explanation and prediction: explanans are grounds for predicting that the explanandum is true. However, many philosophers (e.g., Scriven 1962, Jeffrey 1969, Salmon 1971) object that there seem to be genuine scientific explanations of various propositions that do not also double as grounds for predicting the truth of

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6 Though, see Kitcher 1989, pg. 54 for the claim that this consequence is not, in fact, devastating because some macroscopic chance events are somehow explained by idealizations which suppose that chance events do not actually occur by chance.
those propositions. To borrow an example from Michael Scriven, it seems that we know why a patient develops paresis when we know that he had latent untreated syphilis and that 30% of cases of latent untreated syphilis develop into paresis. However, the fact that a patient has latent untreated syphilis and that 30% of such cases develop into paresis does not give us grounds for predicting that any particular patient will develop paresis.

Nevertheless, even in Scriven’s syphilis case there seems to be a connection between explanation and belief. Knowing that a patient has a 30% chance of developing paresis is not grounds for believing that he will develop paresis, but it is grounds for having very particular expectation regarding the patient’s prognosis. If the patient has a 30% chance of developing paresis, our degree of belief that the patient will develop paresis should also be .3.

Perhaps, then, explanations are not grounds for prediction as Hempel thought, but are instead grounds for what our expectations, should be. As Salmon puts it:

To explain an event is to provide the best possible grounds we could have had for making predictions concerning it. An explanation does not show that the event was to be expected; it shows what sorts of expectations would have been reasonable and under what circumstances it was to be expected. To explain an event is to show to what degree it was to be expected… (1971, pg. 79)

Salmon intends for this passage to motivate his Statistical-Relevance model of scientific explanation, on which explanatorily relevant factors are factors that make a difference to the probability of the event to be explained. An explanation is not an argument at all, on this model, but instead consists of three ingredients: the prior probability of the event to be explained (i.e.,
the probability of the event prior to taking into account statistically relevant factors), the posterior probabilities of the event to be explained (i.e., the probabilities of the event given each possible combination of statistically relevant factors), and a description of which statistically relevant factors are present in the case at hand. In turn, those three ingredients are explanatory because they provide “the best possible grounds we could have had” for forming our expectations about the truth of the explanandum.

Ultimately, the letter of Salmon’s S-R model fails as a theory of scientific explanation because, for a wide variety of cases, we can identify statistically relevant factors that are intuitively explanatorily irrelevant. Barometer readings, for example, are statistically relevant to whether it rains, but information about barometer readings belong in neither explanations of rain (i.e., chance explanations) nor in explanations of the chance of rain (i.e., explanations of chance). Further details of the S-R model aim to defang this objection, but Salmon later concedes (in Salmon 1997) that the S-R model should be supplemented so that it is sensitive to causal relations to avoid these sorts of counterexamples.

Salmon is right to have abandoned the letter of the S-R model in light of its inability to sort causally relevant factors from statistically relevant ones. However, the spirit of the S-R model should not be so quickly dismissed. To clarify Salmon’s idea that scientific explanations are our best grounds for our expectations, return to the paresis example. The fact that a patient has latent untreated syphilis is relevant to our expectations about whether he develops paresis and so, on Salmon’s view, is also explanatorily relevant to why the patient developed paresis. So far, so good. However, the fact that someone tested positive for paresis is even better grounds for our expectations about whether he develops paresis than is his having latent untreated
syphilis. That’s a problem, because the fact that the patient tested positive for paresis in no way helps to explain his paresis.

What Salmon must have had in mind is that scientific explanations are the best possible grounds we could have had for our expectations about whether an event occurs prior to its occurrence. Since we could have known about the latent untreated syphilis before the patient contracted paresis but could not have known that the patient would test positive for paresis prior to the patient contracting paresis, we get the intuitively correct result that information about the positive test result is not explanatory.

Could we really not have had better evidence about whether an event will occur, prior to its occurrence, than information that is intuitively explanatorily relevant to its occurrence? What if we had access to a reliable crystal ball or to the testimony of a time traveler who had just come from witnessing a future occurrence that we want to explain? A time traveler’s testimony might be the best evidence we could have about whether an event occurs prior to its occurrence, but a time traveler’s testimony that an event occurs, given before the event’s occurrence, plays no role in explaining why that event occurred.

That the past could contain evidence about the future that, in some sense, “goes beyond” explanatory information is reminiscent of the problem we encountered when trying to give an account of “admissible” information in section 1. Better, then, to understand Salmon’s suggestion as being that to explain is to provide the best possible grounds one could have had for one’s expectations given that one has access only to admissible information. I’ll call this view of explanation “Best Admissible Grounds”.

Best Admissible Grounds motivates an interesting new account of chance explanation. From the vantage of Best Admissible Grounds, the S-R model turns out to contain too many
ingredients. The prior probability of an event and factors statistically relevant to that event do not belong in the immediate explanation of that event’s occurrence because they are more than is needed for forming expectations about whether the event occurs. Instead, the best possible admissible grounds for forming our expectations about whether an event will occur, and thus all we need in an explanation of the event’s occurrence, is simply information about an event’s chance of occurring.\(^7\)

This new picture of chance explanation successfully avoids the major objections to the S-R model. If we take chances themselves to explain chance events, then the issue of how to sort causes from mere correlations simply does not arise. For example, neither the barometer reading nor the change in atmospheric pressure provides an immediate explanation of today’s rain, and so our theory of chance explanation has no need to sort between them.

However, Best Admissible Grounds is hopeless when applied to explanation of chance. The problem of sorting between causes and correlations rearises when we ask, for example, why today’s chance of rain was so high. Someone with access to only admissible information might know that the barometer reads “storm” and that the chance of a storm is 95% whenever the barometer reads storm. That conjunction is (tied for) being the best admissible grounds for forming expectations about the storm’s chance of occurring. However, facts about barometer readings do not explain the chance of rain any more than they explain the occurrence of rain. So, Best Admissible Grounds cannot motivate a plausible account of explanation of chance and thus, at best, offers us an incomplete account of probabilistic explanation.

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\(^7\) Is the chance value the best grounds for forming your expectations when you have only admissible information? More carefully, the chance value is guaranteed to be among the best grounds one has for forming expectations, since it will tie with other admissible grounds that deductively imply the chance value. However, no admissible information that does not imply the chance value is as good of grounds as is the chance value. The chance value does all the expectation grounding work, and it is in that sense that the chance value is uniquely deserving of the label “best admissible grounds.”
4. Causal Accounts

On my terminology, “causal accounts” of scientific explanation are those on which scientific explanations consist solely of information about causes. On these views, information about laws of nature or about chances might serve to metaphysically ground scientific explanations but they are not, strictly speaking, parts of scientific explanations.\(^8\) Advocates of causal accounts disagree about the correct account of causation, but counterfactual accounts of causation presently enjoy a great deal of popularity among philosophers working on scientific explanation and so will be my focus.

The simplest counterfactual account of causation is one on which \(c\) is a cause of \(e\) if and only if \(e\) would not have occurred had \(c\) not occurred. Indeterministic contexts, however, provide plenty of counterexamples to this simple account. Suppose that my chance of getting cancer is 50%, but would have only been 40% had I not smoked. Intuitively, my smoking is a cause of my getting cancer (if I do), but it is not true that I wouldn’t have gotten cancer had I not smoked; had I not smoked, my chance of getting cancer would have been 40% and so I still might have gotten cancer. The moral is that, when an event occurs by chance, its occurrence need not counterfactually depend on any of its causes.\(^9\) To modify the simple account so that it is able to handle indeterministic contexts, we might allow that counterfactual dependence between a potential cause and an effect’s chance of occurring (rather than between a cause and

\(^8\) For more on the idea that laws ground, but are not part of, causal explanations, see, e.g., Lewis 1986, Woodward 2003, Skow 2013.

\(^9\) Of course, that is not to say that no chance occurrences counterfactually depend on any of their causes. For example, our patient who contracts paresis by chance would not have contracted paresis had he not had syphilis. Nevertheless, that having syphilis was a cause of the patient’s paresis does not imply that he would not have contracted paresis had he not had syphilis—it just happens to be true of this case.
the event’s actual occurrence) is sufficient for causation as follows: c is a cause of e if and only if 
(a) e counterfactually depends on c or (b) e’s chance of occurring counterfactually depends on c.

Even so modified, the simple account faces myriad and well-known counterexamples, 
including cases of early preemption, late preemption, double prevention, and many more. These 
further complications motivate more sophisticated counterfactual accounts, such the chains of 
dependence view of Lewis (1986), the chains of influence view of Lewis (2000), and a variety of 
“de facto” views on which c is a cause of e if and only if e wouldn’t have occurred had c not 
occurred and other factors been held fixed (Hitchcock 2001, Yablo 2002, Woodward 2003). 
However, each of these more sophisticated views contain analogs of clause (b) to handle 
indeterministic contexts. In other words, even sophisticated counterfactual accounts of causation 
analyze causal claims in indeterministic contexts in terms of counterfactual relations that an 
event’s chance of occurring stand in to the event’s causes, rather than in terms of counterfactual 
relations that an event’s occurrence stands in to its causes. This feature of counterfactual 
accounts of causation, however, makes it unclear what counterfactual causal accounts have to 
say about explanation of chance and chance explanation.

From one perspective, counterfactual causal accounts of scientific explanation seem to 
accommodate chance explanation but not explanation of chance. If the reason why scientific 
explanations consist of causal information is that explaining a phenomenon requires citing at 
least some of the causes of that phenomenon, then an event’s chance of occurring is not the right 
kind of thing to be explained by scientific theories. An event’s chance of occurring is a nomic 
feature of the world that might ground causal relations but cannot stand in causal relations. The 
fact that I smoked, for example, is not a cause of my having a 50% chance of developing cancer 
(though it is a cause of my developing cancer if I do) and so seems not to explain my 50%
chance of developing cancer from the current perspective. In contrast, events that occur by chance are caused and so are explicable by reference to those causes.

However, advocates of counterfactual causal accounts of explanation often stress the explanatory power of counterfactual information. For example, James Woodward has influentially argued that “an explanation ought to be such that it can be used to answer… a what-if-things-had-been-different question: the explanation must enable us to see what sort of difference it would have made for the explanandum if the factors cited in the explanans had been different in various possible ways.” (2003, pg. 11) From this perspective, counterfactual causal accounts seem to capture explanation of chance rather than chance explanation. As we have seen, causal claims in indeterministic contexts provide us with information about how chances, rather than actual occurrences, would have been different had those causes not occurred. The fact that, say, my smoking is a cause of my developing cancer seems to answer what-if-things-had-been-different questions about my chance of getting cancer by informing us that my chance of getting cancer differs across various counterfactual suppositions about my smoking. However, the fact that my smoking is a cause of my developing cancer does not seem to answer what-if-things-had-been-different questions about my getting cancer. Had I not smoked (or had I smoked less, or had I smoked more), then I might or might not have gotten cancer; the fact that smoking is a cause of my cancer implies nothing at all about the conditions under which I would or would not have gotten cancer. Accordingly, the fact that smoking is a cause of my cancer seems to answer what-if-things-had-been-different questions about my chance of getting cancer rather than about my getting cancer, and so belongs in an explanation of chance but not in a chance explanation.

Of course, these two perspective are consistent with one another. Combined, they provide a complete but disunified account of indeterministic explanation. On this picture, the
fact that I smoked provides both an explanation of my chance of getting cancer and an explanation of my cancer, but for different reasons: the information that I smoked explains my chance of getting cancer by answering what-if-things-had-been-different questions about my chance of getting cancer and the information that I smoked explains my getting cancer by citing a cause of my getting cancer. On this disunified picture, causation underwrites chance explanation but (some variety of) counterfactual dependence underwrites explanation of chance.

5. “Causes Plus” Accounts

On my terminology, “causes plus” accounts of scientific explanation combine Hempel’s view that scientific explanations contain information about laws of nature or chances with the causal theorist’s view that scientific explanations contain information about causes. I take Peter Railton’s Deductive-Nomological-Probabilistic (D-N-P) model of explanation to be a paradigmatic “causes plus” account of indeterministic explanation.

Recall our earlier D-S explanation of my ice’s chance of melting:

P1. Whenever condition $C$ obtains, the chance that ice melts is equal to $n$ (where $n$ is some value extremely close to 1).

P2. Condition $C$ obtains.

So,

C*. The ice’s chance of melting is equal to $n$. 
According to Railton, this argument falls short of being the full explanatory story of my ice’s chance of melting because P1 and P2 do not illuminate the mechanisms involved in my ice’s melting. He writes,

The goal of understanding the world is a theoretical goal, and if the world is a machine—a vast arrangement of nomic connections—then our theory ought to give us some insight into the structure and workings of the mechanism… Knowing enough to subsume an event under the right kind of laws is not, therefore, tantamount to knowing the how and the why of it. (1978, pg. 208)

To illuminate the “structure and workings of the mechanism” we must, on Railton’s view, supplement our derivation of the chance of my ice’s melting with a further derivation of P1 (i.e., of the relevant covering laws) from the true underlying fundamental physical theory. Of course, that derivation will be incredibly complicated and is not something we have the ability to produce, but the actual explanations we give one another are explanatory to the extent that each conveys information about the content of this idealized collection of derivations.

So, by supplementing our derivation of C* with a further derivation of P1, we achieve an ideal scientific explanation—but an ideal scientific explanation of what? It seems quite plausible that scientific theories explain something or other when they illuminate the structure and mechanisms that underlie nomic connections, but does such illumination provide chance explanations, explanations of chance, or both?

Railton’s official answer is that a derivation of C* and P1 explain the ice’s chance of melting but not the ice’s melting. To have a chance explanation of the ice’s melting, we must
add to these derivations an addendum stating whether or not the ice cubes melted. Recognizing the important difference between explanation of chance and chance explanation, Railton writes, “Dropping off the addendum leaves an explanation, but it is a D-N explanation of the occurrence of a particular probability, not a probabilistic explanation of the occurrence of a [chance outcome].” (1978, pg. 271)

Unfortunately, no matter how convincing we find Railton’s talk of the explanatory power gotten by the illumination of structure and mechanism, that talk will not do as motivation for his idea that adding an addendum transforms an explanation of chance into a chance explanation. On any reading of “structure” and “mechanism” that I understand, it is very hard to see how the statement that my ice cubes did, in fact, melt could further illuminate any of the structure of mechanisms at work in that melting beyond what is already contained in the derivations of C* and P1.10 These two derivations are a complete accounting of all the nomic, structural, and mechanistic connections relevant to the melting. Chance explanation, then, must involve something beyond illuminating the structure and causal mechanisms responsible for an event’s occurrence.

At best, then, Railton provides a disunified account of indeterministic explanation. However, I doubt many readers will be at all attracted to his account of chance explanation. How could merely noting that an outcome occurred transform an explanation of chance into a chance explanation? Better, then, to view Railton’s discussion of indeterministic explanation as being incomplete. He provides a compelling reason why a set of derivations satisfying the D-N-P constitutes an explanation of chance, but little insight into how or why that same set of derivations, combined with an addendum, provides a chance explanation.

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10 For a similar complaint about Railton’s view, see section 9 of Skow 2014.
6. Prospects for a Disunified Account of Indeterministic Explanation

If we resign ourselves to adopting a disunified account of indeterministic explanation, we are free to combine the best account of explanation of chance from our survey with the best account of chance explanation. In this section, I take stock of our options and of their relative merits.

6.1 Explanation of Chance

Three theories of explanation of chance emerged from our discussion. For unificationists like Kitcher, explaining why an event had a particular chance of occurring requires deriving that event’s chance of occurring by using a derivation pattern employed by an ideally unified scientific theory.

For counterfactual causal theorists like Woodward, explaining is a matter of answering what-if-things-had-been-different questions. I’ve argued that if explaining is a matter of answering what-if-things-had-been-different questions about the explanandum, then causal information is best understood as providing explanations of chance rather than chance explanation, because the fact that c is a cause of e conveys the information that the chance of e would have been different across various counterfactual suppositions but does not imply anything about whether or not e would have occurred across those counterfactual suppositions.

Finally, for “causes plus” theorists like Railton, the ideal explanation of an event’s chance of occurring is a pair of derivations that includes both causal and nomological information relevant to that event’s occurrence.
I won’t try to argue for any one of these theories of explanation of chance over the other, but I note a few interesting points of disagreement among the theories. Perhaps the deepest ideological divide among the three is over whether the concept of causation belongs in a philosophical analysis of scientific explanation. Each of the three views implies that my having smoked belongs in an explanation of my chance of getting cancer, for example, but they differ over why. For the unificationist, the reason why my having smoked helps to explain my chance of getting cancer has to do with the unifying power of certain derivation patterns. In contrast, the counterfactual causal theorist and the “causes plus” theorist agree with each other that my smoking helps to explain my chance of getting cancer because my smoking is a cause of my getting cancer.

In the unificationist’s favor are well-known epistemological concerns about causation. The cost of avoiding causal notions in an analysis of scientific explanation, however, is that it is very difficult to give an account of explanation that is both devoid of causal notions and that does not suffer from any counterexamples involving the asymmetry of explanation. Furthermore, our unificationist theory of explanation of chance will need to be paired with a theory of chance explanation that is equally innocent of causal notions, which rules out combining it with the popular position that chance occurrences are explained by their causes.

Should we decide to eschew empiricist scruples and adopt either a counterfactual causal account or a “causes plus” account, two divisions remain. The first involves the question of why causes feature in chance explanations. Is it because citing causes is a way to convey counterfactual information about the explanandum, as Woodward argues? Or is it because causal information provides “insight into the structure and workings” of the great machine that is our world, as Railton argues? Perhaps the solution is to view these answers as compatible rather
than competing; perhaps, say, conveying counterfactual information is a way of conveying insight into the structure and workings of our world.

Harder to dissolve is the disagreement between the counterfactual causal theorist and the “causes plus” theorist over whether laws are essential to full explanations of chance. Adjudicating the matter is complicated by the fact that advocates of the counterfactual casual accounts self-identify as offering theories of chance explanation rather than explanation of chance, and so do not typically discuss the question of whether laws are needed to explain the chances of various occurrences rather than the occurrences themselves. To evaluate causal theories on their own terms, I now turn to chance explanation.

6.2 Chance Explanation

Perhaps surprisingly, our survey of well-known theories of scientific explanation in indeterministic contexts has unearthed only two viable theories of chance explanation: the view that events that occur by chance are explained by information about their causes (discussed in section 4) and the view that events that occur by chance are explained by information about their chances (discussed in section 3.2).

Let’s start with the causal view. Once again, the idea that causes explain their effects is often justified by a counterfactual analysis of causation combined with an appeal to the explanatory power of citing factors that answer what-if-things-had-been-different questions about the explanandum. However, as we have seen, this justification is better suited to the claim that causes feature in explanations of chance rather than in chance explanations. Perhaps, however, the view that causes explain their effects does not require any deeper justification. After all, our ordinary and scientific explanatory practices are filled with examples in which we
satisfy requests for chance explanations by merely one or more of the event’s causes, and the view that causes explain their effects is widely held.

However, I urge caution. Our explanatory practices were formed against an ideological background that assumed determinism, and the indeterministic case is different enough from the deterministic one that our intuitions about the latter are not to be applied to the former without further probing. I have already noted that two important features unique to the indeterministic case are that events that occur by chance are not nomically necessitated and that events that occur by chance need not counterfactually depend on their causes.

Here is yet a third. In the indeterministic case, information about the causes of an event convey nearly no information whatsoever about whether or not that event was to be expected. That I smoked, say, and that my smoking was a cause of my cancer is consistent both with it being utterly unsurprising that I developed cancer and with it being an incredible fluke that I developed cancer; causal information in indeterministic contexts tells us nothing at all about the absolute value of the chances of effects and thus nothing at all about what our expectations about effects should be.

The nearly non-existent predictive value of causal information in indeterministic contexts leads to a counterintuitive consequence for the view that causes explain their effects: an agent could know everything there is to know about why an event occurred and yet have nearly no information about whether or not the event’s occurrence was to be expected. Imagine, for example, that we prepare some sample of radioactive material in a laboratory and note how much of it decays during some time period. After our observations is complete, I ask you why that amount of material decayed in that period of time. You assure me that you know exactly why the decay we just witnessed occurred. That’s good news, because I have a question: was it a
fluke that so much material decayed during that time, or is that the rate of decay that we should have expected? You answer, ‘Oh, for all I know, we could have just witnessed the most surprising of probabilistic miracles or an utterly mundane result. I merely know everything there is to know about why the decay occurred—I haven’t the faintest idea about whether or not we should be surprised that it did.’” This answer would greatly lower my confidence that you did, in fact, know everything there is to know about why the decay occurred. However, if explanatory information about the occurrence of an event is exhausted by information about the event’s causes, then one can know everything there is to know about why a chance event occurred without knowing anything that is at all relevant to forming expectations about that event’s occurrence (apart from that the event was possible.) One does not have to believe anything as drastic as Hempel’s or Salmon’s idea that explanation should be analyzed in terms of prediction to be skeptical that a full explanatory story about an event’s occurrence could be useless for forming expectations about it.

If we take seriously the idea that there is a connection between explaining an event and knowing whether or not that event was to be expected, the view that chances provide chance explanations is more attractive than the view that causes provide chance explanations; by the Principal Principle, information about an event’s chances is the best admissible grounds we could have had for forming our expectations about whether or not the event occurs.

Nevertheless, I am skeptical that analyzing chance explanation in terms of the best admissible grounds for forming expectations about the event to be explained will ultimately succeed. The problem, on my way of viewing things, arises when we try to analyze “admissible” information. Why is it that information about the future and even some information about the past (such as a record of a time traveler’s testimony) is inadmissible? Following my analysis of
admissibility in Elliott 2016, I think that any plausible answer will have to appeal to the fact that information about the future and even some information about the past fails to explain anything about chance processes and their outcomes despite being evidence about chance processes and their outcomes. However, we cannot analyze explanation in terms of admissible grounds for expectation and then go on to analyze admissible information in terms of explanation, on pain of finding ourselves in a very small circle. So, though I agree with Salmon that there is an important connection between expectation and chance explanation, I am skeptical of any attempt to analyze chance explanation in terms of expectation. Just as a causal theory of chance explanation might bottom out in the assertion that information about causes explains chance events, so too might the chance theory of chance explanation bottom out in the assertion that information about chances explains chance events.

7. Conclusion

In our survey of theories of scientific explanation in indeterministic contexts, we have seen many diverse ideas about how it is that indeterministic scientific theories provide explanations, but none of these conceptions of scientific explanation adequately characterizes both explanation of chance and chance explanation. The problem we repeatedly encountered is that the kinds of relations (e.g., nomic necessitation, unification, causation, counterfactual dependence, best admissible grounds for expectation) that plausibly underwrite one sort of explanation do not plausibly underwrite the other sort. I conclude that, to the extent that scientific theories provide both chance explanation and explanation of chance, they do so for different reasons.
When we disentangled explanation of chance from chance explanation, we found plenty of attractive views of explanation of chance but surprisingly few plausible theories of chance explanation. One theory of chance explanation that emerged is that the occurrence of a chance event is explained by information about its causes. However, though we found candidate reasons for why causal information provides explanation of chance (in Woodward and Railton), we found nothing helpful about why causal information provides chance explanations (rather than explanations of chance).

A second theory of chance explanation emerged in our discussion of the S-R model; the occurrence of a chance event is explained by information about its chances. Inspired by Salmon, we might attempt to justify this view by arguing that explanations of events provide the best admissible grounds we could have had for forming our expectations concerning that event and that chances provide these best admissible grounds. However, I suspect that this further claim will lead us into a tight circle when we go on to analyze “admissible” information. Better, then, to just accept that nothing more can be said about why chances explain than that they do.

The causal view of chance explanation implies that one can know everything there is to know about why an event occurred but still have nearly no information that would be of any use for predicting its occurrence. The chance view of chance explanation implies that most of the explanatory content of a scientific theory—everything apart from chance ascriptions—provides explanations of chance rather than of chance explanations. So, both theories have regrettable consequences. Furthermore, both theories have little more to say about chance explanation than that information about some metaphysical posit—either cause or chance—provides chance explanations.
Which theory is more plausible? I think we can explain away our intuition that chance explanations require more than chance ascriptions easier than we can explain the intuitive connection between explanation and prediction. Explanations of chance are, on any of the views considered above, evidence about an event’s chance of occurring. It is a lot to expect of our pre-theoretical intuitions that they correctly distinguish an explanation of chance from a chance explanation if anyone in possession of the former is thereby also in possession of information that is evidence about the content of the latter. Furthermore, any researcher interested in understanding why an event occurs will also be interested in understand why that event had a certain chance of occurring, and so will want a scientific theory that answers both explanatory questions. Perhaps, then, the view that chances provide chance explanations is not so at odds with intuition and scientific practice, so long as it is combined with the view that chances are themselves explained by some combination of laws, antecedent conditions, and causes.

Alternatively, perhaps we should conclude that information about both causes and chance is required to explain a chance event. That view avoids the counterintuitive consequences of the causal view (because information about chances is predictively useful) and the counterintuitive consequences of the chance view (because more is required to explain a chance event than its chance of occurring). However, such a view seems poorly motivated. If we have already accounted for the explanatory import of causes with their role in explanation of chance, and if we already have a theory of chance explanation that accommodates the intuition that chance explanations should be predictively useful, what need do we have for the addition of causes into chance explanations?

At any rate, providing a definitive argument for any particular theory of chance explanation is beyond the scope of this essay. I am content to have shown that, when our study
of scientific explanation is alive to the difference between explanation of chance and chance explanation, the view that information about chances explains the occurrence of chance events emerges as among our most attractive options.

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