The Semantics and Ontology of Dispositions[1]

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The paper looks at the semantics and ontology of dispositions in the light of recent work on the subject. Objections to the simple conditionals apparently entailed by disposition statements are met by replacing them with so-called "reduction sentences" and some implications of this are explored. The usual distinction between categorical and dispositional properties is criticised and the relation between dispositions and their bases examined. Applying this discussion to two typical cases leads to the conclusion that fragility is not a real property and that, while both temperature and its bases are, this does not generate any problem of overdetermination.

1. Introduction

After some years of quiescence, philosophical discussion of dispositions has recently been revived by new work, for example by David Armstrong and others (Armstrong et al. 1996), which has now been ably reviewed and added to by Stephen Mumford (1998). This work has implications for many areas of philosophy where dispositions have long been invoked, such as the philosophy of mind, language, action, value, properties, laws of nature and probability: see for example Ryle (1949), Popper (1957), Levi (1964), Goodman (1965), Harré (1970), Mellor (1971), Armstrong (1973), Tuomela (1978), Kripke (1982), Ehring (1985), Weintraub (1987), Lewis (1989), Mellor (1993), Hüttemann (1998) and Lipton (1999). But while I shall indicate one or two of these implications in passing, my main object

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here is to outline a view of dispositions themselves that I have developed in the light of recent literature.

Dispositions pose two main questions for philosophers: how should we understand statements ascribing them to things; and what in reality are they? The semantic question comes first because we can hardly say what dispositions are without some idea of what we mean by crediting things with them. Our view of that may of course be modified later by our theories of what dispositions are, since here as elsewhere our metaphysics is likely to affect our semantics, but a *prima facie* semantics is still the best place to start.

2. Dispositions and conditionals

What makes the semantics of dispositions both interesting and problematic is their evident link with conditionals of a familiar and undeniably non-truth-functional kind. Take fragility. For any *x*, "*x* is fragile" seems to mean something like "if *x* were dropped it would break", a conditional that no one thinks is entailed, as a truth functional conditional would be, either by *x*'s not being dropped or by its breaking.

More precisely, to cover light or earthbound entities like paper and bridges, what "*x* is fragile" seems to mean is something like "if *x* were relatively suddenly and lightly stressed it would break". Even this cannot of course be the full story, for several reasons. First, what does "relatively" mean here? We need the term to cater for the fact that fragility, like most dispositions, comes by degrees, which raises the question of how fragile a thing must be to be fragile. That however is just an instance of the general question of how to map qualitative predicates onto corresponding quantities: how hot is hot?; how large is large?; and so on. The answers to such questions clearly may depend on our interests and may vary with context: hot for us often means as hot as, or hotter than, we want; large for a mouse is small for an elephant; and so on. But as such questions are by no means confined to dispositions, and tell us nothing much or special about them, the literature on dispositions has generally and rightly ignored them. For present purposes "relatively" can remain unanalysed.

More serious is the fact that dispositions may be more or less generic, i.e. show up in different ways in different circumstances. Fragility is relatively specific in showing up only in breakages, whereas dispositions like bravery or generosity can be displayed by very different behaviour in different situations. Still, as we have noted, the kinds of stress that test the fragility of paper and bridges also differ from those that test the fragility of wine glasses. The circumstances in which fragility can show up are thus more diverse than, for example, those—being immersed in a liquid—in which solubility can show up. So fragility, if not as generic as bravery, is more generic than solubility.

Even for fragility, then, we seem to need not one conditional but many, of the form "if x, of kind K, were (relatively suddenly and lightly) stressed in way W_K, it would break". This complication will pose no problem if the kinds K are mutually exclusive, for then it cannot make a single thing both fragile (because it breaks when stressed in way W_1) and not fragile (because it does not break when stressed in way W_2). So in that case, by reading the necessary qualifications into "stressed"—including the general requirement, which I shall hereafter take for granted, that the stress be relatively sudden and light by the standards of way W_K and of kind K—we can again abbreviate all these conditionals to a single "if x were stressed it would break".

This however is too easy, for two reasons. The first may be put as a dilemma. Nothing more specific than this conditional will make "fragile" mean the same in all its varied applications. But then this common "meaning" will tell us almost nothing about when and why we call things of different kinds "fragile", since that will depend on the more specific conditionals that "if x were stressed it would break" abbreviates. Which these are, however, is not something we can prescribe or discover a priori or once-for-all, but a constantly changing list based to varying and imprecise degrees on our knowledge, conventions and interests.

Still, this limitation is hardly peculiar to dispositions; nor is it news, given what Ramsey (1929) called "the vagueness of the whole idea of understanding, the reference it involves to a multitude of performances any of which may fail and require to be restored". So it is no great objection to our abbreviated conditional that it says very little about what we

should apply the predicate "fragile" to in practice. It may still, in a sufficiently modest sense of "meaning", tell us what the predicate means, i.e. what is common to its diverse uses, and also what makes it dispositional, namely, that what it means is a conditional.

Yet even this modest claim poses a problem, since things may be of more than one relevant kind *K*. Suppose for example that a prefabricated bridge would break if dropped (W_1) on the way to its destination, but not under ordinary traffic vibration (W_2) when in use. Is the bridge fragile or not? The obvious answer is that under some kinds of stress it is and under others it is not, just as most solids will dissolve in some liquids but not in all. So just as we distinguish solubility in water from solubility in oil, we should distinguish fragility under dropping from fragility under vibration.

This removes the risk of contradiction: there is no more contradiction in calling a bridge fragile$_1$ because it would break if stressed in way 1, but not fragile$_2$ because it would not break if stressed in way 2, than in saying that grease is soluble in oil but not in water. Nor, on our modest view of meaning, does relativising fragility and solubility to circumstances make "fragile" and "soluble" ambiguous. For in all relevant circumstances the question remains the same: does the thing break when (relatively suddenly and lightly) stressed in such-and-such a way, or does it dissolve when immersed in (a suitable amount of) such-and-such a liquid?

Nor need this claim about what "fragile" means be threatened by new applications of the predicate. On the contrary, given a suitably generic concept of stress, it shows precisely how a pre-existing concept of fragility can be applied to new domains. Thus it explains how extending our concept of stress to include the thermal stresses that can crack thick but otherwise robust glassware automatically extends our concept of fragility to match. Far from this extension changing the meaning of "fragile", it is the very constancy of that meaning, as stated by our conditional, which explains this extension in its use.

Similarly for many other dispositions, even ones like generosity or bravery which can show up in far more varied ways than fragility and solubility. Think of all the situations that can call forth bravery—warfare, bankruptcy, blindness, humiliation, exposure to infection, bereavement—and of all the ways there are of being brave in them. We may still be able

to say roughly what all these ways of being brave have in common: perhaps by saying that they all involve voluntarily doing or patiently enduring something unpleasant or risky for what is taken to be a good end. If so, that will show how "brave" can be as unambiguous as "fragile", while still letting people be brave in some ways and not others.

3. Multi-conditional dispositions

There are however many arguably dispositional predicates whose usage cannot be summed up in a single conditional. These are scientific predicates linked to each other in different ways by different theories. Take the family of predicates "has mass *m*", linked to force predicates by Newton's laws of motion via an infinity of conditionals of the form "would accelerate at f/m under any net force f", and by his theory of gravity via an infinity of the form "would exert a force proportional to m^2/r^2 on any other body of mass m at any distance r". How is the meaning of "mass *m*" related to these conditionals?

First, it is clear from Hempel (1958) and others that these scientific predicates can rarely if ever entail their associated conditionals. Neither of the (families of) conditionals given above, for example, need be analytic to our concept of mass. Nothing in Newtonian science dictated or depended on which of them would survive in new theories of mechanics or gravity. Nor, now we have those new theories, does it matter whether or not we identify the new concept of relativistic mass with its Newtonian counterpart: such questions of conceptual identity are generally agreed to be as idle as they are usually unanswerable. Predicates like "mass *m*" cannot therefore mean, in the sense of entailing, all or even any one of the many conditionals that now govern their usage.

Still, Quine's (1951) strictures on analyticity show that this may be just as true of "one-conditional" predicates like "fragile". Future discoveries about how things break could make us link that predicate to more conditionals, thus making it more like "mass *m*", without ever clearly changing its meaning. None of this alters the fact that, for now, "if *x* were relatively suddenly and lightly stressed it would break" expresses all the inferences

we think we can safely draw for any *x* from "*x* is fragile", just as conditionals like those I have cited do in Newtonian physics for "*x* has mass *m*". In both cases these conditionals can state all the conditions we take to be sufficient and/or necessary for applying these predicates even if, as Quine and Hempel argue, no one of those conditions is itself conceptually necessary. Neither "fragile" nor "mass *m*" is in this respect at all like Wittgenstein's (1953 §66) "game", which lacks any general sufficient and necessary conditions, and whose applications are linked only by "family resemblances".

I therefore propose to call "mass *m*" and other such "multi-conditional" predicates "dispositional" also, on the grounds that, as with "fragile", all we can say about what they mean—namely what we now think their application conditions are—can be said by conditionals. Whether it takes one or more than one conditional to do this seems to me immaterial; and even if it isn't, the matter is still merely terminological.

This raises the question of how many other predicates are dispositional in this broader sense. Specifically, ignoring predicates like "game" with no generally statable application conditions, how many contingent, non-identity, non-evaluative predicates—which for short I shall call "factual"—are dispositional in this sense? The claim that most if not all are is not of course new, although it remains contentious. Among its advocates are Goodman (1965 ch. 2) and Popper (1990), although Popper puts it in ontological rather than semantic terms by claiming that all factual properties are dispositions. However, as Mumford (1998 ch. 4) and others have noted, the semantic and ontological claims must be distinguished: to say that all factual predicates are dispositional, meaning that their application conditions can all be stated by conditionals, is not to say, in any serious sense, that all factual properties are dispositions (see §6).

Still, even granted this distinction, it is not obvious that all factual predicates are dispositional, i.e. that their application conditions are given by conditionals. Take "triangular", whose obvious application condition—that it applies to all and only triangles—is certainly not conditional. But once we distinguish semantic from ontological issues, we can see that this condition is as semantically vacuous as the condition that "fragile" applies to all and only fragile things. I have argued elsewhere that the only serious

application condition for "triangular" is a conditional, namely that "triangular" applies to all and only things whose corners, if counted correctly, would add up to 3, where "counting correctly" does not mean getting that answer but counting each corner once (Mellor 1974 §8). While this view does face objections (Prior 1982, Mumford 1998 ch 4.2–6), these do not include putting triangularity and fragility on an ontological par; since, as we shall see, it does no such thing.

The other objection to using conditionals to give the current meanings of all factual predicates is that it must eventually be circular, since the predicates used to say what any one such predicate means must get their meanings from conditionals containing other such predicates. But there is nothing wrong with this, even when the circle is very small, as with Newtonian "force" and "mass", each of which occurs in statements of the laws that give us the other's application conditions. This just illustrates the familiar fact that we learn most predicates in groups, as parts of conceptual package deals. The most that our ability to acquire such clusters of factual concepts shows is that there must be some other—demonstrative or otherwise observational—aspect to factual meaning, which our conditionals rely on but none states. But then it can be no objection to our conditionals that they fail to state something that nothing states. The only real question is whether conditionals can be used to state all we can say about what factual predicates apply to, which in most cases I believe they can.

4. Reduction sentences

Even if the application conditions of most and perhaps all factual predicates can be stated by conditionals, there remain two objections to the simple conditionals I have so far considered. One is posed by so-called "antidotes" (Bird 1998). Suppose that stressing a fragile glass *a* by dropping it onto a suitably hard floor would so soften the floor that *a* would not break. Then "*a* is fragile" is true but "if *a* were stressed it would break" is not, because this otherwise suitable way of stressing *a* creates an antidote – a softened floor – that stops *a*'s fragility manifesting itself. And as for fragility so for all dispositions, to which antidotes are always possible

because it is always possible for a contingent conditional to be true only if its antecedent is false.

Fortunately, however, the very contingency that makes antidotes possible can also be used to exclude them, as follows. Suppose for example we replace "if *x* were stressed it would break" with "if *x* were stressed in circumstances of a kind *C* it would break", where being of a kind *C* entails not being made ~*C* by a suitable stressing of *x*. Since by definition antidotes work by making the relevant circumstances ~*C*, their possibility cannot stop these revised conditionals holding just when "*x* is fragile" is true. What these kinds *C* are, and whether we can say what they are, is as immaterial to this claim as we saw in §2 that it is whether we can say what it is to stress something "relatively suddenly and lightly". All that matters is that circumstances of kinds *C* exist and are sufficiently common for the inference from "*x* is fragile" to "if *x* were stressed it would break" to be safe enough in practice.

The other way a predicate's link with its conditionals can fail is by circumstances making a disposition "finkish" (Martin 1994). This happens when, for example, dropping a fragile glass would cause it not to be fragile. In those circumstances, while "*x* is fragile" is true, "if *x* were dropped it would break" is not. But here too we can rescue the link, by amending the antecedent of our conditional to make it read "if *x* were stressed without ceasing to be fragile it would break", and similarly in other cases (Lewis 1997). Such conditionals, containing the very predicates whose application conditions they give, I shall call "reduction sentences", after the similar (but truth-functional) sentences that Carnap (1936–7 §5) uses to do a closely related semantic job.

Reduction sentences undoubtedly provide an effective antidote to finkishness. They may however seem to have unacceptable semantic sideeffects, since to understand "if *x* were stressed without ceasing to be fragile …" we must already know what "fragile" means. This however is no real objection to them, since it does not in fact stop us using them to say what dispositional predicates apply to. We can still, for example, remedy the ignorance of those who do not know what to call "fragile" by saying that, by definition, all and only things that remain or become fragile when (relatively suddenly and lightly) stressed will then break.

Two applications of reduction sentences

Because reduction sentences solve the intractable problem that finkishness poses for standard conditional accounts of dispositions, I shall assume hereafter that these sentences are the conditionals we should use to state the application conditions of dispositional predicates. This assumption does however have important implications for various philosophical applications of the concept of a disposition, two of which we should note before going on.

The first is Ryle's (1949) project of explaining away mental states by identifying them with dispositions. This enables him to reduce ascriptions of these states to conditionals, which he then argues state no actual facts. Now whether and in what sense the conditionals Ryle invokes need not state facts is a moot point, to which we shall return in §5, but even if they do not, that will not save Ryle's project if his conditionals are reduction sentences. For even if "if *x* were stressed without ceasing to be fragile it would break" states no fact, it does require an unconditional sentence containing "fragile"—namely "*x* is (still) fragile"—to have a truth value and hence, if true, to state a fact. On a reduction sentence reading of these conditionals, therefore, Ryle's argument can no longer show that our ascriptions of mental dispositions state no mental facts.

On the other hand, reduction sentences can be used to meet at least two of Kripke's (1982 ch. 3) objections to a dispositional account of rule-following. These are that we cannot, for example, equate following the rule that "+" means addition with being disposed to add any numbers we link with "+", because (1) some numbers are too large for us to grasp, or to add in a finite time, and (2) some numbers may dispose us to add them wrongly.

Objection (1) may in fact be met without invoking reduction sentences. This will be so if it is on a par with saying that a glass *a* that cannot be dropped cannot be fragile, an absurdity that no conditional account of fragility need entail. In particular, "if *a* were dropped it would break" does not entail that *a* can actually be dropped. It is true that on Lewis's (1973) semantics, if it were metaphysically impossible to drop *a*, i.e. if "*a* is dropped" were false in all possible worlds, then "if *a* were dropped it would break" and "if *a* were dropped it would not break" would be equally and trivially true and "*a* is fragile" vacuous. But this consequence of Lewis's semantics seems to me

either an objection to it or irrelevant: for while dropping *a* may be practically impossible, it is certainly not metaphysically impossible. Similarly with the fact that some numbers *n* and *m* may be too big for us to add: for even if there must be some upper limit to the numbers we can add, it can still be contingent that, for any given *n* and *m*, we cannot add them.

If objection (1) means more than this, then, like (2), all it shows is that some numbers make our disposition to follow the addition rule finkish: that is, trying to add those numbers would cause us to lose this disposition and hence to add them wrongly or not at all. But that, as we saw in the case of fragility, is no problem for a reduction sentence account of dispositional predicates. For on that account, if "*x* means plus by '+'" ascribes a disposition to *x*, this means that, for any two numbers *n* and *m*, if *x* were to apply "+" to them while having this disposition, *x* would get the answer *n*+*m*. And this seems to me obviously both true and consistent with (1) and (2).[2]

5. Dispositions and properties

So much for the semantics of dispositional predicates. Now for their ontology, i.e. for what makes things satisfy them. The two topics must of course be related. If things can only have dispositions when conditionals like "if *x* were stressed it would break" are true, the ontology of dispositions must be linked in some way to that of those conditionals. Take Ryle's (1949 ch. 5) view that

[2] Even a reduction sentence account of "*x* means plus by '+'" is admittedly open to Kripke's main objection, that it can only tell us how *x* does use "+", whereas the rule says how *x* should use "+". That objection may however be met by invoking a further disposition to coordinate our dispositions to use "+", i.e. to be disposed to have the addition disposition if and only if we all have it (Lewis 1969). More serious, perhaps, is the fact that our reduction sentence for "+", unlike that for "fragile", cannot be used to convey the meaning of "+" to someone who does not know it already, since here the term to be defined occurs in the consequent rather than the antecedent of the conditional. This however does not preclude a different dispositional account of how we acquire our disposition to add the numbers we link by "+", namely that this, rather than its Kripkean rivals, is the disposition we are disposed to acquire when first introduced to arithmetic. And then, given that we are in fact disposed to use "+" as we do, our definition of "+" is no more circular than the standard definition of "&", namely that, for all "P" and "Q", "P&Q" is true if and only if "P" is true and "Q" is true.

> dispositional statements are neither reports of observed or observable states of affairs nor yet reports of unobserved or unobservable states of affairs.

Ryle infers this from his "inference-ticket" view of laws of nature, and hence of the conditionals he takes dispositional statements to entail. Suppose it follows from a law that all glasses of a certain kind are fragile, i.e. would break if dropped, and hence that a particular glass *a* of this kind would do so. Then all "*a* is fragile" says is that we may infer "*a* breaks" from "*a* drops": it does not report a state of affairs distinct from those that make "*a* drops" and "*a* breaks" true or false. So when a fragile glass *a* and a non-fragile glass *b* are not being dropped, there need be no factual difference between them.

I, like Armstrong (1993 ch. 6.6), find this claim incredible: if *a* is fragile and *b* is not, they must differ in some factual respect whether they are being dropped or not. Nor does the claim follow from an inference-ticket view of conditionals. For even if "*a* is fragile" is only a ticket licensing us to infer "*a* breaks" from "*a* drops", that inference, since it is not logically valid, needs something other than logic to make it safe. As Ayer (1956) puts it, "there would be no point in issuing [such] tickets if the trains did not actually run".

What are these trains? For Lewis (1973) they are similarity relations between possible worlds: "if *a* were dropped it would break" is true if and only if *a* breaks in the worlds most like ours where *a* is dropped. But while this may suffice for modal realists like Lewis, who think possible worlds other than ours really exist, it will not do for actualists like Armstrong (1989) and myself, who agree with Goodman (1965 ch. 2) that "all possible worlds lie within the actual one". For us, while possible-world talk may provide a handily visualisable semantics for conditionals and hence dispositional statements, it cannot provide their ontology. That is, while it may tell us what these statements mean, it does not tell us what in this world makes statements with those meanings true or false.

Fortunately we need not settle the dispute between actualists and modal realists here, since if the tickets which license "*a* is fragile" are reduction sentences, even possible-world theorists will need actual-world trains to make the licences effective. For as we noted in §4, "if *a* were dropped

without ceasing to be fragile it would break" requires an unconditional and contingent "*a* is fragile" to have a truth value. Our ontological question therefore is what in the world, by making "*a* is fragile" true, makes it safe to infer "*a* breaks" from "*a* drops".

The obvious answer to this question is that *a* has the property of being fragile, this being what distinguishes *a* from the non-fragile *b*, whose lack of that property is what makes it unsafe to infer "*b* breaks" from "*b* drops". But then, for the fact that *a* has that property to be what makes *a* but not *b* satisfy the predicate "fragile", saying that *a* has this property must mean more than that it does satisfy that predicate. Properties in this sense must be more than the ontological shadows of predicates.

What I mean by "property" is therefore what Alex Oliver and I mean by the title of our edited book *Properties* (1997), namely what Lewis (1986 ch. 1.5) calls "natural" properties, the sharing of which entails real resemblances. So if there is such a property as being fragile, any two things which share it must resemble each other in some way that other things do not. What properties so understood are—universals, classes of all their possible instances, resemblance classes of ordinary particulars or of so-called tropes, or something else again (see e.g. Armstrong 1978 part 2)—is not a question I need to settle here. The only assumption I need here is that properties, whatever they are, are constituents of truthmakers (Armstrong 1997 ch. 8) for propositions like "*a* is fragile" and hence for conditionals like "if *a* were dropped it would break".

That at least most scientific properties fit this truthmaking bill is undeniable. A thing *a*'s mass being *m* units is clearly part of what makes it true for all *f* that any net force of *f* units which did not change *m* would accelerate a at *f*/*m* in the direction of *f*. Why then should we not say the same of fragility? Is not *a*'s fragility the property that is part of what makes it true that, if *a* were stressed without changing this property, it would break?

6. Dispositional and categorical properties

One reason for denying that fragility is a property in the above sense is that we think it need not be the same property which makes all fragile things satisfy fragility's reduction sentence. Things of different kinds may be made fragile by quite different properties, which I shall follow the custom of calling fragility's "bases" (Mackie 1972 ch. 4.2). But then the term "fragility" looks as if it may no more name a property than, it has been argued, terms like "redness" do. That is, just as there is no one property of being red, but only its bases, the quite different properties that make light, and things that emit, transmit and reflect light, satisfy the predicate "red" (Mellor 1997), so there may be no such property as fragility, only its bases, the different properties that make things of different kinds satisfy the predicate "fragile".

This is a widespread view, especially among physicalists (e.g. Smith and Jones 1986 ch. 11), to whom it appeals because it lets them postulate only physical truthmakers for all applications of mental predicates. On it, a dispositional predicate picks out a property only if, unlike fragility and redness, it has a single so-called "categorical" basis, with which the apparently dispositional property can then be identified. This is the view defended by Armstrong in his debate with Martin and Place (Armstrong et al. 1996). Against it Place argues that, besides categorical properties, the world contains irreducibly dispositional ones, whose mark he thinks is the intentionality, i.e. the directedness on possibly non-existent states of affairs (like *a*'s breaking when dropped), that Brentano took to be the mark of the mental. While Martin argues against them both that no real property is either wholly "qualitative" (his term for categorical) or wholly dispositional.

This aspect of their debate seems to me to rest on a category mistake. Dispositionality is a feature not of properties but of predicates, namely of those whose application conditions can be stated in reduction sentences. This gives us no reason to think that the corresponding properties (if any) are all of a kind, and different in this respect from properties corresponding to non-dispositional predicates (if any). If predicates like "of mass *m*" and "triangular" are as dispositional as "fragile", this no more

makes mass and triangularity wholly or partly dispositional than a distinction between fragility and its bases requires the latter to be categorical. Properties in our sense—non-particular constituents of truthmakers, which make particulars that share them resemble each other—need not in themselves be either dispositional or categorical: those that exist can just be.

The question then is whether fragility exists, not whether it differs in kind from its bases. What is wrong with the view that it does not exist, precisely because its bases do? This view certainly looks better than the view that a fragile glass *a* has two properties—namely fragility (*F*) and one of its bases (*B*)—of which only one makes it true that *a* would break if dropped. That seems only to provoke such unwanted questions as: how is *F* related to its bases, if not by being identical to (and hence only having) one such basis; and is it being *F* or being *B* (or both) that causes the effects of *a*'s fragility, such as breaking when dropped?

Some claims about how *F* and *B* are related seem to me unenlightening, notably the claim that *F* is the second-order property of having one, e.g. *B*, of the first-order properties that are its bases (Prior et al. 1982). As it stands, this seems to me empty word-play which, in particular, does nothing to answer the question whether being *F* or being *B* is what makes *a* break when dropped. However, we shall see in §8 how to give this claim a clearer reading on which, at least for fragility, it comes out true. But first we must press our original question: why suppose that there is a property of fragility, over and above the properties that are its bases?

One reason is this. We have noted that Armstrong and others who think that only the bases of dispositions exist assume a dichotomy between dispositional and categorical properties. The former are the merely apparent properties, whose ascription to any *x* is to be analysed by saying that *x* has some property which makes it satisfy such-and-such reduction sentences. The latter are the real properties, over which these second-order existential quantifiers range. It is *x*'s possession of these categorical properties, together (if need be—see §7) with the laws of nature that make the relevant reduction sentences true, which makes it true to say that *x* has such-and-such dispositions.

But if, as I have suggested, to call a property *F* "dispositional" is just to transfer that epithet from the predicate "*F*", this is a false dichotomy. For on the one hand there will then be few if any non-dispositional factual properties, i.e. properties whose predicates have application conditions that are not given by reduction sentences. And on the other hand, any property that is part of what makes a predicate apply to something must be as categorical, i.e. as real, as any other. So it cannot follow that fragility is not a real, i.e. not a categorical, property just because it is a disposition. If it did, masses, like all other standard scientific properties, would not be real either, and we should have no bases for fragility or anything else.

The real reason for being more sceptical of fragility than of mass is not that the former is a disposition and the latter is not. It is that whereas we think the same property makes all things of ten kilogrammes (say) satisfy that predicate, we think, as I have remarked, that different properties may make things of different kinds satisfy the predicate "fragile". But is this really so?

7. Properties and laws

To answer this question we need to know what determines what factual properties there are. One answer is implicit in Shoemaker's (1980) well-known view that factual properties are definable by how they combine to fix the causal powers of things—as when having the properties of being steel and of being sharp-edged combine to give a knife the power to cut. This suggests that the factual properties which actually exist are those that are needed to provide all the causal powers things in our world can have.

On a law-based account of causation, this generalises into the criterion that the actual factual properties are all and only those that occur in actual laws of nature. This is a more general criterion because it also covers properties in laws which may not be causal: such as probabilistic laws (like those of radioactive decay), equilibrium laws (e.g. the gas laws) and conservation laws (e.g. of energy); and also relations, such as distances in space and time. On this criterion, for properties like being 10 kilogrammes

to exist is for them to occur in laws of nature, causal or otherwise, such as those of inertia and gravity.

More specifically, suppose we could conjoin all law-statements and then form that conjunction's so-called Ramsey sentence. That is, suppose we could replace all the predicates in a single sentence stating this conjunction with second-order variables bound by existential quantifiers prefixed to the whole sentence. Then I think the factual properties that exist in our world are those over which the quantifiers of this Ramsey sentence of the conjunction of all laws would need to range to make the sentence true (Mellor 1997).

Either of these criteria of what factual properties there are will fit our use of reduction sentences provided we account for causation and laws in terms of conditionals, as I think we should and many of us do. Thus in a Newtonian world a thing *a* will have any mass *m* if and only if it has a property *m* such that *a* would:

> be accelerated at f/m by any net force f that did not alter m;
>
> exert on other things with this property at any distance r a force proportional to m^2/r^2;

and so on, for all the other actual laws in which masses occur. These reduction sentences will then suffice to distinguish all masses from each other and from all other factual properties.

This account of properties incidentally supports Lowe's (1989 p.170) claim that

> when a disposition is predicated of an individual, it is thereby implied that that individual satisfies some (possibly not as yet fully specifiable) natural law.

This is because, as we have seen, dispositional predicates have application conditions, statable by reduction sentences, which include having or lacking properties whose presence or absence is linked by laws to that of other such properties. This also explains the truth in Lowe's claim that dispositions are properties of kinds rather than of things, namely that a thing's properties and the laws they occur in determine the kinds it belongs to and hence which dispositional predicates apply to it.

The main question raised by this criterion of what properties there are is whether it makes properties entail the laws they occur in. I think it does not; Shoemaker thinks it does. This does not of course require him to deny that laws may be contingent, since a property's existence may be contingent, e.g. on its having instances (Armstrong 1978 ch. 11). However, it takes more than this to let a given property occur in different laws, as I think it sometimes can. Thus I think for example that masses could occur in somewhat different laws, such as those of a Newtonian world where accelerating things did not automatically increase their masses, as it does in our world (Mellor and Oliver 1997 Introduction §14). Yet a causal or law-based criterion of identity for properties may well seem to rule this out.

The reason it does not rule it out is that this criterion, like Davidson's (1969) well-known causal criterion of identity for events, need only be a criterion of actual identity, not of counterfactual identity. Thus for Davidson events e and e' are identical if and only if they have all the same actual causes and effects. This need not entail that the very same event e, i.e. e', could not have had somewhat different causes and effects, as often it clearly could. Equally the thesis that properties F and F' are identical if and only if they occur in the same way in all the same actual laws need not stop the very same property F, i.e. F', occurring in somewhat different laws in other worlds.

Nor need the transitivity of identity rule this out, although it may seem to. For suppose a given property F exists in all and only possible worlds where it occurs in at least nine of the same ten laws, which in our world are L_1 to L_{10}. Now take two worlds with the same laws, except that in one world L_1 is replaced by L_1* and in the other L_{10} is replaced by L_{10}*. Then although a property exists in each world that is identical with our property F, they are not identical with each other, as each occurs in only eight of the other's ten laws, thus violating the undeniable transitivity of identity.

This objection may be met in at least three ways. Actualists, who deny the existence of other possible worlds, may simply equate the contingency of a law that all *F*s are *G*s with its deniability without contradiction. Others, who let any factual predicate define what Lewis (1986 ch. 1.5) calls an "abundant" property, identified with the set of all its possible instances,

can take our criterion to be a test not of identity but of "naturalness" and hence resemblance: for the more properties that laws correlate with *F*, the more resemblances we can use being *F* to "project" (Goodman 1965 ch. 4). While those who deny all trans-world identity, and think therefore that other worlds cannot contain *F* itself but only "counterparts" of *F*, may still take the occurrence of these in all and only worlds where at least nine of L_1 to L_{10} hold to make "*F* could have occurred in L_n*" true for all *n* from 1 to 10 (Lewis 1973 ch. 1).

The best argument for taking properties to entail the laws they occur in rests on the concept of truthmaking, which I have so far taken for granted. The usual definition of a truthmaker for a sentence, statement or proposition "P" is of an entity O such that "O exists" entails "P" (Mulligan et al. 1984, Fox 1987, Restall 1996). What these truthmaking entities are – e.g. Armstrong's (1997 ch.1) states of affairs, my (1995 ch. 13.4) facta, or Williams's (1953) tropes – is a contentious question that fortunately we can ignore. Here for brevity and neutrality I shall simply call them "facts", where "P is a fact" must of course now mean more than that "P" is true.

Suppose then that "P" is one of the reduction sentences given in §7 for a thing *a*'s having a mass *m*, namely that

> *a* would be accelerated at *f*/*m* by any net force *f* that did not alter *m*.

The apparent truthmaker for this "P" is the fact that *a* has mass *m*. But for this to be the whole truthmaker, if the law L of which "P" states an instance is contingent, the existence of the property *m* must entail it. Otherwise the fact, O, that *a* is *m* will not entail "P", since *m* could exist even if L did not. The truthmaker for "P" will then need to include L as well as O.

But the ontology of laws is notoriously problematic, with candidates ranging from Humean regularities to relations between properties (Dretske 1977, Tooley 1977, Armstrong 1983). It is tempting therefore to bypass the problem, or at least reduce it to the question of what properties are, by taking the existence of factual properties to entail the laws they occur in. For then we can dispense with laws as truthmakers, even for law statements, which can all be made true by the existence of the properties and relations they refer to (Mumford 1998 ch.10).

8. The ontology of fragility

Whether properties entail any or all of the laws they occur in is another question I shall leave unsettled. (In what follows I shall write as if they do, by not including laws in my stated truthmakers, but this is just for brevity.) Fortunately we need not settle it in order to decide whether the property of fragility exists. All we need to decide that is our Ramsey-sentence criterion for what factual properties there are.

This criterion tells us first that fragility's bases are probably conjunctive.[3] For any basis for F, in order to differ from F itself, must make at least one extra reduction sentence true. So let S_F be the conjunction of F's reduction sentences, and S_B the extra sentence or sentences that a specific basis B of F makes true. Thus basis 1 makes $S_F\&S_1$ true, basis 2 makes $S_F\&S_2$ true, and so on. But then a basis need not be simple: it can be a conjunction, either of F itself with a different property that makes S_B true, or of one property that makes true some conjuncts of S_F with one or more properties that make true all the other conjuncts of $S_F\&S_B$. In the first case, F will itself be a simple property, in the second it will not; but either way, its basis will be complex.

In particular, this will be so whenever what we call F's basis in things of kind K_1 is a property B_1, in things of kind K_2 another property B_2, and so on, where K_1, K_2 etc. are themselves mutually exclusive properties, simple or complex. (Suppose for example the basis of fragility in glass (K_1) is one molecular structure (B_1), in china (K_2) another such structure (B_2), and so on.) For then F's full basis in any fragile thing x will be the conjunction $K_1\&B_1$ if x is K_1, the conjunction $K_2\&B_2$ if x is K_2, and so on. In short, if F has more than one basis – i.e. is not its own basis – then its bases will almost certainly be complex.

And if F's bases can be complex, why not F? Why, in particular, if anything is (truly called) F if and only if it is either $K_1\&B_1$ or $K_2\&B_2$ or …, cannot F be the property that is the disjunction of these bases, i.e. $K_1\&B_1$-or-$K_2\&B_2$-or-…? The reason is that whether or not conjunctions of prop-

[3] By a "conjunctive basis" I mean one that is either a conjunction of two or more properties or a single conjunctive property, i.e. one that is itself a conjunction of other properties. For present purposes it doesn't matter which, so we can avoid the vexed question of whether there are any conjunctive properties (Mellor 1992, Oliver 1992).

erties can be properties, most disjunctions of properties cannot, given that, as we are assuming, sharing a property entails resemblance. For then, for example, calling being hot-or-cold a property implies that hot and cold things *ipso facto* resemble each other in temperature, which clearly they do not. Similarly, given that K_1, K_2 etc., are quite different and mutually exclusive kinds, for things that are $K_1\&B_1$, $K_2\&B_2$ and so on. So it cannot be the non-existent disjunctive property of being $K_1\&B_1$-or-$K_2\&B_2$-or-… that makes all these things resemble each other. It must be the fact—in the weak non-truthmaking sense of "fact"—that all these things would all break if stressed, i.e. that they are fragile.

It does not however follow from this that every fragile thing x must share a simple, or at least a non-disjunctive, property F in order to make fragile things resemble each other in this way, and to yield an atomic fact, Fx, to cause x to break when stressed. For first, making the sharing of properties entail resemblance does not require the entailment to go the other way: things can resemble each other without sharing a corresponding property. And second, it follows from my view of causation that causes and effects need not be atomic or otherwise truthmaking facts (Mellor 1995 ch. 13). In particular, the cause of any x's breaking when stressed need not be that x has a single property F: it can be the disjunction that x is $K_1\&B_1$, or is $K_2\&B_2$, etc., and hence in the circumstances (that x is, say, K_1) the non-disjunctive truthmaking fact that x is B_1. Thus "x breaks when stressed because it is F (i.e. $K_1\&B_1$ or $K_2\&B_2$ or …)" and "x breaks when stressed because it is B_1" can both be true even though there is no such property as F. This also provides a clear reading, promised in §6, of the claim that "F is the second-order property of having one, e.g. $B_{[1]}$, of the first-order properties that are its bases", which allows x to break when stressed both because it is (truly called) F and because it is B_1. Because facts need not be truthmakers to be causes, both these facts are equally good and perfectly consistent causes of x's breaking when stressed.

This does not, therefore, require x to have two properties, F and B_1. For, since no property F is a constituent of the fact that x is $K_1\&B_1$ or $K_2\&B_2$ or …, no such property need exist. So as there need be no such property as fragility—and by our Ramsey-sentence criterion there is not, since in

no law of nature does fragility occur as such—none of the unwanted questions raised in §6 need arise. There need be no double-counting of the properties that make a fragile *x* break when stressed, and so no overdetermination of its doing so. This and all other effects of *x*'s being fragile are caused, not by *x*'s having the non-existent property of fragility, but by *x*'s having the property that is fragility's basis in things of whatever kind *x* is.

9. Temperature: a real disposition

This easy answer will not however work in all cases, as the case of temperature shows. Many philosophers, misled by Kripke (1971), identify temperature with its basis in gases, namely—assuming for simplicity a certainly false (because deterministic) kinetic theory of gases—the mean kinetic energy of gas molecules. But as an identity thesis, this will not do, for at least three reasons (apart from the falsity of the theory). First, the thesis implies that increasing the velocity, and hence the kinetic energy, of a single molecule would automatically raise its temperature, which is absurd. Second, there is in reality no property of mean kinetic energy to identify temperature with, any more than there are in reality the 2.4 children that average families have: there are only the actual kinetic energies of individual molecules, whose mean value is what the kinetic theory relates to a gas's temperature. Third, and most important here, not all temperatures of entities can be identified with molecular kinetic energies: in particular, radiation temperatures cannot, since radiation contains no molecules. In short, every temperature—e.g. 100°C—resembles fragility in having different bases in entities of different kinds.

Unlike fragility, however, equilibrium temperatures, as defined by the laws of thermodynamics (Denbigh 1955 ch. 1), are real properties, quantified over in these and many other laws, such as those relating the kind, mass, volume, pressure and temperature of gas samples in equilibrium. Here therefore we do face the question of how equilibrium temperatures are related to their different bases in, say, gases and radiation.

To simplify the question we may waive the objections raised above and suppose that the basis of the temperature T of a gas G in thermal equilibrium is indeed the mean kinetic energy E of G's molecules, where E is an increasing function of (and only of) T. In isotropic radiation R in thermal equilibrium (so-called "black body radiation"), T's basis is quite different, namely R's energy flux X, another increasing function of, and only of, T (Zemansky 1957 ch. 5.10).

Now imagine a vessel containing both a gas G and radiation R in thermal equilibrium at a temperature T. The separate laws linking E and X to T, plus the laws of thermodynamics, make E and X functions of each other which entail that increasing either of them will cause the other to increase. Thus suppose for example that the internal walls of our vessel are silvered, and neither emit nor absorb radiation, but that warming them warms the gas G by increasing its molecules' mean kinetic energy E by an amount ΔE. This will raise G's temperature T_G by a corresponding amount ΔT, which will then raise R's temperature T_R by the same amount until it equals T_G, thereby increasing R's energy flux X by an amount ΔX.

This example shows clearly that E, X and T are distinct properties, linked to each other and other properties by laws of nature which thereby fix the causal powers of entities that have them. Now consider the effect of increasing T by ΔT on the pressure P of the gas G in our vessel. The gas laws entail that, if G's volume is constant, this increase in T will cause an increase, ΔP, in P. But what then is the real cause of ΔP? Is it ΔT, the increase in G's temperature T, or ΔE, the increase in T's basis in G, namely the mean kinetic energy of G's molecules? And if we say it is both, are we not double-counting the causes of this increase in G's pressure, and thereby overdetermining it?

10. Overdetermination

The charge of double-counting we may dismiss at once. Nothing in any current account of causation stops effects having several simultaneous causes. Thus suppose we require causes to be, in the circumstances, both sufficient and necessary for their effects, and consider the well-known

example of a spark causing fuel to burn in oxygen. What causes the fire: the spark, the fuel or the oxygen? The answer can be that all three cause it: since each of them, given the other two, can be both sufficient and necessary for this effect.

Overdetermination, on the other hand, really does pose a problem. In the case of the fire there is no overdetermination, since each of the fire's three simultaneous causes needs the other two in order to produce its effect. But that is not so with our gas *G,* where neither ΔT nor ΔE seems to need the other in order to cause the increase ΔP in *G*'s pressure. And this poses a problem for any theory of causation which requires causes to be, in the circumstances, both sufficient and necessary for their effects. For if each of these two apparent causes is, independently of the other, sufficient for the effect, neither of them can also be necessary for it; and so neither can be a sufficient and necessary cause at all, which is absurd. For if neither raising a gas's temperature nor raising the mean kinetic energy of its molecules is what causes its pressure to increase, what is?

The stock response to such cases is to say that, as overdetermination never occurs, ΔT must either not exist, or be identical to ΔE, or at least supervene necessarily on ΔE, meaning that we could not have ΔT without ΔE—and similarly therefore for *T* and *E* themselves (Peacocke 1979 ch. 3.3, Mumford 1998 ch. 7.4). But this ostrich-like answer will not do, since effects often are overdetermined, as when I hold my trousers up with both belt and braces. To deny this, just because it makes an otherwise attractive theory of causation imply that neither my belt nor my braces causes my trousers to stay up, is like trying to solve the problem of evil by denying that there is any. Overdetermination, like evil, exists, and poses a serious problem for the theory of causation, a problem to which I know of no perfect solution (Mellor 1995 ch. 8.6).

Fortunately, however, that problem need not concern us, since although it could arise here, it need not. For all we need, in order to avoid overdetermination, is a counterfactual link between ΔT and its gaseous basis ΔE to ensure that, in the circumstances, we shall get ΔT if and only if we get ΔE. And such a link does not require *T* either to be identical to *E*, or to supervene on *E* necessarily. All it requires is a contingent law of nature to give all gases (or all gases of a certain kind or kinds) a temperature *T* if

and only if their molecules have a mean kinetic energy E. Such a law can make T and E, and hence ΔT and ΔE, supervene contingently on each other in gases, thus enabling each of these changes to be a sufficient and necessary cause of ΔP.

This, I maintain, is the right answer to the question of which of ΔT and its basis ΔE really causes ΔP: they both do. As causes of this effect, we no more have to choose between them than, to take another well-worn example, we have to choose between mental and physical events or states as causes of behaviour. There too laws of nature—in that case psychophysical laws (pace Davidson 1970: see Crane and Mellor 1990 §4)—suffice to make events and states of these two kinds supervene contingently on each other, so that each can be both sufficient and necessary causes of our actions.

In neither case, therefore, should an unfounded fear of overdetermination lead us to deny the existence of real and categorical properties of both kinds: namely, on the one hand, of mental and thermal dispositions and, on the other, of their equally dispositional and distinct physical and kinetic bases. In short, and in general, all a factual property F needs, in order to have in things of any kind K a distinct and non-overdetermining factual basis B, is that among the many laws these two properties occur in is the law that all K things are F if and only if they are B.

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