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Some Stuffs Are Not Sums of Stuff

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Milk, sand, plastic, uranium, wood, carbon, and oil are kinds of stuff. The sand in Hawaii, the uranium in North Korea, and the oil in Iraq are portions of stuff. Not everyone believes in portions of stuff.[1] Those who do are likely to agree that, whatever their more specific natures, portions of stuff can at least be identified with mereological sums of their subportions.[2] It seems after all trivial that a given portion of stuff just is all of its subportions combined—not by a spatiotemporal or any other substantive unifying relation, but by a mere principle of summation, a principle requiring that, if some things exist, there exists the sum, or collection, of those things.[3]

The sum view of portions places restrictions on the persistence conditions of portions. To quote Dean Zimmerman, a recent proponent of the sum view,

> A portion of a certain kind of stuff must include all and only the same portions of that kind among its parts for as long as it exists. … [This] is in fact a rather uninteresting and obvious truism. … [It] tells us that no portion of *K* can survive the loss of any part that is itself a portion of *K*, or "grow" by incorporating new portions of *K*. (1995, 79–83)[4]

By Zimmerman's lights, it is an uninteresting and obvious truism that both of the following pairs are inconsistent:

(a) The carbon that exists today is the very same portion of carbon that existed a century ago.
(b) Some carbon that exists today did not exist a century ago.

(c) The oil that exists today is the very same portion of oil that existed a century ago.
(d) Some oil that exists today did not exist a century ago.

I agree that portions of some kinds of stuff—carbon, for instance—can be identified with sums of their subportions. Because sums are unstructured, the sum of all subportions of extant carbon is identical to the sum of all minimal portions of extant carbon, that is, the sum of all carbon *atoms*. Identifying the totality of carbon with the sum of all carbon atoms comports with the following appealing line of reasoning: if some carbon that exists today did not exist a century ago, then some carbon atom that exists today did not exist a century ago, but if some

carbon atom that exists today did not exist a century ago, then the carbon that exists today is not the very same portion of carbon that existed a century ago. I agree, then, that (a) and (b) are inconsistent.

I doubt however that (c) and (d) are inconsistent. For I doubt that Zimmerman's principle applies to portions of oil. To show that it does not, I will describe a scenario in which a portion of oil survives the destruction and acquisition of proper subportions. The scenario will serve as a counterexample to Zimmerman's principle and to the sum view that entails it.

Two preliminary points are in order. First, we need to distinguish portions of stuff from the primitive objects they sometimes form. For illustration, imagine that before us is a barrel filled with crude oil—a liquid solution of various types of hydrocarbon molecules. The *portion* of oil in the barrel forms, but is not identical to, the *pool* of oil in the barrel. Just as portions of solid matter can form pieces, lumps, and heaps, portions of liquid matter can form pools, puddles, and droplets. There are intuitive differences between portions of stuff, on the one hand, and the primitive pieces, lumps, heaps, pools, puddles, and droplets they sometimes form, on the other. For instance, portions seem capable of existing in scattered states, whereas pieces, lumps, pools, and so on, do not. Were we to dump half our oil on one stretch of pavement and the other half on a distant stretch, the oil that now forms a single pool would come to form two or more puddles. The portion of oil in the barrel would seem to survive the dumping; the pool it now forms would not. Similar considerations hold for portions of solid matter. Portions of tofu seem for instance capable of existing in scattered states, whereas pieces do not. Our present concern, then, is with portions of stuff, rather than the pieces, lumps, heaps, pools, puddles, droplets, and so on they sometimes form.

The second preliminary point concerns a principle governing the persistence conditions of portions of oil. Let 'Crude' refer to the portion of oil that fills our barrel, and let 'Crude_1', 'Crude_2', and 'Crude_3' refer to the portions respectively occupying the top, middle, and bottom thirds of the barrel. Under what conditions would Crude persist? To start, we know already that Crude would survive certain scatterings, say, the shipment of Crude_1 to Mars, of Crude_2 to Jupiter, and of Crude_3 to Venus. The oil now in our barrel would, after the shipment, be partly on Mars, partly on Jupiter, and partly on Venus. Crude would not however survive certain other scatterings, say, the distribution of its *molecules* evenly throughout the universe. For it seems essential to

Crude that it is a portion of *oil*. And even though the molecules now constitutive of Crude would continue to exist, they would no longer form oil any more than they would, say, a dinosaur. To emphasize the point, focus on a single hydrocarbon molecule that is part of Crude, say, a particular C_5H_{12} molecule. If this molecule were isolated miles away from all other matter, it would not qualify as a portion of oil, or even as a part of a portion of oil, but only as minimal portion of *pentane*. For it to be part of a portion of *oil*, it must combine with other sorts of hydrocarbon molecules to form a liquid solution. Thus, for Crude to persist, each of its molecules must stand in the right sort of "oil-forming" relation to a sufficient number of other molecules. Moreover, each such molecule must be so related, not merely to *some* other molecules, but to *some of the other molecules that now constitute Crude*. Crude would be destroyed if just one of its molecules were plucked from the barrel and sent by itself to Venus, even if that molecule happened to join on Venus with some others to form a different portion of oil. To be sure, the *pool* of oil in our barrel might survive such an event, just as a *piece* of tofu might survive the removal of one of its molecules. But *the very portion of oil now in the barrel* would exist no longer if one of its molecules were removed from the others. Intuitively, then, a given portion of oil persists just in case each of its molecules continues to stand to a sufficient number of the others in a relation sufficient for the formation of some oil.

Here, then, is my counterexample. Suppose that we suck the top two thirds of Crude into a very long and narrow straw, leaving Crude_3 at the bottom of the barrel, though still contiguous with the oil that now fills the straw. And suppose that we pull a single molecule from the bottom of the barrel through, and to the far end of, the oil-filled straw. Intuitively, Crude_3 no longer exists, for one of its molecules no longer stands to any of its others in an oil-forming relation. *That very portion of oil*—the one originally occupying the bottom third of the barrel—no longer exists. Crude, on the other hand, survives; for each of its molecules retains an oil-forming relation with some of the others throughout the entire procedure.

Indeed, due to normal motion of Crude's molecules, the lifetime of any small subportion is probably very short, since its constitutive molecules are likely to be dispersed about the barrel in a brief period of time. And, of course, for each subportion destroyed in this manner a new one is born. We see, then, how Crude can survive both the loss and the gain of subportions of oil.

What holds for Crude holds for all the world's oil. The oil that exists today might be the very same portion of oil that existed a century ago, even though some oil that exists today did not exist a century ago. Thus, contrary to Zimmerman's persistence principle—a principle that is part of every sum view of portions—(c) and (d) are not inconsistent.[5]

Our example is not an isolated exception to the rule. It happened to involve oil but could just as well have involved wood, lemonade, milk, blood, or any number of other ordinary kinds of stuff. Portions of these kinds appear to resist the standard sum treatment, for their persistence conditions are not those of the associated sums. Their essential material parts appear united, not by a mere principle of summation, but by a formal element. Unlike mereological sums, they seem essentially structured.

The question arises: if not sums, what are they? Below I propose to identify them with what Kit Fine calls *rigid embodiments* (1999). On the resulting view, there are at least two fundamental categories of portions of stuff: sums and rigid embodiments.

My proposal will employ the notion of a *least portion*:

(e) x is a *least portion* of K iff for all portions y of K, if y is a subportion of x then $y = x$.

Carbon has carbon atoms as least portions; oil has portions of oil so tiny that none of their proper parts qualifies as oil. Although there are doubts as to whether, necessarily, every kind of stuff has least portions, I need not take a stance on the issue, for I will limit my goal to categorizing kinds of stuff that *do* have least portions.[6]

Among these kinds, there is the following distinction:

(f) K is a *discrete* kind of stuff iff least portions of K cannot share parts with one another;
(g) K is a *nondiscrete* kind of stuff iff least portions of K can share parts with one another.

Carbon, SiO_2, and gravel are discrete stuffs: their least portions—carbon atoms, SiO_2 molecules, and certain-sized pieces of rock—cannot share parts with others of their kind.[7] By contrast, crude oil, graphite, quartz, and chalk are nondiscrete stuffs: their least portions *can* share parts with others of their kind, for they are merely tiny portions of stuff and can easily overlap with other portions of their kind.

My view is that portions of discrete stuffs can be identified with sums of their subportions. They can therefore be identified with sums of their least subportions, for sums are unstructured. By contrast, portions of nondiscrete stuffs cannot be identified with sums of their subportions, or with sums at all for that matter, but must rather be identified with objects of a more structured nature.

To illustrate my view of discrete stuffs, focus on the portion of *carbon* in our barrel of oil; call it "Carb." Carb seems to be nothing but the mereological sum of carbon atoms in the barrel. There is nothing more to Carb than this unstructured collection of individuals, which exists where and only where, and when and only when, all of the carbon atoms now in the barrel exist. If these atoms are dispersed about the earth, so is Carb; if any of them ceases to exist, so does Carb.

To illustrate my view of nondiscrete stuffs, focus on the portion of *oil* occupying the barrel—that is, focus again on Crude. We have seen already that Crude cannot be identified with the mereological sum of its subportions, for its persistence conditions differ from those of the sum.

The question arises whether Crude might be identified with a sum of certain of its other material parts. Unlike its subportions, these parts would have to be essential to Crude. The obvious candidates are the hydrocarbon molecules that are now parts of Crude, for without them Crude could not exist. But we are positioned already to see that Crude is not identical to this sum. For we know that Crude and the sum have different persistence conditions. Were the molecules that are now parts of Crude spread evenly throughout the universe, their sum would persist, whereas Crude would not. Crude may be constituted by, but is not identical to, this sum of molecules.

In an effort to maintain that Crude is a mereological sum, one might propose to identify Crude with a sum whose components include a *formal* element.[8] Our barrel contains oil in virtue of the fact that it contains various sorts of hydrocarbon molecules bearing to one another a *relation* sufficient for the formation of oil. It might be suggested, then, that Crude is the sum whose components are the hydrocarbon molecules in our barrel together with the relation hydrocarbon molecules bear to one another just in case they form oil.

A problem with this suggestion is that the proposed sum has different existence conditions from Crude. Crude exists whenever every one of the hydrocarbon molecules now in our barrel stands in an oil-forming relation to a sufficient number of the others. The existence condi-

tions of the considered sum depend, in part, on those of the oil-forming relation. On the *ante rem* view of universals, this relation exists necessarily; on the *in rebus* view it exists just in case it has an instance.

Thus, on the *ante rem* view the relevant sum exists whenever the hydrocarbon molecules now in our barrel exist. It would thus share the persistence conditions of the sum of hydrocarbon molecules now in our barrel, and we have seen that these persistence conditions differ from those of Crude.

On the *in rebus* view, the considered sum exists whenever the hydrocarbon molecules now in our barrel exist *and some oil exists*. Clearly this proposal is no better, for the existence of the hydrocarbon molecules now in our barrel together with the existence of some portion or other of oil does not guarantee the existence of Crude.

It might then be suggested that Crude be identified with the sum whose components are the hydrocarbon molecules in our barrel together with a *particularized* oil-forming relation, one that holds among the hydrocarbon molecules in our barrel and exists when and only when these molecules stand to one another in a relation sufficient for the formation of a possibly scattered portion of oil. This suggestion affords the correct existence conditions to Crude, but there are two reasons to reject it.

First, it is ad hoc. It responds to the objection that the preceding sum views cannot account for the existence conditions of Crude by loading these conditions into a single additional component of the proposed sum, namely, the particularized relation—an entity that by nature has the same existence conditions as Crude. One might as well propose that Crude is the sum whose components are the hydrocarbon molecules in our barrel together with the *fact* that Crude exists.[9]

Second, the material and formal components of Crude come together as coequals to form the proposed sum. But they do not come together as coequals to form Crude. For instance, whereas the material components of Crude are strictly determinative of Crude's location, the formal component may not be. The role of Crude's formal element seems entirely different from that of Crude's material elements. Its role is to combine in a predicative-like way with Crude's matter so as to result in a portion of oil. Just as the pair whose members are Fred and skiing cannot be identified with the proposition *that Fred is skiing* because the pairing operation does not afford a relevant difference to the roles played by Fred and the property of skiing, the considered sum cannot be identified with the portion of oil in our barrel because the

summing operation does not afford a relevant difference to the roles played by the hydrocarbon molecules and the oil-forming relation.

Kit Fine makes the analogous point regarding the proposal that certain material objects might be identified with mereological sums of their matter and form. He writes:

> the components and the relation do not come together as coequals, as in a regular mereological sum. Rather, the relation R preserves its predicative role and somehow serves to modify or qualify the components. However, the result of the modification is not a fact or state. It is a whole, whose components are linked by the relation, rather than the fact or state of the components being so linked.
>
> An object of this special sort will be called a *rigid embodiment*, since the 'form' *R* is embodied in the fixed 'matter' *a, b,* . … Let us agree to designate such an object by the term '*a, b, ... /R*'.
>
> … the rigid embodiment *a, b, c,* … */R* exists at a time t iff *R* holds of *a, b, c,* … at time t.
>
> … if the rigid embodiment *e* = *a, b, c,* … */R* exists at time t, then *e* is located at the point p at t iff at least one of *a, b, c,* … is located at p.
>
> … the rigid embodiments *a, b, c,* … */R* and *a′, b′, c′,* … */R′* are the same if the state of *a, b, c,* … standing in relation *R* is the same as the state of *a′, b′, c′,* … standing in relation *R′*. (1999, 10–12)

Perhaps, then, Crude is the *rigid embodiment* whose material components are the hydrocarbon molecules in our barrel, and whose formal element is the oil-forming relation. In other words, perhaps Crude is the rigid embodiment *of* the oil-forming relation *by* the hydrocarbon molecules in our barrel. This analysis provides intuitively correct existence conditions and avoids the difficulties faced by the preceding analyses.

Crude and other portions of nondiscrete stuffs are *embodiments* in the sense that certain of their material parts embody a form, or relation. They are *rigid* in that these material parts are the same over time and across possible worlds. They share with sums the feature of being rigid, but not that of being embodiments.

We are led, then, to a twofold analysis in terms of sums and rigid embodiments. Carb, the portion of H_2O in my glass, the gravel on the streets, the SiO_2 in my windshield, and all other portions of discrete stuffs are to be analyzed as sums. Crude, the graphite in my pencil, the milk in my glass, the wood composing my chair, and all other portions of nondiscrete stuffs are to be analyzed as rigid embodiments. If *x* is a portion of a discrete kind of stuff and *x*'s least portions are *a, b, c,* …, then *x* is by nature the *sum* whose components are *a, b, c,* …. If *x* is a por-

tion of a nondiscrete kind of stuff K and x's material parts $a, b, c, \ldots$, are all and only those parts that embody the form essential to portions of stuff-kind K, then x is the *rigid embodiment* whose material components are $a, b, c, \ldots$, and whose formal element is R_K.[10]

Though rigid at their level of individuation, neither rigid embodiments nor sums need be rigid at every level. Consider Carb. To the extent that each of Carb's atoms is itself materially nonrigid—say, capable of surviving the replacement of one of its many quarks with a qualitative duplicate—so is Carb.[11] Regardless of what goes on at the subatomic level, as long as the carbon atoms now in our barrel exist, so does Carb. A similar point holds for rigid embodiments: to the extent that their material components are nonrigid, so are they. Thus, at mereological levels below that at which they are individuated, sums and rigid embodiments may well be nonrigid.

Remarkably, certain rigid embodiments that are portions of stuff are nonrigid at the level of *subportions* of the same kind. For illustration, consider again the following two pairs:

(a) The carbon that exists today is the very same portion of carbon that existed a century ago.
(b) Some carbon that exists today did not exist a century ago.

(c) The oil that exists today is the very same portion of oil that existed a century ago.
(d) Some oil that exists today did not exist a century ago.

Our twofold analysis suggests that even though (a) and (b) are inconsistent, (c) and (d) are not. Earlier we found an intuitive illustration of how the extant oil could be the very same portion of oil that existed a century ago, even though some extant oil did not exist a century ago. Now we have a theory to explain the intuition: Oil is a nondiscrete stuff. Portions of nondiscrete stuffs, unlike those of discrete stuffs, are not mere sums of their subportions. They are rigid embodiments of a relevant relation by certain of their essential material parts. They therefore depend for their existence only on the fact that these parts bear the relevant relation to one another. And this fact is independent of any specific fact about which subportions of oil these parts happen to compose. We see, then, how a rigid embodiment that is a portion of stuff may be nonrigid at the level of subportion. We are thereby positioned to see, from both an intuitive and a theoretical perspective, how (c) and (d) are consistent.

There are two obvious worries about my positive proposal. First, to admit rigid embodiments and mereological sums is (on most views) to admit the possibility of perfectly overlapping yet distinct material things; for wherever there is a rigid embodiment there is the sum of its material components. Some find perfectly overlapping material things (coincident objects) objectionable.[12] Second, by positing a rigid embodiment wherever and whenever ordinary material objects stand in a relation, the doctrine of rigid embodiments posits lots of unexpected things (at least in its present unrestricted form). For instance, for every relation borne by my left foot to Venus, the doctrine posits a rigid embodiment of that relation by my left foot and Venus. Some find unexpected things objectionable.

To what degree perfectly overlapping and/or unexpected things should bother us is not an issue I wish to pursue here. Those who are deeply bothered by either possibility will want to revise or reject my proposal. In pursuing alternatives, they will need to pay careful attention to the intuitive distinctions between discrete and nondiscrete kinds of stuff, distinctions that underlie my proposed counterexample to the requirement by the standard sum view that portions cannot gain or lose subportions of their kind. Whether or not by appeal to the doctrine of rigid embodiments, these distinctions need to be addressed by any comprehensive theory of stuffs.

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Notes

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[1] See Bacon (1973), Burke (1994), and Laycock (1972).

[2] See Bunt (1985), Burge (1972, 1977), Cartwright (1965, 1975), Cocchiarella (1976), Grandy (1975), Moravcsik (1970), Sharvy (1980, 1983), Quine (1960), Roeper (1983), Simons (1987), and Zimmerman (1995). Some identify portions with sets rather than sums; for present purposes, the difference will not matter. Note that a portion of stuff with no proper subportions can be identified with the degenerate sum of itself.

[3] A sum, on this understanding, is just one possible type of whole: it is an unstructured whole individuated purely by reference to its summands; it has its summands as parts; not all its parts need be summands; every one of its parts must have a part in common with one of its summands; and its summands may or may not themselves be sums. This notion allows (i) that sums may come into and go out of existence, (ii) that they may gain and lose parts (just not parts that are summands), and (iii) that they may be infinitely divisible and atomless. The notion corresponds, I think, with the intuitive notion of a collection. It is close to Burge's (1977) notion of an aggregate, though it does not require minimal summands, as Burge's notion requires minimal aggregate elements.

[4] I have substituted 'portion' for Zimmerman's preferred term, 'mass'.

[5] Zimmerman might respond by appealing to his distinction between a more and less strict sense of identity for portions of stuff (1995, 79–82). He holds that x and y are "strictly speaking" the same portion of K just in case they have all and only the same portions of K as parts. He holds that x and y are "loosely speaking" the same portion of K just in case there is a set of things that are not K that completely decomposes x and also completely decomposes y. So, if a portion of water, x, and a portion of water, y, are composed of different

H_2O molecules but all the same hydrogen and oxygen atoms, then *x* and *y* are "strictly speaking" different portions but "loosely speaking" the same portion. Applied to my oil example, sucking the molecule up the straw "strictly speaking" destroys Crude but "loosely speaking" does not. What I have called "Zimmerman's persistence principle" is a principle for "strict identity." Zimmerman might respond to my alleged counterexample by claiming that we are misreporting the correct intuition *that "loosely speaking" Crude survives* as the incorrect intuition *that "strictly speaking" Crude survives*. This response would require there to be a sense in which sucking the molecule up the straw threatens to destroy Crude. But it seems to me that there is no such sense. Of course, one could introduce a technical notion of "strict-persistence" according to which Crude "strictly-persists" only if all its subportions persist, just as one could introduce a technical notion of "strict-persistence" according to which Crude "strictly-persists" only when it has exactly the same shape. But such conditions are simply not the correct persistence conditions for portions of oil. When we say that Crude survives the transportation of the molecule up the straw, we *are* speaking strictly.

[6] These doubts have two sources. The first is vagueness: due to vagueness as to what would qualify as a least portion of, say, lemonade, some are inclined to reject least portions of lemonade. Whether this doubt is founded depends on whether vagueness threatens the law of excluded middle (*p* or not-*p*). If not (as on standard supervaluationist and epistemic treatments), then vagueness as to what qualifies as a least portion of *K* is consistent with the existence of least portions of *K*, just not with the existence of anything that *clearly* qualifies as a least portion of *K*. If so, then we must neither accept nor deny the existence of least portions of *K*. Unless, that is, we are willing to *strongly* reject excluded middle, by asserting negations of its instances (thus either admitting contradiction (not-*p* and not-not-*p*) or rejecting the distribution rule by which this contradiction is derived—the rule that takes us from not-(*p* or not-*p*) to (not-*p* and not-not-*p*)). The second source of doubt is the alleged possibility of a homogenous *gunk*—an infinitely divisible, atomless, homogenous stuff. Every portion of this stuff would divide into smaller portions of the same kind. Thus, homogenous gunk would not admit of least portions. Though I am inclined to think that vagueness is not a threat to excluded middle and that gunk is not a genuine possibility, for present purposes I take no stance on either issue. See Zimmerman 1995 for a sum treatment of stuff-kinds that do not admit of least portions.

[7] One might think that atoms can, and often do, share parts with one another, specifically, electrons. I have been working under the simplifying assumption that atoms survive bonding, so that, for instance, when carbon and hydrogen atoms bond to form a hydrocarbon molecule, the resultant molecule is composed of the original carbon and hydrogen atoms. Strictly speaking, this is false: the resultant molecule is composed of a number of electrons together with the carbon and hydrogen *nuclei*; the atoms cease to exist when the molecule is formed. To be sure, chemists often speak loosely of nuclei in terms of the sorts of atoms they can be parts of; they speak for instance of helium nuclei as helium atoms.

[8] Alternatively, one might appeal to the doctrine of four-dimensionalism. I will not discuss this proposal, for I do not find it at all promising, and an adequate discussion would take us too far afield.

[9] I owe this objection to David Christensen.

[10] It is perhaps worth noting that the sum/rigid-embodiment distinction is unrelated to the distinction, often made in the literature on stuffs and mass terms, between "heteromerous" and "homeomerous" stuff-kinds. Roughly, a stuff-kind *K* is *heteromerous* iff necessarily, for any portion *x* of *K*, there exists a *y* such that *y* is part of *x* and *y* is not a portion of *K*. Otherwise, *x* is *homeomerous*. For more precise details, see Sharvy 1980 and Zimmerman 1995. Most ordinary kinds of stuff are heteromerous. Portions of oil, for instance, have as parts individual hydrocarbon molecules, which are not themselves portions of oil. Homeomerous stuffs, as I have defined them, include fundamental matter: any part of a portion of fundamental matter must itself be a portion of fundamental matter.

If atomless gunk is possible, the two distinctions are orthogonal. Sums can be heteromerous (for example, carbon) or homeomerous (for example, fundamental matter). And rigid embodiments can be heteromerous (for example, oil) or homeomerous (imagine a rigid embodiment whose material components are 1,000 rigid embodiments of the same kind; imagine that each of these rigid embodiments has as material components 1,000 rigid embodiments of the same kind; and so on, ad infinitum).

[11] This is not to say that a change in the matter of a component of Carb entails a change in the matter of Carb: two of Carb's atoms could exchange electrons without a difference in Carb's matter. Presumably, however, if Carb's atoms can survive exchanges of parts with one another, they can survive exchanges with atoms that are not components of Carb. And to the extent that they can survive these exchanges, Carb is—on this sub-individuating level—materially nonrigid.

On a related note, Cartwright (1965, 477) and Zimmerman (1995, 80) consider a portion of water wherein a pair of H_2O molecules "exchange" oxygen atoms. As a result, the molecules are destroyed and two new ones are created. Cartwright suggests that the original portion of water nevertheless survives. I find this counterintuitive, and so does Zimmerman (at least when he has in mind what he calls the "strict" sense of sameness of water).

[12] Zimmerman is ultimately inclined to reject his own sum theory because it leads to "unseemly coincidences between distinct but very similar physical objects" (1995, 55).