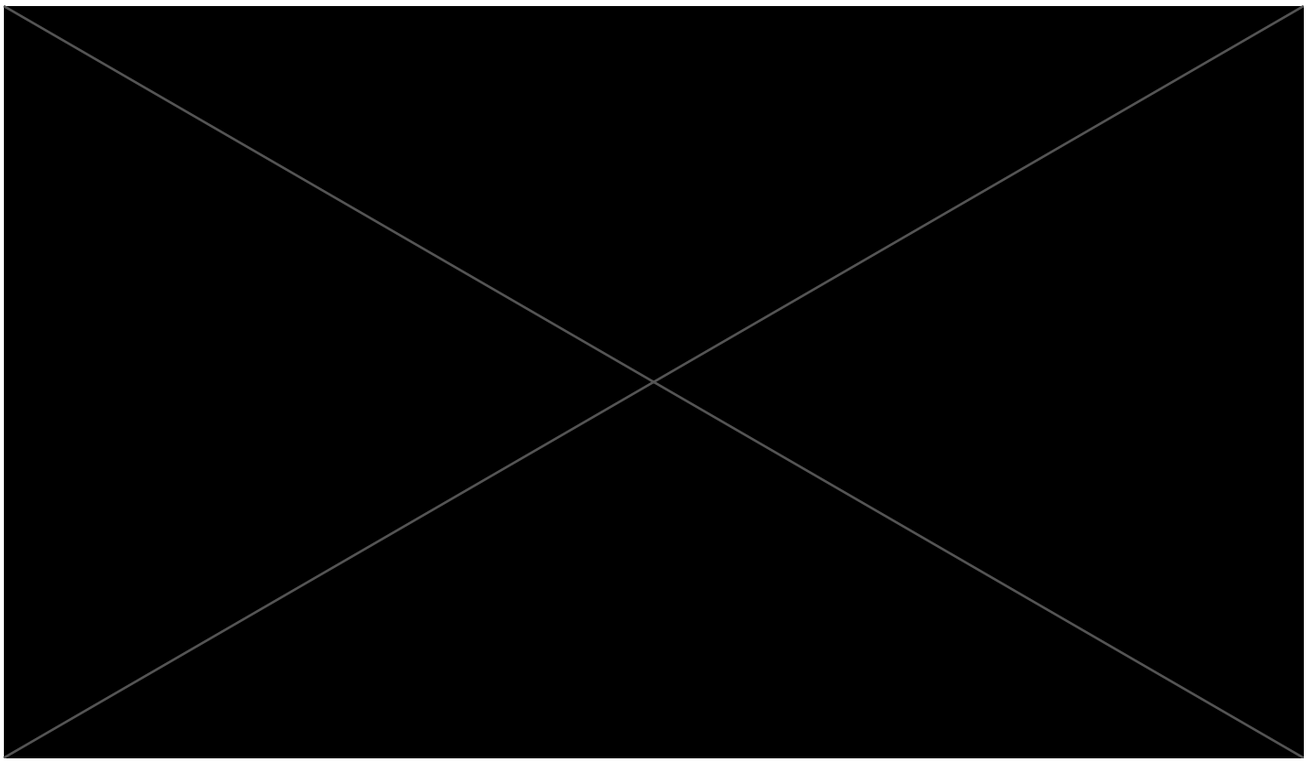

Where are the chances?

Katrina Elliott, [1]✉

Email Katrina.jeanine.elliott@gmail.com

[1] University of California, Los Angeles, USA

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Abstract

Not all probability ascriptions that appear in scientific theories describe *chances*. There is a question about whether probability ascriptions in non-fundamental sciences, such as those found in evolutionary biology and statistical mechanics, describe chances in deterministic worlds and about whether there could be *any* chances in deterministic worlds. Recent debate over whether chance is compatible with determinism has unearthed two strategies for arguing about whether a probability ascription describes chance—that is, to speak metaphorically, two different strategies for figuring out where the chances are: find the chances by focusing on chance's explanatory role or find the chances by focusing on chance's predictive role. These two strategies tend to yield conflicting results about where the chances are, and debate over which strategy is appropriate tends to end in stalemate. After discussing these two strategies, I consider a new view of chance's explanatory role. I argue that one theoretical advantage of this new view is that allows us to make progress on the question of where the chances are by providing a principled way of determining which probability ascriptions describe chances. From the vantage of this new view, the correct application of both strategies involves figuring out where the chances are by figuring out where the probabilistic scientific explanations are and what those explanations are like.

Keywords

Chance
Determinism
Incompatibalism
Scientific explanation

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1. Introduction

According to our commonsense theory of coin flips, a U.S. quarter's probability of landing heads after a decent flip is roughly 50%. To the extent that we believe commonsense, should we also believe that coin flips are genuinely chance processes? It might seem obvious that the answer is no. After all, our commonsense theory of coin flips is compatible with its being true that the world is diachronically deterministic, i.e., that the complete state of the world at a time and the laws of nature determine what the world is like at any other time. Since it seems that there cannot be chance processes in deterministic worlds, our commonsense theory of coin flips is either false or its probabilistic content is not about chances.

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However, philosophers disagree about whether there can be chance processes in deterministic worlds. Compatibilists, i.e., philosophers who argue that there can be non-extremal chances in even fundamentally deterministic worlds, tend to argue from premises about chance's explanatory role. For example, some compatibilists point out that there can be probabilistic explanations in deterministic worlds (such as probabilistic explanations drawn from evolutionary biology and statistical mechanics). They argue that if a probability ascription is explanatory then it describes a chance.[1] Incompatibilists, i.e., philosophers who argue that chance and determinism are incompatible, tend to argue from premises about chance's predictive role. For example, some incompatibilists point out that a deterministic world in which there are (non-extremal) chances would be a world in which the laws of nature and present state of the world are better evidence about the future than are the present chances. However, on widely accepted accounts of chance's predictive role (especially the account found in Lewis, 1980), of all the evidence we might presently have about whether some outcome will occur in the future, no evidence can be better than is the outcome's present chance of occurring (at least so long as we set aside fanciful possibilities, such as that a magical crystal ball might foretell the outcome of a chance process). Since there are no worlds in which the laws of nature and present state of the world are better evidence about the future than are the chances, chance's predictive role seems to motivate incompatibilism.[2]

Perhaps you think that our world is indeterministic, and so are not inclined to care too much about whether chance and determinism are compatible. However, the question of whether chance and determinism are compatible is just a special instance of the more general question of whether there could be macrophysical chances in a world that are not simply the result of microphysical chance processes percolating up into macroscopic phenomena via supervenience relations. For example, if coin flips are processes that supervene on the quantum world then

quantum mechanics might suggest that coin flips really are chance processes; but quantum mechanics will not vindicate the claim that a flipped coin has a 50% chance of landing heads. Could it nevertheless be true that a flipped coin has a 50% chance of landing heads?

Here again chance's explanatory role seems to motivate a different answer than does chance's predictive role. On the one hand, because it seems there could be good explanations found in autonomous probabilistic macrophysical sciences, it seems there could be autonomous macrophysical chances. On the other hand, it seems that there could not be autonomous macrophysical chances since the best evidence about the future is always found in microphysical, rather than macrophysical, sciences.

To put the matter metaphorically, we seem to have two different strategies for figuring out where the chances are. The first strategy is to locate the chances in a given world by locating the probabilistic explanations of that world. For example, to the extent that quantum physics underwrites probabilistic explanations of various phenomena in our world, it seems that the probability ascriptions underwritten by quantum physics also describe chances that obtain in our world. Similarly, one might argue that if there are good probabilistic explanations in a deterministic world, then there are chances in that world described by those good probabilistic explanations. Or, one might argue that if there are good probabilistic explanations in autonomous macrophysical theories of a world, then there are chances to be found among the macroscopic processes of that world that are independent of whatever chances might also be at work in the microscopic processes of that world.

The second strategy is to locate the chances in a given world by locating the best grounds for our expectations about the future in that world. One might argue that if our best grounds for our expectations about the future of a world do not involve any chances, then there are no chances in that world. Or, one might argue that if our best grounds for forming expectations about the future of a world always involve the chances that feature in the microscopic processes of that world rather than in the macroscopic processes, then there are no independent chance processes at work in the macroscopic processes of that world.

In theory, we could make progress toward figuring out where the chances are (e.g., figuring out whether incompatibilism or compatibilism is true) by evaluating each of these two strategies. In practice, however, arguments for or against each strategy —or, more commonly, for or against a particular version of each strategy—often seem to presuppose an answer to the question of where the chances are.

In this essay, I offer a way forward. I being by reviewing arguments concerning the explanation strategy (in Sect. 2) and arguments concerning the grounds-for-expectation strategy (in Sect. 3). Then (in Sect. 4), I present my own view of chance's explanatory role; roughly, information about chances serves to explain the occurrence of events, while information about laws and antecedent conditions serves to explain those chances. I argue that an advantage of this view is that it can be used to vindicate (a version of) the explanatory strategy and that it reduces questions about the merits of the grounds-for-expectation strategy to questions about the nature of scientific explanation—all without making any question begging assumptions about where the chances are. In so doing, my view lights the way

toward progress on abstract metaphysical questions about where the chances are—such as whether there can be chances in deterministic worlds or whether there can be (autonomous) chances at work in macrophysical processes—by reducing those questions to (what I take to be) more tractable questions about the explanatory power of scientific theories.

2. Explanation as a guide to where the chances are

While quantum mechanics is the scientific theory most famous for underwriting probability ascriptions, there are a great many probabilistic theories in non-fundamental sciences as well. For example, (non-equilibrium) statistical thermodynamics tells us that the probability that our ice cubes will melt when left unmolested in our water glass is high but less than 1, evolutionary biology tells us that the probability that a very fit organism will pass on no copies of its genes to the next generation is low but greater than 0, and medical science tells us that the probability of developing paresis after suffering years of untreated syphilis is about 30%.

Chances are formally modeled by probability functions, but so too are many aspects of the world that are not chances. For example, epistemologists sometimes model the doxastic attitudes of agents as probabilities, e.g., my confidence that it will rain this evening is 80%. However, facts about what doxastic attitudes agents happen to have imply nothing about the chances; my being 80% confident that it will rain is consistent with there being any chance of rain whatsoever (including 0 and 1). Or, notice that the frequency with which an event occurs relative to some class of occurrences is also modeled as a probability: for example, it might be that among days like today, 80% were days that it rained. However, that the relative frequencies with which various types of events occur fall between 0 and 1 does not imply that there are any chances with values between 0 and 1; that the frequency of rain is 80%, for example, is consistent with each particular day's chance of rain being either 0 or 1.[3] The moral is that a commitment to a theory that contains probability functions that assign non-extremal values to various propositions does not automatically commit one to there being any non-extremal chances.

How can we tell whether the probabilities that appear in a particular theory are about chances rather than, say, about degrees of confidence or relative frequencies? Let us start by noticing that probability ascriptions that are about the degrees of confidence agents happen to have or that are about the relative frequencies of events play no role in explaining the propositions to which they are ascribed. For example, that I happen to be 80% confident that it will rain in no way helps to explain why it rains if it does. Similarly, the fact that the frequency of rain on days like today has been 80% does not explain why it rains on this particular occasion (though the relative frequency of rain might be evidence of the truth of some further propositions that ultimately explain why it rains).[4]

However, it seems that (at least) some probability ascriptions are (in some way) explanatory. The standard interpretation of quantum mechanics, for example, underwrites theories of radioactivity according to which the probability that a radium-226 atom will decay within 1600 years is roughly 50%. That probability ascription seems to help to explain why it is that roughly half of a sample of radium-226 decays after 1600 years.

Note that the probabilities underwritten by quantum mechanics are, in addition to being explanatory, our paradigm example of probability ascriptions that model chance. Indeed, the explanatory success of quantum physics is (arguably) among our best reasons for thinking that there really are chance processes in our world. After all, though one can see how probabilities underwritten by quantum mechanics might help to predict or help to describe various phenomena without modeling chance, it is much harder to see how those probabilities can explain without modeling chance. The probabilities associated with radioactive decay, for example, might help to predict or to describe how much radioactive material decays within a certain time even if radioactive decay is not a genuine chance process—but how could those probabilities explain *why* radioactive material decays without also accurately describing genuine chance processes at work during decay events?

The alleged connection between explanation and chance that is apparently exemplified by fundamental physics has also been used to motivate the compatibility of determinism and chance. For example, Luke Glynn writes,

> As regards *explanation*, there may be more than one good explanation of an event. If a resulting pea plant turns out to be homozygous, then a good explanation would be that … the Mendelian laws indicate that there was a 0.25 chance that this outcome would result. That is true even though a still more satisfying explanation might be that … the microphysical laws and circumstances entailed a chance 1 for this outcome. (Glynn, p. 71)

In a similar spirit, Nina Emery considers the following sentences, which she numbers (8), (9), and (10):

(8) It is very likely, though not certain, that any ice cube in the experiment will melt.

(9) Most of the ice cubes in the experiment have melted.

(10) Every ice-cube-and-glass system observed so far started off in a normal micro-state (a state that leads deterministically to the ice melting within an hour).

Emery endorses “the explanatory condition” according to which (8) is about chance values (in part) because (8) is an explanation of (9). In clarifying the content of the explanatory condition, Emery writes,

> The recent literature on explanation contains a number of arguments for the conclusion that (8) is a better explanation of (9) than (10) is, but notice that the explanatory criterion as stated above does not require any such argument. The criterion does not require that (8) must be *the best explanation* of (9), only that (8) be *an explanation* of (9), and there is good reason to think that these are two distinct conditions. (Emery, p. 116)

Moved by arguments such as those given by Glynn and Emery, one might initially be drawn to something along the lines of the following test of whether a probability ascription models chance, which I call “Good Explanation Test”.

> Good Explanation Test: If a sentence of the form, “the probability of [event] *o* is equal to [real number] *n*” is a non-eliminable part of a good explanation of *o*’s occurrence, then the sentence is true and the probability ascription is about *o*’s chance of occurring.

Railton (1978) introduced the useful notion of an “ideal explanatory text”. An ideal explanatory text contains all information relevant to explaining the phenomena in question. Explanations that fail to live up to this extremely high standard by containing less information can nevertheless be (merely) good explanations. For example, an ideal explanation of why my car crashed might specify my car’s exact velocity moments before the crash, while a merely good explanation of why my car crashed might simply note that I was speeding.[5] Good Explanation Test makes predictions about probability ascriptions that are non-eliminable parts of explanations of either type. In other words, Good Explanation Test says that appearing in a good explanation is good enough to qualify a probability ascription as being about *o*’s chance of occurring even if that probability ascription does not appear in an ideal explanation of *o*’s occurrence.

Notice that Good Explanation Test makes predictions about probability ascriptions that do not explain anything on their own, so long as they are non-eliminable parts of a good explanation. The caveat “non-eliminable” is meant to prevent Good Explanation Test from (non-trivially) applying to probability ascriptions that, in some intuitive sense, do no explanatory work in the good explanations in which they appear. Roughly, if the quality of an explanation does not depend on its probabilistic content, then that probabilistic content is eliminable.

Notice also that Good Explanation Test is quite modest. It identifies only one sufficient condition on a probability ascription modeling chance, but there may be many more. Someone might doubt that, say, a coin’s 50% probability of landing heads can explain why the coin lands heads on the grounds that only likely occurrences are explicable. Such a philosopher cannot use Good Explanation Test to argue that the coin’s 50% probability models the coin’s chance of landing heads (since the coin’s 50% probability of landing heads does not, by her lights, explain why the coin lands heads). Nevertheless, she might use the same sorts of considerations that motivate Good Explanation Test to argue that the coin really does have a 50% chance of landing heads. She might, for example, hold that a coin’s 50% probability of landing heads *does* explain why the coin lands heads roughly half the times that it’s flipped in a very long series; and, she might use this premise to argue that the coin really does have a 50% chance of landing heads. All of that reasoning would be in the spirit of, but beyond the scope of, Good Explanation Test.[6]

Good Explanation Test agrees with the verdict that the probabilities underwritten by quantum mechanics model chance (on the assumption that these probability ascriptions are non-eliminable parts of good explanations). Furthermore, Good Explanation Test opens the door to the possibility that there are chances in

deterministic worlds by reducing the question of whether there could be non-extremal chances in a deterministic world to the question of whether non-extremal probability ascriptions could be non-eliminable parts of good explanations in deterministic worlds. In so doing, Good Explanation Test allows one to argue that a particular probability ascription models chance while admitting that, in a deterministic world, the very best explanations will never have any non-eliminable probabilistic content.

Were Good Explanation Test true, incompatibilism about chance and determinism would, I think, be an unattractive position. It is one thing to deny that there are any probability ascriptions that are non-eliminable parts of ideal explanatory texts in deterministic worlds, but quite another to deny that there are any probability ascriptions in deterministic worlds that play an important role in merely *good* explanations. Evolutionary biologists, for example, seem to make use of probabilities when they explain the frequency of a given trait among a population (in part) by arguing that the trait contributes to an organism's overall fitness; the explanatory story seems to be that fitter organisms have a greater probability of being selected for as parents and traits that contribute to fitness are more likely to be passed on to subsequent generations. So, evolutionary biology seems to give us good probabilistic explanations whether or not the world is fundamentally deterministic. Or, for another example, the wide acceptance of statistical mechanics in the nineteenth century is typically attributed to the explanatory power of its probabilistic content despite the presupposition that statistical mechanics is consistent with determinism. (See, for example, Strevens, 2000). Once the compatibilist has admitted that probability ascriptions do not appear in the ideal explanations of deterministic worlds, it seems positively ungenerous to insist that, e.g., the probabilities of evolutionary biology and of statistical mechanics are not even non-eliminable parts of merely good explanations in some deterministic worlds.

The problem for the compatibilist, however, is that Good Explanation Test is not very plausible because there are many accounts of how a probability ascription could be a non-eliminable part of a merely good explanation without thereby being true and about chance. For example, the second law of thermodynamics is often expressed probabilistically: the entropy of an isolated system *can* increase, but the probability of such anti-thermodynamic behavior is extraordinarily low. Suppose someone thinks that the probability invoked in the second law does not refer to any genuine chance, but rather refers to the fact that the proportion of initial states that evolve into entropy decreasing states is almost, but not quite, all of them. Let's stipulate that such a philosopher does not think there are any genuine chances involved in the second law. However, there are many options if she nevertheless wants to maintain that, e.g., the fact that the ice in my glass is overwhelmingly likely to melt provides a good but not ideal explanation of why the ice melts.

Kitcher (1989), for example, argues that probability ascriptions of 1 or 0 that are either false or not about chances might nevertheless be explanatory in virtue of being about idealizations of indeterministic phenomena. Following Kitcher, it is similarly available to argue that probability ascriptions between 1 and 0 that are either false or not about chance might nevertheless be explanatory in virtue of being about idealizations of deterministic phenomena. Perhaps, for example, thermodynamic probabilities arise from the idealization that a system's initial

conditions are chosen by a genuinely stochastic process, rather than being merely unknown to us.

Or, we might follow Schaffer (2007), who argues that a probability ascription that is not about chance can nevertheless be explanatory by being a "probability of explanation", which is "merely an ignorance measure over various nonchancy explanatory paths" rather than a "probabilistic explanation" in which chances play an explanatory role (Schaffer, p. 119). We might then take Schaffer's view and argue that at least some "ignorance measures over various nonchancy explanatory paths" are themselves informative enough to convey good, though not ideal, explanatory information.

A related option is Railton's (1981) view that probability ascriptions that are either false or not about chance can nevertheless be explanatory by being evidence about the content of an ideal explanation. For example, Railton argues that the probabilities of thermodynamics can be explanatory even if they are artifacts of combinatorics rather than references to chances. He writes, "such appeals to combinatorics serve to illuminate a significant feature of the causal process underlying the behavior of classical thermodynamic systems…: this sort of causal process is such that its macroscopic outcomes are remarkably insensitive (in the limit) to wide variations in initial microstates." (pp. 250–251).

So, there seem to be several plausible avenues for the non-compatibilist to push back on Good Explanation Test. However, that Good Explanation Test is false does not imply that there is no important connection between being explanatory and being about chance. Both Railton (1978) and Schaffer (2007) (implicitly) endorse a more stringent explanation-based test of when a probability ascription is true and models chance, which I call "Ideal Explanation Test".

> Ideal Explanation Test: If a sentence of the form "the probability of [event] *o* is equal to [real number] *n*" is a non-eliminable part of an ideal explanation of *o*'s occurrence, then the sentence is true and the probability ascription is about *o*'s chance of occurring.

Notice that Ideal Explanation Test does not imply that there can be only one ideal explanation of a particular phenomenon, but that Ideal Explanation Test does raise the bar on which probability ascriptions are true and model chance. While Ideal Explanation Test, like Good Explanation Test, seems to vindicate the objectivity of probabilities underwritten by quantum mechanics, it is much less obvious that Ideal Explanation Test vindicates the objectivity of any non-fundamental probabilistic ascriptions. It is not so widely accepted that the probabilities of non-fundamental sciences are non-eliminable parts of the ideal explanatory text for events that occur in deterministic worlds.

Still, while the compatibilist loses rhetorical ground in the retreat from Good Explanation Test to Ideal Explanation Test, not all hope is lost. As Emery points out in the quoted passage above, it may be that some probability ascriptions that appear in non-fundamental physical sciences are indeed non-eliminable parts of ideal explanations in deterministic worlds.

To shore up the case for incompatibilism, then, incompatibilists such as Schaffer advocate for an additional strategy for determining which probability ascriptions model chance, and this additional strategy seems to favor the conclusion that there cannot be any chance processes in deterministic worlds. This incompatibilist-friendly strategy shifts focus from chance's explanatory role onto chance's predictive role. According to this strategy, we should figure out where the chances are by figuring out what are our best grounds for our expectations about the future.

3. Prediction as a guide to where the chances are

A widely accepted feature of chance's predictive role is that, of all the grounds we might presently have for our opinions about whether some outcome will occur in the future, none is better than the outcome's present chance of occurring.[7] For example, I can have no better grounds for my expectations about whether an atom of radium-226 will decay in the next 1600 years than the atom's present chance of decay. Of course, after the decay occurs I might have access to all sorts of information that is better evidence about whether the decay occurs than is the decay's present chance of occurring, such as a record of the decay or information about the decay's effects. Furthermore, perhaps it is possible to have fantastical kinds of evidence about whether an atom will decay before it does that is even better grounds for my expectations than is the atom's chance of decay, such as a magical crystal ball's prediction. However, if we restrict our attention to presently available and non-fantastical kinds of evidence about the future, it seems that an event's present chance of occurring is as good as it gets.

That we have no better evidence about the future than the present chances of future events suggests a second kind of test for whether a probability ascription models chance. The conjunction of the natural laws and present state of the world is also evidence about what the future will be like—but not better evidence than the present chances of various futures. So, one might argue that if the natural laws combine with the present state of the world to be *better* evidence about whether an event occurs in the future than is that event's present probability of occurring, that event's present probability of occurring must not accurately describe the event's present chance of occurring. In other words, the following test of whether a probability ascription models chance seems to be suggested by chance's predictive role:

> Laws and Present Conditions Test: If a statement of the natural laws and a description of the present state of the world is better grounds for our expectation that event *o* occurs than is a sentence of the form, "the present probability of [event] *o* is equal to [real number] *n*" then either the sentence is false or the sentence is not about chance.

Laws and Present Conditions Test would, were it true, make a strong case for the incompatibilist. In a deterministic world, the laws and present state of the world determine the state of the world at any other time. It seems, then, that any non-extremal probability ascription about an event's occurrence is worse grounds for our expectations about the future than are the natural laws combined with the present state of the world. Or, to put the point another way, it seems that if you were already certain of the natural laws and of the present state of the world (and had the

computational power required use those facts to make predictions), then no probability ascriptions would improve your ability to accurately predict the future in a deterministic world. If instead, however, you started by being certain of the present (non-extremal) probability of a future occurrence, then your ability to accurately predict the future will always be improved by learning the laws and the present state of any deterministic world. So, it seems that—given Laws and Present Conditions Test—the only probability ascriptions that are both true and model chance take values of either 0 or 1 in deterministic worlds.

While Laws and Conditions Test is not explicitly discussed in the literature, it is implicit in various arguments that chance and determinism are compatible. Some versions of these arguments are quite old (e.g., Laplace 1814), but interest in David Lewis's more recent "Principal Principle" (Lewis, 1980) has given rise to contemporary discussions in which Laws and Conditions Test is implicit.

The Principal Principle (henceforth, PP) implies that if a rational agent (i.e., an agent whose opinions come from a reasonable initial credence function by conditionalizing on her total evidence) is certain that an event's chance of occurring is n, then her credence (i.e., her degree of expectation) in that event is equal to n, provided that she has only "admissible" evidence.

The content of the PP depends on what information is admissible. If nothing is admissible, the PP is trivial. If everything is admissible, the PP is false—my rational credence that an outcome occurs need not equal what I am certain is that outcome's chance if I also have the information that the outcome occurred. Lewis himself offered no analysis of admissibility, but he hypothesized that information about the present (and past) state of the world and information about the laws is (at least typically) admissible. After all, suppose that you are certain that an atom of radium-226′s present chance of decaying in the next 1600 years is 50%. What should be your credence that the atom decays after 1600 years? No matter what you know about the laws of nature or about the present state of the world (continuing to ignore fantastical cases involving, e.g., crystal balls) it seems that your confidence that the atom decays within 1600 years should also be 50%. So, it seems that the PP is true when the laws of nature and the present state of the world are taken to be admissible.

The PP combined with the idea that the laws of nature and present state of the world are admissible inspires an argument for incompatibilism that is similar in spirit to the argument for incompatibilism that goes by way of Laws and Conditions Test. The main difference between the two is that the PP-based argument takes a detour through claims about the requirements of rationality. If a rational agent is certain of the laws and present state of a deterministic world, then her credence in every future outcome is either 0 or 1 (assuming that the laws and present state of the world imply a description of everything that happens in the future and assuming that a rational agent's credences satisfy the standard axioms of probability). The PP implies that a rational agent sets her credences equal to what she is certain are the chances, so long as she has only admissible information. So, assuming that the laws of nature and present state of the world are admissible, the present chance of every outcome must also be 0 or 1; otherwise, there could be, in contradiction to the PP, a case in which a rational agent has only admissible information, is certain that the

chance of an outcome is extremal (i.e., is between 0 and 1), and yet has a non-extremal credence in that outcome (i.e., a credence of either 0 or 1).

Of course, a crucial assumption in the PP-based argument for incompatibilism is that the laws of nature and a complete description of the present (or past) state of the world at a time is admissible. If that assumption is denied, then the above argument is no good. Loewer (2001) and Glynn (2010) both offer formulations the Principal Principle on which what is admissible is relativized to a "level". The rough idea is that information about the microphysical state of the world or about the microphysical laws is inadmissible when assessing certain probability ascriptions (such as those that appear in non-fundamental physical theories) but information about the present macrophysical state of the world or about the present macrophysical laws is admissible (provided that it is about the appropriate "level").[8]

The idea that admissible information is at least sometimes restricted to information about the macrophysical present or about the macrophysical laws motivates a more compatibilist-friendly test of whether a probability ascription models chance, which I call "Macrophysical Laws and Macrophysical Conditions Test", or "Macrophysical Test" for short:

> Macrophysical Laws and Macrophysical Conditions Test: If the content of the macrophysical natural laws and a macrophysical description of the present state of the world is better grounds for our expectation that event *o* occurs than is a sentence of the form, "the present probability of [event] *o* is equal to [real number] *n*", then either the sentence is false or the sentence is not about chance.

Macrophysical Test lets the compatibilist square chance's predictive role with compatibilism. That the world is deterministic, she argues, is consistent with there being probabilistic macrophysical laws. These probabilistic macrophysical laws combine with the macrophysical conditions of the world to determine the (non-extremal) macrophysical chances—despite there being more fundamental deterministic laws. In turn, these macrophysical chances play an important predictive role; the macrophysical chances are the best *macrophysical* evidence we have about what the future will like, though information about the microphysical features of the world may be even better evidence about what the future will be like. On this picture, information about the microphysical features of the world is like information about the record of a chance event or about the predictions of a reliable crystal ball; all such evidence about an event's occurrence might be better evidence than is the outcome's chance of occurring, but that such evidence is possible to obtain is simply irrelevant to the question of where the chances are.

From the point of view of the incompatibilist, however, Macrophysical Test seems ad hoc—motivated only by the very premise that the incompatibilist denies. Once we have retreated from Laws and Conditions Test to Macrophysical Test, what non-arbitrary reason can be given to not keep going? If we sufficiently restrict the kinds of evidence that a probability ascription must be as good as if it is to be true and about chance, i.e., if we sufficiently restrict what counts as admissible information,

then we can argue that any old probability ascription models chance. (Schaffer, 2007, for examples, raises this kind of challenge to Loewer, 2001).

On the other hand, Laws and Conditions Test restricts what counts as admissible information to information about the present and past but not information about the future. What non-arbitrary justification is there for counting the present and past as admissible but not the future? In lieu of some argument for either Macrophysical Test or Laws and Conditions Test from premises that do not beg the question against either the compatibilist or the incompatibilist, the strategy of using chance's predictive role as a guide to where the chances ends in stalemate.

4. Moving forward

4.1. Chance's role in probabilistic explanation

Of the four tests discussed above, which, if any, is correct? Let's start answering that question by first considering the tests that go by way of chance's explanatory role.

Whether Good Explanation Test is true depends, of course, on where we draw the line between an ideal explanatory text and no explanation at all. As noted above, however, I think that there are too many ways for probability ascriptions to feature in merely good explanations without being true or without being about chance to warrant much confidence in Good Explanation Test.

Ideal Explanation Test is motivated by the attractive thought that a probability ascription could not be a non-eliminable part of an ideal explanatory text of an event's occurrence without also being an accurate description of the event's chance of occurring. Furthermore, Ideal Explanation Test provides a tractable way into the debate between the compatibilist and the incompatibilist through the somewhat firmer ground of our judgements about the content of ideal scientific explanations. For these reasons, Ideal Explanation Test seems to be a plausible and helpful guide to where the chances are—the chances are wherever the probability ascriptions of ideal scientific explanations say that they are.

It is nowhere near as clear where things stand with the tests that go by way of chance's predictive role. What we would like is an argument for either Laws and Conditions Test or for Macrophysical Test from premises that do not presuppose a verdict on whether chance and determinism are compatible or on whether there can be macrophysical chances that are independent of microphysical chances. And it is obviously no help to replace both Laws and Conditions Test and Macrophysical Test with a more flexible but less informative "admissibility" test. Such a strategy simply passes the buck; now the problem is to give some non-question begging argument about when (or whether) the laws and conditions are admissible and when (or whether) only the macrophysical laws and conditions are admissible. Our problem is not a lack of clever ways to define "admissible information" so as to sidestep one argument or another. Instead, our problem is to provide motivation for some such definition without prejudging the question of where the chances are. Both the compatibilist and incompatibilist should acknowledge that chance plays *some* predictive role and that chance's predictive role can be a guide to which probability ascriptions accurately describe a world's chances. If we are to use chance's predictive role to adjudicate between the compatibilist and incompatibilist,

however, we will need an account of chance's predictive role that does not simply assume either compatibilism or incompatibilism.

To that end, I offer a view of the relationship between chance, explanation, and prediction that provides a framework for motivating Ideal Explanation Test and for deciding between Laws and Conditions Test and Macrophysical Test—all without prejudging the question of where the chances are.

Traditional accounts of scientific explanation have not adequately distinguished between an explanation of an event's chance of occurring (e.g., why did the coin have a 50% chance of landing heads?) and an explanation of the occurrence of a chance event (e.g., why did the coin land heads?). In particular, ingredients of scientific theorizing that are typically taken to explain *the occurrence* of chance events, such as laws, antecedent conditions, and causes, are actually better suited to explain *an event's chance of occurring*.

For example, explanation is sometimes taken to be underwritten by nomic necessitation (see e.g., Railton, 1978). However, it is an event's *chance* rather than the *event itself* that is nomically necessitated by laws and antecedent conditions (in indeterministic contexts). Thus, it seems that chances, rather than chance occurrences, are explained—via nomic necessitation relations—by laws and antecedent conditions. Or, for another example, explanation is sometimes taken to be underwritten by counterfactual dependence (see e.g., Lewis, 1986; Woodward, 2003). Once again, however, it is an event's *chance* rather than the *occurrence itself* that must depend on the event's causes.[9] For example, suppose that smoking is a cause of my cancer. Even so, it is not true that I would not have gotten cancer had I not smoked, since I might have gotten cancer anyway. It is true, however, that my *chance* of smoking would have been different had I not smoked. It thus seems more in keeping with the idea that explanation is backed by counterfactual dependence relations that chances, rather than chance occurrences, are explained by causes.

In contrast, my picture marks a sharp distinction between explaining an event's chance of occurring and explaining the occurrence of a chance event. On my view, the immediate explanatory role of laws, antecedent conditions, and causes, is to explain an event's chance of occurring. That is not to say that these ingredients of scientific theorizing are explanatorily *irrelevant* to events that occur by chance (as is, say, my wishing that the coin lands heads). Rather, my view is that the explanatory contribution of laws, antecedent conditions, and causes is always mediated by the outcome's chance of occurring. The complete *immediate* explanation of an event that occurs by chance is simply its chance of occurring. For example, if the coin's chance of landing heads really is 50%, then the coin landed heads because its chance of landing heads was 50%. In turn, the coin's chance of landing heads was 50% because of, e.g., how the coin was weighted, how the coin was flipped, the laws that govern the chances of coin flips, etc.[10]

While my picture of scientific explanation might seem like a radical revision to more traditional accounts, many of its elements are intuitive and precedented. As we have now seen, perhaps the most pre-theoretically intuitive part of my picture is that an event's chance of occurring is explained by reference to relevant laws, causes, and/or antecedent conditions. It is intuitive, for example, that my significant chance of developing lung cancer at some point in my future is at least partly

explained by my years of smoking combined with underlying laws that connect one's smoking to one's chance of developing lung cancer. Furthermore, the idea that chances are explained by some combination of laws, causes, and antecedent conditions is long precedented; it is endorsed in, e.g., Hempel (1965), Railton (1978) and Kitcher (1989).

Somewhat less intuitive is the idea that every chance outcome, no matter how unlikely, can (in principle) be explained. Many of us have the pre-theoretical intuition that explanations should favor the occurrence of the event explained over its failure to occur. To explain why Adam ate the apple, for example, seems to require citing factors that favor Adam eating the apple over Adam abstaining. But when an unlikely event occurs, there simply are no explanatory factors that favor the event's occurrence over its failure to occur. Pre-theoretically, then, it seems that only likely events can be explained.

However, this familiar pre-theoretic intuition leads to consequences too implausible to accept. It is a serious (epistemic) possibility that our own world is indeterministic.[11] If unlikely outcomes are in principle inexplicable and our world is indeterministic, then it is also a serious (epistemic) possibility that events are regularly happening that science is incapable of explaining. But that consequence strikes many philosophers of science as implausible; learning that our world is governed by indeterministic laws would bring us closer to, rather than foreclose the possibility of, a total understanding of everything that occurs.

Rather than giving up on the possibility of explaining unlikely chance occurrences, we should instead give up on the idea that the targets of explanations are always contrastive facts about why one thing happened *rather than* another. In a deterministic world, we often explain an event by showing why the event occurred rather than not. In an indeterministic world, we will not always be able to explain why one event occurred rather than not. Sometimes unlikely things will happen, and when they do, there will be no explaining why the unlikely happened rather than the likely. However, that we cannot explain every contrastive fact in an indeterministic world should not lead us to conclude that we cannot give explanations of non-contrastive facts, such as the fact that an unlikely event occurred. Of course, not everyone will agree. Most philosophers working on indeterministic explanation, however, have been convinced. The view that unlikely occurrences are no less explicable than likely occurrences is common to a variety of otherwise competing conceptions of scientific explanation, such as those found in, e.g., Jeffrey (1969), Salmon (1971), Railton (1978), Lewis (1986) and Woodward (2003).

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In many ways, then, my picture of scientific explanation is not radical. I agree with orthodoxy that scientific theories allow us to understand our indeterministic world by identifying its nomic ingredients (such as its laws, causes, and chances); I agree that some nomic facts, such as chance facts, are themselves explained by further nomic facts (involving laws, causes, and/or antecedent conditions); I agree that both unlikely and likely occurrences are explicable. The primary modification my picture makes to orthodoxy is to recognize an essential division of labor among the explanatory ingredients found in scientific theorizing; the parts of scientific theories that allow us to understand an event's occurrence are the chances, while other parts

of scientific theorizing (e.g., descriptions of laws, antecedent conditions, or causes) allow us to understand why those chances obtain.[12]

That said, I readily admit that my picture is surprising and requires a good deal of justification. Offering a full motivation and defense is more than I can do here, but it is worth at least commenting on some plausible objections before moving on.

First, according to my view, a complete explanation of, e.g., a radioactive atom's decay, is its chance of decay. But surely scientific researchers interested in understanding atomic decay would never be satisfied with merely knowing the chances of various decay events. Thus, my view might seem radically at odds with scientific practice.

I agree that no scientist would think she had explained atomic decay merely because she had discovered the relevant chance facts. Instead, she will want to know much more, including the laws governing decay events, the causes of decay events, background conditions of decay events, and so on. On my picture, however, her further curiosity is accounted for by the fact that she wants to know not only why our atom decayed but also why our atom has its precise chance of decaying. Perhaps such a position is still at odds with how research scientists would describe the targets of their explanations, but it is not as radical as it might initially seem.

Second, according to my view, the explanation of why our atom decays (if it does) is exactly the same as the explanation of why our atom does not decay (if it does not). Say, for example, that our atom has a 85% chance of decaying in some time interval. Were it to decay in that time interval, it would be because its chance of decaying was 85%. Were the atom instead to not decay during that time interval, the explanation would be the same: its chance of decaying was 85%. (When explaining why the atom did not decay, we might prefer to describe the situation as one in which the atom had a 15% chance of not decaying. But this is simply an alternative description of the same chance fact that would explain the atom's decay). One might reasonably object that it is counterintuitive for the explanation of what happens to be the same no matter what happens.[13]

However, I doubt we have much reason to trust our pre-theoretical intuitions about indeterministic explanation. Most of our intuitions about scientific explanation are formed within an ideology that assumes determinism. Were our world deterministic, we might reasonably expect that complete explanations will rule out all alternative possibilities. From this vantage, an explanation of an event's occurrence could not double as an explanation of an event's failure to occur. When forced to take seriously the possibility that our world is indeterministic, however, we should expect our understanding of scientific explanation will need revisions.

Elsewhere, I have argued that one advantage of my picture is that it helps us to understand why there is no better evidence about what the future will be like than the present chances.[14] Abstracting away from some details, my basic idea is that, if the present chances are the ideal explanations of the future while the present laws and conditions help to explain those chances, then it is no wonder that the chances are as good evidence about the future as are the present laws and conditions; the ideal explanation of an event's occurrence is guaranteed to be at least as good evidence about whether the event occurs as is information that merely helps to

explain information already contained in the ideal explanation of the event's occurrence. In other words, more proximate explanations of an event's occurrence are at least as good evidence about whether the event occurs as are less proximate explanations, which accounts for the fact that chances are at least as good evidence about the future as are laws, prior conditions, causes, etc.

In the remainder of this essay, I argue that a further advantage of this picture is that it gives us a way to assess the merits of the tests we have discussed without presupposing either compatibilism or incompatibilism.

4.2. Motivating the tests

First, because my view of indeterministic explanation has it that the only way a probability ascription can be a non-eliminable part (indeed, the only part) of an ideal scientific explanation of an event's occurrence is by accurately describing the event's chance of occurring, my view agrees with our previous endorsement of Ideal Explanation Test. So, my view vindicates the attractive thought that a probability ascription could not be a non-eliminable part of an ideal scientific explanation of an event's occurrence without also being an accurate description of the event's chance of occurring.

Second, as I explain in more detail below, my view provides a non-question begging route toward picking between Laws and Conditions Test and Macrophysical Test. As we will see, when combined with the assumption that there is only ever one ideal scientific explanation of an event that occurs by chance, my view underwrites an argument for Laws and Conditions Test. However, combined with the contrary assumption that there can be situations in which there is more than one non-competing ideal explanation of an event that occurs by chance and the additional assumption that such non-competing ideal scientific explanations need not be equally good evidence for the event they explain, my view motivates Macrophysical Test. So, one of my view's theoretical advantages is that it reduces the question of which grounds-for-expectations test is correct to the question of how many ideal explanations there are of an event and whether non-competing ideal scientific explanations are necessarily equally good evidence of the occurrence that each explains. In other words, on my view, the issue of whether there can be chances in worlds in which the laws and present conditions are better evidence about the future than the present chances (e.g., deterministic worlds in which events nevertheless occur by chances) turns on whether there can be more than one ideal explanation of an event's occurrence and, if so, on whether non-competing ideal explanations of an event's occurrence must be equally good evidence about whether that event occurs.

To see why my view has such implications about Laws and Conditions Test and Macrophysical Test, let us start by assuming that there is only ever one ideal scientific explanation of an event's occurrence. Imagine that, by chance, a flipped coin lands on heads. On my view, all events that occur by chance have ideal explanations—namely, the chances of those events. Suppose, then, that the present chance of the coin's landing heads in, say, the next few seconds is the ideal explanation of the coin's landing heads in the next few seconds. For easier reading, below I leave as implicit the time at which the chance of heads obtains and the time at which the coin lands on heads.

Now, maintain the above assumption that there is only ever one ideal explanation and consider a case in which our coin lands heads by chance in an indeterministic world. On my picture, the laws and present conditions that determine the coin's chance of landing heads explain the coin's chance of landing heads but do not immediately explain why the coin lands heads. Since the ideal explanation of an event's occurrence must be at least as good evidence about whether the event occurs as is information that merely helps to explain the ideal explanation of the event's occurrence, the coin's chance of landing heads must be at least as good grounds for our expectations about whether the coin lands heads as are the present laws and conditions that determine the event's chance of occurring. So, assuming that there is only ever one ideal scientific explanation of an event's occurrence, my view agrees with Laws and Present Conditions Test about how to locate the chances in indeterministic worlds.

Could there be chances in deterministic worlds? Still maintaining the assumption that there is only one ideal explanation of an event's occurrence, consider whether our coin could land heads by chance in a *deterministi*c world. Once again, my view is that the laws and present state of the world are explanatorily relevant to a chance event's future occurrence only by way of explaining the event's chance of occurring rather than by directly explaining the event's occurrence. So, in a deterministic world in which there is only one ideal explanation of the coin's landing heads—namely, the coin's chance of landing heads—my view implies that the laws and present state of the world explain the coin's chance of landing heads. Because the chance of heads is the ideal scientific explanation of the coin's landing heads and information that helps to explain the ideal scientific explanation of the coin's landing heads cannot be better evidence about whether the coin lands heads than is the ideal scientific explanation of the coin's landing heads itself, my view implies that the laws and present state of the world cannot be better evidence about whether the coin lands heads than is the coin's chance of landing heads. Thus, if the world is deterministic and there is only ever one ideal explanation of an event's occurrence, then the present chance of heads must be at least as good evidence about whether the coin lands heads as are the deterministic laws and present state of the world—just as Laws and Present Conditions Test implies. And, because the deterministic laws and present state of the world are always better evidence about whether an event occurs than is an event's non-extremal probability of occurring (since the former but not the latter determines whether the event occurs), it follows that compatibilism is false: there are no (non-extremal) chances in deterministic worlds.

So far, my view of chance's role in explanation combined with the assumption that there is only ever one ideal scientific explanation of an event vindicates Laws and Conditions Test and incompatibilism. However, that verdict changes if we suppose that there could be more than one ideal scientific explanation of an event.

The assumption that there is more than one chance associated with a single event is consistent with both incompatibilism and compatibilism; the most natural case to imagine is one in which there is both a "macrophysical" chance and a "microphysical" chance of a single event. For the incompatibilist, that situation is possible so long as there is the right kind of coordination between the values of two chances. For example, imagine a hunk of radioactive material is placed in a box. The material in the box has a certain macrophysical chance of no longer being

radioactive after, say, 100 years. The radioactive material in the box is composed of atoms, and each of these atoms has a certain microphysical chance of decaying within 100 years. It could not be, according to the incompatibilist, that each atom has a 100% chance of decaying within 100 years but that the material in the box has a 50% chance of still being radioactive after 100 years.

For the compatibilist, in contrast, there need not be such tight coordination between macrophysical chances and microphysical chances. The details here differ between compatibilists, but a common picture starts with the familiar observation that a single event can have very different chances associated with it *across time*. For example, the current chance of our atom's future decay during some time interval might be 50%. After the atom decays during that time interval, however, its chance of decaying during that time interval becomes 100%. The compatibilist posits that a similar thing happens *across "levels"*. Just as an event's chance of occurring is relative to a particular time, an event's chance of occurring is relative to a particular "level". These levels might not be completely autonomous from one another, but they are disconnected enough to allow for, e.g., all the microphysical chances to be 1 or 0 while at least some macro-chances are non-extremal.

Of course, one will want to hear more about the metaphysics of chance from both the incompatibilist and the compatibilist. I'd recommend primitivism to both, but Humean accounts are presently popular; Lewis's influential Humean account implies incompatibilism, while Loewer's popular Humean alternative implies compatibilism. What's crucial here is that, for all these metaphysical pictures and regardless of whether we are compatibilists or incompatibilists, the assumption that there is more than one chance that explains an event's occurrence is neutral. So long as we make no assumption about the *values* of the two chances, we will not have prejudiced the question against either the compatibilist or the incompatibilist.

Back to the argument. On my view, if there is more than one ideal explanation of an event that occurs by chance then that is because there is also more than one chance that explains the event's occurrence. So, let us imagine that our coin lands heads and that there are two distinct ideal explanations of the coin's landing heads, which consist in two distinct chances of the coin's landing heads. Again, we make no assumption about the values of these distinct chances.

From here, there are two ways to develop the case of the coin flip. First, suppose that the present macrophysical state of the world and the present macrophysical laws explain one of the chances—call this chance the "macrophysical" chance—and that the present microphysical state of the world and the present microphysical laws explains the other chance—call this second chance the "microphysical" chance. So, we have two separate chains of explanation leading to the coin's landing heads. Along one chain, the macrophysical conditions and laws explain the coin's macrophysical chance of landing heads, while the coin's macrophysical chance of landing heads in turn explains why the coin lands heads. Along the other chain, the microphysical conditions and laws explain the coin's microphysical chance of landing heads while the coin's microphysical chance of landing heads explains why the coin lands heads. Because the macrophysical laws and conditions directly explain the macrophysical chance that the coin lands heads but the macrophysical chance that the coin lands heads directly explains the coin's landing heads, the macrophysical chance must be at least as good evidence about whether the coin

lands heads as are the macrophysical laws and conditions. Similarly, because the microphysical laws and conditions directly explain the microphysical chance that the coin lands heads and the microphysical chance that the coin lands heads directly explains the coin's landing heads, the microphysical chance that the coin lands heads must be at least as good evidence about whether the coin lands heads as are the microphysical laws and conditions.

The crucial question for the incompatibilist and compatibilist is whether the macrophysical chance that the coin lands heads must be at least as good evidence about whether the coin lands heads as are the microphysical laws and conditions. Since we are presently supposing that the microphysical laws do not explain the macrophysical chance, my view gives us no motivation for supposing that the macrophysical chance is at least as good evidence as are the microphysical laws and conditions. The only exception would be if there were some general reason to suppose that two distinct ideal scientific explanations of an event must be equally good evidence about whether that event occurs, but I know of no good motivation of such a supposition. So, in this case in which the macrophysical explanatory chain and microphysical explanatory chain are distinct, my view of scientific explanation (combined with the assumption that distinct ideal explanations of events need not be equally good evidence about those events) motivates Macrophysical Test but not Laws and Conditions Test. The macrophysical chance of an event must be as good evidence about whether the event occurs as are the macrophysical laws and conditions (since the latter explains the former, while the former explains the event). However, the macrophysical chance of an event might not be as good evidence about whether the event occurs as are the microphysical laws and conditions, since the microphysical laws and conditions lie on a distinct explanatory chain leading up to the event's occurrence and that distinct explanatory chain might be even better evidence about whether the coin lands heads than is the non-competing and ideal macrophysical explanatory chain.

Notice: the above reasoning in support of Macrophysical Test did not presuppose compatibilism. We made no assumptions about the *values* of the two explanatory chances and so made no assumptions that contradict incompatibilism (e.g., that there is an extremal micro-chance but a non-extremal macro-chance) or that presuppose that there could be macrophysical chances that are independent of microphysical chances (e.g., that the value of the macrophysical chance is unconstrained by the value of the microphysical chance).

We now have only one more case to consider. Continue to allow that there are multiple ideal explanations of an event's occurrence, but rather than imagining that the chains of explanation are distinct instead imagine that the microphysical conditions and laws help to explain *both* the microphysical chance that the coin lands heads and the macrophysical chance that the coin lands heads. For example, suppose that coin's 50% macrophysical chance of landing heads is partly explained by both the macrophysical fact that it is evenly weighted and the microphysical fact that it is in some particular microstate that is consistent with its being evenly weighted.

So far I have been supposing that the ideal scientific explanation of the coin's landing heads must be at least as good evidence about whether the coin lands heads as is information that merely helps to explain the ideal explanation of the coin's

landing heads. It might seem, then, that the macrophysical chance of the coin's landing heads must be at least as good evidence about whether the coin lands heads as are the microphysical laws and conditions in any situation in which the microphysical laws and conditions help to explain the coin's macrophysical chance of landing heads.

However, in the present case we not only have two ideal scientific explanations of the coin's landing heads, but we are also supposing that the microphysical laws and conditions help to explain *both* of these ideal explanations of the coin's landing heads. While I maintain that an ideal explanation of an event's occurrence is guaranteed to be at least as good evidence about whether the event occurs as is information that merely explains that ideal explanation, information that *additionally* helps to explain a second distinct ideal explanation of the event's occurrence might well be better evidence about whether the event occurs than is any single ideal explanation of that event's occurrence.

To see why, recall that (as far as I know) there is no general reason to suppose that two distinct ideal explanations of an event's occurrence must be equally good evidence about whether that event occurs. So, two ideal scientific explanations of an event's occurrence taken together might be better evidence about whether that event occurs than is either ideal explanation on its own. Similarly, information that helps to explain *both* ideal scientific explanations (e.g., microphysical facts about the coin that help to explain both its macrophysical chance and microphysical chance of landing heads) might be better evidence about whether the coin lands heads than is either ideal scientific explanation on its own. In this case, since the microphysical laws and conditions are evidentially relevant to whether the coin lands heads in virtue of helping to explain *both* the macrophysical and microphysical chance of the coin's landing heads, then the microphysical laws and conditions might be better evidence about whether the coin lands heads than is either ideal explanations of the coin's landing heads on its own.

According to my view, then, the macrophysical chance that the coin lands heads need not be better evidence about whether the coin lands heads than are the microphysical laws and conditions even if the microphysical laws and conditions help to explain the macrophysical chance that the coin lands heads, because the microphysical laws and conditions also help to explain the microphysical chance that the coin lands heads. Here again, then, my view motivates Macrophysical Test and not Laws and Conditions Test; the macrophysical chance of an event is as good evidence about whether the event occurs as are the macrophysical laws and conditions, but the macrophysical chance of an event might not be as good evidence about whether the event occurs as are the microphysical laws and conditions.

In summary, my view of chance's role in scientific explanation give us a principled way of adjudicating between Laws and Conditions Test and Macrophysical Test. If we decide that there is only ever one ideal scientific explanation of an event, my view underwrites Laws and Conditions Test and also incompatibilism. However, if we think that there could be more than one ideal scientific explanation of an event and if we also think that non-competing ideal scientific explanations need not be equally good grounds for our expectations about the event that they explain, then my view motivations Macrophysical Test but not Laws and Conditions Test. Thus, my view of chance's role in scientific explanation underwrites reasons for choosing

between Laws and Conditions Test and Macrophysical Test that do not beg the question against either the compatibilist or incompatibilist.

Furthermore, it seems to me that my view yields an intuitive way of deciding between Laws and Conditions Test and Macrophysical Test. It seems fitting that whether compatibilism or incompatibilism is true should ultimately turn on whether there can be ideal explanations in deterministic worlds that are distinct from the ideal explanations provided by the deterministic laws and conditions of that world —just as my view implies.

5. Conclusion

This essay began with the observation that there are two different strategies for determining where the chances are, i.e., for determining whether the probabilities that appear in scientific theories that describe a world also accurately describe the chances in that world: locate the chances in a world by finding the explanations in that world, or locate the chances in a world by finding the best grounds for our expectations about the future of that world. These two strategies have been used to deliver conflicting results about whether there can be chances in deterministic worlds and about whether there can be worlds in which macrophysical chances are independent of microphysical chances. Moreover, using the second of these strategies turns out to be complicated by the fact that there are two plausible but competing ways to apply that strategy—Laws and Conditions Test and Macrophysical Test—and knowing which way is correct seems to require already knowing where the chances are.

To help us to make progress, I offered my view of chance's role in scientific explanation and I argued that my view provides a way to adjudicate between Laws and Conditions Test and Macrophysical Test without prejudging questions about where the chances are. If there can only be one ideal scientific explanation of an event, or if multiple ideal scientific explanations of an event must be equally good evidence about whether the event occurs, then my view gives us reason to believe Laws and Conditions Test and incompatibilism. If instead, however, there can be multiple ideal scientific explanations of an event that are not all equally good evidence for that event, my view motivates Macrophysical Test and compatibilism.

On my view, then, the correct explanation-based strategy for figuring out where the chances are turns out to not be so different after all from the correct grounds-for-expectation strategy for figuring out where the chances are; both strategies yield results about chance that are sensitive to further claims about what the ideal scientific explanations are and about what ideal scientific explanations are like. Where are the chances, then? They are exactly where the ideal probabilistic explanations say they are, wherever that might be.

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[1] For recent examples of this kind of argument for compatibilism, see Loewer (2001), Glynn (2010) and Emery (2013).

[2] For recent examples of this kind of argument for incompatibilism, see Hoefer (2007) and Sober (2010) (wherein the argument is described) and Schaffer (2007) (wherein the argument is endorsed).

[3] It might nevertheless be true that chances are ultimately *grounded in* facts about relative frequencies, as on David Lewis's popular Humean treatment of objective chance (Lewis, 1980). Furthermore, history does contain authors who have defended the view that chances simply are the frequencies with which events occur relative to a reference class (e.g., Venn, 1876). However, I assume that frequentism is incorrect, for reasons such as those detailed in Hájek (1996). I additionally assume that at least some objective chances are "single-case" chances: chances of a particular event occurring. Some philosophers are skeptical of single-case chances (e.g., Gillies, 2000; Howson and Urbach, 1993; von Mises, 1957), but the authors I discuss in the main text all allow that chances can attach to particular events.

[4] Frequencies *do* have the power to explain things. For example, the fact that I've lost all of the thousands of lotteries I've entered helps to explain why I'm not rich. Nevertheless, the frequency with which an event of some type has occurred seems incapable of explaining why that very event, whose occurrence (or non-occurrence) helps constitute that frequency, occurred. For example, the fact that the frequency with which I have won the lottery is equal to 0 seems to report that, rather than to explain why, I have lost each of the lotteries I've entered.

[5] The question of what kind of information goes into an ideal explanatory text is just the question of what is the correct theory of scientific explanation.

[6] Thanks to an anonymous referee for pressing me to clarify this point.

[7] Well-known discussions of chance's unique predictive role appear in, e.g., Butler (1736), Salmon (1967) and Lewis (1980).

[8] Hoefer (2007) denies that the conjunction of the laws and history of the world is admissible in a deterministic world on the grounds that that conjunction implies the truth of every proposition about the future and thus contains information that does not "go by way of" the chances. Perhaps that is right, but without some independent account of which information, in fact, "goes by way of" the chances, Hoefer's rejection of the PP-based argument for compatibilism—unlike Loewer's and Glynn's—does not motivate an alternative prediction-based test of which probability ascriptions model chance.

[9] Sometimes events that occur by chance counterfactually depend on their causes, but sometimes causes merely change an event's chance of occurring.

[10] The distinction between mediate and immediate explanatory information is crucial to this view. In contrast, the view that scientific explanation is transitive functionally collapses this distinction by

implying that mediate explanatory information is, *ipso facto*, immediate explanatory information. In my experience, the alleged transitivity of explanation is typically assumed rather than supported by argument. At any rate, this essay is meant to push back on the transitivity assumption by demonstrating one of the theoretical advantages that comes with preserving the distinction between mediate and immediate explanations of an event's occurrence.

[11] That is, it is a serious epistemic possibility that the "standard" interpretation of quantum mechanics is correct.

[12] Importantly, my view should be interpreted as a view about the structure of scientific explanation rather than as a view about acceptable answers to why-questions. Many philosophers have pointed out that a sentence might be part of an ideal explanation of an event's occurrence yet not be part of an appropriate answer to a question about why the event occurred in a particular context. (See, for example, Railton 1978, Lewis 1986) For example, it might be true that the presence of oxygen helps to explain a fire even though it is inappropriate to cite the presence of oxygen when answering the question, "Why was there a fire?" across a wide variety of standard contexts. Similarly, it may be that there are many contexts in which the question, "Why did this [chance] event occur?" is appropriately answered by mediate explanatory information about laws, prior conditions or causes, rather than by immediate explanatory information about the event's chance of occurring.

[13] Thanks to an anonymous referee for pressing this point, which Hempel called "the problem of explanatory ambiguity" (Hempel 1695, p. 709).

[14] See my manuscript *Chance Explanation*.