Probability, Modality and Triviality[*]

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Abstract Many philosophers accept the following three theses: (1) that probability is a modal concept; (2) that, if determinism is true, there would still be objective modal facts; and (3) that if determinism is true, there are no genuine objective probabilities (chances). I argue that these 3 claims are inconsistent, and that their widespread acceptance is thus quite troubling. I suggest, as others have, that we should reject the last thesis: objective probability is perfectly compatible with determinism. Nevertheless we must still explain why this thesis seems attractive; I suggest that a subtle equivocation is to blame.

THE BROADEST TAXONOMIC DIVISION amongst analyses of probability is the distinction between subjective and objective analyses. Objective analyses are a diverse bunch; their unifying thread is that all such analyses maintain that there are true probabilistic claims that do not reduce to any truths concerning credences. The probabilities involved in such claims are called objective probabilities, or *chances*.

Recently, philosophers of probability have done much to clarify the relations between, on one hand, objective probability and determinism, and on the other, probability and modality. Unfortunately, not enough attention has been paid to the collective interaction of all three concepts. This has lead to an unfortunate situation in which three apparently inconsistent theses have come to be accepted as received wisdom. One of my main purposes here is not just to

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dissolve this inconsistency, but also to highlight these three assumptions, often left tacit. It seems to me that unravelling the intricacies and details they reveal on closer inspection is helpful when we come to examine any of the three topics, and the emphasis I give here on solving the puzzle shouldn't hide the far wider significance I take these three theses to have.

In the next three sections (1–3) I propose to describe these three theses, and to examine the justifications that have been provided for each of them in the literature. In so doing, I also hope to demonstrate that each of these claims is *widely* held, and that the importance of disentangling them is correspondingly more pressing. Thesis 1 is, I think, the least well known of the three, so I propose to spend the most time clarifying precisely what it says. In section 4, I demonstrate the inconsistency that fairly immediately arises from them. From this it is clear that at least one of the theses must be given up; and when one combines the intrinsic plausibility of Theses 1 and 2 with the fact that other philosophers have already advocated abandoning Thesis 3, it is appealing to deny that thesis. In 5 I discuss these other proposals to abandon this thesis, yet find them wanting. I go on in 6 to discuss my own proposal, and make the task of abandoning that thesis easier by explaining away the justification that has been provided for it.

1 Thesis 1: Objective Probability as a Modality

Thesis 1 (Probability): *Objective probability is a modal concept, and chances supervene not just upon actual facts, but upon facts about other possibilities.*

Support for this thesis goes back to the very beginnings of probability theory, with the *classical* theory of probability. In its simplest form, this theory runs something like this:

DEFINITION 1 (CLASSICAL THEORY OF PROBABILITY). The *probability* $\Pr(\varphi)$ of a proposition φ is the *proportion* of φ-favourable cases n_φ in a set of n *equipossible* outcomes $\left(\frac{n_\varphi}{n}\right)$.

According to the classical theory, then, the probability of some outcome is tied directly to some kind of quantified possibility: the more possible some out-

come is, the more probable. Leibniz glosses 'greater possibility' as something like *easier* or more feasible. Probability is then the degree of possibility, that is, the ease with which an event can be brought about. In the case of epistemic possibilities, it is how feasible we regard bringing the possibility about to be; in the case of objective possibilities, it is linked to how objectively easy a possibility is to bring into existence, which is roughly measured by our observations of the frequencies for various possibilities (the more frequent, the easier the possibility). This leads to Leibniz' famous claim that 'probabilitas est gradus possibilitas' (Hacking, 1971, esp. 345–6).[1]

This emphasis on 'gradations' of possibility is also reflected in justifications that are sometimes given for basic Kolmogorov axioms of probability. For example, the axiom $\Pr(\top) = 1$ is sometimes justified by citing the fact that $\top$ is a *necessary* truth (and correspondingly, $\Pr(\bot) = 0$ because $\bot$ is impossible). These uses of 'necessary' and 'impossible' are controversial; a better suggestion is Mellor's necessity principle (1995, 31–2):

(Necessity) $\qquad\qquad \Pr(\varphi) = 1 \Rightarrow \varphi.$[2]

Mellor motivates this principle by considering probabilistic causation: for him, a sufficient cause 'necessitates' its effect, where that does not involve metaphysical necessity, but rather means that, conditional on the cause, the chance of the effect is 1. Mellor goes on to say (1995, 44–5) that the necessity principle is constitutive of objective probability. But we should note that the necessity principle captures the idea that high probability events are bound to happen in some sense. (The necessity principle also entails that $\ulcorner \varphi \Rightarrow \Pr(\varphi) > 0 \urcorner$; roughly, that if φ actually occurs it must have a non-zero chance of occurring.) The natural consequence of such justifications is that we should regard propositions of intermediate probability as somehow also falling between necessity and im-

[1] Though it is of no consequence for our thesis, it is interesting to note that it is not clear whether Leibniz, or other defenders of the classical theory, allowed for the situation where atomic possibilities had unequal possibility, or whether any variability in ease or feasibility between two propositions must derive from an imbalance in the number of equipossible subcases that realise those propositions.

[2] '$\Rightarrow$' stands for 'entails'.

possibility, and the probability attaching to them measures how close to necessary those propositions are.

Again, intuitively, not every event that actually happens can be considered equally expected: some actual truths are more *surprising*, or unexpected, than others. The natural definition of this notion is:

DEFINITION 2 (SURPRISE). The *surprisingness* $s(\varphi)$ of a proposition φ is defined:

$$s(\varphi) =_{\text{df}} \frac{1}{\Pr(\varphi)}.$$

It is already clear that whether an event is surprising is not a function of its truth value alone, as two actual events can differ in surprisingness. It is therefore clear that the probability ascription in the definition of surprisingness cannot be an extensional truth-function, but must be intensional: a modality.

Having surveyed this piecemeal anecdotal support, we are now in position to give a more systematic defense of Thesis 1. We will devote most of our energies towards demonstrating the modal nature of objective probability ascriptions. This is not only because these probabilities are the most important for our purposes, but also because it is far easier to demonstrate that epistemic probability is a modality, largely because non-probabilistic credential states like belief and knowledge are pretty clearly modalities.

The first bit of more rigorous support for this thesis comes from considering the nature of the items to which probabilities attach. They cannot be actual events, or true propositions, as there are false propositions, and non-occurrent events, which receive non-zero probabilities. Insofar as probabilities are assigned to events or propositions, they must be assigned to all possible events, and all propositions, without regard to actuality or actual truth.[3] Therefore there must be true probability statements '$\Pr(\varphi) = p$' where φ is actually false (speaking tenselessly). There is already a suggestive analogy with modal operators, which we can make more apparent as follows. Let us introduce as

[3]Of course, 'all' possible events and propositions must be understood in most uses of probability as involving some contextual restriction on the space of possible outcomes, as not every scientifically or otherwise useful probability function is defined over every outcome. That does not remove the requirement that at least some of the incompatible outcomes must of necessity be non-actual.

many $\Diamond_p$ operators as there are distinguishable probability values in a finitely additive probability function Pr, and let $\Diamond_p(\varphi)$ be true just in case $\Pr(\varphi) = p$. This introduction of possibility operators to correspond to probability values is ultimately suggested by the strong analogy between the following two entailments

(1a) $\varphi \Rightarrow \Diamond\varphi$ (actuality entails possibility),

(1b) $\varphi \Rightarrow \Pr(\varphi) > 0$ (a consequence of (Necessity)).

Then, for every actually false proposition ψ in the domain of the function Pr, $\Diamond\psi$ is true iff there exists some $\Diamond_p$ such that $\Diamond_p\psi$ is true.

This elementary construction makes it intuitively quite plausible that probability is a modality: as van Fraassen says (echoing Leibniz), 'it is a kind of graded possibility' (1980, 198). Mellor gives this example of the general thesis:

> Chances measure a contingent and quantitative kind of possibility... No radium atom must decay, or must not decay, in any given time; it is merely possible for it to decay, a possibility that is both contingent and comes by degrees. The possibility is contingent on the structure and state of the atom's nucleus, and its degree is measured by the chance of decay. (1995, 21)

1.1 THE BASIC CHANCE PRINCIPLE AND ITS CONVERSE

But how are we to understand the sense in which probability is quantitative possibility? A natural proposal is to regard possibility claims as metaphysically equivalent to the claim that the objective probability is non-zero. We shall now explore the prospects for this natural proposal.

We begin with an appeal to the modal consequences of probability claims, together with the generally plausible claim that merely actual facts cannot suffice to establish such consequences, which yields immediately that probability facts must be modal. The first, and most obvious, connection between probability claims and modal claims is the *Basic Chance Principle* (Bigelow *et al.*,

1993):

(BCP) $$\Pr(\varphi) > 0 \Rightarrow \Diamond\varphi.$$

This doesn't automatically show that '$\Pr(\varphi) > 0$' is a modal fact; consider that $\ulcorner \varphi \Rightarrow \Diamond\varphi \urcorner$ is a feature of any reasonable logic of metaphysical modality.[4] But once we note that the probability claim is not equivalent to φ (or any truth-function of φ), it is apparent that the probability claim is modal.

Of course this argument only works if we can defend the BCP as really being a basic principle describing any objective probability. This seems plausible. There are good reasons to think that not all probability zero events are impossible, reasons imposed by the mathematical structure of continuous outcome spaces. Given this, it would be extraordinarily odd if some event of non-zero probability turned out to be impossible.

In general, what we need is that φ can have a positive chance of occurring because in at least one possible world relevantly like our own in terms of history and especially laws, φ occurs. The relevant sense of similarity here must presumably be sharing of past histories, and this fairly immediately yields the following proposal:

> In general, if the chance of A is positive there must be a possible future in which A is true. (Bigelow *et al.*, 1993, 459)

With this proposal in place, it is clear that the BCP follows, just from the nature of objective probabilities. Indeed, our version of the BCP follows from the slightly weaker assumption that if the chance of A is positive, A must be possible. It may be, of course, that our weaker assumption attains its plausibility from the truth of the stronger assumption that Bigelow *et al.* make, but we should note that no matter which proposal one adopts, the truth of an objective probability claim must involve the possibility of the proposition in question.

But the BCP captures only one side of the story. We might think that the converse of the BCP is arguably just as important for capturing the relation be-

[4] Technically, any system containing **T**.

tween probability and modality:

(Converse BCP) $\qquad\qquad \Diamond\varphi \Rightarrow \Pr(\varphi) > 0$

Though this principle might look appealing at first glance, it cannot be right as it stands. For, on the standard mathematics of continuous probability spaces, the only way to assign uniform probabilities to each outcome is to give them all probability 0; but then the Converse BCP would wrongly indicate that each such outcome was impossible. We need, therefore, to propose some restrictions on the BCP, or to modify the standard conception of probability.

It would not be unmotivated or unprincipled to do the latter: many philosophers have regarded the idea that probability 0 doesn't mean impossible (and conversely, that probability 1 doesn't mean certain) as conceptually incoherent. There are a number of reasons for their dissatisfaction, of which I will mention two. First, many philosophers, and almost all mathematicians, adopt the standard 'ratio' definition of conditional probabilities in terms of a ratio of unconditional probabilities: that is, the conditional probability of φ *given* ψ, is defined as

$$\Pr(\varphi|\psi) =_{\text{df}} \frac{\Pr(\varphi \wedge \psi)}{\Pr(\psi)}. \tag{2}$$

Given this, and our insistence that some events are possible and yet have probability 0, we would have any number of absurd conclusions: for instance, that ψ is possible, and that ψ entails φ, yet because $\Pr(\psi) = 0$, $\Pr(\varphi|\psi)$ is undefined, when quite clearly the conditional probability of φ given a proposition that entails it should be 1. A second reason for dissatisfaction comes from epistemology, where probability functions are used to model credences. If a credence function is *regular*, then it assigns probability 0 only to contradictions, and probability 1 only to tautologies. If a credence function is irregular to begin with, and for some φ allows that $\Pr(\varphi) = 0$, then despite any evidence that may be received favouring φ, $\Pr(\varphi)$ must always equal 0 (if the agent updated their beliefs by conditionalising). The most common way of modifying probability functions in the light of these problems is to introduce *infinitesimal* probabil-

ities: probability values less than any standard real but still greater than zero (Bernstein and Wattenberg, 1969). It is felt that these might preserve regularity, and allow for well-defined ratios of infinitesimals, even for continuous outcome spaces.

Whatever the intrinsic merits of this proposal to modify standard probability, it doesn't seem to do particularly well on solving the conditional probability problem (Hájek, 2003), and the complications it introduces makes it implausible in an account of credences. So we may well opt for the first option, to propose some restrictions on the propositions φ for which the Converse BCP holds. Perhaps the most plausible is simply to restrict the Converse BCP to finitely additive probability functions, just as we did when defining the various $\Diamond_p$ operators on page 5. This strikes me as a little too heavy handed; for some non-uniform continuous probability functions would intuitively still satisfy the converse BCP; moreover, if we are ever to give a reductive *analysis* of probability in terms of possibility, we should want a probability function defined over all propositions, which would surely be a continuous outcome space.

Perhaps better is to restrict the possible worlds under consideration to those relevantly similar to our own, that is, having similar laws and history to our world. Then the Converse BCP would say, if φ is possible in one of the relevantly similar worlds, then $\Pr(\varphi) > 0$ actually. Even in the absence of any complete account of these restrictions, we can adopt the working assumption that some such set of restrictions would be adequate; and that for at least some set of propositions Φ, the BCP and the Converse BCP hold for every $\varphi \in \Phi$, at all relevantly similar possible worlds.

Perhaps the best way to understand this is through the idea of a *relative modality* (Lewis, 1973, 5–8). Just as there is 'physical possibility' and 'nomological possibility', so there is a kind of 'probabilistic possibility'. There will be a certain set of worlds $\mathcal{W}_{\Pr}$, picked out by some suitable set of restrictions, such that there is some modality $\Box_{\Pr}$ such that '$\Box_{\Pr}\varphi$' holds iff $\Pr(\varphi) = 1$. In this set of worlds, this will turn out equivalent to the condition $\forall w \in \mathcal{W}_{\Pr}(w \vDash \varphi)$. (To pick some suggestive terminology, we might say that $\Pr(\varphi) = 1$ expresses the *in-*

evitability of φ's coming to pass.[5]) We can then go on to define $\Diamond_{\mathrm{Pr}}$ in the usual way as $\neg\Box_{\mathrm{Pr}}\neg$, and then, neatly, it follows that $\Diamond_{\mathrm{Pr}}\varphi$ iff $\mathrm{Pr}(\varphi) > 0$.[6]

What kind of restrictions will give us this particular relative modality? We've already said that the worlds in $\mathcal{W}_{\mathrm{Pr}}$ should be sufficiently similar, in laws and matters of particular fact, to actuality. I suggest that we should adopt the following as our interim proposal: $\Diamond_{\mathrm{Pr}}\varphi$ if φ is possible relative to holding fixed facts about the properties of a particular chance setup that make it possible to produce a φ outcome, plus the laws which dictate how that setup produces its outcomes. For example, a coin tossing device that has been trialled in the past, and has landed both heads and tails over time, clearly has a possibility of tossing coins so that they might land heads, and might land tails; hold fixed whatever properties serve to make a coin tossing device of *this* kind, as well as whatever laws let this tossing device operate so as to toss coins. This proposal, rough as it is, nevertheless has some nice features. It shows that objective probabilities, like all other serious possibilities, depend on the actual properties of the kinds of setups that produce the outcomes. It also shows that 'inevitability' is a defensible choice of terminology, for the outcome φ is inevitable iff, given the laws and the properties of the setup that can produce φ, φ is bound to happen with probability 1. Finally, this proposal allows for probabilistic possibilities to mesh nicely with all of our ordinary counterfactual judgements about statistical situations. Consider a situation in which a coin is tossed and landed heads, and then is set aside. The counterfactual, 'if I had tossed the coin again, it might have landed tails', is intuitively true. This is true because ordinary coin tossing devices, tossing fair coins, when they behave normally, are compossible with both kinds of outcome. But these two requirements, that the coin and tossing device be normal and behave ordinarily, delimit a relevant possibility space: exactly the space of probabilistically accessible worlds, holding fixed the properties of the kind of coin and tossing device, and the laws. Given the truth of this counterfactual in these worlds, it is clear that, for this coin and toss-

[5]See Mellor (1991, 159)—though I should wish to treat the propensity-style account that Mellor there gives with great caution.

[6]Bigelow *et al.* (1993, 458) argue that, if we define modalities in this way, the resulting logic ('the modal logic of chance') is **S5**.

ing system, Pr(Tails) > 0, as it should be. Other proposed sets of worlds may not yield this result: narrower sets, holding more fixed (e.g. holding the entire prior state of the coin tossing system fixed) may make it impossible that this coin tossing device could have tossed tails; and wider sets of worlds, for example, nomologically possible sets of worlds, may fail to tie probabilities closely enough to the chance setups that support those probability claims.[7]

However, defending any particular proposal isn't my main concern here; I do hope to have shown that it is extremely plausible that probabilistic claims correspond to *some* relative modality or other, corresponding to some natural condition on the facts to be held fixed when considering the truth of probability claims.

Given some plausible set of restrictions, the Converse BCP has tremendous intrinsic plausibility. It seems intuitively right that if something is a serious possibility, in relevant lawlike worlds, then it should have some, perhaps small but nevertheless non-zero, probability of coming to pass. If it is possible for a coin to land heads when tossed, then it should have some objective probability of doing so. It may be much easier to come to know that something is possible, than it might be to find out exactly how probable it is, but that seems perfectly compatible with the suggestion that there is some probability or other. Perhaps the probability lies in some interval, because the relevant constraints on the situations in which the event would be possible do not suffice to delimit the probability values completely—that is also compatible with the principle. The only situation which would not be compatible with the restricted converse BCP is perhaps one where an event is possible but has no well defined probability value at all. However, any such event will be a very unusual type of event, and presumably will fall foul of any plausible set of restrictions on worlds relevant to the converse BCP.

If we go on to consider some of the other roles that probability plays in our conceptual economy, we can canvass yet more support for the BCP, and for the

[7]Of course, for *some* counterfactuals involving probabilistic outcomes, we do want to hold the actual facts fixed: consider if the coin came up heads, and you had bet on tails, I could truly say 'Had you bet on heads, you would have won'. This only reinforces my point: what is to be held fixed is no absolute matter, but depends on context.

restricted version of its converse that is our more central concern.

PROBABILITY AND EXPECTATION Bishop Butler's aphorism 'probability is the very guide of life' is perhaps the most obscenely overused quotation in the philosophy of probability, but with good reason do I perpetuate the abuse here. Probability must connect with expectations about what may or may not come to pass, as Butler clearly and concisely expressed. In doing so, probability must connect with the objective possibilities about which we have expectations—indeed, decisions (and action explanations) that involve probabilistic considerations are continuous with, even whilst more sophisticated than, decisions (and action explanations) that refer simply to the possible outcomes that the agent has or had open to them. Since the non-probabilistic theories of decision and action are clearly modally loaded, the probabilistic elaborations of those theories are modally involved also. Probability enters basically to yield a means of ranking or quantifying the possible outcomes consequent upon our actions in order for us to decide what to do; it doesn't alter the fact that what is assigned a probability are possibilities, and this in turn means that the existence of a correct probability assignment to an outcome means that outcome is possible: as the BCP says. Moreover, if probability is a kind of graded possibility, we should think that acknowledgement of the genuine possibility that a certain outcome might result from our actions will give rise to a demand to quantify the likelihood of that outcome; in normal cases, that will be non-trivial. Given that restriction to normal cases, we have the Converse BCP.

PROBABILITY AND FREQUENCY We might observe that if the chance of φ is positive and equal to p, then we should expect φ to occur with a certain relative frequency, approximately equal to p. But if the actual frequency of φ deviates from p, generally speaking we should not wish to revise our judgement of the probability of φ (especially if the trials of φ are relatively few in number). In this case, the probability claim entails that, possibly, the frequency of φ might have been precisely p, even though it was not actually. Let us assume that $p < \Pr(\varphi)$: it must then be the case that for some $\neg\varphi$-satisfying event, possibly that event might have turned out to satisfy φ (since there is a possible

world where that is so, namely the one in which the frequency exactly equals the probability). Again, if there is some possible world in which φ holds, and that world is relevantly like our own in terms of history and laws, then that is a world in which the frequency of φ-satisfaction is non-trivial and that should reflect itself in a non-trivial probability for φ actually. Similarly, in any ordinary world in which φ is possible, φ has some non-trivial relative frequency. There are worlds in which φ might occur and yet have a relative frequency of zero: worlds where φ-satisfaction occurs only finitely many times and yet there are infinitely many trials. But such worlds are, quite rightly, regarded as abnormal: we are invited to consider how, for instance, a coin would behave when tossed infinitely many times, and yet does not wear away or wear unevenly, when infinite tasks can be actually completed, and so on. Such worlds seem very far from actuality, so far that they would be eliminated from any serious consideration of the possibilities in question.[8] Having eliminated them, non-trivial possibility gives rise to non-trivial frequency, which in turn should in all ordinary circumstances be strong evidence for non-zero probability. This kind of example illustrates not only that probabilities attaching to single events or propositions have modal consequences concerning that single entity, but also consequences about related matters like frequencies of events, expectations concerning those frequencies—and modal facts concerning possible frequencies have consequences for probabilities in our world. Non-trivial probabilities both entail, and are entailed by, claims of possibility, at least in relevantly similar worlds.

What about the second part of the thesis, the supervenience claim? Spelled out informally, the supervenience claim is that there can be no difference in objective probability value for some proposition without the distribution of facts over some collection of actual and possible worlds being in some way different; but that there can be difference in probability value for some proposition while the actual world remains as it is. A little more carefully, this amounts to the claim that fixing the totality of non-modal facts about the actual world does not suffice to fix the facts about probability—and it is quite clear that this is

[8]Consideration of such bizarre and distant possibilities is yet one more reason why infinite hypothetical frequentism is an implausible analysis of probability: see 5.1.

true. It is obvious that the mere fact of φ's actual occurrence or actual non-occurrence won't fix the probability values, but no more obscure actual facts will do so either. For example, fixing the actual frequencies won't fix on the precise probability value; and indeed that value might be arbitrarily far from the observed frequencies (consider the situation in which a fair coin is tossed only once, or the stranger situation in which a single point is chosen at random from the real line). These illustrations depend on our discussion of the first part of the thesis, above; the supervenience claim is revealed to follow naturally from the claim about modality. It may be, however, that the restrictions we placed on the converse BCP do confine the supervenience base for probability ascriptions to relatively nearby worlds; for a modality of some physical and nomic significance, as probability is supposed to be, this seems a natural and desirable restriction.

2 Thesis 2: The Compatibility of Objective Modality and Determinism

Thesis 2 (Modality): *If determinism were true, then there would still be objective non-trivial modal facts. The fact that there would be precisely one future evolution of the actual world would not render all modal claims degenerately true or false.*

The defense of this thesis starts from the simple observation that there are many ways the world is that it also must be: it must be, for example, that everything is self-identical. Similarly, there are many ways the world might have been, other than the way that it is. It might have been the case that I had a sister; it might have been the case that kangaroos have no tails. Indeed, for every way the world is, but needn't have been, there is some truth of mere possibility:

> For each contingent truth, a shadow truth accompanies it: the possibility (metaphysical possibility) of its contradictory. (Armstrong, 2004, 84)

So 'possibly $\neg\varphi$' is true, made true by whatever makes φ contingent in the first place. Hence the existence of contingency plausibly entails the existence of genuine objective possibilities.

The standard way to understand these foregoing modal claims is to appeal to *possible worlds semantics* (Hughes and Cresswell, 1996, Kripke, 1963). On

this picture, 'it might have been the case that kangaroos have no tails' is true iff there is at least one (accessible) possible world w in which kangaroos have no tails. Similarly, a necessary truth (what must be) is true in all possible worlds. Modal idioms, therefore, are to be understood as implicitly quantifying over possible worlds.

If this semantic picture is right, and there is broad philosophical consensus that it is, then the truth of a modal claim depends on the situation at other possible worlds, not just the actual world. Indeed, we can go further: for many propositions φ, the fact that 'possibly φ' is actually true is *independent* of the way the actual world happens to be, in the following sense: 'possibly φ' is actually true whether or not φ is actually true. If this is so, then *a fortiori* 'possibly φ' will be true in many cases whether or not φ will *come to be* actually true.

We can picture the situation as follows. The actual world, @ is characterised at each moment t of its history by a certain proposition, $H_{@,t}$, that captures the complete state of the world at that time. The set $H_@$ of all such *historical propositions*, plus the laws of nature $\mathscr{L}_@$, plausibly characterise all the non-modal facts about @. Indeed, for every possible world w, there is a history H_w and a set of laws $\mathscr{L}_w$ which completely characterise the non-modal facts of that worlds. The modal facts at a world are characterised by appealing to the non-modal facts of other (accessible) worlds: 'possibly φ' is true at w iff for some w', φ is true at w', which for particular and local propositions means that for some t, '$H_{w',t} \rightarrow \varphi$' is true. We are now in a position to define determinism.

DEFINITION 3 (DETERMINISM). Some laws of nature $\mathscr{L}$ are *deterministic* just in case for any world w at which those laws obtain, for any time t, $H_{w,t}$ is compatible with exactly one total history H_w.[9] In other words, if $H_{w,t} = H_{w',t}$ then $w = w'$ (Earman, 1986, 13).

Given this terminology, it is now possible to examine the interactions of determinism and modality, in a way that clearly supports Thesis 2. Firstly, the consequences of determinism can only constrain matters of fact at worlds at which the deterministic laws obtain. But almost all philosophers agree that the laws

[9]Here and in what follows we will ignore the possibility that two worlds might differ only by a time translation of states, that is, that for all t there is some n such that $H_{w,t} = H_{w',t+n}$.

of nature are themselves contingent (Sidelle, 2002). So there are clearly possible worlds where the laws of nature are different, and hence arbitrary consistent states might follow consequently upon a history that matches the actual history precisely—and determinism places no constraint at all on these possibilities. It is a plausible thought, however, that possibilities at these law-violating worlds are of little interest—and if that is the best defense that can be given of Thesis 2, then the Thesis looks quite shaky.

I think that judgement would be too hasty, because it relies on a conception of laws that is quite strong and not universally shared. For instance, most kinds of *empiricism* about laws of nature take it that the laws supervene on the local and particular matters of fact, and depend on those matters of fact. Then it might well be that two very similar worlds have different laws, but that this distinction is of little import when considering alternative possibilities. Consider, for example, Lewis' *best-system* analysis of laws (1973, 72–77). In such a theory, laws are the axioms of that systematisation of matters of particular fact that best balances simplicity of formulation and strength or informativeness. On this picture, as Lewis plausibly argues, violations of the laws of nature can be outweighed by vast match of particular matters of fact when considering which are the serious alternative possibilities.[10] In these cases, shared history might count for far more than shared laws in judgements of similarity between possible worlds, and so for judgements of whether some proposition is possible or not.

We can largely set aside these controversial matters, for if Thesis 2 can be shown to work even with robust laws of nature, it can be as easily done with weaker empiricist substitutes. So now consider just those worlds where determinism is true, and where we are interested in alternative possibilities in worlds that share our laws. If determinism is actually true, then there is no distinct world that could be in the same state s as the actual world and which shares the same laws of nature. There are, however, distinct worlds that share the same laws of nature and are in some distinct state s'. If this is so, and if σ' is the proposition true just if s' holds, then 'possibly σ'' is actually true, while σ' is

[10]Indeed the law may survive as a law, if the violation is infrequent or minor enough.

actually false.

Another way of seeing this is as follows. Let $\mathscr{W}_{\mathscr{L}}$ be the set of worlds at which some deterministic laws of nature $\mathscr{L}$ hold, and let $w \in \mathscr{W}_{\mathscr{L}}$. If $H_{w,t}$ describes the state at w at t, then by determinism, there is just one future evolution of states in w. But this fact about the future trajectory of w through the space of states has no bearing whatsoever on the trajectory of any other world w' through the state space. In particular, that the current state of w uniquely determines w's future history places no constraints on states in w'. Even supposing that determinism places constraints on our actual future, there are no such constraints imposed on alternative possibilities, even those which share the same laws.[11]

Now it might be thought that this kind of defense of Thesis 2 is irrelevant, because there is a sense of possibility which is trivialised by determinism. Call φ *futuristically possible* iff there is a possible world w which which shares a history with the actual world up until a certain point t, such that for some $t' > t$, $H_{w',t'}$ entails φ. If determinism is true, there is only one world which shares a history with the actual world, and hence φ is futuristically possible in a deterministic world iff φ is actual, which does trivialise the concept of futuristic possibility. However this is not all that can be said.

There is the quick response that since the laws are plausibly contingent, futuristic possibility does not exhaust genuine possibility. Yet we might regard law-violating worlds as quite bizarre, not worthy of serious consideration for the standard uses to which alternative possibilities are put. We might then prefer this response: that futuristic possibility is not the right kind of possibility to be worthy of serious consideration either. Standardly, when we consider alternative possibilities, we are considering situations that are compatible with certain actual facts that we should like to hold fixed. When we are considering future possibilities, no less than any other kind of possibility, these contextual matters of holding certain facts fixed apply:

> To say that something can happen means that its happening is compossible with certain facts. *Which* facts? That is determined, but sometimes not determined well enough, by context. (Lewis, 1976, 77)

[11] This is in some ways reminiscent of the 'horizontal-vertical' problem in van Fraassen (1989, 84–5).

Futuristic possibility attempts to remove this contextual determining of relevant fixed facts, to replace it by a set of perfectly detailed facts about the past. In the case we've been considering, it is futuristically impossible that φ, if φ doesn't actually occur, given the entirety of the past. But so what? It is only impossible simpliciter relative to a set of facts that we will never consider, because it will never be contextually salient to do so: the set of facts specifying perfectly and precisely the past history of the actual world. Relative to another set of facts, say the facts concerning the observed or macroscopic history of the actual world, or just the facts we have some kind of ordinary epistemic access to, φ might well be possible. Moreover, it is not as though when appealing to contextually fixed facts we are somehow appealing only to epistemic possibilities or some other less 'real' kind of possibility: relative to those facts, the possibilities are perfectly objective, because they hold in some world which shares those fixed facts with our own. In most cases the facts we consider relevant to the assessment of the possibility, which are of course the ones we hold fixed, are the ordinary macroscopic constraints. Rarely will any microscopic proposition be relevant, not only because of problems of epistemic access, but also because that level of detail and precision is inappropriate when judging the truth of any ordinary possibility ascription. The problem for futuristic possibility is that the standards it requires to trivialise possibility are ones that no ordinary context will ever meet; and hence it cannot be a good account of ordinary possibility, and cannot trivialise ordinary possibility with its ordinary standards of relevance and compossibility. Of course holding the entire past fixed in a deterministic world trivialises possibility. But that just shows that futuristic possibility cannot be the sense of objective possibility which we are trying to explicate. And these standards are not ad hoc attempts to eliminate futuristic possibility, since they hold whether we are determinists or not. Lewis explains them as follows:

> If you make *any* counterfactual supposition and hold all else fixed you get a contradiction. The thing to do is rather to make the counterfactual supposition and hold all else as closed to fixed as you consistently can. (Lewis, 1976, 79)

In many deterministic cases (say in classical statistical mechanics) we can hold

all macroscopic events precisely fixed, varying only the microscopic level; then we have worlds that precisely resemble our own in all respects relevant to our judgements of possibility. If this doesn't suffice for objective possibility, what could?[12]

The denial of our thesis amounts to what might be termed *necessitarianism*: the view that if determinism is actually true, then if φ is actually true, φ is necessarily true.[13] It is the view that

> nobody could ever do anything different, except what he actually does, and, in general, that only the actual is possible. (Ayers, 1968, 6)

It is difficult to find anyone who would explicitly defend this necessitarianist thesis. But it is suggested by considerations that have swayed philosophers concerned with free will and determinism, the basic idea being that if determinism is true, every action performed by an agent was fixed by circumstances outside of the agent's control, and hence the agent has no capacity or power to do otherwise than he did. This basic idea is easy enough to dismiss, once stated so baldly—it is clear that the *powers* of an agent do not depend on the external considerations, but only in internal capacities of the agent. Those internal

[12]A final illustration: consider an indeterministic situation, where past history might evolve into either world w or world w'. But it is not the case that, somehow, which world we inhabit is indeterminate between w and w'—how could it be? Some might at this stage attempt to regard w as somehow 'incomplete' and being continually extended as more facts about w become fixed; this cure is worse than the disease. Whatever the 'openness' of the future amounts to, it cannot be that somehow the world is incomplete and is being continually formed as time passes. Easier to say the following: we inhabit the actual world, the only really existing world on most views, and it is in no way indeterminate which world this *is*. It may not be clear what all the facts about actuality are, and how this world is described; in an indeterministic situation all those facts *cannot* be known. But perfectly ordinary claims about the compatibility of the actual initial history with the initial histories of other possible worlds should not be mistaken for some strange ontological claim about the non-existence of the future segment of actual history, which clearly must exist. Determinism and indeterminism are claims about the relation between past and future sequence of history; the former, but not the latter, claims that the future supervenes on the past and the laws. This supervenience claim has nothing to do with whether or not actuality exists in some straightforward manner. And if it has no such significance, why should the truth of the supervenience claim impact on our preexisting judgement that there are significant and non-trivial objective possibilities, alternatives to actuality?

[13]The term may be reserved for the stronger thesis that if φ is actually true, then φ is necessary—but since this kind of necessitarianism is incompatible with indeterminism, it seems best to use the conditional formulation I gave in the main text.

capacities supervene on actual properties the agent possesses, and provide a ground for the ascription of causal powers that is completely independent of whether or not the external situation allows for the expression of those powers.[14] In judging those powers and capacities, we rely precisely on the usual and ordinary unviolated laws of nature, since those provide the only handle we have on how the actual properties of agents might manifest themselves in various counterfactual situations.

As might now be apparent, I wish to extend this same general line to possibility more generally, not just the possibility of various actions by agents. The argument is precisely the same: when judging possibility, we don't need, and cannot without contradiction, hold fixed the entire state of the world, but only the relevant (intrinsic) properties of the object that participates in the possible event in question. Since those properties are real, so too are the capacities consequent upon them, given the laws of nature. So, again, there are real possibilities, even given determinism—objective possibilities for objects to behave in certain ways, and hence objective possibilities for propositions to be true.

It might be thought that this sense of possibility is too weak, since it seems to depend on ignoring certain externally relevant factors. Similarly, the idea that some actual facts must be varied to get real possibilities, and not trivial 'futuristic possibilities', also seems to yield only a weakened concept of possibility. Those who would make this objection, however, seem to have an incorrect view of the nature of possibility. If we are actualists in the sense that we think everything that exists is actual (Loux, 1979, 48–64), and it is relatively uncontroversial that we should be (with one stupendous exception), we cannot but think that truths of *mere* possibility are in some way derivative from various actual truths. Whether those dependencies come from recombination , or the consideration of possible situations that make truth some but not all actual facts, it is clear that the actual has priority. To wish for a more robust sense of possibility, perhaps one that may have some kind of actual 'force' to do things in the actual world, is to implausibly reify possibility, in a way that even Lewis would have baulked at.

[14] Much the same line is urged by Lewis (1976, 77-80) and Ayers (1968, 89–95).

Of course all this terminology and technicality might serve only to *obscure* the main point, which is this. It is a (Moorean, I'd suggest) fact that things might have been otherwise and objects might have behaved differently, however this gets spelled out in the metaphysics of modality. This fact is true regardless of whether our world is deterministic or not, as we have seen. This last claim is all that Thesis 2 really amounts to, and that claim should be fairly uncontroversial on almost any reasonable view of the nature of possibility.

3 Thesis 3: The Incompatibility of Objective Probability and Determinism

Thesis 3 (Triviality): *If determinism were true, then there would be no genuine objective probabilities. All chances would be degenerate, either zero or one.*

This thesis probably has the status of orthodoxy: so much so that even if it is explicitly stated, the arguments for it are most often not. For example, here are Lewis' forceful remarks on the thesis:

> To the question how chance can be reconciled with determinism,... my answer is: *it can't be done.* (Lewis, 1980, 118)

Or later on:

> There is no chance without chance. If our world is deterministic, there are no chances in it, save chances of zero and one. Likewise if our world contains deterministic enclaves, there are no chances in those enclaves. If a determinist says a tossed coin is fair, and has an equal chance of falling heads or tails, he does not mean what I mean when he speaks of chance (Lewis, 1980, 120)

What then does the determinist mean when he speaks of 'chance'? Those espousing Thesis 3 typically suggest that determinists must regard chance as an *epistemic* (or subjective) probability:

> I can see why so many determinists... seriously believe in the subjectivist interpretation of probability: it is in a way the only reasonable possibility which they can accept: for objective physical probabilities are incompatible with determinism... (Popper, 1992, 105)

> [I]n a deterministic world, all chance is reducible, and hence epistemic. It follows that the only objective chances are irreducible chances. (Dowe, 2003, 154)

(By 'reducible', Dowe means that chance is able to be given some kind of hidden variables analysis, typically pointing to proportions or measures over an ensemble.) One more example, for good measure:

> If propensities [chance distributions] are ever displayed, determinism is false. (Mellor, 1971, 151)

Dowe (2003, 156–60) goes on to pose further problems for objective chance in a deterministic world. Since he (along with everyone else party to this debate) regards objective probabilities as imposing some kind of normative constraint on everyday credences, he proposes a dilemma: ordinary macroscopic chances cannot be reducible, as in that case they would not be objective. But according to the determinist they cannot be irreducible either, hence objective chances cannot guide credence. Given any reasonable chance-credence coordination principle, determinism leads us to make radically improper credence assignments to certain events, most saliently macroscopic everyday events. So for Dowe and others who believe in Thesis 3, determinism forces both chance and chance-derived credence to be trivial; the only alternative is subjectivism about all chances.

But why should we accept Thesis 3? No argument is given, in any of the sources we cite. It is easy enough, however, to reconstruct some line of thought which may seem to make this thesis obvious enough to its proponents as to not require explicit defence. That line of argument runs as follows: if determinism is true, then the state of the system at a time, plus the laws that govern the state evolution of the system, suffice to fix the state of the system at any other time. If that is so, there are no objective facts left unfixed by the state and the laws. The chance of any event E is such a system would naturally be taken as the conditional probability of E given the state and laws of the system; given that the state and laws either fix on E's occurring, or fix on $\neg E$'s occurring, that conditional probability cannot be anything other than 0 or 1.

Persuasive as this line of argument might seem, there are a number of reasons for initial dissatisfaction. For example, to prefigure an argument we shall

consider in some detail (and reject) later (5.1), if chances are given by *frequencies*, determinism poses so special problem for chance: it will be an objective fact, entailed by the state and the laws, that the frequency of E-type events in a suitable reference class is p; and that is the chance of E. It is a perfectly objective fact that the frequency is p, one that is (perhaps) even more readily established in a deterministic system than an indeterministic one!

A second reason for dissatisfaction is provided by the so-called *paradox of deterministic probabilities* (Loewer, 2001, §1). We shall discuss this further in 5.2. If chances are merely subjective in deterministic physical theories, such as classical statistical mechanics, how do those probabilities play such essential roles in reliable predictions, explanations and laws, which are not about subjective credences at all, and would (presumably) hold even if there were no credence-having agents in the universe. The paradox is that if these probabilities are really subjective, they are inadequate to their role; and yet given determinism they must be subjective!

Having noted those initial dissatisfactions, we must nevertheless recognise the intuitive force of Thesis 3. Indeed, a common response to the paradox of deterministic probabilities ends up *denying* that the dynamics underlying statistical mechanics are really deterministic (Albert, 2000, ch.7)—which just serves to underscore how entrenched and plausible Thesis 3 is.

Finally, it is crucial to note that this thesis is effectively the probabilistic analogue of the thesis of necessitarianism about possibility. This thesis effectively says that whatever actually happens must have probability 1; necessitarianism says that whatever actually happens must be necessary. Similarly, whatever actually does not happen has probability 0, and according to necessitarianism, must be impossible. We might, then, also term thesis 3 the thesis of *probabilistic necessitarianism*. We might also, with good reason, term it *incompatibilism* about probability and determinism, by analogy with (one version of) the denial of Thesis 2.

4 The Problem

The problem should be clear, especially given the suggestive terminology I just deployed, but less us take the time to spell it out. The informal version is quick. Begin by making the assumption of determinism. Since actualism is false, in virtue of thesis 2, the truth of determinism does not therefore suffice to make all modal facts trivial. As probabilistic facts are themselves modal facts, by thesis 1, determinism by itself shouldn't suffice to make probabilistic facts trivial. But thesis 3 amounts to precisely the denial of that claim.

There would be no problem here if it were somehow the case that probabilistic facts were exceptional amongst modal facts, subject to trivialisation even when other modalities were not so subject. But we have no reason to suspect this, were it not for this argument, and indeed every reason to think that probabilistic claims are regular ordinary modalities. As the discussion of thesis 1 indicated, a basic intuition is that probability is a kind of quantified possibility, and that non-trivial possibilities should in at least some cases give rise to non-trivial probabilities. Moreover, as the converse BCP does hold in ordinary cases, there are many situations in which we can characterise exactly how non-trivial probability interacts with possibility, and see that if Thesis 2 is true, there are many non-zero probabilities in deterministic situations. But this is incompatible with Thesis 3: for *every* proposition φ, if determinism is true, the non-trivial possibility of φ is irrelevant to the probability of φ.

Even in the absence of a complete analysis of the many and subtle relations between probability and possibility, 1, particularly the BCP and its Converse, gives us an explicit tension between our three theses in the context of determinism. Consider some proposition φ which has not yet been decided. By Thesis 3, $\Pr(\varphi) = 0$ or $\Pr(\varphi) = 1$. By Thesis 2, there is no general argument that every possibility is trivialised by determinism; let φ be one of the possibilities that is not trivialised, so that $\ulcorner\Diamond\varphi\urcorner$ is true, and let it be true at some relevantly similar world. For the same reasons, let $\ulcorner\Diamond\neg\varphi\urcorner$ be true also. By Thesis 1 and the Converse BCP, $\Pr(\varphi) > 0$; so by Thesis 3, $\Pr(\varphi) = 1$. But again, by Thesis 1 and the Converse BCP, $\Pr(\neg\varphi) > 0$; so by the probability calculus $\Pr(\varphi) \neq 1$. But this is an explicit contradiction—something has gone very wrong.

How should we resolve this problem? The reasoning seems sound, from both a formal and informal perspective, so we must, it seems, abandon one of our plausible theses.

The natural candidate, it seems to me, is Thesis 3: the claim that determinism trivialises objective probability. In fact, this particular claim has long seemed dubious to me, simply because it fits so ill with the existence of successful and explanatory scientific theories that essentially involve probabilities and yet whose underlying dynamics are deterministic. This class of theories does not only include classical statistical mechanics, though that is the most commonly cited example, but also Bohmian and Everettian versions of quantum mechanics, not to mention almost all the probabilistic models in the higher sciences that are more or less independent of the underlying physics, deterministic or not. These kinds of considerations have led a number of philosophers to reject Thesis 3.

However, as we shall see in the following section (5), those attempts are tainted by the fact that their defenders feel an intuitive pull towards Thesis 3, and consequently feel compelled to give novel accounts of the nature of deterministic probabilities, so that 'regular' probabilities still satisfy the thesis. It seems to me, however, that the problem I've raised in this section is not susceptible to this kind of ad hoc case-by-case response, where we give a new kind of probability for each new scientific context. The problem I've raised depends only on a most general and undeniable feature of probability, and a straightforward and independently plausible principle not involving probability at all. It should arise for any probability worth the name; hence it cannot be satisfactorily solved by piecemeal reinterpretation. It is, as I will go on to argue, simply a confusion to think that non-trivial objective probability in the most general sense is incompatible with determinism.

Of course, those hard-line incompatibilists who have already set themselves against Thesis 2 will see no reason to reject Thesis 3: indeed, if my arguments have any force at all, those of an incompatibilist persuasion should also be incompatibilists about determinism and non-trivial objective probability. But for the rest of us, what I aim to show is that there is no hybrid position—no position, that is, which allows for non-trivial possibilities in a deterministic situa-

tion and yet trivialises probabilities in the same situation.

5 Two Unsatisfactory Ways of Denying Thesis 3

Before detailing my own reasons for doubting Thesis 3, we should go into a little more detail on other possible grounds for rejecting it. We alluded to these other reasons earlier (page 21); now we go into greater detail. In the end, however, I don't think either of them is adequate to dissolve the tension between our three theses.

5.1 FREQUENTIST ANALYSES OF OBJECTIVE PROBABILITY

One may think that Thesis 3 is *already* dubious. For instance, if one thinks about the justification of probabilistic assumptions in classical physics, this is usually done in terms of *relative frequencies*. If one thinks that this justification is a matter of objective probability being analysed in terms of relative frequencies, then one might well regard any link between determinism and trivial probabilities as grossly implausible.

On this view, if φ has some actual non-trivial frequency $f(\varphi)$ in some class of outcomes, then $\Pr(\varphi) \approx f(\varphi)$. So, for instance, in a fair coin the frequencies of heads and tails are about the same; so the probability of heads, and of tails, is about 0.5. The existence of these frequencies is a perfectly objective fact which just depends on the actual pattern of instantiation of the particular events which make φ true. Of course, for many different classes of outcomes, the frequencies, and hence the objective probabilities, will be different. Yet the fact that chance is parameterised by outcome class does not impugn the objectivity of the probability values thereby obtained.

The resulting analysis has some nice features. Probability is an empirical quantity, accessible enough to ordinary scientific investigation: we do an experiment, and relative to the class of outcomes of that experiment, there is a certain frequency which is the probability of that outcome given that experimental setup. Furthermore, it is uncontroversial that observed frequencies guide rational credence; this analysis makes it clear that probability guides credence for much the same reason.

Given this last fact, it is extremely curious that Lewis thinks that objective chance is incompatible with determinism. Many have reckoned Lewis' position on chance to be the following: the Principal Principle captures everything we know about chance; therefore if some quantity constrains credence in the way that the PP suggests ('plays the chance role', according to the PP), it is a good candidate to be chance. As Lewis (1994) goes on to remark, frequencies can play this role (though he is less than ringing in his endorsement!). Hence one would think that by his own reasoning, chance and determinism are perfectly compatible—at least if chance is relative frequency.

This last claim is the sticking point. Unfortunately, though frequencies play some role in constraining credence, they do not play the whole role. This would not be so bad, except that the role they fail to fulfill is that of objective probability! The most telling failure for our purposes is that actual frequencies fail to provide the right kind of modal facts that are required for objective chances to satisfy Thesis 1. In particular, even if $\Diamond_{\mathrm{Pr}}\varphi$, that does not entail that $f(\varphi) > 0$ in some arbitrarily selected outcome class: for example, consider an outcome class consisting of 10 outcomes, but where there are 11 possible outcomes φ_i. For at least one φ_i, $f(\varphi_i) = 0$ yet $\Diamond_{\mathrm{Pr}}(\varphi)$: so actual frequencies fail to correctly satisfy the modal logic of chance.

The natural response, to move to some kind of *hypothetical* frequentism, provides modal facts, but mostly of the wrong sort. For example, these accounts demand that there be a determinate fact of the matter about what the relative frequencies *would be*, were the outcome sequences to continue long enough. But any such counterfactual claims about probability must be false: for no matter what the probability value, it is possible that the frequency diverges arbitrarily from that value. Hypothetical frequentism requires many true 'would' counterfactuals about what the outcomes of probabilistic processes would be. But it is a basic principle of probability that such processes do not have determinate outcomes in hypothetical situations—any outcome *might* occur, so all the corresponding 'would' counterfactuals must be false.

These points are damning enough. When combined with the many other objections that have been made, the case against frequency analyses of probability looks convincing— see Jeffrey (1977) and Hájek (1997). If we are to find an

analysis of objective probability compatible with determinism, it must still be an analysis of probability—and this cannot be provided by relative frequencies. We must therefore turn aside from this initially promising suggestion.

5.2 DETERMINISM AND CHANCE IN PHYSICAL THEORY

Thesis 3 has come in for sustained criticism by philosophers working on the foundations of classical statistical mechanics (Clark, 1987, Loewer, 2001). They are primarily concerned with what Loewer calls 'the paradox of deterministic probabilities':

> If, as Popper and Lewis claim, objective probabilities cannot co-exist with deterministic dynamical laws then the probabilities that occur in these theories are subjective. But if that is so then... these probabilities do not ground the lawfulness of principles that are usually taken to be lawful. Loewer (2001, 612)

> Whether determinism is true or false, we must be prepared to assert that there is a chance of 1/2 that a particular coin tossed in a certain way will come up heads, a chance of 1/2 that a certain molecule will be located in the left half of a container of gas at some particular time... To suppose that the truth of such statements depends on the truth of indeterminism flies in the face of virtually universal common and scientific usage. (Salmon, 1979, 199)

In other words, if determinism rules out objective probabilities, it rules out any objective understanding of statistical laws in science, and undermines the explanatory force of those sciences. But it is absurd to suppose that determinism could so disrupt the foundations of statistical science.

Philosophers have usually opted to solve this paradox in one of two main ways. The first is to make claims that are dependent on very narrow formulations of the physical theories in question, as Clark (1987) does when he appeals to ergodic theory in classical statistical mechanics. If a statistical mechanical system is *ergodic*, then for almost all initial conditions, the resulting trajectory passes through every region in the state space (phase space). Moreover, the time the system spends in each region, in the long run, is the same as the measure of that region given by the standard measure on phase space. On the approach, the average time spent in region R is to be interpreted as the

probability of R for that system—a probability that is perfectly objective feature of the trajectory in question. Moreover, the proof of the result that average sojourn time corresponds to the microcanonical distribution *depends* on determinism. However, this approach is problematic for many reasons. Not least among these is the fact that in this particular example, the analysis of probability is explicitly frequentistic, as the probabilities are basically frequencies of region-inhabitance in the infinite long run of trials. But frequentism won't do any better as an analysis of probability just because it is disguised in fancier terminology. Again, as on all such views, the connection between long run time averages and single case chances cannot be secured without dubious additional principles. But worse is to come: the proof of this result depends on a very exacting hypothesis, the ergodic hypothesis, which doesn't apply to most statistical mechanical systems, let alone all the other statistical sciences. In some higher level statistical sciences, like population genetics, there seems no likelihood at all that anything like a mathematical proof in line with the ergodic theorem would be available.

The second approach is less subject to the fortunes of the particular sciences, but hostage rather to the fortunes of particular philosophical theories. Loewer (2001) proposes a theory of this second sort. He adopts Lewis' best-system analysis of laws (1994),[15] and defines an *L-chance* as a probability specified by a consequence of the best system, if the world has a unique such system. He then argues that at least some L-chances are compatible with determinism, because not every probability statement entailed by the best systematisation of a statistical theory has the form $\Pr(\varphi|H_{w,t}) = p$, i.e. a dynamical chance, conditional on history. There can be probabilistic statements about *initial conditions* (conditional on the null history). A claim about initial conditions, if it is part of the best system, can be perfectly objective, lawful, true, and non-trivial, despite determinism. Of course, one needs to establish that for any particular type of world, there is a probability-mentioning best system, but since constructing such systems is important for discovering laws of nature, we have no special task to perform simply to justify objective probabilities, and we have a very gen-

[15]Also discussed above, 2.

eral strategy that will apply to any reasonably formalisable theory, not just very specific cases. In the case of statistical mechanics, it has recently been argued that the best systematisation of that theory which is compatible with observed entropic behaviour is to postulate that the initial conditions were low-entropy and to postulate that the initial distribution is the microcanonical distribution conditional on low-entropy.[16]

Of course, as Loewer admits, there are only very limited propositions that have non-trivial chances on this view: only those about initial conditions. All the chances of events after the initial time are 0 or 1, because those events are entailed by the laws and the initial state. Loewer (2001, 618–9) provides a kind of surrogate chance, that he calls *macroscopic* chance:

$$\Pr_{\text{macro}}(\varphi) =_{\text{df}} \operatorname{Ch}_{\text{initial}}(\varphi | M_{w,t}), \tag{3}$$

where $\text{Ch}_{\text{initial}}$ is the initial chance distribution and $M_{w,t}$ is the macroscopic history of w up until t. Macroscopic chances are non-trivial, despite determinism, and plausibly guide credences, since if only macroscopic differences are directly empirically contentful, it seems reasonable that the evidence propositions we receive are claims about the macroscopically available trajectory of a system.[17]

This seems okay, as far as it goes, but it *still* yields, as Loewer himself admits 'the chances of any event A after the initial time will either be 1 or 0 since A's occurrence or non-occurrence will be entailed by the initial state and the deterministic laws'. Macroscopic chance, helpful as it might be, is not helpful enough: we still have triviality for *real* chance. Moreover, macroscopic chances

[16] See Loewer (2001, 618), and Albert (2000).

[17] Ismael (2003) provides a similar kind of surrogate chance in deterministic worlds in the context of the Everett interpretation of quantum mechanics (at least the 'many-worlds' formulation thereof). She suggests that while the global dynamics is deterministic, since Everett is a no-collapse interpretation of quantum mechanics, we are not forced to regard the local dynamics of an individual worlds as deterministic (indeed we cannot: it can be shown that the future of a local system [a particular branch] cannot supervene on the local state alone, which is to deny local determinism). But, again, this won't help with our general problem, since it seems the only probabilities here are epistemic—subjective uncertainty about which branch I will end up in (Saunders, 1998)—and that puts us firmly back in the grip of Loewer's paradox. Indeed, Ismael's proposal only rescues chance by reinstituting indeterminism!

and L-chances make sense only if a law of initial conditions makes sense, and it must be admitted (as Lower does) that such laws are at least unusual. And there are still big questions about the philosophical foundations: are L-chances capable of being an analysis of chance? are the axioms of the best system really capable of playing the role of laws? For these reasons it doesn't seem that Loewer's account really provides us with the compatibility of chance and determinism; rather, given some fairly controversial metaphysics, it provides us with some quantities that behave rather like chances, if our epistemic capacities are a certain way. But as the explicit mention of epistemic capacities dramatises, this is hardly likely to give us the full-blooded objectivity we desire. All is not lost, however: Loewer's macroscopic chances will reappear below, reinterpreted, and will be seen to play an extremely important role in fixing the relationship between chance and possibility (basically because macroscopic quantities are contextually salient and hence held fixed in counterfactual reasoning about possibilities).

6 Resolution of the Problem

Having made that detour, it is time to present my positive solution. The ingredients are all present in 1 and 2, and it is just a matter of putting them together.

We do so in the most natural way. If probability and possibility are linked by the BCP and the Converse BCP, then there is a certain relative modality $\Diamond_{\mathrm{Pr}}$, such that $\ulcorner\Diamond_{\mathrm{Pr}}\varphi\urcorner$ is true iff $\mathrm{Pr}(\varphi) > 0$. But this modality is also a kind of possibility: having selected in some way a set of actual facts to be held fixed, there is a set of worlds that are compatible with those facts. A possibility relative to those facts is a proposition that holds true at some one or more worlds in that set.

But just as there no reason to think that the complete total actual past history and the laws must always be held fixed in judgements of possibility, so too there is no reason to hold those facts fixed when we make a judgement that the probability of some proposition is greater than zero. To put it another way: if we can argue that the relative modality that corresponds to probability is not always fixed relative to the complete set of laws and complete set of historical

facts, then there will remain non-trivial probabilities for propositions, despite the fact that determinism is true, and the complete laws and history fix all the matters of particular fact.

We certainly argue for this thesis in the case of possibility: though determinism might be true, there are still perfectly ordinary non-trivial claims about what it is possible and impossible to happen, about the capacities and abilities of an object, or about what I can or cannot do. Those claims rely on holding a certain set of facts fixed: most saliently, facts about the intrinsic properties of the entity in question, but also contextually relevant facts about the surroundings that object is embedded within, and also enough facts about the laws so that we might predict how the object would behave given they way it is. What is conspicuously absent from this list is, say, the total set of extrinsic and relational properties that the object has, or the complete description of the spatial and temporal surroundings of the object. These are omitted, not because they are irrelevant to what will actually happen—of course they are—but because they are irrelevant to claims about the possibilities for, and abilities of, the experimental setup we are talking about. Those claims depend on the way the object is, and how objects of that sort can behave, not on the way this one will behave in these extremely limited and precise circumstances. To hold everything fixed trivialises the very natural distinction between the object under consideration and the rest of the world.

That exactly the same is true for probability, follows fairly immediately from Thesis 1, particularly the BCP and Converse BCP. On the most natural reading of this thesis, when we ascribe probabilities to certain outcomes we are implicitly making some kind of claim about the system which generates that outcome—that the outcome is possible for that kind of system, and we should expect it to occur in such a system with a certain frequency, and if we altered the system in certain ways that would alter the distribution of possibilities, and so on. These claims depend on specifiable physical features of the experimental setup which produces the outcome in question, on the reasonable presupposition that we can talk about that setup in relative isolation from the particular circumstances in which it happens to be embedded.

As I said earlier (1), I don't wish to defend any one set of facts as the canon-

ical set to be held fixed in every evaluation of a probability claim. All we need to undermine Thesis 3 is the obvious fact that, when evaluating probabilities, we do not always hold every actual fact about the system fixed. We do not, for example, hold the outcome fixed. A more interesting example: we do not hold the external constraints fixed. Imagine if we have a fair coin-tossing system, but that when the system is trialled, a nefarious rival will come in and interfere with the outcome, ensuring that it ends up heads. In some sense, it is not possible for this system to land tails; but given that it is an fair coin, the system certainly has some chance of landing heads. Having some chance of landing heads is equivalent, by Thesis 1, to there being some kind of possibility of landing heads. This cannot be a possibility given all the surrounding circumstances, including the nefarious rival—so when evaluating that relative possibility we must not always hold all the surrounding circumstances fixed. It is quite clear that, in general, we attribute probabilities to outcomes of particular experimental setups, and we call coins fair or biased, in isolation from their surroundings, just as we ascribe the outcome probabilities in a quantum mechanical situation to the piece of apparatus.

But once have admitted that not all the surrounding facts are always fixed when evaluating probability claims, then we have *already* denied the necessary connection of indeterminism and chance. For indeterminism is a property of a *world*: that the entire instantaneous state and laws of that world fix every state. Even in a deterministic universe, there is no guarantee of *local* determinism, which would be the further thesis that the instantaneous state of every part of the universe, plus the laws, fixes every state of that part. Local determinism would be necessary to trivialise the probabilities that are ascribed on the basis of the intrinsic nature of a system—but local determinism is not true of any deterministic theory that has ever been seriously proposed, and therefore cannot be meant to interpret the word 'determinism' in Thesis 3.

The overall picture, then, is that when we ascribe φ a non-trivial chance of being the outcome of a given experimental setup, we do so because φ being the outcome is a genuine possibility for that system. That latter claim is true if, holding fixed the relevant facts about the system, there are possible worlds where φ is true. The relevant facts are just those we would normally take to

govern our counterfactual and hypothetical judgements about how the system would behave, and how likely it is to behave that way, which may include salient facts about the surroundings and the way they interact with the system, the laws governing those interactions and the production of the outcome, and the intrinsic structure of the system. In all ordinary cases, the existence of a genuinely possible outcome indicates that that outcomes has some non-zero probability—consider how ridiculous it would be to claim that 'this coin could land heads if tossed, but has no chance of landing heads if tossed'. Whatever facts about the coin underlie the possibility of the outcome, also underlie the non-zero chance of that same outcome.

Prominent amongst such facts are those describing the intrinsic properties that make the system the type of system that it is. In a coin tossing system, those facts will include the structure and mass distribution of the coin, facts circumscribing the range of velocities that the flipper can impart to the coin, the properties of the surface the coin lands upon, and so on. It seems to me, however, that we will not include facts about what velocity and angular momentum the flipper *does* impart to be amongst those intrinsic properties, because that will trivialise the modal judgements we wish to make about how the coin would land, if it were tossed again. Holding fixed all actual facts, that is, trivialises hypothetical judgments. If we are to say that the coin when tossed can land heads and that it can land tails, as we should, we must be varying some parameters of the situation, whilst keeping others fixed. The natural parameters to hold fixed are those that make this particular situation an instance of a general type about which we wish to make hypothetical judgements, for instance the general type of coin tosses with this apparatus.

Part of the explanation for holding fixed these particular facts is pragmatic. As we make our way through the world, we must act in various ways, hopefully in such a way as to bring about the satisfaction of our interests. Acting in an effective manner is in part a matter of making reasonable hypothetical judgements about what effects our actions may have. Such judgements are, however, not an all or nothing matter: we make those judgements in a particular context, in which particular facts are salient, and others, though perhaps relevant in some extremely tolerant sense, are deemed contextually irrelevant. For

instance, in some sense every event in the past light cone of a particular space-time point is causally relevant to what goes on at that point, because all are causally connectible to whatever event happens to go on there. But of course we do not regard every past fact as salient when we make hypothetical judgements about what may or may not happen consequent upon our actions: we hold fixed certain important factors and neglect the rest. We hold fixed those factors that will enable us to make an objective judgement about what kinds of events can happen consequent upon our action, and we hold fixed those factors that will enable us to make a similar judgement in when and if the situation we are in recurs. A similar judgement, but not necessarily an identical judgement, because the outcome of a past action should guide us in how we assign credences to the various possible consequences. Judgements of possibility are thus context dependent: our situation makes various facts salient and demands that they be held fixed, while other facts may vary.

We've already claimed that that features that describe what kind of system in under consideration must be held fixed, for otherwise we have no handle on the abilities of the system in question and no handle therefore on the probabilities. Other salient facts include the past behaviour of the system, the past outcomes, for these give us a strong fix on how likely it is that a system will exercise its abilities in a particular way, to produce the outcome in question, and this is obviously important for figuring out the particular values that non-trivial probabilities might have. (Note that even to talk of past frequencies is to make a particular choice about which facts to hold fixed in order to identify the relevant reference class.) But for our purposes it is more important to note that past outcome frequencies give a kind of 'macroscopic history' of the system in question. Since consideration of past frequencies is undeniably relevant to evaluation of probabilities, the macroscopic outcome history of the system is salient to current evaluation of serious possibilities. Now we are in a position to see how Loewer's 'macroscopic chances' (page 29) can be implemented in this framework. For many systems, the past outcomes will be enormously important in judging what is possible for that system now. If the system is of the right sort, as in classical statistical mechanics, the past outcomes history provides a partial fix on the actual trajectory and thus can provide significant limits

on the possible temporal evolution of that system. For some systems, like coin tossing systems, where the trials are independent (Bernoulli), past data doesn't do much more than constrain chances of outcomes. But independence of trials is exceptional, and for many systems past data has a significant impact on the space of possibilities. In any case, Loewer's proposal about macroscopic chance is clearly a chance proposal: facts about the macroscopic history, when held fixed, constrain the space of possibilities, and hence non-trivial probabilities, and in the absence of further relevant information certainly should circumscribe rational credence, by narrowing the space of worlds to those where that type of system has produced a similar macroscopic history. Unlike Loewer, however, I don't regard macroscopic chance as a surrogate chance: it is a genuine probability, and it may be an extremely important one because it depends on facts that are salient in many situations, but it is not the only genuine probability: for many other sets of fixed facts there may be genuine non-trivial probabilities.

For all that we've granted, what will rarely be salient for a judgement of probabilistic possibility is the complete set of antecedent and surrounding microphysical facts. But if our judgements of probability are to be trivialised by determinism, it is exactly this extremely rich set of facts which must *always* be held fixed. But I have argued that it is just not true that these facts always are held fixed; nor is it true that the complete set of microphysical facts is somehow the canonical set that fixes what the real possibilities and probabilities are. The canonical set to be held fixed are surely those that identify the system as the kind of setup it is, and dictate what outcomes have some chance of coming about in a setup like that, on the basis of intrinsic properties that are robust across parametric variations in that kind of setup.

6.1 EQUIVOCATION

We still need to explain the seductive appeal of Thesis 3. In some sense, this is easy to explain. The proposition 'The coin has no chance of landing heads, because the history and laws together entail that the coin will land tails' is intuitively compelling. Given determinism, those facts about the history really do

fix whether or not a coin will land heads or tails, and mentioning those facts therefore seems to be equivalent to 'the coin must land tails'. The claim 'the coin has no chance of landing heads because it must inevitably land tails' seems obviously true.

But we have a seeming contradiction. On the one hand, we have '*The coin has no chance of landing heads because given the history and the laws it is inevitable that it land tails*'. On the other hand, we have '*The coin has some chance of landing heads because it is unbiased*', or more generally '*The coin has some chance of landing heads because it, and the tossing system, are of the sort that can land heads*'. Does the coin have a chance of landing heads, or doesn't it? This seeming contradiction is illusory: both these claims are true, and true because of the reasons cited. They are compatible because 'having some chance', like 'can', is *equivocal*.

In 2 I argued, following Lewis (1976, 77), that 'can' is equivocal (as is 'possibly'). Relative to which actual facts we hold fixed, different things can happen ('are possible'). But which facts are held fixed depends itself on which facts are relevant to the judgement under consideration, and there is no single absolute unrelativised sense of 'possibly' that will do for every contextually salient set of facts.

Precisely the same argument is available for 'has some chance', or 'has non-zero probability'. Relative to some facts, for example, facts about the whole past history and laws, together with determinism, there is only one possible outcome and hence no chance of that outcome being other than it will actually happen to be. But such a rich and inclusive set of facts cannot reasonably be claimed to be always contextually salient. In fact, as I argued above, there is every reason to expect that the facts that matter are (i) coarse-grained macroscopic facts about past history and surrounding circumstances; (ii) facts about intrinsic properties of the experimental setup; (iii) facts about the causal/nomic consequences of the experimental setup having the properties it has. But the general point is clear: since it is possible for us to hold fixed different sets of facts in different contexts, it is possible for us to equivocate.

There is, of course, a sense in which sometimes we do wish to hold all the historical facts fixed, just as we do when talking about 'futuristic possibility'

(page 16). Determinism does trivialise some sense of probability, which we might call *capricious probability*. The capricious probability of φ might be defined as the conditional probability $\Pr(\varphi|H_{w,t} \wedge \mathscr{L})$: i.e. the probability of φ conditional on *everything*. If determinism is true, then all capricious probabilities are trivial: holding everything fixed necessitates either φ or $\neg\varphi$. This fact might be expressed in the following true thesis.

Thesis 4 (Capricious Triviality): *If determinism were true, then there would be no genuine objective capricious probabilities.*

If determinism is true, then the world is empty of genuine capriciousness, just as it is empty of genuine alternative futuristic possibilities. For there to be a non-trivial capricious probability, there would have to be two possible worlds, each sharing the entire history and laws of our world, but where φ is true in one but false in the other. Given determinism there can be no two such worlds.

There may well be contexts in which futuristic possibility and capricious probability are relevant: contexts in which a very rich set of historical and microphysical facts have been mentioned. Perhaps contexts where determinism has been mentioned are such contexts, because the contextually salient facts then include those relevant to assessing the content of determinism, and this makes the entire history and laws relevant. But it is quite clear that not every context is one where absolutely everything is relevant: no set of facts as rich as $H_{w,t} \wedge \mathscr{L}$ could always be salient to judgements of probability. As such, there is no sense in which capricious probability is the only kind, or even the most important kind, of probability.

It is the possibility of equivocation over 'has some probability' that makes it possible to confuse Thesis 3, which is false, with Thesis 4, which is true. That is, the phrase 'objective probabilities' in Thesis 3 has two readings: either 'capricious probabilities', or 'probabilities' simpliciter. If we are not careful, we shall confuse the fact that determinism trivialises the former with the falsehood that determinism trivialises the latter. It does not; so Thesis 3 is false, though its close relative Thesis 4 is true.

Consider these claims: '*It is probable that this coin will land heads (after all, the coin is biased towards heads)*' and '*It is improbable that the coin will land*

heads (after all, the entire past state of the universe determines that it will land tails)' . The parenthetical glosses make the context explicit: those are the facts that are to be held fixed when considering what is, or is not, possible for this system. Having understood that these differently fixed facts can actually make a difference to the probability claims that are true, we might say that there are two concepts of probability that are relevant in these different contexts. We might also say that 'probability' is a context-sensitive term. But what we certainly can say that one of these concepts is the canonical one. However, as I argued, it is not capricious probability, but rather the ordinary garden variety objective probability that corresponds to the genuine capacities of the chance setup. That ordinary concept of probability is the one that connects in the right way with all the facts that we normally take to be relevant to whether that outcome can happen, and how likely it is that it will.

6.2 OBJECTIVITY AND MODALITY

All this work would come to nothing if we have failed to give an account of *objective* probability. But it is quite clear that probability in our sense is perfectly objective. Once the facts to be held fixed are specified, which in the canonical case will be those facts about the system which ground its probabilistic abilities, it is a perfectly objective matter which outcomes are compatible with those facts and which are not, hence which outcomes will have non-trivial probabilities.

Of course, relative to a different set of facts, the non-trivial probabilities may well be different. But just as in the case of possibility, the mere fact that which events have non-trivial probabilities can vary from situation to situation doesn't mean that, somehow, those probabilistic facts are not objective. On the contrary: it is the properties of the chance setups themselves which dictate, given the laws, how they might behave under varying counterfactual conditions. There is nothing subjective or epistemic about these possibilities, which derive from intrinsic properties of the experimental setups and would do so whether or not there were any creatures with epistemic states or not.

There are certainly many more probabilities than one might have expected:

indeed, relative to any set of facts held fixed, there will be a set of worlds compatible with those facts, and corresponding non-trivial probabilities deriving from the happenings at those worlds. This too, accords with the situation with respect to possibility. But the analogy goes further, for just as there are privileged relative modalities, which demand that facts be held fixed which correspond to natural sets of relevant worlds, so there seems to be a privileged set of facts held fixed in the probabilistic case too: facts that ground the abilities of the systems under consideration, and facts about the laws that govern how those abilities manifest themselves.

Some may still be dissatisfied, because probability is not a fundamental feature of the actual world on this view. It is, rather, a relational property: relative to a certain set of facts about the generating conditions, the probability of the outcome is such-and-such. It is a natural thought that a relational, contextual property like this is somehow less than respectable. I agree that this is a natural thought: but I don't see any problem with accepting it. For, if we refrain from buying into Lewis-style modal realism, we have to accept that it is facts about actuality that provide truthmakers for modal truths, probabilities amongst them. It is very clear that, since modal truths are derivative in some way from actual truths, ineliminably modal properties will inevitably end up looking derivative. Probabilities will be no exception, deriving as they do from holding some actual facts fixed and varying others.

Finally, I wish quickly to return to Dowe's (2003) 'dilemma' for objective chance, mentioned above (page 21). In arguing for the compatibility of objective probability and determinism, I reject the claim that in a deterministic world, all chance is reducible. Dowe's claim depends on an impoverished conception of chance as a kind of objective 'force' guiding the evolution of outcomes in the world; it is natural to think that in a deterministic universe that force is trivialised. But chance isn't like that, and needn't be like that to be objective. Objective probability is a kind of modality, and the truth of modal claims does not reduce to any set of actual facts, however rich and inclusive.

One approach to probability that fits quite naturally into this framework for probability and possibility is the *propensity* analysis. This approach takes the truthmakers for propositions about objective probability to be intrinsic dispositions of a chance setup to produce outcomes: on some versions, to produce outcomes with a certain distribution , and on others to cause outcomes to a certain degree. For a wide range of reasons, I don't think that propensity theories succeed as an analysis of probability (Eagle, 2004). But what I have only recently come to appreciate is that the propensity approach has the considerable merit of taking the modal aspects of probability seriously. Propensities are supposed to be actual properties of object that support modal claims about what frequencies of outcomes the experiment habitually produces, or how strongly the experimental apparatus usually causes the outcome, when the experiment is trialled.

Probability claims, on the propensity view, are grounded in objective abilities of chance setups to produce outcomes, which themselves are grounded in special probabilistic dispositions. The first stage of the analysis I agree with: probability and ability claims are closely linked. But it is not the case that probabilistic ability claims must be explained in propensity terms.

Consider the analogous situation with possibility. We could explain the possible outcomes for a particular system with reference to some kind of intrinsic property which governs what is and is not possible for a thing of that sort. This would be something like an *essence*, an intrinsic modal property that is the truthmaker for all other modal facts about this particular entity, or entities of this type. The flavour is given by this naive analysis: system S is essentially φ iff 'necessarily, S is φ' is true. These claims about essence, and the causal powers that derive from that essence, will ultimately govern what is and is not possible for an entity:

> From the perspective of scientific essentialism, the world is not an agglomeration of logically independent states of affairs or self-contained atoms of any other kind. The world consists ultimately of thing that have their causal powers essentially that determine what they can, must, or cannot do in relation to other things. (Ellis, 2001, 5)

Certainly the distinction between essence and accident is an intuitively compelling one; nevertheless I don't think we need believe in essences to give an actualist account of objective modality, and there are a number of undesirable features that would seem to militate against thoroughgoing essentialism. Certainly essences seem more obscure than the *de dicto* modal truths we attempt to explain in terms of them, and essences seem to make no distinctive contribution to the behaviour of objects that possess them (since all the same behaviours will be observed of two objects with the same total set of properties but different subsets of those marked out as essential properties); and essences don't seem contextually variable, yet possibility claims clearly are.

As I see it, the propensity theory is a kind of essentialism about probability. I see it as a version of an essentialist approach because an actual second-order property, the propensity, governs the modal profile of the other properties of the object. (Just as 'being essential' is an actual second-order property that governs the modal profile of properties of the object.) As before, though, the fact that propensity theories can give a modal account of probability in no way indicates that we should accept them. Propensities provide one way of explaining why there is a canonical set of facts to be held fixed when evaluating probability claims: because those facts derive from the propensity. But propensities share all the flaws of essentialist theories more generally: they are mysterious posits, and they work they do in explaining empirical phenomena is done entirely by the non-propensity categorical properties of the objects. Again, propensity theories have no way of explaining the contextual variability of probability claims, because the propensity should be constant across all possible situations. Given this last point, it is particularly ironic that so many propensity theorists connected propensities with indeterminism, when their framework easily allows a separation of the intrinsic probabilistic properties from the total situation which determines particular outcomes.[18]

Whatever account of chance and probability one accepts, it should at base

[18]Mellor, a longstanding defender of the indeterminist propensity approach, has more recently come to abandon the idea that chance and determinism are incompatible (Mellor, 1991, 158), claiming that the existence of the propensity which grounds non-trivial probabilistic laws is in no way impugned by the truth of some further determining fact.

depend on the modal significance of various actual properties of the systems which bear the probabilities. Propensity theories have at least this virtue, but in light of their failings a more minimal model might seem preferable. Perhaps in the end a 'theoretical term' view of chance, explicitly linked to abilities conveyed by certain fixed statistically relevant properties, will work best (Levi, 1980, Ch. 11–2), though I cannot go into it here.

7 Conclusion

Three widely accepted theses about the relationship between objective probability, objective possibility and determinism are inconsistent. Hence we must give at least one of them up. I argued that we should abandon the claim that objective probability is incompatible with determinism. Once we considered the correct account of the relationship between probability and modality, it seems the perfectly natural thing to do, especially since we can account for the plausibility of the claim in a quite straightforward way, as an equivocation. On the considered view, ascriptions of non-trivial probability amount to claims of serious possibility when one holds fixed certain canonical properties of chance setups and the laws which govern them. Holding all other properties fixed does trivialise probability in a deterministic universe; but those properties need not be held fixed, and in fact doing so is pragmatically completely unreasonable.

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