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Micro-composition[1]

1. Introduction

Entities of many kinds, not just material things, have been credited with parts. Armstrong (1978: 36), for example, has taken propositions and properties to be parts of their conjunctions, sets to be parts of sets that include them, and geographical regions and events to be parts of regions and events that contain them. The justification for bringing all these diverse relations under a single 'part–whole' concept is that they share all or most of the formal features articulated in mereology (Simons 1987). But the concept has also prompted an ontological thesis that has been expressed in various ways: that wholes are 'no ontological addition' to their parts (meaning their *proper* parts, i.e. not counting a whole as a part of itself); that to list both a whole and its parts is 'double counting'; and that there is 'no more' to a whole than its parts: for example, that there is no more to a conjunction (i.e. to its truth conditions) than the conjuncts that are its parts, and whose truth or falsity determines whether it is true or false. For brevity, I shall express the thesis in the last of these ways, as the claim that entities with parts are 'nothing but' those parts.

The first thing to be said about this thesis is that, to be serious, it must not just mean that a whole is the mereological *sum* of its parts: for since a whole is just what the term 'sum' means in mereology, that is a tautology. Just what a non-trivial reading of the thesis amounts to is a good question, whose answer may well vary from case to case. Here, however, I shall only ask it about *things*, meaning material things, including us (or at least our bodies). My question then is this: how must a thing with parts be related to those parts for a serious nothing-but thesis to be true of it, and are such things in fact so related to their parts? And to avoid the question of whether things have temporal parts, and to allow their non-temporal parts to change over time, I shall only consider a thing's relation to the *spatial* parts it has at any one time, a temporal proviso that from now on I shall mostly take as read.

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[1] Common ancestors of this paper and of (Mellor 2006) were given at the University of St Andrews on 11/6/2005 and at the Central European University in Budapest on 11/10/2005. Earlier versions of this paper have been given at the University of Cambridge on 13/2/06, to the Royal Institute of Philosophy Conference at the University of Leeds on 1-3/9/2006 and, on 12/9/2007, at the University of Otago, to whom I am also indebted for awarding me a visiting De Carle Lectureship that has given me ample time and good company in which to complete a final revision of the paper. The end result, such as it is, owes much to comments made on all the above occasions, but especially to Robert Williams's reply to the version given in Leeds.

2. Containment

Part of the answer to my question is easy: a thing B can only be a part of another thing A if B is *inside* A, i.e. if A *contains* B. Yet easy though this answer is, it is also not very clear. Some unclarity can be dispelled by requiring the parts of things to be *wholly* inside them, and by stipulating that, if surfaces are things too, a thing's surface is also inside it. But that will not be enough if it is unclear, as it often is, where a thing's surface is. Take a plastic bucket half full of water: if its surface includes a plane across the top of the bucket, the water will be inside it; if its surface is just the inner and outer surfaces of the plastic, the water will be outside it. In short, 'the water is inside the bucket' will be true if 'the bucket' refers to what we might call the 'full' bucket, false if it refers to what we might call the 'empty' one.

Similarly, a plane's crew and passengers will be inside it if 'the plane' refers to the 'full' plane, whose surface is that of its outer skin, and outside it if 'the plane' refers to the 'empty' one, whose surface is the outer and inner surfaces of its skin (but including, let us suppose, its furniture and fittings). And as in these cases, so in others: what things contain is often relative to a somewhat arbitrary specification of their surfaces.

This, however, will not stop the containment condition making things constrain the spatial distribution of their parts.[2] The reason the constraint is this way round, with the locations of wholes constraining those of their parts, and not *vice versa*, is that, by definition, nothing outside a thing can be a part of it. So when a thing moves, it does not move because its parts do: they move because it does, simply because any part that stays behind will thereby cease to *be* one of its parts. That is why severing a new-born child's umbilical cord makes the child cease to be a part of its mother, and why water removed from full buckets, and people removed from full planes, cease to be parts of them: detaching parts stops whatever they are parts of automatically taking them with it when it moves.

3. Causation

Yet why does detaching parts of people, buckets and planes stop them being parts of those things? Why does giving birth shrink a mother's surface to exclude her now-detached child instead of extending it to continue to include the child? The obvious answer is that detaching parts of a thing severs the causal links that make that thing take those parts with it. But then

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[2] I say 'constrain' rather than 'entail' to let the surfaces of things enclose gaps between their parts. We can then deny, for reasons to be given in §5, that small cracks within the plastic of an 'empty' bucket, or the air above the water in our 'full' bucket, are among its parts while accepting, for the same reasons, that the vapour above the brandy in a brandy glass *is* a part of the 'full' glass.

there must be more to being part of a thing (if not to being part of a spatial region) than being inside it: something else, by constraining where its surface is, thereby constrains what other things can be parts of it. That something else is, of course, causation: we require a thing A's surface to contain, and thereby to allow to be parts of A, all the things whose causal links give A the causal unity that makes it a single thing: for example, by making all its parts accelerate together when forces are applied to only some of them.

This inevitably makes the causal condition vague, by making it context-dependent: for example, the surface of a thing that an applied force would accelerate as a whole may vary with how large the force is and to which parts of the thing it is applied. This dependence may then allow us, or force us, to make an arbitrary stipulation about exactly where a thing's surface is. But not any stipulation, since some will be ruled out by the relevant causation which while it may, for example, let the context determine whether my surface contains the clothes I am wearing, will always require it to contain my head and not to contain my exhaled breath, and other widely dispersed bodily effluent, just as it will require a mother's surface not to contain her grown-up children and all their descendants (see fn. 2).

That the parts of things must meet some such causal condition is no news, as van Inwagen's (1991: 81) claim that 'parthood essentially involves causation' shows. And while this cannot be true of the parts of propositions, properties, sets, or regions of space or spacetime, it can certainly be true of the parts of things. Its truth will also explain why some things inside a thing are not parts of it. For example, if (*pace* van Inwagen) my body contains cells, organs and limbs, it also contains an uncountable number of spatial points and regions. The fact that these are all parts of the larger region my whole body occupies need not make them also parts of it, because they fail this causal condition: they are not among the things inside me whose causal links contribute to my body's causal unity.

It is for the same reason that most photons passing through a window are not, while they do so, among its parts: they too, like spatial regions inside the window, lack enough causal links to the molecules and other things it contains whose causal links do make them parts of it. And similarly in other cases. So while the causal condition's context-dependence can stop it being clear whether some entities inside a given thing are parts of it, the causal limits the condition sets to this dependence can also make it clear that other things inside it are not.

4. Working parts

This causal condition, which I shall call the 'working parts' condition,[3] also implies that there is more to a thing's causal unity than the inertial unity that makes forces applied to parts of it move all of it. For inertial mass is not the only property of a thing that depends on the interactions of its parts. Its temperature, for example, depends on the kinetic interactions of the molecules it contains, a dependency that makes all those molecules parts of it, even those that would not move if it moved and on which, therefore, its mass does not depend.

But why then should the molecules on which a thing's temperature depends be contained within the very same surface that contains those on which its mass depends? The reason is that a thing's surface marks a spatial cut-off not just of one but of most if not all of those causal interactions of its parts on which its non-relational properties (hereafter *properties* for short) depend. The fact that it does so is both shown by and explains the fact that the surfaces of macroscopic things usually separate different phases,[4] either of a single substance, as with those of lumps of ice, or bubbles of steam, in water, or of different substances, as with the surfaces that separate us from the air around us, or drops of oil from the surrounding vinegar in a vinaigrette.

That we expect a thing's surface to provide several coincident causal cut-offs is also shown by our attitude to apparent things whose surfaces do not do this. Take clouds, for example, or holograms, or mirror images: although they look like single things, we may be reluctant to accept them as such, because their visual surfaces coincide with few if any other causal cut-offs. That is why we try to explain them away by showing how all the truths that are apparently about them can be made true by facts about such things as the drops of water that clouds contain. Hence the appeal of the thesis that clouds are 'nothing but' these drops, a thesis that lets us explain the appearance of clouds while denying them an independent reality. But while this nothing-but thesis may well be true of clouds, it remains to be seen whether it is true of all apparent things with parts, including things like water drops.

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[3] I owe the term to David Lewis who, apropos temporal parts, called concepts of the parts of things which, unlike his, include some such causal condition, 'working parts concepts'.

[4] Not always, since the surface of a 'full' plane (§2) must include the apertures by which air enters its engines and their exhausts leave it; exceptions explicable by the way crucial properties of the plane depend on properties and relations of the gases flowing between these apertures, which is what makes the plane's parts include the gases that they and the engines' inner surfaces enclose. Cf. the orifices that our bodies' surfaces include, and the top surface of the 'full' brandy glass of fn. 2. By the same token, fn. 2's 'full' bucket half full of water will only be a real thing, i.e. the plane across the bucket's top will only be part of a real surface, if the context makes that plane a relevant causal boundary between the air above and below it.

5. Significant effects

I have said that the working parts condition can let a thing's parts include any of the things inside it whose causal links affect any of its properties, not just its inertial or thermal ones. But not every effect, however slight, on any of a thing's properties, however trivial, will do. For, as we have seen, the existence of a thing's surface, and thus of the thing that has it, presupposes causal cut-offs at that surface; cut-offs which, however, on any credible theory of causation, will certainly fall short of complete causal isolation. This being so, the working parts condition must, if it is to set any limit to the surfaces of things, allow things outside a thing A to have *some* effects on A's properties.[5] But then it must also admit that things *inside* A can have effects on A's properties that are too slight to make them parts of A. It can only require a thing's parts to have effects that are both significantly large and on properties that we take to be important to things of that kind. That is why a window's parts need not include the spatial regions inside it, despite their spacetime curvature having an effect on its inertial properties, i.e. on how it moves when no forces act on it: the effect is negligible. Similarly for the effects on a window's properties of photons passing through it: those effects are usually far too slight to make the photons parts of it.

The trouble with all this, of course, is that it threatens to reintroduce context-dependence into our part–whole concept, a threat that may prompt us to look for some other reason to deny that photons are parts of everything they are passing through. One such reason might be that photons pass through things too quickly to meet a requirement that parts be relatively permanent. So maybe a thing's parts are the things inside it that stay inside it far longer than photons do? Not so; for a permanence condition that ruled out photons might also rule out such indubitable parts as the molecules we continually gain and lose through our skin and lungs. Worse, it would make spatial points and regions parts of any sufficiently slow-moving things that contained them. To rule these out, as well as most passing photons, requires something like the working parts condition which, as we have seen, we need anyway in order to set causal limits to the surfaces of things.

Still, there are objections to the working parts condition. One arises from requiring a thing's parts to have significant effects on it when, for example, no one molecule out of the millions that I take to be parts of my body will affect it significantly. Nor will any one of the many hairs on Geach's (1967) and Lewis's (1993) imaginary cat Tibbles have any significant

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[5] See §10 for examples, and for how the nothing-but thesis can accommodate them, by requiring them to be mediated by their effects on A's parts.

effect on that cat. How then can a working parts condition rule out spatial regions, and most passing photons, without also ruling out our bodies' molecules and Tibbles's hairs?

The answer to that question comes in two parts. One part lets each of Tibbles's hairs count as parts because collectively they have significant effects on Tibbles's shape, colour, thermal insulation, etc. The other part exploits a postulated transitivity of the part–whole concept to let my haemoglobin molecules, for example, be parts of my body because collectively they have significant effects on my blood, which in turn has significant effects on my body; and similarly for the many other kinds of molecules that are also parts of my body.[6] Whereas not even collectively do spatial regions inside a window, or photons passing through it, usually have significant effects on it. When photons do, as when solar radiation causes a stained glass window's colour to fade, the working parts condition will let the photons inside it be parts of it; and to that I see no stronger objection than an unmotivated prejudice.

6. Vagueness

To all this it may again be objected that it makes the working parts condition irredeemably vague. But vagueness here is not a defect but a merit, since it enables the condition to explain why it often *is* a vague matter whether one thing is part of another. Take Tibbles again, for a reason that differs from Lewis's, which was this: consider the many actual cat-like things that differ from Tibbles by excluding just one of Tibbles's hairs, a different one in each case; if each of these things is a cat, then while all are equally good candidates for being Tibbles, they cannot all *be* Tibbles, since a given hair cannot both be and not be a part of a single cat. That is Lewis's problem, which he solves by replacing a single actual cat with all these actual and overlapping ones. I reject his solution, as I reject his problem, by denying that any Tibbles-less-one-hair *is* an actual cat, as opposed to a merely possible cat that would be actual if Tibbles actually lost that hair (Mellor 2006).

My Tibbles problem is different. For me, the problematic hairs are not those that are definitely parts of Tibbles, but those that are borderline parts of Tibbles, perhaps because they are falling out and thereby ceasing to be among those that collectively affect Tibbles's shape, colour, thermal insulation, etc. For what the existence of these hairs shows is that whether one thing is a part of another can be, and often is, as vague a matter as how many hairs Tibbles would have to lose to become bald. And many other examples show this too,

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[6] The relevant causation may not be transitive, since the significant effects of haemoglobin molecules on my blood might not be what makes my blood have significant effects on my body as a whole. Still, our part–whole concept can always be made transitive by letting the *ancestral* of these cause-effect links make it apply.

such as a snake's not-quite-sloughed-off skin, or the semi-detached molecules on the surfaces of things. In all these cases it is the vagueness of the working parts condition that explains that of the 'is a part of' predicate.[7]

An explanatory vagueness is not the working parts condition's only merit. The condition can also settle some otherwise hard cases. Take aircraft pilots: are they parts of the planes they fly, where by 'planes' I mean 'full' planes that contain their passengers and crew (§2)? When a plane's pilots are built-in autopilots, the working parts condition certainly makes them parts of it, because their causal interactions with other parts – the plane's engines, wings, etc, – affect important properties of the plane as a whole; and that seems right. Why then might we decline to call human pilots parts of their planes? If it is because there is a lot more to human pilots than flying planes, which most of the time they are not doing, that is irrelevant when the question is what parts things have at a given time, and hence whether human pilots are parts of their planes while they are flying them. To that question the working parts condition clearly entails the otherwise unobvious answer that they are.

Similarly in cases, like those of passengers in buses, trains and ships, that may be both hard and vague. If the working parts condition tells us that these vehicles' drivers usually are parts of them, it may also tell us that their passengers are usually not, since even collectively they usually affect important properties of the vehicles far less than do their drivers. On the other hand, the condition may well make a plane's parts include its passengers, whose collective effect on its weight matters far more to a plane than it does to most vehicles on sea or land. This not-implausible distinction nicely illustrates a working parts condition's ability to tell us that, and why, some things are parts of the things that contain them, others are not, and, in yet other cases, whether they are or not is a vague matter.

7. Microreduction

Having said what makes one thing part of another, I can now return to the question of what it means to say, seriously, that a thing with parts is, at any one time, nothing but the parts it has at that time. This claim is an ontological version of *microreductionism*, the thesis that facts about spatially extended entities can or should be reduced to facts about their spatial parts (Oppenheim and Putnam 1958; Schlesinger 1963: ch. 2).

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[7] I do not claim that being entailed by vagueness in the working parts condition enables vagueness in instances of this predicate to escape the problems raised by vagueness in general (see Keefe and Smith 1996), only that whatever solutions work for predicates like 'is bald' should also work for 'is a part of': see §9.

Microreductionism, so understood, is a significant thesis in the philosophy of science. In the social sciences, it takes the form of *individualism*, which says that facts about social entities – governments, firms, unions, bands, etc. – can or should be reduced to facts about their human members (Bhargava 1992). Individualism may be read ontologically, as saying that talk of social entities is only a convenient way of talking collectively about their members, who are in reality all there is to them. And even when it is read methodologically, as saying merely that facts about social entities should be explained by facts about their members, its rationale may be ontological, the tacit justification for requiring facts apparently about social entities to be explained by facts about socially related people being that the latter are all the social facts there really are.

Mrs Thatcher's reported claim that 'There is no such thing as society' can be read this way, as can the ideas that only people are Kantian ends in themselves (Hill 1998) and that the legal responsibilities of social agents reduce to those of people (see e.g. Duff 1998 §4). The first idea is that social entities, as opposed to their members, are not independent moral patients, and the second that they are not independent legal agents. And I suspect that behind both of these lies the idea that, really, only people exist, so that the moral patiency and legal agency of governments, firms, etc., must reduce to that of their members because those members are all there really is to them.

In the physical sciences, the paradigm of ontological microreductionism is Eddington's (1929: xi–xiv) view of his two tables: his commonplace one, with extension, colour and permanence; and his scientific one, that is nothing but myriad minute particles in empty space. The latter, he says, 'modern physics has by delicate test and remorseless logic assured me … is the only one which is really there'. In other words, all there is in reality to the macroscopic entities we see around us are the microscopic entities that are their ultimate parts. This doctrine is still widely if often tacitly held, being implicit in the ontological deference that many philosophers show to microphysics and which can only be a symptom of the nothing-but syndrome: the conviction that things with parts are really nothing but those parts. Whether that thesis is true is thus a serious question in the philosophy of several sciences, as well as in metaphysics itself. But before I can answer it I need to say more about what the nothing-but thesis entails.

8. Supervenience

The first thing the nothing-but thesis must entail is that the existence of a thing with parts is guaranteed by the existence of those parts, where the guarantee is not just causal but

metaphysical. By this I mean that the thing must supervene on its parts, in the strong sense of there being no possible world in which it (or a counterpart of it)[8] does not exist but all its parts do. For only then will the thing's existence be entailed by that of its parts, which I take to be implied by saying that things are 'nothing but', or 'no ontological addition to', their parts.

This, however, is not all the nothing-but thesis implies, as we can see by supposing that while all of Tibbles's parts exist, they are not all connected. Suppose, for example, that while the head is in Leeds, the rest of the body is in Nottingham, thereby stopping these would-be cat-parts meeting the working parts condition that requires a thing's parts to be causally linked. So what our supervenience thesis (S for short) really needs to say is that what entails the existence of a thing with parts is that all its parts exist *and* have all the properties and causal relations they need to have in order to be parts of a single thing of the relevant kind. So, for a cat like Tibbles to exist, its head must not only exist, it must also have enough properties of a cat's head and be suitably attached to the rest of a cat's body. And similarly for other things with parts.

In assessing the thesis S, so understood, the first thing to note is that it is weaker than it may appear to be; since it implies neither that a thing must have all the parts it actually has, nor that those parts must have all the properties and relations they actually have. For because S's entailment is from parts to wholes, and not the other way round, S does not stop different parts composing the very same whole – e.g. Tibbles – at different times or in other possible worlds. So even if Tibbles is, at any one time, nothing but the parts, including the hairs, it actually has at that time, it could have had different hairs without being a different cat, and it could lose hairs without becoming a different cat. So far so good for the supervenience thesis S.

9. Supervenience and vagueness

But not good enough. The fact is that S is both too strong and too weak. It is too strong to be credible in fact and too weak to be a credible reading of microreduction. And I see no way of making it more credible in either respect that does not make it even less credible in the other.

One reason for thinking S too strong is the vagueness, noted in §6, of many instances of '… is a part of …'. The problem this poses is that, while S can let a hair H be a part of Tibbles at one time, or at one world, and not at another, it seems to require H, at any one time

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[8] Lewis (1973: ch. 1.9): an alternative which for brevity I shall hereafter leave unstated.

and in any one world, to definitely be, or definitely not be, a part of Tibbles. For however vague in this respect our concept of a cat may be, we may well be reluctant to let S make cats themselves vague, by letting Tibbles be nothing but a vague set of cat-parts, when not even Lewis's incredible replacement of a single Tibbles with as many actual cats as Tibbles has hairs (§5) gives any of those cats a vague number of parts.

Fortunately there is at least one view of the vagueness of 'is a part of Tibbles' that credits a single Tibbles with a definite set of parts: Williamson's (1994) epistemic view. For on this view there is always a fact of the matter about whether one thing is a part of another, even if we do not know, and could not discover, what that fact is. So, on this view, just as there is a definite if unknowable number of hairs such that losing just one more would make Tibbles bald, there is also a definite if often unknowable fact about whether any given hair is or is not a part of the one and only actual Tibbles. This, then, may be the view of vagueness that S needs; but as it as also highly contentious, our metaphysics of parts and wholes should, if possible, avoid entailing it.

10. Supervenience and microreduction

Accepting an epistemic view of vagueness might, however, be worth biting a bullet for if the frequent vagueness of the 'is a part of ' predicate was the only problem facing the supervenience thesis S. But it is not: S faces at least two other problems, which between them present microreductionists with an insoluble dilemma. The first horn of the dilemma is that, as I have said, S is too weak a reading of microreduction. What makes it so is that S only requires the *existence* of things with parts to supervene on the existence, properties and relations of those parts. It does not require all their properties to supervene on the properties and relations of their parts, which is what everything I have said about microreduction, and supposed examples of it, presupposes.

Take the particles inside Eddington's 'commonplace table' (§7). Because all it takes to satisfy S is that facts about those particles entail that there *is* a table there, these facts need not entail any more of the table's properties than are needed to make it a table: they need not, for example, entail the table's shape, size, or colour, or even what it is made of. Yet unless facts about a table's parts entail all these facts too, there will be more to the table than its parts. Specifically, applying Quine's (1948) ontological commitment test, our quantifiers will still have to range over the table, as well as over its parts, for every truth that is apparently about it to be statable without using singular terms. But then Quine's test will falsify Eddington's claim that his 'scientific table' – which by definition does satisfy S – is the only one that is

really there. And as with physical, so with social entities. For there to be 'no such thing as society', Quine's test requires every apparently social fact, including every fact about the moral standing and legal liabilities of social entities, to be statable without referring to or quantifying over those entities.

It is S's failure to pass Quine's test that makes it too weak a reading of microreduction. And the only way to strengthen S sufficiently – to what I shall call S* – is to make it require the properties and relations of a thing's parts to entail *all* that thing's properties, not just those the thing must have in order to exist. But then S* will be too strong to be credible in fact, which is the other horn of the microreductionists' dilemma.

However, before saying what makes S* too strong, I should dispose of one specious objection to it. This stems from the fact that many of a thing's properties can be affected by other things that are not parts of it because they are outside it. Take the fact that a table's temperature can be raised by things outside it conducting or radiating heat into it. How can that happen if the table's temperature, like its other properties, supervenes on the properties and relations of its parts? The answer is, of course, that outside things can raise a table's temperature, consistently with S*, by affecting its parts, in this case by raising their mean kinetic energy.

Similarly in other cases. S* need not deny, for example, that our childhood nurture, as well as our genetic nature, affects our abilities, such as our ability to speak English. Nor need it deny that we can be affected by all the outside things that our senses enable us to see and hear. All S* need claim is that outside things can only affect us by affecting parts of us, such as our eyes, ears and skin, a claim to which I can see no obvious counter-examples. In short, what we might call the 'outside-influence' objection to S* is not a serious one.

11. Microreduction, causation and laws

The real objection to S* arises when we ask how the properties and relations of a thing's parts are to entail its properties. There is, of course, an easy answer to this question when asked about the shape of a thing with parts: its shape is linked to the spatial distribution of its parts by their having, by definition, to be inside it. But since, as argued in §2, this link makes a thing's surface constrain where its parts are, rather than the other way round, the link is, if anything, evidence against microreductionism rather than for it.

Shape, however, is a special case, since it is the only property of a thing that is linked by definition to relations – namely the spatial relations – of its parts. Its other properties, such as its mass and its temperature, could still supervene on these and other properties and relations

of its parts. The question is how; and as the condition that things must contain their parts will not tell us, we must turn to the working parts condition. For how, after all, could properties and relations of a thing's parts entail its properties, if not by causing it to have them?

There are, however, two objections to this idea. The first is that causation is rarely if ever simultaneous (Mellor 1995, ch. 17.2), which this supervenience must be. Take mass. Since a thing can always change its mass by gaining or losing parts, its mass at any one time can only supervene on the masses of the parts it has at that time, not on those of the possibly different parts it had earlier. And similarly for all other changeable properties. A gas's temperature at a time can only supervene on the mean kinetic energy of the molecules it contains at that time, not on that of those it contained earlier, some of which may by now have been replaced by molecules with higher or lower kinetic energies. But then, if causes precede their effects, whatever makes the properties of things supervene on the simultaneous properties and relations of their parts, it cannot be causation.

This objection is too quick. For even if causation itself does not link simultaneous properties of things, many of the laws that entail it do. Take Boyle's Law, which says that, at a constant temperature T, the product of the simultaneous pressure P and volume V of any given sample *g* of an ideal gas is a constant. This is an equilibrium law, which only relates P and V when they are unchanging and then entails neither that P causes V nor that V causes P. Yet Boyle's Law does have causal consequences: in particular that, other things being equal, changing V will cause P to change, and *vice versa*. It entails, for example, that halving V by moving a piston into a rigid cylinder containing *g* will, if T is unchanged, double P's subsequent equilibrium value. It also entails that doubling P by doubling the pressure on a balloon containing *g* will, if T is unchanged, halve V's subsequent equilibrium value.

And as with Boyle's Law, so with any deterministic law linking a thing's properties to simultaneous properties and relations of its parts. These laws can also entail that changing the latter will cause the former to change. Suppose, for example, that the temperature T of our gas sample *g* is proportional to the simultaneous mean kinetic energy E of all the particles it contains. This too is an equilibrium law, which only relates T and E when neither is changing and then entails neither that T causes E nor that E causes T. What it does entail is that raising E by injecting fast-moving particles into *g* will cause *g* to have a higher temperature T when its new and existing particles reach kinetic equilibrium.

These examples show how laws of nature linking simultaneous properties and relations of things can entail asynchronous causation. So even if causation itself is never simultaneous,

the laws that entail it might still make a thing's properties supervene on the simultaneous properties and relations of its parts; and I cannot see what else could make the supervenience thesis S* true if they do not.[9] But do they?

12. Contingency and indeterminism

For laws of nature to make S* true, they must relate all of a thing's properties (except perhaps its shape) to simultaneous properties and relations of its parts. Yet even if they do so, they may still fail to make S* true, for two reasons.

First, some of the laws that S* needs may be contingent. And if they are, then some of a thing's intrinsic properties will not be entailed by the properties and relations of its parts. S* must therefore require all the laws it depends on to hold in all possible worlds, or at least, as Mumford (2004) argues, in all worlds where all the properties and relations that occur in those laws exist. Yet not even these, highly contentious, views of laws will save S*.

The reason is that not even a metaphysically necessary law linking a thing's properties to properties and relations of its parts will make the latter entail the former if the law is indeterministic, as many laws postulated by modern physics are. To take the simplest case, suppose an indeterministic law L links a thing's property G to a property F of its parts. Then even if L holds in all possible worlds, it will not entail that anything with F-parts is G, merely that it has a chance of being G which, however close to 1, will still be less than 1. But as this gives everything with F-parts a non-zero chance of not being G, its having F-parts cannot entail that it is G. So even if L is necessary, there will still be possible worlds, almost certainly including ours, where some things with F-parts are not G.

Take for example the actual kinetic theory of gases, which many philosophers may be surprised to learn cannot identify a gas sample's temperature T with the mean kinetic energy E of its particles, since it does not even link T and E deterministically. What it does say is that the temperature T of any sample containing enough particles to be perceptibly gaseous has a chance of corresponding closely to E that is very near to but still less than 1; and that is consistent with T's and E's values not corresponding closely at all. So even if the kinetic theory is necessarily true, far from making E entail that T does correspond closely to it, it entails that E does not entail this. In short, like the statistical and quantum mechanics that

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[9] Even a thing's mass needs a law of nature to relate it to the masses of its parts, as is shown by the fact that it need not be their arithmetic sum. Indeed it will normally be less than this, since combining parts into a whole will normally convert some of their mass into the binding energy needed to hold them together. And even if it does not, and a thing's mass does in fact equal the sum of the masses of its parts, that will not be a law of arithmetic or mereology, knowable *a priori*, but a law of nature that can only be known *a posteriori*.

have superseded it, even a necessarily true kinetic theory not merely fails to support the supervenience thesis S*, it entails that S* is false.

This leaves microreductionists with two equally incredible options. One is to assert, in the teeth of modern physics, that all the laws of nature that S* needs are both necessary and deterministic. The other is to be an eliminativist, which is indeed one way to read Eddington's view of his two tables, i.e. as the view that there are no things with parts, like commonplace tables, only things like fundamental particles that have no parts. But this is not only factually incredible, it also begs the question by presupposing that partless things exist:[10] an assumption that the history of physical atomism shows to be a very poor bet, and certainly not one to which our metaphysics should commit us *a priori*.

I conclude that ontological microreductionism is false. Apart from such highly deniable entities as clouds, few if any things with parts are nothing but those parts. Why then is the idea that they are as tempting as it clearly is? I think its appeal derives from the fact that so many properties of things do depend on properties and relations of things that are their parts. So the real question about parts and wholes is why things of so many kinds meet both of our two relatively independent containment and working parts conditions on parthood: why, in other words, do so many kinds of entities with causally defined spatial surfaces exist, and why do so many of them have other such entities as parts? However, if these questions have general answers, which I doubt, finding and stating them must be matter for another story.

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[10] I do not count the partless spatial or spatiotemporal points whose lack, by definition, of non-spatiotemporal properties (such as kinetic energy) stops them providing a causally adequate ontology even if they do exist and are, despite the argument of §5, among the parts of the material things that contain them.

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