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Abstract

What explains the outcomes of chance processes? We claim that their setups do. Chances, we think, mediate these explanations of outcome by setup but do not feature in them. Facts about chances do feature in explanations of a different kind: higher-order explanations, which explain how and why setups explain their outcomes. In this paper, we elucidate this 'mediator view' of chancy explanation and defend it from a series of objections. We then show how it changes the playing field in four metaphysical disputes concerning chance. First, it makes it more plausible that even low chances can have explanatory power. Second, it undercuts a circularity objection against reductionist theories of chance. Third, it redirects the debate about a prominent argument against epistemic theories of chance. Finally, it sheds light on potential chancy explanations of the Universe's origin.

1 | THE MEDIATOR VIEW OF CHANCY EXPLANATION

1.1 | Introduction: Three views

There has been a lot of ambivalence in the philosophy of scientific explanation about how explanation works in the case of objectively chancy events, of the sort that one might encounter in fundamental physics, in genetics, or in meteorology. In this paper we aim to clarify the debate about chance and explanation, to motivate and defend the view that chances mediate event

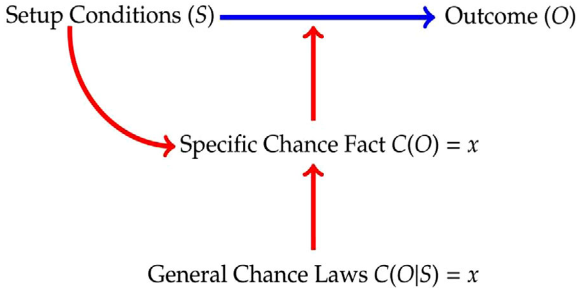

FIGURE 1 Arrows represent explanatory relationships between facts, with blue arrows indicating causal explanation and red arrows indicating non-causal explanation [Color figure can be viewed at wileyonlinelibrary.com]

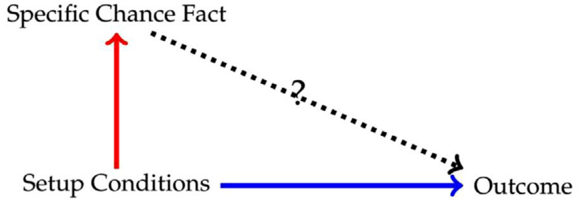

FIGURE 2 Solid red lines indicate grounding dependence, solid blue lines indicate causal dependence, and dotted lines indicate our disapproval [Color figure can be viewed at wileyonlinelibrary.com]

explanations without themselves explaining chancy events, and to explore the implications of this view for some controversial topics in recent scientific metaphysics.

There are three core approaches to explaining the occurrence of objectively chancy events:

- No explanation: nothing explains chancy events.
- Chances explain: facts about chances explain chancy events.
- Setups explain: facts about chance setups explain chancy events.

The first approach ties scientific explanation to determinism. Where an event is undetermined by the preceding states of the world, there is simply nothing true and informative to say about why that event happened. At most we may be able to say why it was likely to happen.

The second approach comes in at least two versions: high-chance and any-chance. According to the high-chance version, chances explain events only when the chance of the event is sufficiently high; for views on which higher chances explain better, see Hempel (1965), Strevens (2006), and Skow (2014).[1] According to the any-chance version, an event's chance explains it no matter how high or low that chance may have been.[2]

The third approach is the one which we prefer. On this *mediator view* of chancy explanation, chances don't directly explain chancy events; instead, they mediate chancy explanations holding between events. In such explanations, we will say that the *setup* explains the *outcome*. Chance itself is not an explainer of events but a mediator of event explanations.

The mediator view does not have the implausible consequence that chances do not explain anything at all. On the contrary, the role which chances play in mediating chancy explanations gives them a central explanatory role, at a level once removed: chances directly explain *why, and/or how, and/or that, the setup explains the outcome*. Precursors to this view include Scriven (1959), Humphreys (1989) and Skow (2014, 2016).

[1] Skow has a mixed view, according to which chances feature in "nearly necessary" explanations of events with very high chances, but don't feature at all in chancy causal explanations. As we see it, Skow's view is a precursor to our view in cases of chancy causal explanation, but we go further than Skow in arguing that chances mediate explanation even in the "nearly necessary" case.

[2] This view is defended by Elliott (forthcoming, MS).

In the remainder of section 1, we set the scene for our discussion and present the mediator view. We then defend the first component of the view, that chances don't explain particular events, in section 2. In section 3, we defend the second component of the view, that chances explain these first-order explanatory facts. In section 4 we apply the view to cast potential light on four controversies within scientific metaphysics: the explanation of unlikely events, the circularity objection against Humeanism, the adequacy of epistemic accounts of chance, and the explanation of why there is something rather than nothing. Section 5 is a conclusion.

1.2 | Distinctions and background

We aim to remain neutral on some foundational questions about chance. In particular, the mediator view does not commit us to any particular metaphysics of chance; it is instead a view about the structure and explanatory target of chance-based explanations. Although we will discuss its bearing on some metaphysical debates below (in section 4), we take the view to be compatible with any account of chance which takes chance-based explanation seriously. In particular, we address our arguments to anyone who acknowledges that there are true statements ascribing objective probabilities to events.

A key distinction on which the mediator view of chance is based is the distinction between first-order and higher-order explanations. At a first pass, in a first-order explanation, one thing explains another thing, while in a higher-order explanation something explains why some first order explanation obtains. This distinction has recently been developed in detail by Bradford Skow in his book *Reasons Why* (2016), but the idea goes back at least to Scriven (1959). Hitherto the distinction between orders of explanation has mainly been applied in the context of laws of nature (where, intuitively, it has been thought inappropriate that laws of nature should be first-order explainers alongside other first-order explainers such as physical causes). The primary task of this paper is to apply the distinction between orders of explanation to the case of chancy explanation; we think the distinction helps make sense of chancy explanation just as well as it helps make sense of non-chancy explanation.

We will take it that explanations hold in full generality between facts; that is, facts feature as both the explanantia (the explainers) and the explananda (the explained) of explanations. This fact-based approach allows us to offer a unified treatment of chancy event explanations and the higher-level explanations which we think chances themselves provide. However, our primary focus is on cases of chancy event explanation. In these cases, the relevant facts are what we call *occurrence facts*: facts which specify that some particular event occurs. Where an event C causes an event E, the occurrence fact F_C explains the occurrence fact F_E. Many of the first-order explanations we discuss will be straightforward (albeit chancy) causal explanations, and causation (at least in the most familiar sense) is a relation between events. Roughly speaking, we assume that a relation of causal explanation holds between facts when those facts specify the occurrence of events which themselves stand in a causal relation. However, we try not to presuppose any specific account of causation in what follows.

In our examples we will refer to (what we take to be) the explanans event(s) for a chancy event explanation as the *setup*, and to the explanandum event as the *outcome*. The *setup fact* is then the fact that the setup occurs, and the *outcome fact* is the fact that the outcome occurs. Finally, the *chance fact* is the fact which specifies the chance of the outcome fact conditional on the setup fact: $ch(O|S) = x$. Thus the setup might be the rolling of a fair die (or the activation of a suitably-configured laboratory apparatus) and the outcome would be the die landing '5'; the setup fact would be the fact that the die is rolled and the outcome fact the fact that it lands '5'; the chance fact would be the fact that the chance of rolling a '5' is equal to ⅙. Where there is no risk of confusion, and to streamline our discussion, we sometimes drop the 'fact' and talk simply of setups explaining outcomes, mediated by chances.

While in some cases it may be vague or context-dependent or simply unclear whether some fact is part of the setup fact or instead part of the background conditions for the explanation, we will not need to worry much about that distinction; our focus is on the explanatory role of the chance facts, and all we need for our purposes is that these be kept distinct from the setup facts. Chance facts say that the chance of a specific event occurring conditional on some other specific event occurring takes some real value between 0 and 1. For the most part, we will be interested in chance values that are not equal to 0 or 1; we set aside complications that arise from the possibility of probability-zero events occurring.

Can we say anything positive and informative about the setup facts? Yes; but what we say will depend on which theory of chance is in the background. For a theory according to which chances are intrinsic (most realist theories of chance), one can identify the setup fact with the facts about the physical system in question. On difference-making accounts of chancy causation, the setup fact is whatever increases the chance of the outcome fact.

It's worth noting that setups can be quite complex. For example, the setups which explain stable frequencies are not one-off events, but instead uniform features of groups of events. The fact that about half of the coins came up heads is explained by the fact that all of the coins were fairly flipped; the fact that about half of our atoms decayed over a 20-minute interval is explained by the fact that they were all carbon-11 atoms. This does not make the explanation any less chancy: stable frequencies are not guaranteed to result from such setups. It's possible for you to flip your fair coin any number of times and get heads each time, as in Tom Stoppard's play *Rosencrantz and Guildenstern are Dead*. It's simply that the chance of this long-term outcome is very, very low. Just as one-off setups explain one-off outcomes by making them likely, or more likely than they would otherwise be, complex temporally-extended setups explain long-term outcome frequencies by making them likely, or more likely than they would otherwise be.

In addition to neutrality on the background theory of chance at work, we aim for neutrality (insofar as is possible) on the background metaphysics of causal explanation in a world with genuine chances. This also goes for the background metaphysics of fundamentality. We are aiming to stay neutral on whether there is a fundamental level, and (if so) whether the chances at that level have a special kind of metaphysical status. Everything we say is intended to apply both to putative fundamental chances and to putative non-fundamental chances. For further discussion, see Hoefer (2007, 2019), Glynn (2011), Handfield and Wilson (2014), Emery (2015, 2017).

With the preliminaries complete, it's time to state the view which we aim to defend.

1.3 | Statement of the mediator view

The mediator view of chancy explanation involves two principal claims:[3]

[3] We understand explanation to be contrastive in nature; but explicitly identifying the contrasts is often cumbersome, so in our presentation of the view we suppress them. For avoidance of doubt, however, we expect there to sometimes be no explanation at all of why one outcome of a chance process occurs rather than some other outcome, even though there will be an explanation of the fact that it occurs rather than itself not occuring. For more detail on chancy contrasts, see section 3.4.

Setups Explain Outcomes: Outcome facts are directly explained only by their setup facts: chance facts do not explain outcome facts.

Chances Mediate Explanation: Chance facts are explanantia in higher-order explanations: a particular chance fact explains why some particular setup fact explains some particular outcome fact.[4]

Take *Setups Explain Outcomes* first. It is both a positive claim – explanations of outcomes of chancy processes are explained by their setup facts – and a negative claim – nothing other than the setup fact explains the outcome fact. In particular, the chance of the outcome does not explain it. Although most extant views of chancy explanation accept the positive claim, most of them would deny the negative claim and give chances a direct role in the explanation of outcomes. We think that this is a mistake: chances play a different explanatory role, at one level removed, by explaining the explanation of outcomes by their setups.

The indirect explanatory role of chances is captured on our view by *Chances Mediate Explanation*. As described in the previous section, we distinguish between first-order explanations – roughly, explanations of one event by another – and higher-order explanations of facts about first-order explanations. To say that something mediates a first-order explanation is, in our terms, to say that it is part of the higher-order explanation of why the first-order explanation holds. So to say that chances mediate chancy explanations is to say that chance facts higher-order-explain why first-order chancy explanations of outcome facts by setup facts obtain.

Our aim is to stay as neutral as possible between different accounts of scientific explanation; consequently we aim to stay as neutral as possible on the details of how higher-order explanations involving chances work. But to give a taste: if probability-raising accounts of chancy explanation are correct, then since the chances are what ground the fact that the setup raises the probability of the outcome, the chances will also ground the fact that the setup explains the outcome.

It will help to see an example of the mediator view in action. Suppose we isolate an unstable atom (say, bohrium, which has a half life of about a minute); call the process of preparing an isolated bohrium atom *P*. Individual atoms prepared in way *P* each have a chance 0.*999999999999999999999999999999999999999999999999999999999999999999999999*[5] of decaying within a few hours. Now suppose we prepare an atom in way *P* and it decays 30 seconds later. According to the mediator view, it is not the fact that its chance of decaying within a few hours was so high that explains its decay within a few hours; instead, it's the fact that the atom was prepared in way *P* that explains why it decayed within that time-frame. The chancy fact – that atoms prepared in way *P* have a chance of decay within a few hours very near 1 – explains the first-order explanatory fact, that the atom's being prepared in way *P* explains its decay within a few hours.

In most chancy cases, when a setup explains an outcome, it does not guarantee it. We hypothesize that this is one of the reasons that some philosophers reject **Setups Explain Outcomes**. On one way of thinking about explanation, to show that something is explained is (at least) to show that it should be expected. But if the setup doesn't necessitate the outcome, as in chancy cases, we can get into trouble if we predict the outcome with certainty.

We suggest that, in cases of full explanation, the setup does necessitate the outcome. Chancy explanations, then, are mere partial explanations. What is interesting about irreducibly chancy

[4] To accommodate the null-explanation suggestion floated in section 4.5, we might prefer a slight variant:**Chances Mediate Explanation***: Chance facts are explanantia in higher-order explanations: a particular chance fact explains how some particular outcome fact is explained.

[5] Thanks to Sylvia Rose for selecting this value.

events is that they can be partially but not fully explained by other events. Even though the setup partially explains the outcome, no event is a full explanation of the outcome. The setup is then an irreducibly partial explanation, which cannot be completed into a full explanation by citing additional events. So, in the atomic decay case above, the event of the atom being prepared in way P partially explains the atom's decay within a few hours. But nothing fully explains that decay; that is, nothing explains why the atom did not on this occasion flukily persist for days. It was just a matter of chance.

The view of chance explanations as partial retains the connection between explanation and expectation. A full explanation, on this view, posits reasons which would justify full confidence in the outcome. A partial explanation justifies partial confidence. (We discuss the connection between explanation and expectation in more detail in section 3.1.) In chancy explanation, where the chance of the outcome is less than 1, the explanation is always partial. This is, in some ways, a merely terminological choicepoint: one could instead choose to count the setup as a full explanation, simply because there are no other facts that could be added to it. We think that, although the setup is complete in this sense, it does not fully explain the outcome.[6] In chancy cases, we can keep the connection between full explanation and necessitation, or the connection between full explanation and completeness, but not both. We choose the former.

To what degree does the setup explain the outcome in these partial cases? It's tempting to identify the amount that the setup explains the outcome with the chance of the outcome conditional on the setup. If that chance is 1, the outcome is guaranteed and so fully explained; if it is less than 1, then the outcome is explained to the extent that the setup makes it likely. While this identification is tempting, we are not sure that it will work on all accounts of chancy explanation – for example, on a chance-raising account, is the degree of explanation the difference between the actual chance and what it would have been without the setup, or just the chance given the setup? So we will set this aside.[7]

We have said that first-order explanations of chancy outcomes by their setups are irreducibly partial: they cannot be filled out into a full explanation. Are the higher-order explanations similarly partial? When I toss a fair coin and it lands heads, the 50% chance of heads higher-order-explains why the tossing of the coin first-order-explains the coin's landing heads. This higher-order explanation does not necessitate the landing heads – after all, the value of the chance is equally compatible with the incompatible scenario in which the coin is tossed and lands tails. But, presupposing that the coin does land heads, the chance fact *does* necessitate that this result was explained by the tossing. So, given the facts that the coin is tossed and that it lands heads, the chance fact fully explains the fact that the tossing explains the landing.[8] Similarly, in the atomic decay case above, the fact that atoms prepared in way *P* have a chance of decaying within a few hours near (but not quite) 1 explains the fact that the atom's state explains its decay within a few hours. Given the fact that the atom decays, the chance fact fully explains the fact that its decay is explained by its preparation.

Can we appeal to the occurrence of the outcome in giving this explanation? We are not sure. The chance fact does not, by itself, guarantee that either the setup or outcome occurs, only that if they do, the former explains the latter. One might worry that if the chance doesn't guarantee the

[6] For a similar view, see Humphreys (1989: 112). Like us, Humphreys argues that in chancy cases, there is a partial but not a full explanation of the outcome.

[7] Thanks to Martin Pickup for discussion of this point.

[8] See Hicks (2021: 539-540) for a discussion of this point.

existence of the outcome fact it cannot guarantee that the setup explains it, or that it is problematically circular to appeal to the occurrence of the outcome in explaining why the setup explains it. So, if we cannot presuppose the occurrence of the outcome for the higher-order explanation, then the higher-order explanation is also partial.[9] The partiality of the first-order explanation infects the higher level. Whether the higher-order explanation is full or partial, on our view, depends on whether we are explaining an explanatory relationship between two events, given that they occur, or instead explaining the fact that the first event has anything to explain at all.

Our view that chancy outcomes are only partially explained accommodates some of the intuitions driving the the no-explanation view. We take it that the no-explanation view derives much of its support from the idea that full explanations are necessitating. Here, we've shown that we can accept the connection between full explanation and necessity and still retain the view that chancy outcomes are explained by their setups. In what follows, we will assume that outcomes of chance processes do have explanations, albeit partial ones, and proceed to investigate how those explanations work.

In this paper our focus is on first-order event explanations and on higher-order explanations of first-order explanatory facts by chance facts. Of course, explanatory demands can in general be iterated, so we can also pose the third-order explanatory question: what explains the higher-order explanatory fact that chances explain first-order explanatory facts? While we do not need to commit to any specific answer to these third- and higher-order explanatory questions, we think these questions are well-posed and admit of various coherent possible answers. One possibility (reminiscent of the 'upwards anti-primitivism' of Bennett, 2017), is to say that the chance fact itself is the answer to all explanatory questions at the third order and above; another possibility (reminiscent of Wilson, 2019) is to cite the chance fact along with some relevant law of metaphysics; a third possibility (reminiscent of Dasgupta, 2014) is to cite the essence of the higher-order explanatory fact at the third order while rejecting explanatory questions at fourth and higher orders. All these options seem in principle available to a defender of the mediator view.

Although for simplicity we have formulated our view against a background of fundamental chance, we are sympathetic to the view that there are chances at many different levels of description. And we are also sympathetic to the view that any particular event can have multiple explanations. So, if there are chances at some higher level – the level of economics or sociology, for example – but these chances result from coarse-graining a deterministic lower-level theory, we think that the higher-level chancy explanation of some outcome is a partial explanation, but the deterministic lower-level theory provides a full explanation of the outcome. But we also think it quite plausible that there are chances all the way down; if fundamental-level explanations are chancy, then there are partial explanations without any underlying full explanation.

2 | ARGUMENTS FOR THE MEDIATOR VIEW

The view that laws of nature don't directly feature in scientific explanations has been growing in popularity in the recent literature.[10] We take the basic insight of this 'higher-order' view to be as follows. In (at least a large class of) scientific explanations, particular events are explained by

[9] Leuenberger (2020) provides an extended discussion of the possibility of partial ground without full ground.

[10] Proponents of this view, including Scriven (1959), Ruben (1990), and Skow (2016), have argued that laws of nature don't explain, but instead feature in higher-order explanations or background justifications. Skow (2014) argues for a mixed view on which chances feature in higher-order explanations of causal relations, but directly feature in "near-necessity" explanation; here we argue for a view on which explanations invoking chance are always higher-order.

other particular events. Laws, by contrast, determine which particular events explain which other particular events. Often, one event explains another event by causing it. The laws are part of the explanation of why this particular event is a cause of that one. So the laws feature directly in a higher-order explanation: the explanation of the holding of the explanatory relation.

The same general considerations which support the higher-order view of the explanatory role of laws also support the mediator view of the explanatory role of chances. In this section, we explore how these considerations play out in the specific context of chancy explanation. We identify three distinct arguments in favour of the mediator view: an argument from ontological type mismatch (2.1), an argument from redundant dependence (2.2), and an argument from chance reductionism (2.3). The first two of these arguments form our principal case for the mediator view and are available to most views of the metaphysics of chance, while the third relies on more specific combinations of views about chance. Our focus here is on defending the claim that chances do not feature in first-order explanation. However, our arguments also tell against the no-explanation view, since their premises entail that chancy outcomes often have explanations: the events that (indeterministically) cause them.

2.1 | Type mismatch between chances and causes

Causal explanations provide information about causal relations. Causation, as ordinarily conceived, is a relation between events; causal explanation is then a relation between facts specifying the occurrence of events, which we are calling occurrence facts. Probabilistic facts, by contrast, do not specify the occurrence of any particular events; they are modal facts over and above all the occurrence facts. The chance fact is not just a fact about what happens: it's a statement probabilistically linking the occurrence of the setup to the occurrence of the outcome. And like explanations involving laws of nature, this statement has a modal component: rather than merely talking about what actually happens, it provides additional information about what is possible, necessary, or likely. This leads to the following argument:

The argument from ontological mismatch

Premise 1: Causal explanations hold between occurrence facts.
Premise 2: Chance facts are not occurrence facts.
Conclusion: Chance facts are not the right sort of things to be explanantia in a causal explanation.

This argument seems most compelling in the context of process theories, which hold that causation involves the transmission of conserved quantities; since the chances don't transmit such quantities they aren't suited to be causes. But while other theories of chancy causation have more room for manoeuvre, we think this argument is sound.

First, a note: we do not mean to imply that chance facts feature in no explanations. Don't forget that one of the components of our view is **Chances mediate explanation**, which commits us to the view that chance facts feature directly in higher-order explanations. On our view, though, the chance facts aren't explanantia in causal explanations – instead, they mediate these explanations, by grounding (and therefore explaining) the fact that some particular setup fact explains some outcome fact.

Premise 1 says that the only explanantia in a causal explanation are facts specifying the occurrence of certain events (the causes). This premise might at first appear to be tautologous. For what makes an explanation causal, one might think, is just that its explanantia events cause its explanandum event. But at least some philosophers will resist Premise 1. For example, Lewis (1986) claims that any information about the causal history of an event can feature in a causal explanation of that event and Railton (1981) holds that an explanation can be any part of an *ideal explanatory text*, where the complete ideal explanatory text will not just provide the causes of the event, but also information about why or how they cause the outcome (and perhaps more: for Railton the ideal explanatory text "reflects not only an ideal of explanation, but of *scientific understanding*" (Railton 1981: 243-4). On both views, a causal explanation can include facts which are not – or at least not directly – about causes.

Nonetheless, on Lewis's view, non-causal facts are included in explanations only because they give us information about the causes. For Lewis, information about the causal history can include the information that the event was uncaused, or that some particular event was not a cause of the event. We agree that this is explanatorily relevant information. But we think that it is relevant insofar as it provides information about the occurrence facts; the occurrence facts are the explanantia, and facts feature in a causal explanation insofar as they tell us about the explanantia.

We take Lewis to be explicating a form of what Andersen (2018: 488) calls *narrow causal explanation*. Narrow causal explanations seek to explain events by positing causes of those events. By contrast, Andersen's *broad scientific explanations* explain "by virtue of situating an explanandum in the network of causal relations in the world" and include explanations in which "any of the explanans, explanandum, or connection between them involves a causal relationship(s) or relata" (Andersen 2018: 488).

Railton's notion of an ideal explanatory text is of this broader sort. Railton holds that an ideal or complete causal explanation needs to include, in addition to information about the causes, information about the relationship between the causes and the explanandum.[11] For Railton, the ideal explanation "comprises the things a research program seeks to discover in developing the capacity to produce better explanations of chance phenomena" (Railton 1981: 243). Here, we disagree. A research program, in order to produce better explanations of chance phenomena, needs to explain not just the phenomena, but also the relationship between the phenomena and their explanantia. And that might not be all! To produce explanations, a scientific research program may also include things which are not themselves explanations at all, including instructions or recipes for constructing scientific models. We conclude that Railton's *ideal explanatory text* is too broad; as Anderson (2018: 490) points out, a too broad notion of explanation risks collapsing important distinctions in the target of the explanation – not, in our view, an ideal way of illuminating the subtleties of scientific explanation.[12] We will return to Railton in section 3.1, when we discuss how explanation relates to understanding in more detail.

Premise 2 may also be controversial. In support of it: occurrence facts specify that some event occurs, and the occurrence of an event is spatiotemporally located. By contrast, chances are not located in space and time, and, intuitively, are not occurrences; they are modal facts over and above events. There is a (future) event of your finishing this paper; but there is no event of your possibly finishing the paper; similarly, there is no event of your probably finishing the paper. The modal fact is not about any particular occurrence.

[11] Railton distinguishes causal explanations, which he takes to be deterministic, from probabilistic explanations. Since we hold that causation can be probabilistic, we do not follow him in making this distinction. Nonetheless we think our arguments here apply generally to scientific event-explanation.

[12] Thanks to Noelia Iranzo Ribera for discussion of this point.

This claim could be resisted, especially by philosophers who hold epistemic or subjectivist views about chance. On these views of chance, chance facts give us partial information about events. So while a chance may not be a cause, a chancy fact may give us information about causes; it may therefore be eligible to act as an explanans in a causal explanation, insofar as it provides partial information about occurrence facts.

Chancy facts, as they feature in causal explanation, are not facts about the cause. Rather, they are modal facts about the effect. If some setup makes some outcome likely, then (on an epistemic or subjectivist view of chance) the chance fact gives us partial information about the outcome, not the setup. For example, in our decay example, the setup makes it overwhelmingly likely that the Bohrium atom will decay. The setup here is the isolation of the unstable Bohrium atom, and the outcome is alpha decay. So the chance fact – that alpha decay is overwhelmingly likely – is a fact about the likelihood of the *outcome*. Facts about the outcome, whether complete or partial, are simply not the right sort of thing to feature as an explanans in a causal explanation. If chance facts are about events in this way, then causal explanations which invoke them as explanantia are problematically circular.

We conclude that chance facts are not suited to be explanantia in causal explanation.

2.2 | Redundant dependence

Everyone (or nearly everyone) agrees that chances have something to do with explanations of outcomes. Chances being objective probabilities, the corresponding explanations are also naturally taken to be objective in nature. We follow Kim (1994) in holding that objective explanations are backed by real-world dependence relations. So we may ask: what dependence relations hold between the chance facts and the other facts involved in chancy event explanations? Reflecting on this question yields our second argument for the mediator view: unless we adopt the view, we are obliged to recognise an unattractive *redundant dependence* with two distinct paths of dependence between the setup and the outcome.

The argument from redundant dependence

Premise 1: Outcome facts are causally explained – at least in part – by setup facts.
Premise 2: Chance facts non-causally depend on setup facts.
Conclusion: If chance facts – even partially – explain outcome facts, then there are two distinct explanatory dependencies between setup facts and outcome facts.

Since the chance facts themselves are (we assume) non-causally dependent on the setup fact, and since the outcome (we assume) causally depends on the setup in at least some cases, then any explanation of the outcome in terms of the chance fact will give rise to redundancy in the explanatory dependency between setup and outcome. We are left with two routes between setup and outcome: one route going via the chances (with a non-causal component), one direct (and purely causal) route. This redundancy is implausible, and so it provides a reason to reject the view that chances explain outcomes.

As with the argument from ontological mismatch of the previous section, the argument from redundant dependence turns on cases of chancy causal explanation. Perhaps not all cases of chancy event explanation are of this sort; for example, perhaps some cases of chancy event explanation involve only nomic dependence without any appeal to causal concepts. However, we think that there are a number of important cases of chancy causal explanation, and there is pressure to understand chancy explanation uniformly across both causal and non-causal scenarios.

The argument is sound both given the view that setups explain outcomes by making them very probable (the high-probability view) and given the view that setups explain outcomes by making them more probable than they would be (the probability raising view). Both views connect chance to causation, and so are compatible with Premise 1. On the first view, the setup causes the outcome in virtue of making it very probable; on the second view, the setup causes the outcome in virtue of making it more probable than it would have been.

Premise 2 also holds on nearly every account of chance: the precise chances of outcomes are, at least partially, grounded in the features of setups. This feature is built into the Lewisian account of chance, for example, since Lewisian chances at time t are implicitly conditioned on the entire history of the world up to t. Other accounts of chance often make chance setups more localized than that; for example, Schaffer (2007) imposes an Intrinsicness Requirement that "chance values should remain constant across intrinsically duplicate trials" (p.125). The chance of heads on the next flip of this coin depends on how the coin is shaped and how it is tossed; the chance of an atom decaying depends on the balance between neutrons and protons in its nucleus. The dependence is non-causal: the intermolecular forces partially ground the chances, but they don't cause the chances to be what they are.

However, the Conclusion is unpalatable: it renders our explanandum problematically overdetermined. It also seems to over-state (or double-count) the explanatory role of the chances: the chances feature both as a contributing cause or explanans of the explanandum and as the connector between the setup and the outcome.

One way out of this overdependence jam would be to posit the chances as an intermediary explainer of the outcome: the explanans non-causally produces the chances, and the chances explain the outcome – whether by causing it, or in some other way. This sort of view is advocated by Elliot (manuscript); for Elliot both explanations are non-causal. But the non-causal version of this view is also susceptible to significant hurdles: it seems that adding in these intermediate explainers unnecessarily multiplies the number of links in the explanatory chain. In indeterministic cases, there will always be a chance-event between a cause and an effect, non-causally produced by the cause and explaining the effect. And if this view is to be applied uniformly to deterministic cases (where the chance of the outcome given the setup is 1), this view seems to imply that there is always an intermediate explainer (the outcome's having chance 1) between any deterministic setup and its outcome. We think that this proliferation of links in the explanatory chain is best avoided.

Another response to the overdependence pickle would be to hold that the two routes from setup to outcome – the chance-involving route and the direct route – present distinct, non-competing, complementary explanations of the same outcome. Distinguishing levels of explanation is a common theme of the contemporary literature on causal explanation. For example, a number of interventionist-style responses to Kim's causal exclusion argument permit both mental variables and underlying physical variables to be causes of mental events, but only relative to different models or levels of grain for the model's variables. According to this response, chances would be higher-level variables, giving partial information about the underlying setups. Then chance facts explain in the same way that other higher-level facts explain. We think this response makes an important category error: it represents chances as (coarse-grained) events, whereas we think they are properties of events (of whatever grain). We also note that this response makes an important concession to our view. For the response accepts that there are explanations of chancy events which do not invoke the chances as explanans. However, it differs from our view by also accepting explanations of the outcome which only invoke the chance, and not the setup. We argued in the previous section that such explanations cannot be causal explanations, and since they are intended to be objective explanations we are assuming that they need to be backed by some objective dependency relation. In the absence of any plausible candidate for that dependency relation, we are doubtful that the interventionist treatment of redundant explanations in chancy contexts as non-competing can be sustained.

A further problem for either of these ways of preserving chances as direct explainers of outcomes is that it is wholly unclear what the nature of an objective dependence relation between chance and outcome might look like. We have already argued in the previous section that the dependence relation cannot be a causal one. What else could it be? It doesn't seem like metaphysical or modal dependence, since the chance facts don't necessitate the outcome any more than the setup does.[13] Nor can it be a probabilistic dependence – this is subtle, but the outcome doesn't depend probabilistically on the probabilities (unless a distinct set of higher-order probabilities are mediating that dependence). Rather, outcomes depend causally or probabilistically on features of setups: the weight of the dice, or the number of balls in the urn that are a certain colour, are what determines the likelihood of the outcome. This probabilistic fact determines whether the setup explains the outcome. But if the setup does explain the outcome, it does so on its own.

Recently, Nina Emery (forthcoming) has argued that events depend on laws, but that this dependence is neither causal nor metaphysical. On Emery's view, causal and metaphysical explanation are members of a family of dependence relations, but they are not the only members: lawful dependence is another, distinct form of dependence. Facts about chances and laws back explanations, but these explanations are neither metaphysical (grounding) explanations nor are they causal explanations. Similarly, Skow (2014) argues that chances feature in "near-necessity" explanations. On Skow's view, we can explain something by showing that it must happen; the modal fact can directly explain an outcome. If a chance is high enough, it can provide an explanation by showing that something is nearly necessary. Like Emery, Skow holds that the chance explanation invokes a dependence relation that is similar to, but distinct from, metaphysical necessitation.[14] These views might accept the conclusion of our argument and embrace overdetermination, albeit with a different flavour of dependence for each route from setup to outcome. We do not have a knock-down argument against these views, but we can get in a couple of sucker-punch arguments. First, these views unnecessarily multiply dependence relations, and so violate Occam's razor. If a view like ours can account for the explanatory data, then it should be preferred on grounds of parsimony. Second, we wonder whether these near-necessity or nomic dependence relations crowd out causal explanations. Surely some chancy explanations of outcomes are causal. But if these explanations always include the chances, and the outcome depends on the chances via some non-causal dependence relation, it is difficult to see when or how causal dependence enters the picture.

2.3 | Fundamental explanations and chance reductionism

Our final argument will only appeal to philosophers with specific commitments, but we think those commitments are sufficiently widespread to make the argument interesting. Many

[13] Though see Emery (2019) for an argument that metaphysical dependence need not necessitate in these chancy cases.

[14] Skow admits that in many cases, this near-necessitation is conditional. For example, the near necessity of alpha decay for a particular atomic nucleus is conditional on its being prepared with an unstable balance of neutrons and protons. Skow holds that the chance fact directly explains the outcome in these setups; we hold that the setup explains the outcome, mediated by the chance, and that in general when some outcome is conditionally nearly necessitated, the explanation is whatever the chances are conditional on.

philosophers hold that chance facts are not fundamental facts; instead, they are grounded in fundamental facts. Call this view *chance reductionism*. Chance reductionism is in strong tension with the claim that chances are explanantia in explanations of events. For, if quantum mechanics is correct, some fundamental events have chancy explanations. But fundamental events cannot be explained by non-fundamental events. That gets the direction of explanation backwards. This leads to:

The argument from chance reductionism

Premise 1 (*Chance Reductionism*): Chance facts reduce to non-chance facts.
Premise 2 (*Explanatory Purity*): Only fundamental facts can explain fundamental facts.
Premise 3 (*Chancy Explanation*): Some fundamental occurrence facts have chancy explanations.
Conclusion: There are chancy explanations that do not include chance facts.

Many philosophers reject Premise 1, but some prominent views are committed to it. The most prominent is the Humean modified frequentist view, on which chances feature in the most efficient summary of all facts (Lewis 1980, 1996, Loewer, 2004). But Humeans are not the only chance-reductionists. For example, hypothetical frequentists hold that chances are made true by counterfactuals about infinite sequences. The hypothetical frequentist holds that coin flips have a 0.5 chance of coming up heads because, were you to flip a coin infinitely many times, the limiting relative frequency of heads in that sequence would be 0.5. If these counterfactuals are basic, along the lines of Lange (2009) or made true by dispositions (Bird 2007: 129), then the chance facts are neither fundamental nor Humean. See also Hoefer (2019) for a recent non-Humean reductionist view.

Premise 2 is connected to widely held views concerning the explanation of the fundamental. We take Premise 2 to be motivated by the same sort of thinking that motivates the causal closure of the physical: if physics is fundamental, how could something non-physical cause something physical? Premise 2 will also be hard to reject for those who accept Sider's (2013: 106) notion of *purity*. For Sider, the fundamental facts can be expressed without recourse to non-fundamental vocabulary. It is no stretch to hold that fundamental facts should be explained without recourse to non-fundamental facts as well. It is also similar to Field (1980)'s intrinsicness requirement on explanation: explanations should cite facts which are intrinsic to the explanans and explanandum. For similar principles, see Eddon (2014), Field (1980), Milne (1986), and Shumener (2021).

We take Premise 3 to be an empirical fact about our world, which is very likely true. If quantum events are fundamental, and if they are produced by chancy processes, then Premise 3 holds. If the successor theory to quantum mechanics retains the chancy nature of quantum mechanics – something we think is likely – then Premise 3 is also true.

We note that while the mediator view of chances allows chance-reductionists to accept chancy explanations of fundamental facts, it requires them to take these explanatory facts to be non-fundamental. For on the mediator view, chances feature in higher-level explanations. They explain the fact that some fundamental events explain other fundamental events. So, given *Explanatory Purity*, when the setup and outcome in some explanation are fundamental facts, the fact that the setup explains the outcome is not itself a fundamental fact. Rather than being a cost of the view, this looks to us like a friendly conclusion for chance reductionists. Just as the chances are non-fundamental, facts about chancy explanation are non-fundamental. They hold in virtue of the chances and whatever those chance facts reduce to. It is similar in many ways to the Sider's (2013: 107) argument that facts about what grounds what are non-fundamental facts.

3 | IN DEFENSE OF THE MEDIATOR VIEW

Thus far, our arguments have aimed to show that chances don't feature in first order explanation. Given all we've said so far, chances might have no role to play in explanation at all. But there are powerful reasons to think that chances do have some role to play in the explanation of chance events. We will now argue that the role of chance is to *mediate* explanations. To do so, we will consider three motivations for taking chances to feature in explanation, and argue that in each case the role of chance facts is higher-order: the chance facts explain the first-order explanatory dependence. First (section 3.1) we'll argue that the mediator view elucidates the connection between explanation and understanding. Next, we will show how the connection between explanation and expectation supports the mediator view (section 3.2). Then, we'll show how the mediator view accommodates inference to the best explanation (section 3.3). In each case, our strategy will be to identify a misconstrual of chance's higher-order explanatory role for a first-order role. In this way, our view reconciles the powerful intuition that chances explain with our arguments in section 2 that they do not.

3.1 | Explanation and understanding

Explanations lead to understanding, but (one might worry) understanding a phenomenon requires an understanding of how it came about. Fully understanding a phenomenon doesn't just involve knowing its particular causes; it additionally requires us to situate the phenomenon in a larger causal web. Here's Jonathan Schaffer making this point:

> What I am primarily rejecting at this stage are causes-only accounts of causal explanation. Scriven (1959) and Skow (2016) both hold something like this view, on which laws play no role in causal explanation. Against such accounts, I [...] hold that such accounts fail to illuminate the connections between explanations and unification, manipulation, and understanding. For instance, consider a double-slit experiment in which repeated firings of a laser cause an interference pattern to appear on a screen. This is a quantum effect which cannot be understood from a classical perspective. My claim is that information about the causes (the firings of the laser) is not enough to understand why there was an interference pattern. For that one also needs information about the laws (the quantum dynamics governing light), to reveal how the causes and the effect are connected. (Schaffer, 2017: 308)

Schaffer argues that explanation leads to understanding, and uses this connection to argue that chances and laws are explainers (note that in Schaffer's example the laws are indeterministic). But this argument seems to us to draw on too blunt a connection between explanation and understanding. We agree that knowing the causes of an event is not enough to fully understand the event. Understanding requires knowing the explanation, but knowing the explanation is not sufficient for understanding. A full understanding of some event requires us to know more than just what explains the event; we need to also know how the explanans explain the explanandum.[15] Knowing how an explanandum was brought about *does* take more than just

[15] Further complications are involved when philosophers consider explanations to primarily be communicative acts, such as answers to *why-questions*, as in van Fraassen (1980), Skow (2016), and Potochnik (2017: ch. 5.1). For when we communi-

knowing what the causes of the event are. But that is no objection to our view, because knowing how an explandum was brought about is different from knowing why the event happened. Knowing why an event happened involves knowing which events explain the event; knowing how an event was brought about involves knowing why those events explain it. Knowing how a chancy event was brought about involves the chances, at least in part because knowing how the event was brought about requires us to explain not just the event, but also the explanatory relationship between the event and its explanantia. This additional knowledge comes from the explanation of the explanation, and these higher-order explanations do involve chances. Although higher-order explanations have a different explanatory target than the direct explanation of the event, they add to our understanding of it by showing how the (first-order) explanantia produced it.

This recalls Railton's discussion of an *ideal explanatory text* containing everything relevant to understanding an event. When pursuing scientific understanding of some event, we need to do much more than just explain that event. We need to situate that explanation in a hierarchy of other explanations. And, in our view, not all of these explanations will be of the target phenomena. Some of them will be of distinct, but similar phenomena; others will be higher-order explanations which elucidate the ways in which the phenomena are explained. Schaffer and Railton collapse first-order explanations of particular events, explanations of repeated phenomena and event types, and higher-order explanations which elucidate these explanatory relations into one ideal text. Perhaps a Railtonian ideal explanatory text does contain both a first-order explanation of a phenomenon and a higher-order explanation telling us why or how that explanation works; perhaps it even includes explanation at some or all higher orders as well. If higher-order explanations are included, then (on the mediator view) chances feature in the ideal explanatory text for particular events. But we think that if they do, they are not included as explanans; rather, they are included to elucidate how the explanans bring about or explain the explanandum.[16] This connection between chances and understanding, then, provides evidence for the mediator view: the fact that chances explain the first-order explanatory facts itself explains the fact that the chance facts are necessary for understanding a phenomenon.

3.2 | Explanation and expectation

A similar connection between explanation and rational expectation can be explained by the mediator view:

> "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

cate in a context, we aim to add to the common ground, that is, the shared storehouse of propositions which are not only known by all participants, but also known to be known by all participants. So, when cooperative interlocutors answer a question, they are required not only to provide an answer to the question, but also to ensure that their audience knows that they have answered the question. This second step often requires cooperative communicators to include information that explains why the (first-order) explanation is an explanation. Despite the fact that communicative contexts require us to provide this information in answering a why-question, it has a different target than the original question.

[16] Why does this distinction matter? First, if our aim is to understand how explanations lead to understanding, correctly differentiating the way in which different parts of an ideal explanatory text contribute to understanding is a valuable and important part of that task on its own. Second, it is useful in what Railton calls "stringing together [...] explanations or amalgamating them with larger explanations" (1981: 236). As we argue in section 4.3, whether we can apply the transitivity of explanation depends quite a bit on what the explanans are, as do metaphysical constraints on what can be explanatory.

> be expected. To explain an event is to show to what degree it was to be expected…" (Salmon 1971: 79, quoted in Elliot MS: 15)

Katrina Elliot, drawing on Salmon, claims that "scientific explanations are the best possible grounds we could have had for our expectations about whether an event occurs prior to its occurrence" (Elliot MS: 17), and argues that "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" (Elliot MS: 19).

We agree with Elliot that explanantia provide grounds for expectations. But we do not think this requires them to include the chances. If you know that a Bohrium atom is prepared in an unstable state, then you have grounds for expecting (with credence near 1) that the atom will soon decay; if you know that the fair coin will be flipped, then you have grounds for expecting (with credence 0.5) that the coin will come up heads.

We think that knowledge of the explanantia provides the grounds for these credences all by themselves. But one might wonder *how* you are supposed to know what credence to have on the basis of the explanans. This is a different question, and answering it brings in higher-order evidence: evidence about what attitude your first-order evidence supports regarding the outcome. This desire for higher-order evidence requires a higher-order explanation. The chance facts feature in this higher-order explanation by telling you precisely what attitude the explanantia ground regarding the explanandum. The first-order explanation provides the best grounds for your expectation of the outcome; the higher-order explanation provides your best grounds for beliefs about what expectation to have concerning the outcome. Thus the connection between explanation and expectation also provides evidence for the mediator view, once first-order evidence and higher-order evidence are properly distinguished. The fact that chances provide the best grounds for beliefs about what expectations to form supports the view that they feature in higher-order explanations of the events.

We suspect that philosophers who collapse these distinct explanations, with distinct explananda, into one explanation may be smuggling in internalist notions of evidence. On our view, one could have evidence which supports a certain attitude towards, say, the Bohrium decay without knowing that one's evidence required that attitude. Someone who lacked this higher-order evidence might not know what expectation to form despite knowing the explanation for the decay. Their evidence would decisively favor a certain attitude but they would not know it. For confident externalists like us, this is not an unusual or surprising situation for a person to be in, but we understand that it rubs internalists the wrong way.

We agree with internalists, though, that there is a sense in which such a person would not fully understand the phenomena, even though they had an explanation of it. Plausibly, understanding a phenomenon does require more than having the right expectations regarding that outcome. Those expectations should not be lucky; they should themselves be based on evidence. We do not aim for a complete account of scientific understanding here – far from it! But we humbly suggest that, in cases like these, understanding a phenomenon requires more than just an explanation of that phenomenon. It also requires a higher-order explanation. When agents have both, they have both the evidence they need to form expectations about that phenomenon, and they know why those are the right attitudes to have regarding the phenomenon. So we agree that there are deep connections between explanation, expectation, and understanding; but we take a nuanced view of these connections which distinguishes first-order and higher-order beliefs and explanations.

3.3 | Inferring chances as the best explanation

Our epistemic access to the chances comes, at least in part, from observing frequencies. Our experimental confirmation of quantum mechanics comes predominantly from observing the outcomes of chancy quantum events like atomic decays or particle deflections; our evidence for everyday chances, like dice rolls and coin flips, similarly comes from observing the long term frequencies of outcomes of similarly prepared setups.

One way of understanding this is via inference to the best explanation (IBE). We posit simple chance theories to explain observed stable long-run frequencies. Philosophers sympathetic to IBE might worry that since we've rejected the view that chances explain, we can't accept the view that chances are the best explanation of outcomes. And if chances aren't the best explanation of outcomes, the IBE doesn't get off the ground. How, then, do we gain knowledge of the chances via observed outcomes?

IBE provides further evidence that the chances are involved in higher-order explanation.[17] For the mediator view shows how chances can be inferred via IBE without featuring in first-order explanation. To successfully learn the chances via IBE, on the mediator view, takes three steps. First, one observes an outcome. Next, one infers that the outcome was explained by its setup. Finally, one infers the chance theory as the best explanation of this explanatory relationship.

In practice, inferring that the setup explains the outcome and inferring the chance theory which mediates this explanation may happen at the same time. To show that some setup explains an outcome, it's best to also show how or why it explains that outcome. Answering this how or why question requires us to provide a higher-level explanation. Therefore we will often infer the best meta-explanation at the same time that we infer the best explanation of the outcome. Our point here is that, even when these two inferences happen concurrently, they consist in separate inferential steps. These steps can come together, but they might not happen concurrently: formulating an explanatory chance theory often requires observing multiple instances of chancy causation in different contexts.

The mediator view has further advantages: it connects apparently disparate features of IBE. On the mediator view, we prefer unifying theories for the same reason we prefer explanations with few causes. When making an inference about particular events, Occam's razor tells us to find an explanation with as few causes as possible. For example, if I come home to find that all of the rooms in my house have been ransacked, I typically infer that one burglar has ransacked the entire house, rather than a series of burglars independently ransacking each room.

Applying the same principle to the explanations of explanatory relationships requires us to prefer unificatory theories, for a unificatory theory explains a wider variety of first-order explanations than a non-unificatory theory. For example, Newtonian gravity unified the terrestrial mechanics of projectiles with the astronomical behavior of the planets and moon; it did this by providing a common ground for the distinct explanations of these apparently disparate phenomena. Our preference for a unified higher-order explanation of these disparate first-order explanations is directly analogous to our preference for a unified causal factor in causal explanation. Chance theories can be similarly unificatory – for example, the method of arbitrary functions explains why stable frequencies result from chance setups ranging from dice to coins to roulette wheels.

[17] We're not convinced that the only way of modeling this inference is via IBE – for example, it can also be modelled via Bayesian conditionalization on observed frequencies. But these might not actually be different inference methods – we are sympathetic to compatibilism between I and Bayesian inference, as in Henderson (2014).

4 | BEARING ON ARGUMENTS IN METAPHYSICS

The mediator view has consequences for a number of debates about the metaphysics of chance. Here, we will address some of these. First, we discuss questions concerning particular chance explanations: in section 4.1 we show how the mediator view bears on the explanatory power of low chances. Next we consider the view's implications for accounts of chance: chance reductionism (section 4.2) and epistemic views of chances (section 4.3). Finally, (section 4.4) we discuss the question of why there is something rather than nothing from the perspective of the mediator view.

4.1 | Low chance and explanation

Both Strevens (2000) and Skow (2014) argue that higher chances are better explanations than lower chances. They pit this view against Railton's (1981) *egalitarianism*, according to which the explanatory power of chances doesn't depend on their size: small chances explain just as well as large ones.

Suppose that some unlikely event occurs. For example, imagine that our sample of Bohrium atoms from section 1.3 entirely fails to decay after a few hours. By stipulation, the chance that this happens, given the Bohrium atom's setup, is near zero. What explains that it failed to decay? On the mediator view, this is explained by the setup, just as its decay would have been explained by the setup had the decay occurred instead. In the case of non-decay, the setup did not make this outcome likely (quite the reverse). Nonetheless, we maintain that the setup explains its (very unlikely) outcome. After all, the setup did enable the failure to decay and made it possible; this is explanatorily non-negligible, and in a case of a very low-chance outcome it may be as much explanatory information as can be given.

We acknowledge that this consequence of the mediator view initially seems implausible. We offer two routes to defusing its implausibility. The first route highlights the role of explanatory contrast classes in driving our judgments of implausibility, and the second route highlights the matching unlikeliness of the meta-explanation for the first-order explanation.

Begin with the role of contrast classes. What the mediator account maintains is that the setup explains why the outcome occurred, simpliciter. In contrastive terms, this answers the explanatory question: why did the outcome occur rather than the outcome not occurring? An alternative contrastive question would ask: why did the outcome occur rather than some other possible outcome of the same setup occurring? These are not equivalent questions, and they do not have equivalent answers. In particular, the mediator account does not entail that the setup explains why the low-chance outcome occurred rather than the high-chance outcome. Plausibly, low chances can explain why some outcome occurred simpliciter, but only high chances can explain why it occurred rather than another outcome. Rather, according to the mediator account, in low-chance cases there often is no explanation whatsoever of why one chancy outcome occurred rather than another. That is just what it is for the process to be objectively chancy.

Distinguishing these different contrastive questions allows defenders of the mediator view to respond to the charge of implausibility levelled against their claim that the Bohrium setup entails the lack of decay. If we wanted to know why the less probable outcome occurred rather than the more probable outcome, it would indeed be wrong to cite the setup. But if we want to know why the less probable outcome occurred rather than not occurring, or rather than no outcome at all occurring, then it is correct to cite the setup. That is not to say that the setup will in such cases provide a full or satisfying explanation of the outcome, just that it provides as good an explanation of the outcome as reality affords.

The second route to defusing the implausibility of the implication that the Bohrium setup explains the failure to decay is to draw attention again (echoing the discussion in section 3.1) to the role of the higher-level explanation. Even after contrast classes have been carefully distinguished, readers may think that the explanation of the outcome in terms of the setup remains unsatisfactory. How can anything explain an outcome when it makes that outcome so overwhelmingly improbable? Our response to this rhetorical question is to agree that the situation is extremely surprising, but to locate this surprisingness in the fact that the chance explanation itself had an extremely low probability of holding. Before the experiment was switched on, it was extremely improbable that the Bohrium would fail to decay. A fortiori, it was extremely improbable that switching on the experiment would explain the Bohrium failing to decay. Just as the failure to decay surprising, so too is the explanatory fact which holds partially in virtue of that failure to decay. We accordingly would like to diagnose any residual implausibility of our (suitably disambiguated) claim that in such a situation the setup explains the failure to decay as issuing from a (correct!) recognition of the deep objective likelihood of this situation in fact coming to pass. It is a feature and not a bug of our view that it renders true some surprising claims in situations which are – in and of themselves – extremely surprising.

4.2 | Explanation and chance reductionism

Proponents of the view that chances explain events take this view to constrain our theory of chances. The idea is simple: if the chances explain, then they have to be the sort of thing that *can* explain. This is especially worrisome if the chances are supposed to explain frequencies since some theories of chances make chances look more like descriptions of frequencies than explanations of them. Here's Hájek (1996: 219) presenting this as an argument against finite frequentism:

"We posit chances in order to explain the stability of these relative frequencies. But there is no explaining to be done if chance just is actual relative frequency: you can't explain something by reference to itself."

Very few philosophers now defend finite frequentism.[18] But many defend a related view, *chance reductionism*, according to which chances are grounded in non-chancy facts. Most chance reductionists take those non-chancy facts to include the frequencies. One popular way to be a chance reductionist is to subscribe to the Humean Best System Analysis (BSA) (although see Hoefer 2019[19]

[18] Naive frequentism presents an interesting counterexample to our view which does not arise on more developed chance reductionist accounts. For the naive frequentist identifies chances with certain events. Consequently, on the frequentist view, there will be some cases in which setups *are* chances. For example, we might explain the fact that 15% of smokers get cancer by appealing to the fact that 20% of smokers have a particular gene which increases the likelihood of cancer. On the frequentist view, the fact that 20% of smokers have the gene is *both* the chance of having the gene *and* a setup condition for a chance-based explanation of having cancer. Since our thesis **Setups Explain Outcomes** holds both that setups do explain outcomes and that chances don't, the dual nature of frequentist chances leads us to a contradiction. Naive frequentists should revise our two theses: frequencies *qua* setup events explain other events, and frequencies *qua* chances explain explanatory facts. Note, though, that even on this revised view frequencies never explain themselves, and instead only explain other frequencies. Thanks to Gonzalo Rodriguez-Pereyra for discussion of this case.

[19] Although Hoefer's theory of chance is Humean, he doesn't commit to the full Humean metaphysical view and is comfortable with the prospect of deterministic non-Humean laws at a fundamental level.

for a Non-Humean chance reductionism). This subscription comes with a metaphysical picture according to which the world is made up of an array of particular matters of fact, the *Humean mosaic*, named for Hume because these matters of fact have no modal connections. The laws and chances are part of the *best system* of these matters of fact, where the best system is the most informative summary of these matters of fact.

Nina Emery (2016: 495) points out that this view is subject to the same explanatory objection that besets finite frequentism: "although (on the BSA) probabilities are not equivalent to frequencies, the reason why some probability function ends up being a part of the best system will, at least in paradigm cases, be because of the existence of some corresponding frequency." Similarly, Elliott (2016: 498) claims that "theories of chance according to which chances supervene on the Humean mosaic have a prima facie difficulty allowing that chances are explanations of (any part of) the Humean mosaic. The worry is that if the Humean mosaic helps to constitute the chances, then the chances are ill placed to explain the Humean mosaic."

But the circularity argument against reductionism doesn't even get off the ground if, as we argue, chances do not explain parts of the mosaic at all. If the first-order facts are explained by one another through probabilistic dependence or chancy causal dependence, there will only be a worrying circularity if there are chancy causal circles (whether there are looks to us like an empirical matter not connected to the metaphysics of chance).

We do think that the chances feature in higher-order explanations. Could circularity worries arise here? Perhaps Elliot and Emery would argue that the frequencies should not appear in any explanation of *what explains the frequencies*. We would be interested in seeing such an argument.[20] But we don't see how this constraint could follow from any sort of general principle about explanation. Naively, it seems quite natural for facts about X to feature in explanations of what can explain X. In order to show that some Y explains that X, we will need to bring up features of *both* X *and* Y. To explain why your stepping on my tomato plant explains its stunted growth, I will need to point out features of its stunted growth – for example the fact that the branches that died are the ones you stepped on. Rather than being circular, this is straightforwardly good practice in higher-order explanation.

Some Humeans have responded to the circularity worry, in the case of laws, by distinguishing between metaphysical explanation and scientific explanation (Loewer 2012; see also Marshall 2015, Miller 2015, Hicks and van Elswyk 2015, and Bhogal 2020); on this view the chances are metaphysically explained by facts about the frequencies but scientifically explain those same frequencies. For this move to work, scientific and metaphysical explanation must be distinct enough that they cannot be strung together or combined into a single mixed explanation (see Lange 2018). If we're right, the scientific explanation and metaphysical explanation have different targets and different explanantia, so the circularity argument fails even if these distinct sorts of explanation can be combined or feature in the same explanation.

4.3 | Explanation and epistemic views about chance

One historically prominent view about chances is the *epistemic* view. This view takes the chances in various scientific theories to represent the degrees of beliefs of either the scientists using the theory or an ideally rational agent with the evidence provided by the theory. So, the epistemic view

[20] One of us has responded to similar arguments in Hicks (2021).

about chances in statistical mechanics takes statistical mechanical chances to represent the *rational credence* one should have that the system is in a certain microstate, given all the information we have about its macrostate. Similarly, an epistemic view about quantum mechanical chances holds that the chances of quantum mechanics (encoded in the quantum wavefunction) represent the credences rational agents should aim for when using the theory to predict the outcomes of measurements. One popular version of this view is *Quantum Bayesianism*,[21] which holds that the quantum state represents the credences of agent, and that the apparent collapse when a measurement occurs is best understood as a form of conditionalization. Finally, the method of arbitrary functions takes objective chances to be subjective credences "objectified" by deterministic processes (Myrvold, 2010; Rosenthal, 2009, Rosenthal 2016, Gallow, 2021).

One popular line of argument against such views is that they leave the relevant physical facts unexplanatory. Here, for example, is Chris Timpson arguing against Quantum Bayesianism: "Ultimately we are just not interested in agents' expectation that matter structured like sodium would conduct; we are interested in why in fact it does so" (Timpson, 2008: 600). David Albert makes a similar complaint against epistemic views of the probabilities in statistical mechanics: "Can anybody seriously think that our merely being ignorant of the exact microconditions of thermodynamic systems plays some part in bringing it about, in making it the case, that (say) milk dissolves in coffee? How could that be?" (Albert, 2003: 64).

Albert's worry here is that if the probabilities of statistical mechanics represent the degrees of belief of an ideal agent who is ignorant of the precise state the coffee cup is in, but knows its temperature, volume, and other coarse-grained features, then these probabilities are completely unsuited to explain why milk mixes with the coffee when they are combined. Similarly, Timpson's complaint is that agent's credences are unsuited to explain why sodium conducts, but the quantum mechanical chances should explain this.

This argument against epistemic views about chances seems to go like this:

Premise 1: Chance facts explain why certain outcomes obtain or certain processes occur (e.g. why sodium conducts or milk dissolves in coffee).
Premise 2: Nobody's epistemic state (not even an ideal person's) explains why those outcomes obtain or processes occur[22].
Conclusion: Chance facts don't represent anybody's epistemic state, not even that of an ideal agent.

Most discussion of Quantum Bayesianism and epistemic accounts of statistical mechanical chances focus on Premise 2 of this argument. Premise 2 is *prima facie* plausible; rejecting Premise 2 seems to make apparently mind-independent occurrences depend on the mental states of real or imagined ideal agents. If QBism or epistemic theories of statistical mechanics are committed to rejecting Premise 2, they are in a pretty bad spot. But on the mediator view, the probabilities of quantum mechanics do not explain why matter structured like sodium conducts; the

[21] See for example Fuchs (2002) and Fuchs and Schack (2004).

[22] Plausibly, some features of our epistemic state can be relevant to whether outcomes obtain. For example, the fact that someone knows rather than merely believes that the explanans event occurred might be relevant, because (by the factivity of knowledge) this implies that the explanans event occurred. We take it that whenever someone's epistemic state is relevant to an explanation, it is because of these non-epistemic implications (except of course in the special case in which the outcome is itself epistemic or the effect of a rational decision-making process). Thanks to Katrina Elliot for discussion of this point.

probabilities of statistical mechanics do not explain why milk dissolves in coffee. Rather, these facts are explained by their respective setup facts: the fact that the milk dissolves in the coffee is explained by the fact that the milk was poured into the coffee, together with some other macroscopic facts (the temperature of the fluids, their volumes, etc). The fact that sodium conducts is explained by its microstructure. The chance facts, recall, explain the fact that the microstructure of sodium explains is conductivity, or the fact that the combining of milk with coffee explains the milk's dissolving. So we've argued that Premise 1 of this argument is false.

Can the argument be modified to accommodate the mediator view? Whether this is possible depends on the correct view of explanation. On pragmatic or epistemic views of explanation, to explain something is just to show that it was to be expected. On these views epistemic states, real and ideal, are very well suited to feature in higher-order explanations. An epistemic view of chance fits nicely with an epistemic view of explanation.

But – as we indicated in section 2.1 – we are sympathetic to more robust views of explanation, according to which explanations track real-world dependence relations. We take chancy explanation to be an *ontic* form of explanation (a la Salmon (1984)). While these real-world dependence relations may generate rational expectations or constrain our epistemic states, they are not those states. So, we think that the argument above can be modified as follows:

Premise 1*: Chance facts explain why outcome facts depend on their setup facts.
Premise 2*: Nobody's epistemic state (not even an ideal person's) explains why outcome facts depend on their setup facts.
Conclusion: Chance facts don't represent anybody's epistemic state, not even that of an ideal agent.

We think that this argument will convince philosophers who subscribe to ontic views of explanation. But philosophers tempted towards epistemic views of explanation would reject Premise 2*, because these philosophers doubt that explanations are backed by mind-independent dependence relations. If the relevant sort of dependence is epistemic, Premise 2* looks much more dubious. This gives the epistemic view of chances much more room to manoeuvre than it had previously; if we're right, the view is no longer committed to denying Premise 2 of the original argument, and holding that somebody's ignorance explains why milk dissolves in coffee.

4.4 | Why there is something rather than nothing

The final application of the mediator view which we shall discuss is the most speculative, and we want to emphasize that it doesn't form any part of our argument for the mediator view. Nonetheless, it illustrates the view's flexibility.

Perhaps the most notorious of all puzzles of causal explanation involves the idea of a first cause, itself uncaused. If there is a beginning to time, then two possibilities present themselves: either the first event is unexplained, or it is explained by something outside the temporal order. Either way, it is hard to make sense of the universe coming into being 'by chance', even though this is the scenario which is frequently contrasted with design scenarios in the fine-tuning argument and other arguments from design.

The mediator view offers the prospect that chance might play a role in explaining why an undesigned universe begins, not by acting as a direct explainer of the first event, but by mediating a *null explanation* of the first event. The idea of null explanation has been discussed in the recent literature on grounding (cf. Litland 2017, Schaffer 2021), originating with Fine's (2012) notion of *zero-grounding*. In a null explanation, we have an explanandum with no explanans – the explandum is explained, but by nothing in particular.

Null explanation is weird. But if it is possible, there seems no reason why it should not be possible for chancy explanation too. In a chancy null explanation, the null explanation is mediated by objective chances: to take a toy example, there might have been a 0.5 chance of the universe coming into existence with more matter than anti-matter, and 0.5 chance of the opposite, even without any prior chance setup.[23] Chances are not around before the universe exists to act as direct explainers of any universe commencement event. But there doesn't seem to be any reason why they can't mediate the transition from nothing to something nonetheless. The chances explain how nothing gives rise to something.

How might the chances mediating a null explanation be grounded? Certain accounts of chance, for example those which ground them in a real quantum state, will not fit naturally with a null explanation. By contrast, Humean accounts appear to have no special problem accounting for null mediation. There is much more that could be said on this topic; but our aim here has only been to raise the prospect of null chancy explanation, not to vindicate it.

5 | CONCLUSION

Chance is implicated in and indispensable for most of our best scientific explanations. We have argued for a particular view of the role of chance in scientific explanation, the mediator view, according to which chance acts as an explanatory link between the worldly facts which feature in first-order scientific explanations. The mediator view is a plausible and metaphysically conservative account of the explanatory role of chance hypotheses, and it has interesting consequences for some active debates in contemporary metaphysics.

The mediator view combines the best features of the two main alternative views. Like the no explanation view, it does not require us to make chances into physical properties with causal power, and hence makes room for higher-level chance explanations. Like the chances explain view, it gives chance a robust explanatory role which makes sense of its ubiquity in science. Chances don't explain events in the world, but they explain how events in the world can be explained.[24]

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[23] Demarest (2016) defends the idea of initial chance events with no chance setup in a more physically realistic context: the foundations of Boltzmannian statistical mechanics.

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