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## Theories of Masses and Problems of Constitution

Dean W. Zimmerman

### 1. What is a Theory of Masses?

The distinction between “mass nouns” and “count nouns” has proven to be of considerable interest to both linguists and philosophers. There are familiar syntactic criteria for the distinction: count nouns admit of pluralization, can occur with numerals, take ‘a’ and ‘every’ in the singular and ‘few’ and ‘many’ in the plural; while mass nouns always take singular verbs, cannot occur with numerals, take determiners like ‘much’ and ‘little’ rather than ‘few’ and ‘many’, and so on.<sup>1</sup> Such criteria for mass nouns put words like ‘gold’, ‘water’, ‘air’, ‘time’, ‘freedom’, ‘happiness’, etc. into the same *syntactic* category; but this fact is not likely to suggest to us that, for example, ‘the gold in his pocket’ and ‘the freedom he enjoys’ denote entities belonging to the same *ontological* category. In order to arrive at an interesting philosophical subject by way of mass terms, let us consider just those mass nouns that promise to be of importance for the ontology of physical objects—Tyler Burge’s “concrete mass terms”:<sup>2</sup>

(D1) ‘*K*’ is a concrete mass term =<sub>df</sub> ‘*K*’ satisfies the syntactic criteria for mass terms, and ‘Necessarily, any sum of parts that are *K* is *K*’ is true.

(D1) insures that ‘*K*’ is an English mass term that, in at least one of its uses, must refer to or be true of things that have parts or that can serve as parts of larger wholes. “Abstract mass nouns,” such as ‘freedom’ and ‘happiness’, though mass terms syntactically,

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<sup>1</sup>For discussion of syntactic criteria for mass terms, see Francis Jeffrey Pelletier, “Non-Singular Reference: Some Preliminaries,” in *Mass Terms: Some Philosophical Problems* (hereafter, *MT*), ed. Pelletier (Dordrecht: D. Reidel, 1979), 1–14; and Francis Jeffrey Pelletier and Lenhart K. Schubert, “Mass Expressions,” in *Handbook of Philosophical Logic*, vol. 4: *Topics in the Philosophy of Language*, ed. D. Gabbay and F. Guenther (Dordrecht: D. Reidel, 1989), 327–407.

<sup>2</sup>Burge, “Truth and Mass Terms,” *Journal of Philosophy* 69 (1972): 263–82; see esp. 263.

are not concrete mass terms; for “[m]ereological concepts simply do not have any straightforward application to these nouns.”<sup>3</sup> It is to be understood that in the definitions and axioms that follow, ‘*K*’ (with or without subscript or superscript) is a schematic letter replaceable only by concrete mass terms.<sup>4</sup>

Helen Morris Cartwright has pointed out that an unstressed occurrence of the word ‘some’ (which she writes “*Sm*”) before a mass term functions as an indefinite article for mass nouns, as in ‘Heraclitus bathed in some water’.<sup>5</sup> But what sort of thing (if any) is typically referred to by expressions consisting of a concrete mass term preceded by either the definite article or the peculiar indefinite article for mass terms, the unstressed ‘some’? Such constructions are common enough, and, as Cartwright has also emphasized, seem to require quantification over things that are, for example, ‘some water’. Consider ‘Heraclitus bathed in some water yesterday, and he bathed in it again today’. To what would the occurrence of ‘it’ in the second clause refer, if the sentence were true? Under what conditions is the water in Heraclitus’s tub today the same water as the water in it yesterday? Let us call a “theory of masses” any systematic attempt to answer questions of this sort with respect to all concrete mass terms by giving an account of the metaphysical status and most general properties of the referents of such mass expressions. A theory of masses may begin with the following schematic principle (which is good only for extensional contexts):

- (A1) . . . the (*Sm*) *K* — if and only if there is an *x* such that *x* is a mass of *K* and . . . *x* —.

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<sup>3</sup>Ibid., 264.

<sup>4</sup>Concrete mass terms may be given what Burge calls a “kind of” reading: for example, the sentence ‘How many feldspars have geologists distinguished?’ is arguably synonymous with ‘How many *kinds of* feldspar have geologists distinguished?’ (Burge, “Truth and Mass Terms,” 264). In order to keep the spotlight on the relationship between mass terms and particular physical objects, let’s also stipulate that in the sequel, no context in which the ‘*K*’-schemata for mass terms occurs admits of a “kind of” reading.

<sup>5</sup>See Cartwright, “Heraclitus and the Bath Water,” *Philosophical Review* 74 (1965): 466–85; and “Amounts and Measures of Amount,” in *MT*, 179–98.

A theory of masses will then go on to tell us what masses of *K* are like.

Attention to the presuppositions of our ordinary use of mass terms reveals a “proto-theory” of masses, the general contours of which are widely recognized by both philosophers and linguists. Sections 2-8 of this paper will be devoted to the articulation of some of our most central proto-theoretical assumptions about the referents of mass expressions of the form ‘the *K*’ and ‘*Sm K*’. The basic assumptions about masses discovered in these sections will be translated into a pure “sum theory” of masses as we go along—a theory according to which each referent of an expression like ‘the *K*’ or ‘*Sm K*’ is the mereological sum of one or more bits of *K*. Sums are significantly different from sets.<sup>6</sup> If the *sum* of several physical objects exists, then there is at least one physical object (namely, the sum itself) that has those objects as parts; but the bare fact that there is a *set* of several objects does not ensure that any of the objects is a part of a larger physical whole. Thus, a set with physical objects for members cannot plausibly be identified with a physical object having those objects as literal parts, while the sum of those objects is exactly that.<sup>7</sup>

The sum theory of masses leads to unseemly coincidences between distinct but very similar physical objects; an alternative set-theoretical approach to masses is explored in sections 9 and 10 with an eye to eliminating such coincidences. Unfortunately, the unwanted coincident objects also have a way of sneaking into every set theory of masses. In the end, it seems we must treat at least the most fundamental sorts of masses within the context of the sum theory. Problems of coincidence will have to be solved by other—more radical—means.

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<sup>6</sup>Even if sets are construed as a *kind* of sum, as in David Lewis’s proposed grounding of set theory in mereology, it will remain true that the sum of several objects is significantly different from the set of those objects. On Lewis’s view, for instance, the set of objects *a*, *b*, and *c* is identified with the sum of the *singletons*  $\langle a \rangle$ ,  $\langle b \rangle$ , and  $\langle c \rangle$ , and not with the sum of *a*, *b*, and *c* themselves. See Lewis, *Parts of Classes* (Oxford: Basil Blackwell, 1991).

<sup>7</sup>The masses of my sum theory resemble the aggregates of Burge’s “theory of aggregates,” but with some important differences. Most significantly, Burge’s aggregates are built out of minimal aggregate-elements; but for the purposes of a theory of masses it is, as I shall show, important to allow for masses that are infinitely divisible and atomless. See Burge, “A Theory of Aggregates,” *Noûs* 11 (1977): 97–117.

## 2. Masses Are a Special Category of Physical Things

The true theory of masses would be a pretty dull affair if it turned out that expressions of the form 'the *K*' or '*Sm K*' never in fact refer to anything. I take it as obvious that they often do. But the theory of masses would also be quite uninteresting were such mass expressions systematically ambiguous, sometimes standing in for one ordinary count noun, sometimes another. In that case the theory of masses would have no proper subject matter. Helen Morris Cartwright laid this worry to rest in her seminal paper "Heraclitus and the Bath Water." Her conclusions about the kinds of entities denoted by phrases of the form '*Sm K*' and 'the *K*', which now seem to be universally accepted by linguists and philosophers working on mass terms, provide a natural starting point for any theory of masses.

Cartwright finds Quine saying that when something is said to be the same *K* as something—for example, when some water in a certain tub is said to be the same water as the water that was in the tub yesterday—"some special individuating standard is understood from the circumstances."<sup>8</sup> Cartwright takes Quine's suggestion to be that every occurrence of a mass expression having the form '*Sm K*', 'the *K*', 'the same *K*', etc. is really a masked reference to a portion of *K* to which an ordinary count noun applies. In other words, in a sentence like: "The sugar in my coffee is the same sugar as the sugar that was in that cube," all three definite descriptions refer (if the sentence is true) to a single thing that can also be referred to by means of some ordinary count noun. But, as Cartwright indicates, no ordinary count noun seems to suffice: the sugar referred to twice in this sentence cannot be a cube or spoonful of sugar, nor even a heap of sugar crystals. The sugar, when it is in my coffee, is none of these things. More generally, the same sugar may at one time be a cube, at another be scattered throughout a larger quantity of sugar, at another be a heap of loose grains in a packet, and at another be dissolved in a cup of coffee. We must, therefore, conclude that some sugar that lasts through the transition from loose grains to lump to suspended molecules in a solution cannot be a thing whose "individuating standard" is

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<sup>8</sup>Quine, review of Peter Geach, *Reference and Generality*, *Philosophical Review* 73 (1964): 100-4, at 102.

that of either 'cube', 'spoonful', 'packet', 'heap of crystals', etc. Similarly, 'the water' cannot, in some contexts, pick out a thing individuated according to the standards for puddles of water, and in another a thing individuated by reference to glassfuls or tubfuls. The water that is now a puddle on the floor may be the same water that was in that glass or tub; but no glass of water is the same *glass of water* as any puddle of water. Cartwright concludes that "it would seem to be a contingent matter whether, given *any* ordinary word or phrase of the required kind [i.e., a familiar count noun applicable to portions of *K*], its individuating standard will apply where what we have is some acid or water or sugar."<sup>9</sup>

Not even recourse to such colorless count nouns as 'piece', 'bit', 'lump', etc. will help. 'The sugar in the bowl' cannot denote anything that is essentially a lump, cube, bit, piece, portion, fragment, etc. "These sortal terms all have an ordinary usage in which physical coherence is required for their individuation and identity over time. But it is precisely the absence of these restrictions which we need in a term which will pick out the referent of an expression like 'the bronze' or 'the gold' . . ." <sup>10</sup> Consequently, philosophers and linguists have been forced to introduce technical terms or give special meanings to familiar sortals in order to find terms that will apply to the referents of such mass expressions throughout the whole of their existence: Cartwright and Burge choose to talk about "quantities" of a given stuff-kind;<sup>11</sup> others strip words like 'portion'<sup>12</sup> or 'parcel'<sup>13</sup> or 'bit'<sup>14</sup> of their usual connotation of physical coherence, so that portions or parcels or bits of stuff are simple mereological sums that persist through scattering. Whatever entities are ultimately to be chosen as the referents for mass expressions like 'the *K*' and '*Sm K*', I suggest that we call them "masses of *K*." The word 'mass' seems particularly appropriate for the den-

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<sup>9</sup>Cartwright, "Heraclitus and the Bath Water," 477.

<sup>10</sup>Kathleen C. Cook, "On the Usefulness of Quantities," in *MT*, 121–35.

<sup>11</sup>See Cartwright, "Amounts and Measures of Amount"; and Burge, "Mass Terms, Count Nouns, and Change," in *MT*, 199–218.

<sup>12</sup>Richard Montague, "The Proper Treatment of Mass Terms in English," in *MT*, 173–78.

<sup>13</sup>Chappell, "Stuff and Things," *Proceedings of the Aristotelian Society* 71 (1970–71): 61–76.

<sup>14</sup>Terence Parsons, "An Analysis of Mass Terms and Amount Terms," in *MT*, 137–66.

otata of mass terms, and preferable to rivals like 'quantity' and 'portion' for a number of reasons.<sup>15</sup>

### 3. Sums vs. Sets

But to what ontological category do masses belong? Philosophers and linguists working on mass terms divide fairly neatly into two camps: the friends and enemies of *sums*. Presently, the friends of sums predominate. It has in fact become commonplace to treat a mass term '*K*' preceded by the definite or indefinite article ('*Sm*') as denoting a mereological sum of portions of *K* that is a literal *part* of the corresponding sum of the world's total *K*. This view is suggested by some remarks of Quine's,<sup>16</sup> and versions of it may be found in the work of Tyler Burge, J. M. E. Moravcsik, Helen Cartwright, N. B. Cocchiarella, Richard Sharvy, Richard Grandy, and Harry C. Bunt.<sup>17</sup> There is, however, a small but persistent opposition party: those who eschew mereological sums, and instead regard occurrences of mass expressions beginning with the definite article or indefinite article as denoting sets or as plural referring terms (that is, expressions that may denote a number of things).<sup>18</sup>

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<sup>15</sup>'Quantity' has the disadvantage of suggesting that in order for something to remain "the same *K*," it must retain the same measure. Of course we might, as Cartwright does, qualify our use of 'quantity' so as to make it clear that the same quantity of wax can have different measures at different times (Cartwright, "Quantities," 34). But 'quantity' is also not general enough to describe the domain of a truly comprehensive theory of masses, as Cartwright herself would admit ("Quantities," 35–40). 'Mass' also seems to me to be preferable to 'portion', 'bit', 'lump', etc. Perhaps *all* of these terms, including 'mass', commonly carry some connotation of physical coherence; but 'mass' simply has fewer ordinary uses, and consequently has fewer misleading associations clinging to it.

<sup>16</sup>See Quine, review of Geach, 100–4; and *Word and Object* (Cambridge: MIT Press, 1960), 101.

<sup>17</sup>See Burge, "Truth and Mass Terms" and "A Theory of Aggregates"; Moravcsik, "Mass Terms in English," in *Approaches to Natural Language*, ed. J. Hintikka, J. M. E. Moravcsik, and P. Suppes (Dordrecht: D. Reidel), 263–85; Helen Cartwright, "Heraclitus and the Bath Water" and "Amounts and Measures of Amount"; Cocchiarella, "On the Logic of Natural Kinds," *Philosophy of Science* 43 (1976): 202–22; Richard Sharvy, "A More General Theory of Definite Descriptions," *Philosophical Review* 89 (1980): 607–24; Richard Grandy, "Stuff and Things"; and Harry C. Bunt, *Mass Terms and Model-Theoretic Semantics* (Cambridge: Cambridge University Press, 1985).

<sup>18</sup>See Henry Laycock, "Some Questions of Ontology," *Philosophical Re-*

These two approaches exhaust the live options for a theory of masses. Concrete mass terms, when they occur preceded by the definite article or by 'Sm', are used to pick out things that have, in some sense, all the kinds of physical properties associated with concrete material objects. The water in Heraclitus's tub occupies a certain region of space, weighs a certain amount, can be transported, etc. A theory of masses that identifies the referent of 'the water in Heraclitus's tub' with something that cannot, in any obvious sense, occupy a region or have a weight or be moved around is, at best, an "error theory" of masses—a theory shackled with the counterintuitive implication that most of the beliefs we express using mass terms are false. The same must be said about a theory according to which all mass expressions of this form are empty terms. Surely concrete mass terms should apply to things that are fairly concrete—particular portions of various kinds of spatiotemporally located, physical stuffs.

Construing the portions of physical stuffs in question as physical objects may be, in some respects, the most natural attitude to take toward them. But it does not seem absurd to suppose on the contrary that some occurrences of 'the *K*' or '*Sm K*' may refer to sets, or that they may be plural referring terms. A set of gold atoms, or a number of gold atoms (where the phrase "a number of gold atoms" is used as a plural term), surely represents a particular portion of the world's gold. And although it is often said that sets are "abstract," and "outside of space and time," one can quite sensibly introduce special modes of spatial occupancy and other patently physical attributes that sets will have in virtue of having physical objects as members. After all, a set of bits of bronze is, in a way, located where its members are; and it makes perfect sense to ascribe to it the weight the sum of its members would have if there were such a sum. Thus, corresponding to the *truly* physical properties possessed by the *members* of a set of physical objects, there are *quasi*-physical, derivative properties exemplified by the set itself.<sup>19</sup> Similar moves should be available to someone who pre-

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*view* 81 (1972): 3–42; and John Bacon, "Do Generic Descriptions Denote?" *Mind* 82 (1973): 331–47. See also Richard Grandy, "Comments on Moravcsik's Paper," in *Approaches to Natural Language*, 295–300.

<sup>19</sup>In the case of filling a region of space, for instance, there is an obvious analogue for sets:

(D2) The set *S* "quasi-fills" region  $R =_{df} R$  is the union of a set of subre-

fers to treat mass expressions of the form ‘the  $K$ ’ as plural terms, on the order of ‘Tom, Dick, and Harry’.

What should be clear, in any case, is that if expressions like ‘the water in Heraclitus’s tub’ are to find a foothold in the real world, they must be anchored either in particular physical objects, or else in particular sets or pluralities of physical objects. A theory of masses must therefore restrict itself to one or the other of these alternatives, or to some hybrid view that takes some occurrences of the forms ‘the  $K$ ’ or ‘ $Sm K$ ’ to denote sums and others to denote sets or to be plural referring terms.

In the next five sections, as further presuppositions of our use of mass terms are discovered, each additional element of our “proto-theory” of masses will be given a more precise translation within a “pure” sum theory of masses—a theory that takes the referents of expressions like ‘the  $K$ ’ and ‘ $Sm K$ ’ to be, in every case, physical objects that behave as mereological sums of each part that is some  $K$ .

#### 4. Homeomerous and Heteromerous Stuff-Kinds

A physical object can, it seems, *be* some  $K$  without being *identical with* some  $K$ . For instance, we might sensibly say that a statue is some clay. But if the clay continues to exist when it is flattened,

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gions  $R^*$  which is such that every member of  $R^*$  is filled by a member of the transitive closure of  $S$ .

A set-theoretic analogue to mass requires a bit more ingenuity. One simple way to assign a “quasi-mass” to a set would be to just add up the masses of each of its members (or members of members, or members of members of members, . . .). But a set containing objects that shared parts (for example, {my torso, my head, my limbs, my whole body}) would have an inflated mass on this simple method. Suitable complications may be introduced to make sure that the mass of every part of a physical object anywhere within a given set gets counted only once:

- (D3) The set  $S$  has “quasi-mass”  $n =_{\text{df}} (1) \{s_1, s_2, \dots, s_i\}$  includes all and only the members of the transitive closure of  $S$  that have a mass, (2) the mass of  $s_1 = m_1$ , of  $s_2 = m_2, \dots$ , of  $s_i = m_i$ , and (3)  $n = (m_1 + m_2 + \dots + m_i)$ , unless any of  $\{s_1, s_2, \dots, s_i\}$  have parts in common, in which case: let  $i_1, i_2, \dots, i_m$  be all the parts shared among one or more of the members of  $\{s_1, s_2, \dots, s_i\}$ ; let  $j_1$  be the number of members that have  $i_1$  as a part,  $j_2$  the number that have  $i_2$  as a part, etc.; and let  $k_1, k_2, \dots, k_m$  be the masses of  $i_1, i_2, \dots, i_m$ ; then  $n = (m_1 + m_2 + \dots + m_i) - [(j_1 - 1)k_1 + (j_2 - 1)k_2 + \dots + (j_m - 1)k_m]$ .

while the statue does not, then the statue cannot simply be identified with the clay which it now "is." If an object "is some  $K$ ," even though it can undergo changes that the  $K$  it now "is" cannot undergo, or vice versa, then it is natural to say that it is *merely constituted by*, even though it is *not identical with* some  $K$ .

This fact provides a relatively straightforward way for a sum theory of masses to distinguish between those physical objects that are masses and those that are not:

(D4)  $x$  is a mass of  $K =_{df}$   $x$  is a physical object and  $x$  is identical with some  $K$ .

By itself, (D4) does not say very much about the nature of masses; but in conjunction with the principles about masses in this and subsequent sections, a more detailed picture of masses-*qua*-sums will emerge. In section 6 the constitution relation holding between a mass and a thing that "is," but is not identical with, that mass will be examined in more detail. In this section we shall explore a distinction between two sorts of masses: the "heteromerous" and the "homeomerous."

One of the most noteworthy features of mass terms has been emphasized by Quine: mass terms, unlike true general terms, do not "possess built-in modes . . . of dividing their reference."<sup>20</sup> The use of a mass term does not presuppose that there are minimal quantities of the kind of thing to which the mass term applies. Impressed by this fact, the linguist James D. McCawley argues that mass expressions of the form 'the  $K$ ' or ' $Sm$   $K$ ' should *never* be treated as denoting sets of minimal quantities of  $K$ , even when the  $K$ -stuff in question always contains minimal portions of  $K$ . According to McCawley, 'the water in the cup', for example, should not be taken to denote a set of  $H_2O$  molecules for the following reason: a valid inference involving a mass term like 'water' (for example, "All water is wet; this puddle is water; therefore, this puddle is wet") "is valid not only for a believer in the modern atomic and molecular conception of matter but also for someone of A.D. 1700 who believed that matter is continuous and infinitely divisible, and an adequate account of mass terms must be as consistent with the latter view as with the former, since the logic of quantifiers cannot by itself establish or refute any theory of matter."<sup>21</sup>

<sup>20</sup>Quine, *Word and Object*, 91.

<sup>21</sup>McCawley, *Everything that Linguists have Always Wanted to Know about*

The moral I draw from the fact that mass terms do not divide their reference is considerably weaker than McCawley's. Whether or not it is appropriate (in the theory of masses *or* in semantics) to construe mass terms for *some* kinds as referring to sets of minimal elements of those kinds, surely a theory of masses must at least *allow for the possibility* of kinds of stuff that are continuous and infinitely divisible. Mass terms are built to handle such stuff-kinds; there is no reason to think such kinds intrinsically impossible; and so a theory of masses must allow for occurrences of '*Sm K*' and 'the *K*' that denote what would be called, in the traditional Aristotelian terminology, "homeomerous" masses.

A sum theory of masses can easily make sense of the proto-theoretical distinction between homeomerous and non-homeomerous—or "heteromerous"—stuff-kinds. The distinction and later developments in the theory are considerably simplified if we introduce the notion of a "complete decomposition" of an object:

- (D5) *S* is a complete decomposition of *x* =<sub>df</sub> Every member of *S* is a part of *x*, no members of *S* have any parts in common, and every part of *x* not in *S* has a part in common with some member of *S*.

Heteromerous stuff-kinds are those like copper and water, all masses of which have parts that are not composed of the same kind of stuff:

- (D6) *K* is a heteromerous stuff =<sub>df</sub> Every mass *x* of *K* is such that it has a proper part having no complete decomposition into a set of masses of *K*.

*Every* part of a mass belonging to a homeomerous stuff-kind is made out of parts belonging to the same kind:

- (D7) *K* is a homeomerous stuff =<sub>df</sub> Every mass *x* of *K* is such that every part of *x* has a complete decomposition into a set of masses of *K*.

There are two ways for a stuff-kind to be homeomerous. If there were a stuff-kind *K* which consisted of partless atoms—absolutely unextended Boscovichian simples, for example—then *K* would be

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*Logic but were ashamed to ask* (Chicago: University of Chicago Press, 1981), 436.

a homeomerous stuff-kind. Every heap of  $K$ -atoms would be a mass of  $K$ , and every part of the heap would be a mass of  $K$ —right down to the limiting case of each single (partless) particle. If a homeomerous stuff-kind  $K$  is like Aristotelian matter, however, it has no  $K$ -atomic decomposition; it is a hunk of “atomless gunk,”<sup>22</sup> infinitely divisible, each proper part having a proper part that is itself some  $K$ .<sup>23</sup>

Some mass terms apply to kinds of stuff that are *observably* heteromerous—that is, masses of the stuff are composed of minimal parts that are distinguishable with the naked eye. Examples of observably heteromerous stuffs are the cutlery in the kitchen and the furniture in the dining room. Other mass terms connote kinds of stuff that are not obviously heteromerous, but that have been discovered to have minimal elements belonging to the kind; these may be called “non-observably heteromerous.” For example, it

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<sup>22</sup>The term ‘atomless gunk’ was coined by David Lewis; see *Parts of Classes*, 20. In conversation, Lewis has confessed that the word ‘gunk’ is opprobrious; it is meant to suggest a disagreeable and unidentifiable sludge that is stuck to the bottom of a chemist’s beaker. Lewis takes the following attitude toward atomless gunk: we may not like it, or the philosophical problems it poses; but we should not pretend that it isn’t possible.

<sup>23</sup>Could there be substitutions for ‘ $K$ ’ that do not satisfy the conditions for either heteromerous or homeomerous stuff-kinds? Possibly—but only for uninteresting reasons. Mass terms are sometimes discovered to connote the disjunction of more than one natural kind, as ‘jade’ in fact refers to two quite distinct substances, jadeite and nephrite. Now imagine that, for example, jadeite had turned out to be homeomerous, while nephrite was heteromerous. Then jade itself would be neither a heteromerous nor a homeomerous stuff-kind. Note, however, that whenever a striking underlying structural difference is found in the substances connoted by a natural kind term, we have *ipso facto* discovered that there are in fact two more fundamental natural kinds associated with the term. Consequent to such a discovery, there is considerable pressure to identify the connotation of the original term with one or the other of the more fundamental kinds—as jadeite is also called “true jade,” threatening to demote nephrite to the status of “false jade.” Now no substitution for ‘ $K$ ’ could be true of both heteromerous and homeomerous masses of  $K$  except by virtue of sometimes applying to every part of a thing composed of  $K$ -stuff, and sometimes not; and so the only cases of neither homeomerous nor heteromerous stuff-kinds are cases in which  $K$ -stuff sometimes comes with minimal elements having proper parts not of that kind and sometimes not. But this is, necessarily, an important structural difference;  $K$ -stuff that comes in homeomerous form obviously has a quite different underlying structure from  $K$ -stuff that comes in heteromerous form. So any mass term for a natural kind that happens to be neither heteromerous nor homeomerous is really a disjunction of distinct natural kinds.

turns out that the potable stuff filling the earth's lakes and streams is always constituted by aggregations of  $H_2O$  molecules. Any aggregate of  $H_2O$  molecules that reaches an observable size (whether it comes in the form of water vapor, ice, or liquid), is obviously some water (that is, it can take on liquid form, and has been discovered to belong to the same kind as the stuff in lakes and streams); by contrast, it is *not* the case that just any aggregate of hydrogen and oxygen atoms constitutes some potable stuff of the sort found in our lakes and streams (consider a case in which the hydrogen and oxygen are in separate balloons). So we conclude that 'water' denotes any aggregate of  $H_2O$  molecules (observable or not), but not just any aggregate of hydrogen and oxygen atoms arranged any old way. Thus, if it is, as many believe, an a posteriori necessity that water is  $H_2O$ , then it is also an a posteriori necessity that water is heteromerous—assuming that nothing could possibly be an  $H_2O$  molecule without having parts that were not  $H_2O$  molecules.

There is a sort of pseudo-homeomerosity typically induced by vagueness in otherwise heteromerous stuff-kinds. Before discussing it, we may as well introduce the following technical terms, which will prove indispensable in the sequel:

- (D8)  $x$  is a  $K$ -atom =<sub>df</sub>  $x$  is a mass of  $K$ , but no proper part of  $x$  is a mass of  $K$ .
- (D9)  $S$  is a  $K$ -atomic decomposition of  $x$  =<sub>df</sub>  $S$  is a complete decomposition of  $x$ , and every member of  $S$  is a  $K$ -atom.

Some heteromerous stuff-kinds lack a  $K$ -atomic decomposition; although every bit of a mass belonging to such a stuff-kind  $K$  is decomposable into parts that are not themselves masses of  $K$ , it is also true that there are no minimal masses of  $K$ —no masses of  $K$  that do not have smaller masses of  $K$  as parts. *Muddy water* and *succotash* exemplify this sort of oddity: even though some muddy water or some succotash will always have a complete decomposition into parts that are not muddy water or not succotash, still every proper part that is some muddy water or some succotash has proper parts that are of the same kind.<sup>24</sup> Perhaps *wood* displays a similar vagueness at the boundary between those parts big enough to count as some wood and those too small to count as such. Or perhaps, like 'water', 'wood' is a natural kind term whose meaning

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<sup>24</sup>The examples are from McCawley, 434.

has been filled in by the relevant experts in such a way that it has a scientifically determined minimal element—say, an individual (living or dead) cell of a sort that belongs in some kind of tree.

The heteromerous stuff-kinds lacking minimal elements that spring most readily to mind are all vague kinds like succotash and muddy water—that is, they are such that it is sometimes neither true nor false that a certain object is a mass of that kind.<sup>25</sup> And I am convinced by the “linguistic theory of vagueness”: vagueness is a product of our sloppy ways of talking about the world; there are no “vague objects” in the real world, nor do any objects have “vague properties,” although they do have real properties that we sometimes grasp only imprecisely and indeterminately. Consequently, I shall say nothing more about stuff-kinds that display this sort of vagueness-induced pseudo-homeomerousity. So far as I can see, however, nothing in what follows turns upon the rejection of vague stuff-kinds.

We have seen that masses belonging to homeomerous kinds obey the following “downward-looking” principle: any proper part of a mass of such a kind is also a mass of that kind. But a converse, “upward-looking” principle is true for both homeomerous and heteromerous mass kinds: for any two masses of the same kind, there is a larger mass of the same kind made of just those two masses and their parts. Whenever two objects are both made out of  $K$ , there is the  $K$  out of which both are made; if there are a number of, say, bronze statues in a certain room, we can always ask how much the bronze in all the statues is worth, what it weighs, whether it once formed a single larger statue, etc. This fact requires a comprehensive “summing” or fusion principle for masses. There are several familiar ways to formulate a fusion principle—for example, by means of “fusion” defined in terms of “being a part of”:

- (D10)  $x$  is a fusion of the set  $S =_{\text{df}}$   $x$  is such that for every  $y$ ,  $y$  is a part of  $x$  if and only if, for every  $z$  such that  $z$  is a part of  $y$ ,  $z$  has a part in common with a member of  $S$ .

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<sup>25</sup>If it is possible for there to be mass kinds that are “homeomerous mixtures” of two distinct types of mass, then such mixtures would be heteromerous, lacking minimal elements, but not necessarily displaying any vagueness. See Richard Sharvy, “Aristotle on Mixtures,” *Journal of Philosophy* 80 (1983): 439–57.

- (A2) For any set  $S$  of masses of  $K$ , there is a unique  $x$  such that  $x$  is a fusion of  $S$  and  $x$  is a mass of  $K$ .

Some philosophers hold that a single set of parts can constitute two or more distinct physical objects at the same time—that is, that the same objects can have more than one fusion at a time. (A2) allows for this possibility, while insisting that a set of masses of  $K$ , whatever else they may “fuse” into, have only one fusion that is itself a mass of  $K$ .

### 5. Masses Are Everywhere

When properly understood, the claim that every physical object is identical with a mass of some kind (is identical with some  $K$ ) has practically the nature of a truism. A consideration of the reasons one might have for questioning this thesis will reveal why it must be so. Take some allegedly partless entities—electrons, say, or perhaps quarks. One might argue that since English has no mass term denoting masses having just heaps of electrons or quarks for parts, there is therefore no reason to recognize masses consisting of one or more such simple entities. In that case a single electron or quark would not be identical with a mass of any kind; nor, being (apparently) partless, would it seem to be constituted by some more fundamental stuff—unless, perhaps, by some “prime matter,” a somewhat dubious candidate anyway. Similarly, one might contend that there are things neither identical with any mass, nor constituted by any mass, even though they are constituted by several individuals. A proton, for instance, might be thought to be constituted by a number of quarks; but since English has no mass term for objects with just protons for parts, nor for objects with just quarks for parts, there might seem to be no reason to say that the proton is either identical with or constituted by a mass of any kind.

The dearth of mass terms here is no real impediment, however; for, as a moment’s reflection reveals, “[p]ractically every noun can be used both as a count noun and as a mass noun.”<sup>26</sup> In fact, it is astonishingly easy to transform count nouns into mass nouns; it happens all the time, as Quine reminds us, when “full fledged

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<sup>26</sup>H. C. Bunt, “Ensembles and the Formal Semantic Properties of Mass Terms,” in *MT*, 249.

general terms like 'apple' are also commonly made to double as mass terms."<sup>27</sup> Perhaps the following example represents the simplest sort of transformation of count noun to mass noun: we can talk about the *cells* that make up my body, but we can also talk about the *cellular tissue* that makes up my body; and this amounts to no more than switching from the word 'cells' to a mass expression on the order of 'cell-stuff'. Surely we can perform a similar trick with any other count noun that applies to physical objects; and the ease of transition in every case shows that it would be a simple matter to introduce mass term uses for 'proton', 'electron', and 'quark' according to which they obey the syntactic rules for mass terms, fail to "divide their reference," etc. In fact, it is easy enough to imagine experimental situations in which mass term uses for 'proton' or 'electron' would naturally evolve—"There is too much electron in the particle accelerator!" And since ontology should not depend upon purely contingent features of our language, these contrived or not yet introduced mass terms must be given equal status with familiar mass terms for the purposes of drawing ontological conclusions. After all, we do not want to hold that a simple change in how we use a word could be sufficient to create new entities—speaking things into existence is God's prerogative, not ours. The relationship between ontology and the semantics of ordinary language is obviously a complex one; but one feature of this complexity may be expressed in the slogan, "Ontology must not *simply* recapitulate philology; it must also *anticipate* it."

Thus, even in seemingly recalcitrant cases, we must admit that every physical object is identical with a mass of some kind—if only of a kind for which we do not presently have a name. Physical objects that cannot be said to "be identical with some *K*" for some familiar English mass term '*K*' may still "be identical with some *K*" for some mass term that could and perhaps will be introduced. In general, for any count noun '*C*' that applies just to physical objects, there is a trivial sort of mass term derivable from '*C*', call it '*C*-stuff', where something is some *C*-stuff just in case it is either an individual *C* or a heap of *C*s. It is no more difficult, for any count noun '*C*', to imagine situations in which mass-term usages would evolve than it was in the case of electrons. Thus a sum theory

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<sup>27</sup>Quine, *Word and Object*, 91.

of masses should recognize schematic principles for the wholesale production of mass terms from count nouns.

Here and throughout, '*C*' is replaceable by any physical object count noun—where '*C*' is a physical object count noun just in case 'every *C* is a physical object' expresses a necessary truth.<sup>28</sup> Mass terms may be generated from count nouns according to the following simple pattern (among others):

- (A3) '*C*-stuff' is a concrete mass term, every mass of *C*-stuff has *C*-stuff-atoms, and every *C*-stuff-atom is an individual *C*.
- (A4) For every set *S* whose members are all *C*s, there is the fusion of *S* that is a mass of *C*-stuff.<sup>29</sup>

From (A4) it follows that every physical object is itself a mass, and that every physical object that is constituted by several physical objects to which the same physical object count noun is applicable is also constituted by a mass composed of just those objects.

Could science ever disclose that, at a certain level, one reaches a category of physical entity whose nature is such that any attempt to talk about things in this category using concrete mass terms necessarily fails? It is sometimes said that fundamental particles are really "just" energy, or "just" disturbances in substantial fields, or "just" distortions in the shape of space-time. One might argue that just as 'significance' is not a concrete mass term and 'joy' resists transformation into a concrete mass term on the order of 'joy-stuff' because neither significance nor joy comes in identifiable units that may form larger wholes, so 'energy' is not a concrete mass term, and no mass term usage could be introduced that applied to disturbances in fields or distortions of space-time, since mereological notions do not apply in any straightforward way to energy or disturbances or distortions.

But this seems simply false: mereological notions would be inapplicable here only if it made no sense to talk about the difference between the energy constituting this particle, the energy con-

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<sup>28</sup>It is to be understood that substitutions into *C*-contexts are allowed only if the substituted term retains its use as a physical object count noun—for example, when used to denote a piece of playground equipment, 'swing' is being used as a physical object count noun; when used to denote an event or sudden change, as in 'taking a swing at someone' or 'the electorate's swing to the right', it is not.

<sup>29</sup>Cf. Burge, "A Theory of Aggregates," 101 (axiom (A5)) and 103–4.

stituting that particle, and the distinct (spatially scattered and quantitatively larger) energy that is the energy in both particles; or if it made no sense to talk about the disturbance in a field or distortion in space-time constituting this particle, and the disturbance or distortion constituting that particle, and the distinct (spatially scattered) disturbance or distortion that constitutes both particles. But how could such talk fail to make sense?<sup>30</sup> Even at the bizarre and ever-changing outer limits of our present scientific picture, then, it appears that mass-term talk can be applied to all the entities that go into the constitution of the physical world.

There may, however, be physical phenomena that cannot sensibly be said to persist from one moment to the next. Perhaps it makes no sense to ask whether the “very same energy” out of which this particle is now made will continue to exist and will constitute the same or another particle. In that case, if particles are made of energy, they are constituted by different masses of energy at different times—or at least, at each moment, each particle is constituted by a mass of energy of which it is not determinately true that it is identical with some energy existing at some other time. Perhaps substantial fields are similar. Since substantial fields have distinguishable parts (that is, there is a different part of the field for every subregion of the region a field fills), mass terms can be introduced that refer to sums and portions of fields. But does it make sense to ask whether the substantial field filling a certain region of space now is the same as the field filling that or another region at some other time? If not, then the ephemerality of fields will infect any mass-term language we might introduce to apply to fields; and so something persisting that is constituted by “some field-stuff” is not constituted by “the same field-stuff” at any two moments.

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<sup>30</sup>On every energy or field or geometrodynamical theory of matter that I have encountered, such distinctions can be made—and the required sums will exist so long as our metaphysics countenances liberal fusion principles according to which the energy in several particles qualifies as some energy, and several disturbances in fields or distortions in space-time are allowed to have a fusion that is also a disturbance or a distortion. Jonathan Bennett makes a good case for the plausibility of liberal “zonal fusion” principles for events or “tropes” (the category to which disturbances and distortions presumably belong); see Bennett, *Events and Their Names* (Indianapolis: Hackett, 1988), 153–56. I am grateful to Phil Quinn for suggesting this line of response.

## 6. The Constitution Relation

On a sum theory of masses, a mass expression like ‘the cellular tissue now constituting my body’ picks out a mass that is itself a physical object. The consideration, in section 8, of the persistence conditions for masses will reveal that such a mass cannot survive the gain or loss of any cellular tissue. Since my body would seem to be precisely the sort of physical object that *can* undergo the gradual gain or loss of cellular tissue, but that is also made up entirely of the cellular tissue now constituting it, a sum theory of masses leads very quickly to the conclusion that a physical object like my body is constituted by but not identical with whatever mass of tissue happens to constitute it at present. Thus an instance of the copula in a sentence like ‘My body is some cellular tissue’ is often called the ‘is’ of *constitution*, as opposed, for example, to the ‘is’ of *identity*.<sup>31</sup> But what is the constitution relation like? A theory of masses should have something to say about this.

Some views about the way things may be constituted by masses are “single-category” theories of constitution; that is, they imply that constituting mass and constituted thing belong to the same basic ontological category. Presently, the dominant theories of constitution are single-category accounts. First, there are metaphysics according to which masses are physical objects that constitute distinct but coincident physical objects. The friend of coincident objects can say that although the mass of tissue making up my body and my body itself are two different physical objects with different histories, they happen to be made of the same stuff at present and so fill precisely the same region.<sup>32</sup> Another popular single-category theory of constitution is offered by the friends of temporal parts: masses and the things they constitute are all physical objects; persisting physical objects are four-dimensional wholes, having different (temporal) parts at different times just as they have different (spatial) parts at different places; and a mass constitutes a distinct

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<sup>31</sup>See Burge, “Mass Terms, Count Nouns, and Change,” 204; E. J. Lowe, *Kinds of Being* (Oxford: Basil Blackwell, 1989), 3; and David Wiggins, *Sameness and Substance* (Cambridge: Harvard University Press, 1980), 30–35.

<sup>32</sup>According to Michael Burke, this view of constitution is so popular as to deserve to be called “the standard account.” For references, see Michael B. Burke, “Copper Statues and Pieces of Copper: A Challenge to the Standard Account,” *Analysis* 52 (1992): 12–17; see esp. 12–13, notes 1 and 2.

physical object when the two share one or more temporal parts.<sup>33</sup> Attempts to treat constitution as a kind of weakened, pseudo-identity relation (à la Geach's "relative identity" or Prior's "temporary identity") represent a somewhat less popular sort of single-category theory.<sup>34</sup>

In contrast to these views, there are "multiple-category" theories of constitution: analyses of constitution according to which masses often constitute things belonging to a very different ontological category from themselves. Multiple-category theories take many forms. Each constituting mass may be construed as a plurality (for example, a set), and the constituted physical object as a unity—a whole made out of the elements in the constituting plurality. A theory of constitution along these lines will be examined in sections 9 and 10. A number of different multiple-category accounts result when "mereologically incontinent" objects (objects that can gain or lose parts) are treated as logical constructions out of the "mereologically stable" masses of stuff constituting them at different times. A logical construction is "conservative" if it finds *something* with which mereologically changeable things may be identified. A constituted body might, for example, be treated as a function from times to the particular masses of matter that (we would ordinarily say) constitute the body at those times.<sup>35</sup> Some logical constructions, however, have been eliminative: ultimately, the non-masses constituted by masses are consigned to the ignoble "category" of fictions.<sup>36</sup> Other multiple-category theorists identify a con-

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<sup>33</sup>See W. V. Quine, "Identity, Ostension, and Hypostasis," reprinted in *From a Logical Point of View* (New York: Harper and Row, 1963), 65–79; and David Lewis, *On the Plurality of Worlds* (Oxford: Basil Blackwell, 1986), 253.

<sup>34</sup>See Peter Geach, *Reference and Generality*, 3d ed. (Ithaca: Cornell University Press, 1980), 63–64 (§30) and 215–18 (§110); and A. N. Prior, "'Opposite Number'," *Review of Metaphysics* 11 (1957): 196–201. See also Harold W. Noonan, *Objects and Identity* (The Hague: Martinus Nijhoff, 1980); and Nicholas Griffin, *Relative Identity* (Oxford: Oxford University Press, Clarendon Press, 1977), chap. 9.

<sup>35</sup>According to Richard E. Grandy, an ostensibly part-changing object "is to be considered as a set of pairs consisting of bits of matter and times" ("Stuff and Things," 224).

<sup>36</sup>Roderick Chisholm, in one place, offers an eliminative logical construction. The constructed mereologically incontinent entities, his "*entia successiva*," are in fact fictions: all apparent quantification over tables, human bodies, and any other thing that can gain or lose parts is paraphrased away in favor of a language in which variables range only over objects characterized by a strict mereological essentialism. See Chisholm, *Person and Object* (La Salle: Open Court, 1976), chap. 3 and appendix B. The

stituted object with a prolonged event or process that “passes through” the various ultimate masses making it up at different times. Toomas Karmo suggests, for instance, that constituted objects are “disturbances” in an underlying medium: a human body, for example, “can be conceived of as a disturbance migrating through a consignment of organic chemicals.”<sup>37</sup>

For the moment, let us restrict ourselves to the task of giving a single-category account of constitution within our sum theory of masses. The theory of constitution we shall construct should be acceptable to all single-category proponents—the friends of coincident objects, temporal parts, and relative identity alike. Disillusionment with the metaphysics of the resulting single-category sum theory will, however, lead us to consider the merits of a set-theoretical approach to masses that will allow for the least radical sort of multiple-category analysis of constitution.

In attempting to explicate the relationship between constituting mass and constituted thing, I shall make use of a couple of assumptions about the constitution relation that should prove uncontroversial. First, if  $x$  constitutes  $y$ , then at some level  $x$  and  $y$  share all the same parts—that is, there is at least one complete decomposition of  $x$  that is also a complete decomposition of  $y$ . For if  $y$  is wholly constituted by  $x$ , then it must in some sense be made up entirely of parts in  $x$ ; and if there were some part of  $y$  that had absolutely no parts in common with  $x$ , then this part of  $y$  could not in any way qualify as made up entirely of parts of  $x$ — $y$  would have to be constituted not just by  $x$  but by  $x$  plus something else. Furthermore, if  $y$  is a mass of  $K^*$  constituted by some mass  $x$  of  $K$ , then every part of  $y$  that is some  $K^*$  must itself be constituted by some part of  $x$  that is a mass of  $K$ ; and therefore every part of  $y$  that is some  $K^*$  shares a complete decomposition with some mass of  $K$  in  $x$ . If some furniture, for example, is constituted by some

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“Port-Royal Logic” of Arnauld and Nicole is also committed to the eliminative reduction of mereologically incontinent objects in terms of mereologically stable masses of matter. See *The Art of Thinking*, trans. James Dickoff and Patricia James (Indianapolis: Bobbs-Merrill, 1964), part 2, chap. 12.

<sup>37</sup>Karmo, “Disturbances,” *Analysis* 37 (1977): 147–48, at 147. For similar views, see Roderick Chisholm, “Self-Profile,” in *Roderick M. Chisholm*, ed. Radu J. Bogdan (Dordrecht: D. Reidel, 1986), 66–67; and C. D. Broad, *Mind and Its Place in Nature* (Paterson, New Jersey: Littlefield Adams, 1960), 34–38.

wood, then every piece of furniture in the mass in question must itself be constituted by, and thus share a complete decomposition with, some of the wood.

Now there are a number of different sorts of physical things that a mass of matter may properly be said to constitute. For example, it seems entirely appropriate to say that a mass of *K* “makes up” or “constitutes” one part of a larger mass of *K*. Here, the *part* of the larger mass “consists of” or “is constituted by” the smaller mass in a sense which can only be that of *identity*: the smaller mass of *K* just *is* the part of the larger mass. So we should allow identity as a sort of limiting case of constitution.

More interestingly, one mass may constitute a distinct mass of some different kind, as when some furniture is constituted by some wood or some silverware is constituted by some silver. Why do we say that the wood constitutes the furniture, and not the other way around? Because all the furniture is made of smaller masses of wood but it is not the case that all the wood is made of smaller masses of furniture. That is, every mass of furniture is decomposable into a set of masses of wood, but not the reverse.

These facts together suggest the following definition of constitution for masses:

- (D11) The mass *x* of kind *K* constitutes the mass *y* of kind *K\**  
 =<sub>df</sub> (1) *x* is a mass of *K* and *y* is a mass of *K\**, and (2)  
 either (a) *x* is identical with *y*; or (b) *x* is not identical  
 with *y*, in which case (i) *x* and *y* share a complete decom-  
 position, and (ii) every mass of *K\** in *y* is decomposable  
 into a set of masses of *K* in *x*.<sup>38</sup>

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<sup>38</sup>The friends of temporal parts should have no problem accepting a properly “de-tensed” version of (D11). They will take masses of matter to be four-dimensional wholes, and read a temporal index (introduced by the present tense of our definition) into clause (2b). For four-dimensional wholes *x* and *y*, “*x* and *y*’s sharing (*now*) a complete decomposition” can only be a matter of the sharing of a decomposition by momentary “*t*-stages” of *x* and *y* (where *t* is the time indicated by the “now” of the present tense). Thus, for friends of temporal parts, the most natural de-tensed reading of clause (2b) is: “*x* is not identical with *y*, in which case (i) *x*’s *t*-stage and *y*’s *t*-stage share a complete decomposition, and (ii) every mass of *K\** in *y*’s *t*-stage is decomposable into a set of masses of *K* in *x*’s *t*-stage.” The relative identity theorist can accept (D11) with even greater equanimity—although she will no doubt try to convince us that (2a) and (2b) are not the mutually exclusive alternatives they appear to be.

The adequacy of (D11) seems to me to be demonstrable. Since identity is just a trivial case of constitution, the only ways (D11) could go wrong would be by (2b)'s ruling out pairs of distinct masses that should qualify as related by constitution, or by its allowing in distinct masses that clearly are not so related. Could the latter happen? If  $x$  and  $y$  share a complete decomposition, they are obviously very intimately related. Surely one *must* constitute the other; thus the only real danger is that (2b) could be satisfied but have the order wrong: that is, there is a case in which every mass of  $K^*$  in  $y$  is decomposable into a set of masses of  $K$  in  $x$ , yet  $y$  constitutes  $x$  and not the reverse. There is really no danger of this happening, however. (2b) assures us that every mass of  $K^*$  in  $y$  is made out of or identical with some of the  $K$  in  $x$ ; even if it were *also* true that  $y$  constitutes  $x$  (and thus that every part of  $x$  is also identical with or made out of some of the  $K^*$  in  $y$ ), this would only suggest that  $x$  and  $y$  constitute *one another*—and so there is nothing wrong with  $y$ 's qualifying as constituted by  $x$ .<sup>39</sup>

But is (2b) too stringent? It would only disqualify pairs that should qualify as related by constitution if there were a mass  $y$  of kind  $K^*$  constituted by a distinct mass  $x$  of kind  $K$  that was such that, even though  $x$  and  $y$  share a complete decomposition, there is a mass of  $K^*$  in  $y$  that is not decomposable into a set of masses of  $K$  in  $x$ . This contradicts one of our assumptions about constitution; namely, that if a mass  $x$  of  $K$  constitutes a mass  $y$  of  $K^*$ , then every mass of  $K^*$  in  $y$  shares a complete decomposition with a mass of  $K$  in  $x$ . Surely if, for example, some of the furniture in the dining room is not made entirely out of bits of wood, then no mass of wood could properly be said to constitute the furniture—at best, the furniture could be constituted only *in part* by some wood.

What are perhaps the most important cases of a mass constituting something may seem to have been left out of our definition,

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<sup>39</sup>There are two ways such mutual constitution between distinct masses could occur. In the one case, some bit of  $K$  is made of smaller bits of  $K^*$ , each of which in turn is made of even smaller bits of  $K$ , and so on, until one reaches a level at which every constituent mass of  $K$  or  $K^*$  is identical with a mass of the other kind. In the second case, each bit of  $K$  is made of smaller bits of  $K^*$ , each in turn is made of smaller bits of  $K$ , and so on, *ad infinitum*. One might well wonder whether the second case represents a real possibility; but either case, if possible, ought to qualify as mutual constitution.

which covers only cases of one mass constituting *another mass*. Of course some wood may constitute some furniture, but some wood may also constitute a single chair or a ship. Most of the paradigmatic cases of constitution—some bronze constituting a statue, some cellular tissue constituting a human body—are of this latter sort, in which a mass constitutes a single individual. In our simple sum theory, however, these examples do not really fall outside the scope of (D11). By the principles governing ‘*C*-stuff’, anything falling under a physical object count noun ‘*C*’ is also a mass of *C*-stuff—that is, a *C*-stuff-atom (for example, a single ship is a “ship-stuff” atom, just as a single piece of furniture is a furniture-atom). Therefore all cases of a mass constituting a distinct physical object may be assimilated to the case of one mass constituting a distinct mass.<sup>40</sup>

Our theory of masses can now introduce a further existence postulate for masses. The principle asserts that when, for example, a statue is bronze (or made of bronze) or an ice sculpture is some water, there are the constituting masses of bronze and water.

- (A5) If there is an *x* such that *x* is *K* (or made of *K*) or *x* is some *K*, then there is a *y* such that *y* is a mass of *K*, and *y* constitutes *x*.

## 7. Ultimate Stuff-Kinds

We have seen that some physical objects are constituted by masses from which they are distinct. This observation naturally prompts the question, Are there a number of fundamental kinds of stuff out of which everything else is made? A mass belonging to a homoeomerous stuff-kind *K* would obviously be an “ultimate” mass—since it is *K* “through and through,” it could not be made out of some other, more fundamental kind or kinds of stuff. So our ques-

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<sup>40</sup>Furthermore, if we are willing to recognize disjunctive kinds, (D11) can be applied to cases in which masses of two or more kinds constitute a distinct physical object. For instance, a mass of hydrogen and a mass of oxygen are parts of a larger mass belonging to the disjunctive mass-kind *hydrogen-or-oxygen*—where something is some hydrogen-or-oxygen just in case it is a heap of one or more hydrogen or oxygen atoms. And a mass of hydrogen-or-oxygen, when it takes the form of H<sub>2</sub>O, will constitute a mass belonging to the distinct stuff-kind *water*. Thus (D11) appears to be adequate to every possible sort of constitution relation.

tion becomes, Are all physical things, at bottom, made out of stuffs belonging to one or more homeomerous kinds?

It is natural, I think, to suppose that everything has a decomposition into a number of these ultimate, homeomerous masses:

- (A6) For every physical object  $x$ , either (1) there is a homeomerous mass  $y$  such that  $x$  is constituted by  $y$ , or (2) there are homeomerous masses  $y_1, y_2, \dots$ , such that, for some complete decomposition of  $x$  into a set of parts  $x_1, x_2, \dots$ ,  $x_1$  is constituted by  $y_1$ ,  $x_2$  by  $y_2, \dots$ .<sup>41</sup>

But perhaps it is at least possible that (A6) be false. Martin Gardner points out that a dog knows something about the structure of a tree but knows nothing about atoms, while physicists know about atoms, "but there is always that cut off point beyond which the tree's 'stuff' continues to elude understanding. . . . For all we know, the structure of matter may have infinite levels like an infinite set of Oriental Boxes."<sup>42</sup> Assuming that everything is decomposable into some kind or kinds of stuff, the falsity of (A6) would imply an Oriental Boxes theory of at least some physical things. If every thing (including every mass) is decomposable into masses, the only way to avoid ultimate, homeomerous masses is to suppose that some mass has distinct masses for parts, some of which are themselves made out of distinct masses, and so on, *ad infinitum*.

Whether or not we decide to take seriously Gardner's speculations about Oriental Boxes (I cannot help but wonder whether there isn't some hidden impossibility here), no metaphysician should feel comfortable positing such a theory of matter as a necessary truth!<sup>43</sup> Consequently, in a plausible theory of masses it must at least be possible to formulate a thesis about ultimate masses corresponding to (A6).

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<sup>41</sup>Given our recognition of disjunctive kinds above (see the previous note), the second clause is not strictly necessary.

<sup>42</sup>Martin Gardner, *The Whys of a Philosophical Scrivener* (Brighton: Harvester Press, 1983), 26. See also David Bohm, *Causality and Chance in Modern Physics* (Philadelphia: University of Pennsylvania Press, 1971), 131–40; and Rudy Rucker, *Infinity and the Mind* (New York: Bantam Books, 1982), 28.

<sup>43</sup>But see James Ross, "Creation II," in *The Existence and Nature of God*, ed. Alfred J. Freddoso (Notre Dame: University of Notre Dame Press, 1983), 115–41.

For some, however, (A6) is too weak. Aristotle seems to have held that there is a single kind of ultimate mass—matter of the most primary sort, the substratum of substantial change—which is such that every substance or quantity of stuff is constituted by a mass of this kind. Aristotle's view suggests a "prime matter postulate":

(PMP) There is a nondisjunctive kind  $K$  that is necessarily such that for every  $x$ , if  $x$  is a physical object, then there is a mass  $y$  of  $K$  such that  $x$  is constituted by  $y$  and  $y$  is homeomerous.

If there were a prime matter stuff-kind, then every physical object and every mass of bronze, wood, etc. would be made out of a mass of prime matter; and no mass of prime matter would itself be made out of any other more basic kind of stuff. I have no idea whether (PMP) is true—although a few philosophers and scientists seem to think that modern science is in the process of vindicating Aristotle in this regard.<sup>44</sup>

If we could be sure that matter does not resemble Oriental Boxes, the homeomerous masses would provide the basis for a very natural way to understand descriptions beginning with 'the mass of matter . . .', such as 'the mass of matter now constituting my body'. Assuming that for any set of homeomerous masses there is an object composed of just those masses, (A6) above ensures that, for any physical object, there is *the mass of matter* out of which it is constituted, in the following sense:

(D12)  $x$  is the mass of matter constituting  $y =_{df}$   $x$  is the sum of every homeomerous mass constituting any part of  $y$ .<sup>45</sup>

Of course, (D12) is adequate only if matter is not infinitely

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<sup>44</sup>See Werner Heisenberg, *Physics and Philosophy* (New York: Harper and Row, 1962), 70–71; and Patrick Suppes, "Aristotle's Concept of Matter and its Relation to Modern Concepts of Matter," *Synthese* 28 (1974): 27–50.

<sup>45</sup>The implications of quantum theory for the question whether I am constituted by the same mass of matter from one moment to the next are difficult to assess. On one interpretation, electrons are spatiotemporally located entities (though sometimes not located in a precisely circumscribed region) that cannot be supposed to continue to exist for any stretch of time. If this interpretation were correct, then we should have to conclude that the mass of matter making me up cannot possibly remain the same for even the smallest period of time, since at least one of the ultimate masses constituting part of my body is constantly changing.

complex in the way posited by the Oriental Boxes theory. If there are no homeomerous masses—if, to take Rudy Rucker's example, everything is made out of quarks, all quarks are made of "darks," all "darks" are made of . . . , and so on, *ad infinitum*<sup>46</sup>—then it is less clear how to make sense of descriptive phrases like 'the mass of matter now constituting *x*'. If quarks can survive changes in their "dark"-parts, and so on, then perhaps we should say that something continues to be made of "the same mass of matter" just in case it has at least one complete decomposition such that no member of the decomposition loses or gains a part of *any* kind.

Whatever puzzles the Oriental Boxes theory may pose for the interpretation of descriptions like 'the mass of matter now constituting my body', it is clear that any sensible theory of masses should at least allow for the *possibility* that the theory is false. Thus a theory of masses should be consistent with the less extravagant hypothesis (A6): that every physical object is ultimately composed of one or more masses of homeomerous stuff.

## 8. Persistence Conditions for Masses

We have seen that some *K* can be the same *K* as something even if the *K* in question does not remain the same  $\phi$ , where ' $\phi$ ' is any ordinary "count" sortal like 'piece' or 'puddle' or 'packet'. But if the standards for sameness of piece or packet or any other everyday sortal are inapplicable, what standards apply to masses?

First, consider masses belonging to observably heteromerous stuff-kinds. Under what conditions does the furniture in our dining room persist? The answer is obvious: our dining room furniture will continue to exist just so long as no furniture now a part of our dining room furniture is destroyed. This furniture can be stored away, sold to several families, etc., but as long as no minimal element—no single piece of furniture—is lost, the furniture now in our dining room continues to exist. Could the furniture in our dining room acquire a minimal furniture-element which it does not now have? On one interpretation, of course, the answer is yes: giving the two definite descriptions small scope, we can truly say, "The furniture in the dining room could come to include a chair

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<sup>46</sup>Rucker, 28.

that is not now a part of the furniture in the dining room”—we could, that is, put one more chair in the dining room. But giving ‘the furniture in the dining room’ large scope turns the quoted sentence false: if we bring a new chair into the dining room tomorrow, the furniture I refer to *today* as ‘the furniture in the dining room’ will be only *some* of the furniture that is in the dining room tomorrow; so the furniture in the dining room tomorrow will not be exactly the same as the furniture in the dining room today. These obvious truisms, which hold for any mass term that picks out an observably heteromerous stuff-kind, reveal the mereological constancy of masses of such stuff-kinds: in these cases it is clear that  $x$  is the same  $K$  as  $y$  if and only if there is no  $K$  in the one that is not in the other.

This schematic principle has the ring of truth when ‘ $K$ ’ is replaced by all sorts of mass terms. The ship is no longer constituted by the same wood after any bit of wood, however small, is lost; and the wood now constituting the ship will at best constitute only a part of the ship as soon as a new piece of wood or any other substance becomes a part of the ship. The first prospector did not lay claim to precisely the same gold yesterday as the second prospector claimed today if there is any gold anywhere claimed by the first that is not now being claimed by the second, and *vice versa*. And so on. It would seem, then, that, in general, one of the distinctive features of the masses of stuff denoted by concrete mass terms preceded by the definite article or indefinite article ‘ $Sm$ ’ is their mereological constancy. A mass of a certain kind of stuff must include all and only the same masses of that kind among its parts for as long as it exists:

- (A7) If  $x$  is a mass of  $K$ , then, for every  $y$  such that  $y$  is a mass of  $K$ ,  $y$  is a part of  $x$  if and only if it always was and always will be the case that, if  $x$  exists, then  $y$  is a part of  $x$ .

There are some cases that may make us wonder about the universal applicability of (A7), however. In certain contexts we seem to allow for sameness of  $K$  under less stringent conditions. The details of these “looser” criteria need to be explored; but (A7) will remain the most fundamental principle governing mass identity, since  $x$  and  $y$  being “the same mass” in the loose sense will turn out to be simply a matter of both  $x$  and  $y$  being constituted by

masses that persist in accordance with the "strict" standards of (A7).

Here is the counterintuitive implication of (A7) that suggests we sometimes use a looser criterion. In a mass of heteromerous *K*-stuff, each *K*-atom is itself a mass of *K*. If a simple rearrangement of the proper parts of some *K*-atoms suffices to destroy even one *K*-atom, then the rearrangement is sufficient to destroy the mass of *K* itself—for the loss of a *K*-atom is the loss of some *K*. This result seems perfectly appropriate in the case of masses belonging to observably heteromerous kinds, like the furniture in our dining room or the silverware in our kitchen. If two chairs are broken up and their wood used to make a table, we no longer have all the same furniture, even if we have all the same wood; if two forks are melted down and recast to make one knife, we no longer have all the same silverware even if we have all the same silver. But there are numerous cases in which we seem to be less inclined to hold to so strict a standard for judging sameness of stuff, allowing that we have all "the same *K*" even though some *K*-atoms have been lost due simply to changes in the relationships among the parts of the missing *K*-atoms.

The attraction of a looser criterion is perhaps keenest when either the heteromerous stuff-kind in question is not observably heteromerous, or the stuff-kind is constantly gaining and losing masses due simply to rearrangements of its proper parts.

We may not be prepared to apply the rigorous standards of (A7) to  $H_2O$ , for example, for the first sort of reason. If two water molecules trade oxygen atoms, then the two original water molecules have ceased to be (or have at least ceased to be some water, if they still exist as widely scattered objects). By (A7), any mass of water of which they were a part has also ceased to be. But if the only mereological change undergone by the water in a certain basin is such a reshuffling of the parts of a couple of water molecules, we clearly have all the same stuff in some sense, and the stuff was some water both before and after the reshuffling. So why bother denying that the water in the basin after the change is the same water as before? After all, the only missing "drop" of water is too small to see, and all its parts remain parts of the water now in the basin.

In the second circumstance described above, even the minimal elements of an *observably heteromerous* stuff-kind may fade into insig-

nificance. Suppose my family's living room furniture is exceptionally modular; that the "modules" are smallish cubes that do not qualify individually as pieces of furniture of any kind; and that we restlessly rearrange them so as to form now three tables and a sofa, now a bed and two chairs, now a single large table, etc. In a way, it is no longer true after one of these transitions that we have the same furniture in the living room; after all, no single piece of furniture survives the rearrangement. However, if we rearrange the cubes incessantly, it would become a bit of a joke to go on insisting that at the end of each rearrangement our living room contains different furniture. As the furniture-elements become more ephemeral, we naturally become more apt to attend only to the persistence of the underlying modules, allowing that the living room contains the same furniture from one day to the next even when a bed, say, has disappeared—so long as all the same *modules* are still there.

Of course, in the case of many 'K's, these two reasons for neglecting *K*-atoms come together. Acids, for example, are heteromeric but not observably so; and the molecules of an acid naturally dissociate in solution. In any case, for a mass term '*K*' that turns out to apply to an unobservably heteromeric kind of stuff, or to a heteromeric stuff-kind whose minimal elements are in constant flux due to the perpetual reshuffling of their proper parts, we may very well want to allow for usages of '*x* is the same *K* as *y*' that do not imply that *x* and *y* contain all the same *K*. Cartwright, responding to such intuitions, allows that some hydrochloric acid or water "could, on different occasions, be constituted by different aggregates of molecules."<sup>47</sup> But it is also important to emphasize (as Cartwright does not) that if there are no masses of stuff or sets of objects at a level "below" that of the molecules of H<sub>2</sub>O that completely constitute the water in a particular basin both before and after the loss or gain of some H<sub>2</sub>O molecules, then it is not really true in even a "loose" sense that the basin contains the same water. In such a case, some water has

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<sup>47</sup>Cartwright, "Heraclitus and the Bath Water," 477. Although Cartwright recognizes this phenomenon, she takes it as evidence that masses of heteromeric *K*-stuff are *not* aggregates of their smallest constituent *K*-parts. This blocks a uniform treatment of concrete mass terms, since a kind of mass whose smallest parts of that kind are *visible* (furniture, cutlery, etc.) clearly obeys the more stringent requirement.

come or gone, and the water that came or went was not made up of parts that were already there and are still there in the basin; so some water—even if only a molecule—either slipped in or slipped out, taking at least some of its parts with it.

We have already seen that for any set of physical objects falling under a given physical object count noun *C* (like ‘hydrogen atom’ or ‘oxygen atom’), there is a mass of “*C*-stuff” made out of those parts (a heap of “hydrogen-stuff” or “oxygen-stuff”). So we can give the following simplified assessment of the sense in which the water in the basin is “the same water” after the loss of some water molecules due to simple rearrangement: every mass of water that was in the basin before the reshuffling was made out of a mass of hydrogen-stuff and a mass of oxygen-stuff; all these more basic masses continue to exist, and they now constitute the water that is in the basin. This looser standard may be further generalized. The following accounts for the case in which a mass that ceased to exist nonetheless “survives” due to the present existence of a mass made out of the same stuff:

- (D13) *x* was, in the loose sense, the same mass of *K* as *y* =<sub>df</sub> there *was* an *x* and there *is* a *y* such that (1) *x* was and *y* is a mass of *K*, and (2) for every complete decomposition *S* of *x* into masses of *K*, there was a set *S\** of masses belonging to non-*K* stuff-kinds, and *S\** is such that: (a) every member of *S* had a complete decomposition that was a subset of *S\**, and (b) *S\** was a complete decomposition of *x*, and *S\** is a complete decomposition of *y*.

The criterion governing presently existing masses that *will* “survive” in the loose sense is the obvious future-tense analogue.

I submit that the tendency to allow for sameness of *K* in cases where minimal elements of *K* are lost always signals one of two things: either we are just being sloppy, and really mean “mostly the same *K*” (as when we say at the end of the day that the glass contains the same water we poured into it in the morning, even though we know that *some* of the water must have been lost due to evaporation); or else we are applying the looser standard of (D13) to masses of *K* whose minimal elements are either too small or too ephemeral to keep our interest.

What more can be said about the persistence conditions for masses of matter? (A7), the strict standard for sameness of mass,

is in fact a rather uninteresting and obvious truism. Like many truisms, its exceeding generality leaves us with a host of unanswered questions. (A7) tells us that no mass of  $K$  can survive the loss of any part that is itself a mass of  $K$ , or “grow” by incorporating new masses of  $K$ . But such information is not very helpful unless one already knows how to “trace” individual masses of  $K$ . Can we formulate equally general but more informative necessary and sufficient conditions for sameness of mass? Different mass terms are used to refer to very different sorts of stuff, and—so far as I can see—any more interesting conditions one could state would apply to masses of some kinds of stuff but not to masses belonging to some other kinds.

Compare, for instance, the persistence conditions for cellular tissue, water, and silverware. (A7) implies that one has all the same cellular tissue or water or silverware just in case one has all the same cells, molecules of water, or pieces of silverware—and no more. Since the persistence of masses of cellular tissue, water, and silverware depend wholly upon the persistence of their minimal elements, more informative persistence conditions for these masses will differ if those pertaining to their minimal elements differ. But surely if it is possible to provide anything like precise and informative necessary and sufficient conditions for the persistence of cells, molecules, and forks, these conditions will be somewhat different. Since a cell, molecule, or fork is no doubt constituted by a mass of stuff with different persistence conditions than the constituted cell, molecule, or fork, it is not enough simply to look for chains of “object-stages” connected spatiotemporally or by immanent causation; one must trace each different kind of minimal element “under” its own appropriate “sortal.”

In fact, it is very difficult to come up with informative necessary and sufficient conditions for the persistence of *any* sort of physical object. We shall be able to provide such conditions for masses of heteromerous kinds just to the extent that we can find them for the minimal elements of those kinds; and for homeomerous kinds, it is quite likely that not much at all can be said.

Here is why: Perhaps one can state semi-informative necessary and sufficient conditions for the persistence of a complex object of a certain kind in terms of the persistence of and relationships among its parts of some other kinds. If we knew that, necessarily,  $x$  is the same ship as  $y$  if and only if  $R$ , where  $R$  is some condition

on the planks making up  $x$  and  $y$  that constrains only what happens to the planks over time, then the persistence of ships could be explained in terms of the persistence of planks. But could there be an “absolutely informative” criterion for the persistence of some kind of physical object, a set of jointly necessary and sufficient conditions for the persistence of some kind of thing that did not make reference to any other persisting physical object? If not, there is no hope for discovering informative persistence criteria for homeomerous kinds. The persistence of a mass belonging to a homeomerous kind depends only upon the persistence of all its parts of that kind; and since it does not have any parts not of that kind, its persistence conditions could not be given in terms of the persistence of parts belonging to any other kind. Thus, homeomerous masses have *absolutely* informative persistence conditions if they have informative persistence conditions at all. But it is doubtful whether anything has absolutely informative persistence conditions.

It is tempting to look for absolutely informative persistence conditions in the vicinity of spatiotemporal continuity: the “career” of any sort of physical object must “be traceable along a change-minimizing or sortal covered [spatiotemporally continuous] path,” and the existence of a change-minimizing or sortal-covered spatiotemporally continuous series of “physical-object stages” is sufficient for those stages to constitute the career of a single object of a given sort.<sup>48</sup> D. M. Armstrong, Sydney Shoemaker, and Saul Kripke have argued quite persuasively that sortal-covered or change-minimizing spatiotemporal continuity is *not* thus sufficient, since it is consistent with the “immaculate replacement” of one object by another; “[s]patiotemporal continuity of phases of things appears to be a mere result of, an observable sign of, the existence of a certain sort of causal relation between the phases.”<sup>49</sup> Their conclusion seems right. The special kind of

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<sup>48</sup>Hirsch, *The Concept of Identity* (Oxford: Oxford University Press, 1982), 120.

<sup>49</sup>D. M. Armstrong, “Identity Through Time,” in *Time and Cause*, ed. Peter van Inwagen (Dordrecht: D. Reidel, 1980), 67–78, at 76. See also Shoemaker, “Identity, Properties, and Causality,” *Midwest Studies in Philosophy*, vol. 4: *Studies in Metaphysics*, ed. Peter A. French, Theodore E. Uehling Jr., and Howard K. Wettstein (Minneapolis: University of Minnesota Press, 1979), 321–42. Shoemaker notes that Kripke raised objections like Armstrong’s against spatiotemporal continuity criteria of persistence (and tem-

causal relationship supposed to be peculiar to stages of the same object is usually denominated “immanent causation,” but until more is said about this brand of causation (other than that it holds among stages of the same object), and we see it deployed in an absolutely informative persistence criterion for *any* kind of physical object, we must remain skeptical about whether such criteria are even formulable. But the prospect that some sort of object may lack informative persistence criteria should not make us doubt the possibility of there being objects of that sort; in particular, it should not make us doubt the possibility of there being homeomerous masses.<sup>50</sup>

### 9. Constructing a Set Theory of Masses

The sum theory of masses developed in the preceding sections has had the resources to capture some of our most basic proto-theoretical assumptions about masses. But it implies that masses are physical objects. Although it is perhaps most natural to identify the gold in my watch or the cellular tissue in my body with a physical object—the heap or mereological sum of all the relevant gold atoms or cells—there are reasons to be unhappy with such a theory. If the cellular tissue in my body now is a physical object, it would seem to be an object distinct from my body. After all, the precise mass of cellular tissue making up my body changes from minute to minute, as skin cells are sloughed off; but surely I can gain or lose a single cell without changing bodies! If so, then body and mass are distinct. But these “two” physical objects are, for all practical purposes, indiscernible: they are made out of the same stuff, they exhibit the same structure, have the same mass, etc. Isn’t there something wrong with this picture?

Of course, someone who accepts a temporal parts metaphysics need not worry quite so much about problems of coincidence between constituting masses and constituted objects. On a metaphysics of temporal parts, the coincidence of an object and the mass

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poral parts metaphysics in general) in influential but unpublished lectures on time and identity. The same sort of objections can be found much earlier, however, in C. D. Broad’s *Mind and Its Place in Nature*, 36–38.

<sup>50</sup>For further discussion of “identity criteria” for masses of matter, see Hirsch, chap. 4.

that now constitutes it is really a matter of the two sharing a *single* temporal part. Thus the three-dimensional region that both occupy at present has only one thing strictly filling it, not two.<sup>51</sup> Likewise, some fiddling with the nature of identity may also be used to dismiss problems of coincidence between mass and constituted object. One might say, for example, that there are not, in any absolute sense, two physical objects here: a human body may be “the same human body as” a certain mass of matter, but still not be “the same mass of matter as” this mass; and if there is no such thing as absolute identity and absolute distinctness, there is no absolute sense in which there are two physical objects and not one in the region occupied by “both” human body and mass. However, for those of us who take our identity straight up and will have no truck with the metaphysics of temporal parts, the coincidence of masses of matter with the objects they constitute cannot be so easily dismissed.

In this paper, I shall take it for granted that neither spatializing time nor relativizing identity is a viable option. Given these constraints, a single-category account of constitution will almost inevitably be forced to recognize coincident but distinct physical objects. If the only identity worthy of the name is *absolute* identity, then my body and the mass of cellular tissue now constituting it must be *absolutely* non-identical—for they obviously differ in their histories and modal properties. The rejection of temporal parts requires that if both masses and the things constituted by them fall in the same category, it is a category of objects that are “wholly present” at each moment they exist.<sup>52</sup> Thus, in a single-category theory, body and constituting mass must be distinct objects wholly present in the same place at the same time. If, as I shall argue, coincident objects are unacceptable, we must either deny that any mass ever constitutes something from which it is distinct, or—more plausibly—adopt a multiple-category theory of constitution.

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<sup>51</sup>This explanation does not help the temporal parts theorist with the apparent *modal* differences between a mass and a constituted object which, as a matter of mere contingent fact, happen always to coincide. See Allan Gibbard, “Contingent Identity,” *Journal of Philosophical Logic* 4 (1975): 187–221, especially 190–91; David Lewis, *On the Plurality of Worlds*, 252–53; and W. R. Carter, “Contingent Identity and Temporal Worms,” *Philosophical Studies* 41 (1982): 213–30.

<sup>52</sup>See Lewis, *On the Plurality of Worlds*, 202.

What is so bad about coincident objects? The fundamental problem is this: if both my body and this mass of cells are physical objects that, though momentarily coincident and indiscernible, differ in their persistence conditions, then there are two objects exactly alike in every empirically discriminable intrinsic respect, one of which has the stamina to withstand pressures and survive changes that the other cannot. Should not two physical objects constructed in precisely the same way out of qualitatively identical parts have the same capacities for survival under similar conditions? Of course one may say that the big difference between the two is found in the *sort* each belongs to—one is a mere mass, the other a living animal. But can sortal properties be *basic*, not possessed in virtue of any other features of a thing?<sup>53</sup> If we admit that sortal differences are ungrounded in this way, we would seem to be committed to the possibility of a world in which a four-dimensional path through space and time is successively filled by a series of masses of cellular tissue *S* that—in every other respect—is exactly like the series of masses *S\** making up my body in the actual world, but that differs only in that *S\** constitutes a persisting human body and *S* does not. Surely this is absurd.

And there are further puzzles. Some properties of physical wholes—for example, mass, weight, and shape—seem to be determined by or “supervenient upon” the physical properties of and relations holding among an object’s proper parts. Weight would seem to be thus supervenient; my living body and its constituting mass of cellular tissue are both made of physical parts so propertied and related that any whole made of such parts must weigh 140 pounds. But then how can it be so easy to lift *both* of these 140-pound physical objects at once?<sup>54</sup> Similarly, many be-

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<sup>53</sup>See Michael B. Burke, “Copper Statues and Pieces of Copper”; and Mark Heller, *The Ontology of Physical Objects* (Cambridge: Cambridge University Press, 1990), 30–32. See also Mark Johnston, “Constitution is Not Identity,” *Mind* 99 (1992): 89–105. If I understand him, Johnston’s claim is that the modal differences and differences in persistence conditions between constituted and constituting object are grounded not in any intrinsic characteristics of these objects, but rather in some facts about human beings and their interests and practices. It is tempting to give his view this unkind paraphrase: Coincident objects are distinguishable because we distinguish them, not because they differ.

<sup>54</sup>For a brief discussion of this sort of “counting” problem, see Denis Robinson, “Can Amoebae Divide Without Multiplying?” *Australasian Journal of Philosophy* 63 (1985): 299–319, esp. 316–17.

lieve that mental properties supervene upon physical properties, so that precise physical duplicates cannot differ in their mental states; then are there *two* thinkers here, the mass of cellular tissue and the human being, each thinking the same thought?<sup>55</sup>

These quite familiar objections to coincident objects are far from being the last word on the subject. Some conceptions of supervenience fit into a coincident objects metaphysics better than others; and coincident-friendly doctrines of supervenience may go some way toward rebutting some of the above objections to coincident objects.<sup>56</sup> One may, for instance, hold that the mental supervenes upon the physical while denying that every object with physical properties sufficient to guarantee the existence of a thinker with a certain mental state is *itself* a thinking thing. The possession of certain physical properties may be held to merely ensure that there is *some* coinciding physical object displaying the supervening mental state. On this view, a mass of cellular tissue, for example, although not itself possessing mental states, can be so disposed physically that mentality is ensured *in a coinciding but distinct human body* constituted by that mass. A similar move seems to help with the problem of “grounding” sortal differences: one may insist that sortal properties *do* supervene upon the intrinsic physical properties of things, but that an object possessing intrinsic properties sufficient to ensure that *something* falls under the supervening sort may not *itself* be of that sort; its having these grounding properties merely guarantees that there is something coincident that is of this sort. If sortal properties so supervene, then my earlier objection based on the ungroundedness of sortals fades a bit; for if the posited supervenience is strong enough, there is no possible world devoid of living human bodies but containing a mass of tissue organized just like the one now constituting my body.

This proposal does not, however, completely solve the most serious problems facing a metaphysics of coincident objects. For one

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<sup>55</sup>I owe this argument to Peter van Inwagen; see “Materialism and the Psychological Continuity Account of Personal Identity,” in a forthcoming volume of *Philosophical Perspectives*, ed. James Tomberlin (Atascadero, California: Ridgeview Publishing Co.). See also van Inwagen, *Material Beings* (Ithaca: Cornell University Press, 1990), 126–27.

<sup>56</sup>This line of response was suggested by the editors of the *Philosophical Review*.

thing, the altered account of supervenience cannot very plausibly be used to solve the mystery of the vanishing weight. Does my living body weigh 140 pounds, while the mass of cellular tissue is weightless? The mass of tissue could, it seems to me, survive at least briefly without constituting a living human body (imagine a thorough but very careful dismemberment); and the surviving mass would still weigh in at 140 pounds. So it would be better to attribute the weight to the mass; but do we really want to say that our bodies are, strictly speaking, weightless? Of course we are free to say that if my body is coincident with a mass that weighs 140 pounds, then it too can be said to weigh 140 pounds in virtue of its close relationship to something that *really* has this weight. But why should my body—a physical object in its own right, made of physical parts each with its own proper weight—have to “borrow” its weight from some *other* object?<sup>57</sup> At least in the multiple-category accounts of constitution described in section 6, above, it was obvious why one or the other of the constituted or constituting things would have to possess certain empirical properties derivatively. If a mass were a plurality—a set of objects, say, or just “a number of objects”—and not an object in its own right, then, as indicated in section 3, the sense in which masses would have weight, location, etc. would be very different from and parasitical upon the sense in which objects have these properties. The other multiple-category theories—conservative and eliminative logical constructions, and those identifying constituted objects with processes—favor constituting masses with the nonderivative empirical properties. If my body were a mere *function* from times to masses of tissue, it could have a weight at a time only in virtue of some mass of tissue’s weighing

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<sup>57</sup>In response to my commentary on a paper of his, Peter van Inwagen has suggested a principle governing the attribution of mass to an object that would go something like this:  $x$  has mass  $n$  iff there is a complete decomposition  $S$  of  $x$  such that the sum of the masses of the members of  $S$  is  $n$ . Presumably, similar principles will hold for weight and other additive physical properties. If one adopts such principles, the combined weight (mass, etc.) of my body and the mass of matter now constituting it turn out to be the same as that of either one taken by itself. For the paper and commentary that provoked this discussion, see van Inwagen, “Der Einfluß der Metaphysik auf andere Bereiche der Philosophie: eine Fallstudie,” and Zimmerman, “Ist ein Körper-Austausch möglich? Kommentar zu Peter van Inwagen,” in *Metaphysik: Neue Zugänge zu alten Fragen*, ed. Johannes Brandl, Alexander Hieke, and Peter Simons (St. Augustin: Academia Verlag, 1995).

something at that time. If my body were a “disturbance” passing through various heaps of living tissue, the only way to attribute a weight to it would be to assign to it the weight of the particular mass of tissue that was currently being “disturbed.” By contrast, the friend of coincident objects who would make living bodies strictly weightless can give no similar reason for attributing non-derivative weight to the constituting mass of tissue but not to my body.

More generally, the alleged differences between coincidents remain just as ungrounded under the revised doctrines of supervenience. Looking just at the physical properties of their proper parts, both my body and the mass of tissue now constituting it are indiscernible. Suppose sortals, mental properties, and weight are completely determined by the physical properties of an object’s parts. According to the coincident objects metaphysics, this means that both my body and the coincident mass of tissue are in certain physical states sufficient to ensure that (i) there is a living human body here, (ii) the living body is thinking, and (iii) there is something weighing 140 pounds here. What the “subvenient” physical states are apparently not sufficient to determine is which object is which—which one has the honor of thinking and of being able to persist through the gain and loss of cellular tissue, and which merely gets to have a weight. If the difference between being a living body and being a mere mass of cellular tissue is *not* grounded in more fundamental intrinsic physical differences, then we still have physical indiscernibles that nonetheless differ in their ability to survive certain physical changes: one can persist in scattered form, while the other cannot; one can survive the destruction of some cells, while the other cannot. The friends of coincident objects will no doubt say that the difference here is one of *sort*, and that it is simply a “conceptual truth” that objects of the one sort can do things objects of the other sort cannot. But the fact remains that the mass and living body are supposed to differ in the sorts of physical changes they can undergo *without* differing in their physical construction; explaining these differences by appeal to ungrounded sortal differences is merely to insist that the two do in fact differ in these ways. Surely such a surprising state of affairs demands a better explanation than that.

I shall assume that because of such difficulties coincident physical objects are not to be countenanced; consequently, given the

rejection of temporal parts and relativized identity, a single-category theory of constitution is also out of the question. Several kinds of multiple-category theories were mentioned earlier: conservative and eliminative logical construction accounts, process theories, and theories that identify masses with pluralities and constituted objects with wholes. Each can plausibly promise to free us from objectionable coincidences. A conservative logical construction approach “builds” mereologically incontinent objects out of masses in such a way that the constructed objects do not compete for space with the more fundamental masses. Suppose, for example, that my body *is* a function—something like a set of ordered pairs of the form  $(t, v)$ , where  $t$  is a time at which my body exists and  $v$  the mass that “stands in for” my body at  $t$ . Being a set, my body must inherit its empirical properties in some way from those of its members. It can only have a weight  $n$  or fill a space  $R$  at a time  $t$  in virtue of its including among its members a pair  $(t, v)$  where  $v$  weighs  $n$  or fills region  $R$  at  $t$  in a less derivative fashion. There is no mystery about how a set of ordered pairs can, in this second-hand way, “fill” the same region at  $t$  while a mass (nonderivatively) fills the same region. Nor is it hard to see how a constituted body can survive changes its constituting mass cannot, and vice versa, once we recognize that the body (unlike the mass) is a set-theoretical construct; its “survival” is only a matter of its including pairs that have later times as members. Eliminative logical constructions have an even shorter way with problems of coincidence: there are no non-masses, so there can be no coincidences between masses and mereologically incontinent constituted objects.

Other multiple-category theorists consign constituted objects to the category of *event* or *process*, and identify masses with enduring (*non-event-like*) objects to which these events “happen.” No proposal along these lines has ever been worked out in great detail, but the basic idea is clear enough. Mereologically incontinent bodies are like waves and tornados—they are processes that “migrate through” various masses of matter. The fact that processes are dependent entities—“accidents” or “modifications” of the things to which they happen—is supposed to dispel any air of mystery about how a process and its “substratum” can be in the same place at the same time. After all, there is nothing mysterious about the fact that a wave can coincide with the water it presently modifies, or that a tornado can be in the same place as the masses of gas, liquid,

and dust presently caught up in it. Although earlier stages of a wave or tornado may, for example, have caused the mass of stuff "in" the wave or tornado to be where it is now, it still seems right to say that processes like these fill certain regions, weigh this or that amount, etc., entirely in virtue of the fact that the stuff now caught up in them takes up space or has a certain weight in a more primary sense. And if processes and masses belong to very different ontological categories, it does not seem so strange that a process may outlive the mass through which it is presently passing, and vice versa.

But these three multiple-category theories are quite radical. If my body is just a function from times to masses, then it is not very special; a function jumping randomly from, say, the metal in the Eiffel Tower at one moment to the sugar in my coffee at another is no less "real," no less a "persisting thing." If my body is a mere fiction, it is even less significant. And we would not normally be inclined to regard our bodies as processes passing through some more basic medium—although, upon careful thought, the similarities between the activity of certain self-perpetuating events like tornados and hurricanes, on the one hand, and the "homeodynamic" processes involved in biological life, on the other, might make us reconsider a facile dismissal of this last suggestion.<sup>58</sup>

On the face of it, then, the multiple-category theory identifying masses with pluralities and constituted non-masses with wholes is much more appealing than the logical construction and process accounts. As noted in section 3, it is not altogether implausible to suppose that a mass is really a set (or a plurality of some sort) rather than a physical object. If every mass could be identified with a set of some kind, perhaps a multiple-category theory of constitution could be developed that would circumvent the above problems of coincidence between constituting mass and constituted object. If the cellular tissue in my body were really just the set containing each of the cells now in my body, it would be no mystery how the mass of cells and the body composed of them could coincide while differing in important ways—for example, in their persistence conditions. And if the cells do not go together to compose

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<sup>58</sup>For an excellent description of the homeodynamic activity characteristic of living things, and the analogy with stable weather systems, see van Inwagen, *Material Beings*, chap. 9.

any physical object *other than my body*, there is also no mystery about why the cellular tissue and my body do not have a combined weight of 280 pounds, or why the mass of cells does not think just in case my body does. No interesting empirical property that belongs to a whole constituted by the cells will be exemplified in the same straightforward, nonderivative way by the set of cells—for example, the whole has a *real* mass  $n$  and *really* fills a certain region  $R$ , while the set only has the “quasi-mass”  $n$  and only “quasi-fills”  $R$ , as per (D2) and (D3), above (see note 19).

Problems of coincidence thus provide a strong motivation for developing a set theory of masses as an alternative to the pure sum theory. But how much of the proto-theory can be captured within a set theory of masses? I shall argue in this and the following section that no set-theoretic construal of masses can do justice to homomerous masses.

If masses are to be identified with sets, what sets should be chosen? The answer is obvious in the case of any stuff-kind  $K$  that is always and everywhere decomposable into minimal atoms of  $K$ —parts that are  $K$  but that have no proper parts that are  $K$ . Here, the mass may simply be identified with the set of its  $K$ -atoms. According to (A2), a set of masses “fuse” to form a *unique* mass; so masses, like sets, respect a “principle of extensionality.” And, by (A7), no mass of  $K$  can change its  $K$ -parts over time, just as sets are not allowed to change their members over time. It is natural, then, to see the parthood relation for masses as analogous to the subset relation. So why not just identify the water in Heraclitus’s tub, for example, with the set of all the  $H_2O$  molecules inside the tub, and the cellular tissue in my body with the set of all the cells in my body?

If we could simply assume that *every* mass is of some kind  $K$  such that masses of  $K$  have  $K$ -atomic decompositions, then it would be fairly easy to identify the mass of  $K$  that makes up an object with the set of all its  $K$ -atoms and preserve every proto-theoretical truth we have canvassed. For instance, if every kind of stuff admitted of  $K$ -atomic decomposition (being either heteromerous, or homeomerous and decomposable into partless simples), then we could rest content with a Lockean principle of sameness of mass. Locke takes the identity of an atom over time as primitive and then proposes the following criterion for the sameness of a mass of matter:

[W]hilst [two or more atoms] exist united together, the Mass, consisting of the same Atoms, must be the same Mass, or the same Body, let the parts be never so differently jumbled: But if one of these Atoms be taken away, or one new one added, it is no longer the same Mass, or the same Body.<sup>59</sup>

Locke's masses cannot survive scattering, it appears; but if we remove this restriction, his simple criterion does the trick: same mass if and only if same *K*-atoms.

Let us call the following set theory of masses—built on the assumption that every stuff-kind *K* has *K*-atoms—the “restricted set theory of masses.”<sup>60</sup> The most natural sort of set theory to use for the purpose of identifying portions of stuffs with sets would be a “temporalized” one, according to which a set containing a number of objects exists at a certain time if and only if all of those objects exist at that time. A set theory for masses should also make do without the empty set. The range of capitalized variables *X*, *Y*, etc. will be restricted to sets; *x*, *y*, etc. to individuals. And when I say in what follows that a certain principle or definition in the sum theory can be “retained” or “accepted as it stands,” I mean that the restricted set theory contains a statement that looks exactly the same, but with the variables for masses capitalized. Statements in the restricted set theory are all marked with an asterisk, but they retain the numbers of their sum-theoretic analogues.

(D1) and (A1) can of course be retained—‘*K*’-schemata are still restricted to mass terms, and the theory is intended to reveal the nature of the referents of mass expressions like ‘the *K*’ and ‘*Sm K*’. But instead of identifying masses of *K* with objects, the restricted set theory identifies them with certain sets. In the sum theory, *K*-atoms themselves were masses of *K*; if every mass is to be construed as a set, however, *K*-atoms will be *members* of masses, but no *K*-atom will itself be a mass. After a slight revision of the definition

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<sup>59</sup>John Locke, *An Essay Concerning Human Understanding*, ed. Peter H. Nidditch (Oxford: Oxford University Press, Clarendon Press, 1985), 330 (book 2, chap. 27, §3). Incidentally, Locke himself seems to have recognized the ease with which masses of atoms may be identified with sets, for he occasionally uses ‘*Collection of Matter*’ as a synonym for ‘*Mass of Matter*’ (see 331 (book 2, chap. 27, §4)).

<sup>60</sup>I am deeply indebted to Michael Kremer for pointing out a number of serious errors in an earlier version of this restricted set theory.

of “*K*-atom” to take this into account, masses of *K* are simply identified with sets of *K*-atoms.

(D8\*)  $x$  is a *K*-atom =<sub>df</sub>  $x$  is some *K*, but no proper part of  $x$  is some *K*.

(D2\*)  $X$  is a mass of *K* =<sub>df</sub>  $X$  is a set of (one or more) *K*-atoms.

Heteromerosity and homeomerosity can easily be redefined in a way appropriate for masses-qua-sets:

(D6\*)  $K$  is a heteromerous stuff =<sub>df</sub> For any mass  $X$  of  $K$ , every member of  $X$  has proper parts that are not  $K$ .

Since the *only* members of a mass of *K*, on the present proposal, are *K*-atoms, (D6\*) simply says that a stuff-kind *K* is heteromerous if and only if every *K*-atom has proper parts that are not of kind *K*.

(D7\*)  $K$  is a homeomerous stuff =<sub>df</sub> For any mass  $X$  of  $K$ , every part of a member of  $X$  is itself  $K$ .

Every stuff-kind *K* in the restricted set theory consists of *K*-atoms; so the only homeomerous masses the theory recognizes are those decomposable into sets of partless (“simple”) atoms.

The set-theoretical analogue of a fusion of several objects is simply the union of several sets. So (A2), the “fusion principle” for masses, becomes

(A2\*) For any set  $S$  of masses of  $K$ , there is a unique  $X$  such that (1)  $X$  is a mass of  $K$ , and (2) for every  $y$ ,  $y$  is a member of  $X$  if and only if  $y$  is a member of one of the masses in  $S$  (that is, the union of a set of masses of some kind is a mass of the same kind).

(A3), which posits ‘*C*-stuff’ mass terms for every ‘*C*’, may be retained. But since masses of *C*-stuff are now just sets of *C*-stuff-atoms (that is, sets of *C*s), the behavior of the cooked-up mass terms is governed by an even simpler rule:

(A4\*) Every set whose members are all *C*s is a mass of *C*-stuff.

In the sum theory, every physical object qualified as a mass of some kind; this allowed the theory to treat every instance of constitution as a case of one mass constituting another. On the restricted set theory, a physical object falling under some physical

object count noun  $C$  is never *itself* a mass of  $C$ -stuff (since all masses are sets)—but it *is* a  $C$ -stuff atom, and its *singleton* is a minimal mass of  $C$ -stuff. The restricted set theory must recognize that a mass can constitute both physical objects (non-sets) and other masses (all of which are sets); so constitution in the set theory bifurcates. The cases in which a mass constitutes a single physical object are easily described:

- (D11\*a) The mass  $X$  of kind  $K$  constitutes  $y =_{df}$   $X$  is a mass of some kind  $K$ ,  $y$  is a physical object, and  $X$  is a complete decomposition of  $y$ .

If the members of a mass go together to form a whole, then the object composed of the members should clearly count as constituted by the mass.

The cases in which a mass constitutes a mass bring back all the complexities encountered in the more general account of constitution set forth in the sum theory. The following is simply a set-theoretical analogue of that definition:

- (D11\*b) The mass  $X$  of kind  $K$  constitutes the mass  $Y$  of kind  $K^* =_{df}$  (1)  $X$  is a mass of  $K$  and  $Y$  is a mass of  $K^*$ , and (2) either (a)  $X$  is identical with  $Y$ , or (b)  $X$  is not identical with  $Y$ , in which case (i) every part of every member of  $Y$  has a part in common with some member of  $X$ , and vice versa, and (ii) every member of  $Y$  is decomposable into a set of members of  $X$ .

Just as before, we leave room for identity as a limiting case of constitution (clause (2a)). And again, in the case of non-identity, we require, at some level, complete community of parts between constituting and constituted masses (clause (i) of condition (2b)—a condition that was easier to specify in the sum theory in terms of sharing a complete decomposition); and we insist that every sub-mass of  $K^*$  in the constituted mass be made up entirely of masses of  $K$  in the constituting mass (clause (ii) of condition (2b)).

Given the new definitions of 'constitution', (A5), (A6), and (PMP) may be taken on board as they are, while the proposed definition of 'the mass of matter' constituting an object can be easily rewritten thus:

- (D12\*)  $X$  is the mass of matter constituting  $y =_{df}$   $X$  is the union of every homeomerous mass constituting any part of  $y$ .

(A7), the statement of the “strict” persistence conditions for masses, becomes a trivial truth within the set-theoretical framework—and since there is no temptation to say that sets can change their members over time, it is no longer necessary to introduce past and future tenses in the set-theoretical version:

(A7\*)  $X$  is the same mass of  $K$  as  $Y$  if and only if  $X$  and  $Y$  are masses of  $K$  and, for every  $Z$ ,  $Z$  is a subset of  $X$  if and only if  $Z$  is a subset of  $Y$ .

We said that a mass  $x$  of  $K$  is the same, in the *loose* sense, as a mass  $y$  of  $K$ , just in case there are objects “below” the level of the masses of  $K$  that together constitute both  $x$  and  $y$ . Sets of  $K$ -atoms  $X$  and  $Y$  should likewise count as “the same mass of  $K$ ” in the loose sense just in case the  $K$ -atoms in  $X$  are made out of things that also make up the  $K$ -atoms in  $Y$ :

(D13\*)  $X$  was, in the loose sense, the same mass of  $K$  as  $Y =_{df}$  there *was* an  $X$  and there *is* a  $Y$  such that (1)  $X$  was and  $Y$  is a mass of  $K$ , and (2) there is an  $S$  such that: (a)  $S$  is a set of non- $K$  objects, (b)  $S$  was the union of a set containing exactly one decomposition of each member of  $X$ , and (c)  $S$  is also the union of a set containing exactly one decomposition of each member of  $Y$ .

The assumption that every stuff-kind  $K$  has minimal atoms thus enables us to carry out a straightforward and fairly simple complete translation of the sum theory of masses in set-theoretical terms. Thus, if every stuff-kind has atoms, the restricted set theory can both capture the proto-theoretical assumptions about masses explored in the first part of this paper and eliminate the puzzling coincidences between constituting and constituted objects that confronted the sum theorist.

But must every stuff-kind have minimal atoms? No. I argue elsewhere that any three-dimensionally extended object must contain atomless gunk—that is, any extended solid body having precise spatial boundaries would have to contain parts *all* of whose proper parts had further proper parts.<sup>61</sup> Now perhaps there are no three-

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<sup>61</sup>See my “Could Extended Objects Be Made Out of Simple Parts?” forthcoming in *Philosophy and Phenomenological Research* 56 (March 1996). My general reasons for thinking extended objects could not be made of unextended parts are much like Brentano’s: the idea that a continuous

dimensionally extended, precisely bounded physical objects; perhaps Boscovich was right and every physical object is ultimately made out of a cloud of disconnected point-sized atoms. Nonetheless, there surely *could have been* extended objects. They may be nonexistent, like gold mountains, but they are not impossible, like round squares. A mass of any stuff-kind  $K$  that constituted a homogeneous extended solid would itself, then, include infinitely many "sub-masses": for every proper part of the object, there would have to be a mass of  $K$  making up that part, and for every proper part of such a part, there would be another mass of  $K$ , and so on, *ad infinitum*. Such an extended object could therefore be constituted only by a mass of atomless gunk—a mass of  $K$  that is homeomerous but that does not possess minimal  $K$ -atoms. So it is at least possible for there to be stuff-kinds that cannot be handled by the restricted set theory.

How should the set theorist attempt to make room in her theory for masses of atomless gunk? The original restricted set-theoretical treatment of masses obeyed the following principle: whenever you have a larger mass compounded out of smaller masses of the same kind, identify the larger mass with a set of these smaller masses—make sure, that is, that the set includes no physical object so big as to compete for space with an object constituted by the mass. We might call a set theory that follows this rule a "pure" set theory of masses. Adherence to the rule should suffice to eliminate coincidences between constituting masses and constituted objects. Unfortunately, application of the principle to the case of atomless stuff-kinds proves impossible. By the rule, a mass of atomless gunk must be a set, since it includes submasses; but any portions of the mass you pick to serve as members of this set are themselves masses of atomless gunk, and so must also be construed as sets; likewise, the members of these members must be sets; and so on. Thus a mass of atomless gunk becomes a set

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body is made of point-sized parts "runs counter to the concept of contact and thereby abolishes precisely what makes up the essence of the continuum" (Franz Brentano, *Philosophical Investigations on Space, Time and the Continuum*, trans. Barry Smith (London: Croom Helm, 1988), 147). For a discussion of the views of Brentano, Suarez, Ockham, and others on these matters, see my "Indivisible Parts and Extended Objects: Some Philosophical Episodes from Topology's Prehistory," forthcoming in *Monist* 79 (January 1996).

all of the members of which are sets, all of the members of the members of which are sets, all of the members of the members of the members of which are sets, etc. Masses could not, however, be identified with any such sets.

The mere thought of these “non-well-founded” sets is enough to induce vertigo. How could something as concrete and physical as a mass of matter be made of *nothing* but sets of sets of sets . . . *ad infinitum*?<sup>62</sup> If a set can be said to have any empirical qualities—for example, spatial location, which sets are often said to lack on account of their being in some sense “abstract”—it can only get them parasitically, by inheriting “quasi-empirical properties” from the more fundamental empirical qualities of its members. As noted in section 3, there are perfectly sensible parasitical modes of being “quasi-spatially located” or having a “quasi-mass” that a set will have in virtue of having members that take up space or have a mass in the more fundamental way appropriate to individual physical objects. But a set can “quasi-fill” space or have a “quasi-mass” only in virtue of having members that *really* take up space or *really* have mass. These considerations suggest the following “empirical property inheritance principle” for sets:

- (A8) If  $P$  is a set-theoretical analogue of an empirical property, a set  $S$  has  $P$  only if there are members of the transitive closure of  $S$  that are not themselves sets and that are so propertyed and related that, necessarily, for any objects similarly propertyed and related, the set of those objects has  $P$ .

If masses were really sets of sets of sets . . . “all the way down,” they could not have a mass or be spatially located in even the “quasi” sense appropriate to sets. All their interesting empirical properties would vanish.

Would we do better to interpret every instance of an expression of the form ‘the  $K$ ’ or ‘ $Sm K$ ’ as a plural referring term that denotes a number of things (but not the *set* of those things), and then work out something analogous to a set theory of masses, but using plural quantification and no set theory? No. The sort of “mere plurality” picked out by a plural referring term is not a *single thing* of any sort—that is just the difference, I take it, between the denotations of plural referring terms on the one hand, and

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<sup>62</sup>It was Brian Leftow who first put this question in my head.

sums and sets on the other. So to identify masses with mere pluralities that were pluralities of pluralities “all the way down” would be to identify masses with *nothing at all*.

A mass belonging to an atomless stuff-kind would have empirical properties, and it would be more than nothing. Thus atomless masses cannot be construed as sets within a “pure” set theory of masses; nor is there any hope for the reconstruction of a pure “set theory of masses without sets” using just plural referring expressions and plural quantifiers.

### 10. An “Impure” Set Theory of Homeomerous Masses

So much for a “pure” set-theoretical construal of masses. Could an “impure” set-theoretical approach be made to work? That is, could we identify masses belonging to atomless stuff-kinds with sets if we were willing to admit that some compound masses contain as a member a physical object as large as the mass itself? The pursuit of an impure set theory of masses for atomless stuff-kinds will lead us toward a theory of masses that, although it successfully derails the “vanishing empirical properties” argument used at the end of the previous section, nonetheless proves to be a false friend to anyone seeking to avoid unseemly coincidences between mereologically constant masses and part-changing constituted objects.<sup>63</sup>

In order to simplify matters somewhat, let us suppose that there is only one atomless stuff-kind  $K$ , and that my body is ultimately constituted by a mass of such stuff. Let  $X$  be whatever set is finally to be identified with the mass of  $K$  constituting me now. In order to avoid the problem of vanishing empirical properties, every part of my body must have a part in common with a physical object that is a member of  $X$ , or at least with a physical object that is a member of a member of  $X$ , or a member of a member of a member of  $X$ , etc. If this were *not* true, then there would be some part of my body no part of which overlapped any physical object anywhere

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<sup>63</sup>The proposal discussed in this section owes a great deal to Mark Heller, who advanced an “impure” set theory of masses in comments on a paper of mine at the 1993 Central Division meetings of the APA. It should be noted that Heller himself did not really expect that an impure set theory could facilitate the avoidance of all undesirable coincidences. This section is therefore nothing like a refutation of Heller, who already saw that the search for an impure set theory leads to a dead end.

within  $X$ —a part “unrepresented” by any subset of  $X$  capable of inheriting empirical properties from its members. But whatever set in  $X$  is supposed to be the mass constituting this unrepresented part of my body would then have lost all connection to the physical object it is supposed to be constituting; having no parts of my body anywhere within it, it would be unable to “borrow” its empirical properties from the physical stuff in my body.

So every part of my body must have a part in common with a physical object that is embedded somewhere among the members of  $X$ , or the members of members of  $X$ , etc. And every object in  $X$  must be a part of my body, if it is to constitute me and nothing more. But then there must be a set of physical objects  $S$  each of which is inside  $X$  somewhere and the fusion of which is my body itself—in particular, since every object buried anywhere in  $X$  is a part of my body, and no part of my body has a part that is not made up of parts of the objects in  $X$ , the fusion of the transitive closure of  $X$  must yield my body. The most straightforward way to ensure that  $X$  satisfies this requirement is to identify it with some complete decomposition of my body—some set of non-overlapping parts that make up the whole of my body. One could, of course, identify it with sets that are not decompositions of my body: for example, if  $S^1$  is the set of all the cells in the top half of my body and  $S^2$  is the set of all the cells in the bottom half of my body, then identification of  $X$  with  $\{S^1, S^2\}$  would also satisfy this requirement; as would the identification of  $X$  with the redundant  $\{S^1 \cup S^2, S^1, S^2\}$ . These complications will be neglected for the moment. Once we have seen the problems besetting the simpler “complete decomposition” proposal for  $X$ , we shall see that any of the more complex ways of smuggling a complete decomposition of my body into  $X$  at lower levels or in a redundant, overlapping form are subject to the same difficulties.

What must the members of  $X$  be like if this complete decomposition of my body is to serve as the  $K$  out of which my body is now composed? Well, the  $K$  now constituting my body will not be the same  $K$  as the  $K$  constituting my body at some other time if there is any  $K$  in my body now that will not be in my body then, and vice versa. That, as we saw, is a simple truism—a part of our proto-theory of masses that any metaphysical theory of masses must preserve. If any of the members of  $X$  could survive the gain or loss of parts that are themselves of kind  $K$ , then I could continue to be constituted by  $X$  even if I were not made of the same  $K$  as I am

now. So the members of  $X$  cannot be capable of surviving the gain or loss of any parts that are  $K$  if  $X$  is to do duty as the mass of  $K$  constituting my body.

But now we face the pressing question, How big should the parts of me in  $X$  be? How small a "grid" must we impose upon my body before we reach parts that possess the required mereological stability? Since  $K$  is atomless and homeomerous, we cannot count on there being some built-in structure to the stuff that could provide a natural breakdown into bits of  $K$  that can be treated as atoms. The grid can, it would seem, be as small as you like; but why can it not also be as big as you like?

That it cannot be as big as you like is clear. If just *any* complete decomposition of my body will serve for  $X$ , then take the largest one: let  $X$  be the set having my entire body as its only member. If this set is to serve as the mass making up my body, then my whole body must be unable to survive the gain or loss of any  $K$ . But the whole aim of the set-theoretical approach is to distinguish between the mass of  $K$  that cannot survive such changes, on the one hand, and the mereologically incontinent living body it constitutes, on the other. To admit that my body is just like a mass of  $K$  in this respect would be to give up.

Clearly, then, the opponent of coincident entities will want to choose some set of much smaller parts of my body as the level at which my parts become mereologically constant with respect to proper parts that are some  $K$ . But what level exactly? There must be some real difference between parts of me above a certain size and parts below that size, but it is hard to imagine what this could be. The opponent of coincident objects needs to say, in effect, "I pick whatever size is small enough to ensure that no bit of  $K$  of that size or smaller could possibly constitute a distinct, mereologically incontinent object." But there is no reason to suppose that for every possible kind of atomless stuff there is such a level.

Consider the example of human flesh, blood, and bone—three stuff-kinds that are not observably heteromerous. If my body were really ultimately constituted by some atomless  $K$ , then the masses of flesh, blood, and bone in my body would also be constituted by some of this  $K$ -stuff. Before the discovery that flesh, blood, and bone are really heteromerous, with tiny living cells for minimal elements, we might have been tempted to say, "The set  $X$  that is to do duty as the mass of  $K$  making up my body can be any com-

plete decomposition of my body all the members of which are smaller than, say, one cubic centimeter." But now we realize that this size is too big. If we are willing to say that organisms like human bodies can undergo the gain or loss of parts, then it would surely be pure prejudice to deny the same privilege to smaller living things, like single-cell organisms. And if individual cells outside my body can persist through changes in their parts, then surely the individual cells making up the flesh, blood, and bone in my body can, too. To say that any object made of *K* and smaller than one cubic centimeter cannot survive the gain and loss of parts would be to rule out the possibility of living things—like the blood cells in my body, for example—that are made of *K* if I am, but that can survive changes in their parts if anything can.

I shall not insist that an object could be made of structured mereologically incontinent parts that were in turn made out of smaller structured mereologically incontinent parts, and so on, *ad infinitum*. However I see no basis for denying the possibility of homoeomerous stuff-kinds that can constitute mereologically incontinent living organisms of *any size you like*. Could not God make an extended atomless stuff so malleable that he could fashion creatures as small as he chose out of such stuff? No doubt he could. But now we face a serious problem. Since it always remains possible to make bigger or smaller living things out of a given bit of atomless *K*-stuff, identifying *X* with *any* set of parts of my body—however small—has the result that the mass of *K* making up my body could survive the gain or loss of some bits of *K*. But that, as we have seen, is an impossibility. Mereological stability is *sine qua non* for masses; a mass of *K* cannot possibly persist through the gain or loss of any constituent mass of *K*.

Thus, to do its job as a mass of *K*, the objects chosen to be members of *X* must be such that they cannot survive the gain or loss of any parts; but we are not free to just pick a size limit smaller than any mereologically incontinent object in the actual world and insist that no bit of *K* below that size could gain or lose any *K*. To do so would be to doom all the living things in other possible worlds that are made of *K* but smaller than the chosen size—including infinitely many tiny *metaphysicians*, for whom we should feel a special affinity. Surely ignoring these smaller colleagues would represent an objectionable "sizism"; as Dr. Seuss has taught us, "a person's a person, no matter how small." If *we* are free to pick a

size below which objects made of  $K$  cannot survive changes in their parts, then really *big* metaphysicians made of  $K$  who happen to live in worlds with no constituted objects as small as human beings must be equally justified in selecting much *larger* size limits. But then even a human-sized object made of  $K$  (for example, my own body) is not, after all, able to survive the gain or loss of any  $K$ .

These same difficulties arise for all “impure” set theories, including the more complex ones identifying the mass constituting my body with something other than a simple complete decomposition of my body. Even if the set  $X$  to be identified with the mass of  $K$  in my body has no complete decomposition of my body in it at any level—that is, even if the transitive closure of  $X$  contains no subset that is a complete decomposition of my body—still, in order to avoid the problem of vanishing empirical properties, every part of my body must be “represented” in  $X$ . To ensure that none of my stuff is left out, and that no part of me is constituted by a non-well-founded set of sets of sets . . . , it must be the case that every part of my body is identical with a fusion of parts of members of the transitive closure of  $X$ . And the members (and parts of members) of the transitive closure that “fuse” to form the part of my body in question cannot possibly survive the gain or loss of any  $K$ . If they could, there would be a part of my body whose “representatives” in  $X$  could gain or lose  $K$ ; but then my body could be constituted by the same mass even though it had gained or lost some  $K$ —an impossible result, since a thing is constituted by the same mass of  $K$  just in case it neither gains nor loses any  $K$ . So we face the same question: how big or small are the mereologically constant parts of me in  $X$  that are needed if every part of my body is to be represented in  $X$ ? For the reasons just canvassed, they cannot be as large as you like; and, at least for stuff-kinds capable of constituting creatures of any possible size, whatever size you choose will be too big.

Anyone who shares my worries about coincident physical objects will be disappointed by these results. Neither pure nor impure set theories of masses can provide the resources for avoiding ugly coincidences between constituted objects and distinct constituting objects—at least not in the case of masses belonging to atomless stuff-kinds capable of constituting living things of every possible size.

## 11. Conclusion

The attempt to eliminate all undesirable coincidences by identifying every mass with a plurality of some kind has run aground on a heap of atomless gunk. The significance of this result should not be underestimated. Consider the ingenious—indeed, breathtaking—metaphysics of material objects recently advanced by Peter van Inwagen.<sup>64</sup> According to van Inwagen, the only composite physical objects are living organisms; therefore, ultimately, the mass of matter that makes up any living thing must be identified with a set or plurality of simples. Thus, in part because of his abhorrence of coincident objects, van Inwagen is driven toward a multiple-category account of constitution, much like that found in the restricted set theory of masses.<sup>65</sup> However, given the possibility that living organisms very much like ourselves—if not we ourselves—could be made of atomless stuff-kinds (something that van Inwagen himself allows as an epistemic possibility, at least),<sup>66</sup> it would be quite inappropriate for the ontologist to rest content solving problems of coincidence that arise in the actual world by means of set-theoretical tricks. After all, we cannot solve such problems “elsewhere” by the same methods. Even if, by some happy chance, it turns out that the ultimate stuff-kinds of which our bodies are composed actually have partless minimal elements; and even if, by some further piece of luck, it turns out that we are for some reason *essentially* made out of only such stuff-kinds (and could not, say, gradually have all our parts replaced by parts made of atomless stuff—a possibility that should not be lightly dismissed); even so, it would be absurd

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<sup>64</sup>See his *Material Beings*.

<sup>65</sup>The way in which the rejection of coincident objects supports van Inwagen’s final metaphysics is made clear in his “The Doctrine of Arbitrary Undetached Parts,” *Pacific Philosophical Quarterly* 62 (1981): 123–37; see esp. 125. Although van Inwagen says little about the referents of mass expressions, it is clear that he would deny that ‘the cellular tissue constituting my body’ refers to a physical object. And he asserts that whether two objects are constituted by “the same matter” (or the same “quantity” or “parcel” of matter) is really a question of whether they contain all and only the same ultimate “mereological atoms” (5).

<sup>66</sup>He says, “what we now call ‘modern physics’ may be superseded. Perhaps the physicists will some day decide that quarks and electrons are made of some homoeomerous stuff” (*Metaphysics* (Boulder: Westview Press, 1993), 28).

to simply thank God for our good fortune and move on to other metaphysical puzzles, ignoring the fate of all those unhappy metaphysicians (of every imaginable size!) made of atomless gunk in other possible worlds. To solve problems of coincidence in this way would be like trying to put out a forest fire with a single bucket of water. Perhaps you can keep one little tree from burning, but what about all those other ones? Furthermore, van Inwagen and I both agree that we have no reason to feel so sure that we are not in fact living in one of the problematic worlds. Who knows where some future physics will lead us? If we rely on a set-theoretical approach to masses to solve problems of coincidence, we may even discover that we have doused the wrong tree.<sup>67</sup>

To sum up: Shoes, ships, masses of sealing wax, cabbages, kings—every physical thing that most interests us is constituted by stuff from which it is distinct. The moral of this paper is that we must make some difficult choices regarding the ontological status of *all* such constituted things. If we hold on to a single-category theory of constitution (while rejecting temporal parts and relative identity), unacceptable coincident objects appear. Eliminating the coincidents requires a multiple-category theory of constitution. Multiple-category theories come in more and less radical varieties; the least radical involves something like a set-theoretical construal of masses. Now we also do not want to presuppose the truth of the Oriental Boxes theory of matter—let alone its *necessary* truth—and so must recognize that living things and artifacts will often be constituted by ultimate, homeomerous masses. And we do not want to presuppose the truth of atomism—let alone its *necessary* truth—and so must recognize that living things and artifacts may easily be ultimately constituted by homeomerous masses of atomless gunk. But no set-theoretical construal of masses can make sense of the possibility of mereologically incontinent objects being constituted

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<sup>67</sup>Could we use the set-theoretical approach in worlds without atomless gunk, and appeal to a more radical multiple-category account of constitution only in the other worlds? Then at least we could *hope* that living things in the actual world are not logical constructions or “disturbances.” Contingency of this sort is, I believe, quite out of place when it comes to the fundamental categories into which different kinds of objects fall. Surely if animals or artifacts fall into some broad ontological category (for example, individual thing, event, set, fiction), then they necessarily belong to that category. Human bodies could not merely *contingently* fail to be events or functions.

by masses of atomless gunk; we are stuck, therefore, with one of the more radical multiple-category theories. I believe that the only plausible multiple-category theories remaining are the ones mentioned earlier: those identifying constituted objects with processes, or with logical constructions out of masses. These are, at the very least, the *only* other multiple-category metaphysics that anyone has proposed.

Some philosophers would resist this argument by pleading massive ignorance about what is really possible and impossible with respect to physical substances; such questions, we will be told, can be answered only by a "final physics"—we cannot tell whether atomless stuff is really possible, let alone whether complex objects of any size you like could be made of such stuff, until physics is "through." Perhaps physicists will discover some heretofore unknown facts about reality that make atomless stuffs impossible and atomism necessary—or vice versa.

For one thing, this appeal to science as the final and only arbiter of what physical states of affairs are really possible strikes me as highly problematical, given the important place thought experiments and a priori judgments about what is and is not possible have always played in the actual practice of science. But more importantly, our grasp of matters modal is simply not so weak as this objection alleges. I admit that modal epistemology is a complex matter, and that conceivability is not an *incontrovertible* guide to possibility. The evidence that the conceivability of a certain state of affairs provides for the possibility of that state of affairs may, in some cases, be overridden—for example, by similar evidence for the possibility of a *second* state of affairs that is possible if and only if the first state of affairs is *not* possible.<sup>68</sup> No one, however, has given good reason to doubt that the conceivability of a state of affairs—for example, the conceivability of some living body's being made of extended substances, and thus (if my arguments elsewhere are right) being made of atomless gunk—provides a great deal of evidence for the belief that the state of affairs in question is possible.<sup>69</sup> And how could a physical theory about the nature and be-

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<sup>68</sup>For an example of this sort of case, see my "Two Cartesian Arguments for the Simplicity of the Soul," *American Philosophical Quarterly* 28 (1991): 217–26.

<sup>69</sup>For a recent defense of this claim, see Stephen Yablo, "Is Conceivability a Guide to Possibility?" *Philosophy and Phenomenological Research* 53 (1993): 1–42.

behavior of physical stuffs in *this* world uncover an empirical fact that ruled out atomless gunk in *every possible world*—even in those with laws of nature very different from our own? I stand ready to hear genuine arguments for the absolute impossibility of atomless gunk. But in the absence of such arguments, conceivability provides all the justification we could ever want for the possibility of atomless gunk—evidence that, so far as I can see, has nothing to fear from any future physics.

But suppose the modal skeptic's objection *were* well founded—suppose there *were* reason to doubt the deliverances of conceivability with respect to what's possible in the physical world. This still only leaves us with the pious hope that, for some unforeseeable reason, atomism will turn out to be a necessary truth. Thus, even if the objector is right, we must still be prepared to accept one of the more radical multiple-category theories of constitution.

Our conclusions have some obvious ramifications for the adequacy of the sum theory of masses set forth in the first half of this paper. There is, it seems, no real alternative to using a sum theory to explicate the properties of homeomerous masses. But what of masses that can be constituted by distinct masses? They can only turn out to be constituted entities within a multiple-category theory of constitution—and so must be something like processes passing through homeomerous masses, or logical constructions out of such masses. If tables and chairs, for instance, are logical constructions out of homeomerous masses, then *masses of furniture* will have to be treated as logical constructions as well; and if, according to our logical construction, every *piece* of furniture is, say, a function from times to masses, then each *mass* of furniture should surely be identified with a set of these “furniture-functions.” Suppose, on the other hand, that living things are really *processes* passing through homeomerous constituting masses; then individual cells are tiny “eddies” moving through some underlying ultimate masses of stuff, and a mass expression like “the cellular tissue in my body” will pick out a larger event of which all the cells in my body are parts—the giant disturbance that is made up of each of these tiny eddies.

The truisms of the sum theory can surely be translated into a new idiom appropriate to such masses-*qua*-sets-of-functions, or masses-*qua*-processes. But constituted masses of either sort will have

to be segregated from the ultimate ones in our final theory of masses for obvious reasons.<sup>70</sup> Thus, in the end, the simple sum theory must be given up in favor of a theory of masses with at least two levels or "tiers": a lower-level sum theory just like the sum theory set forth above, but with substitution for *K*-schemata restricted to mass terms that apply only to homeomerous masses; and a higher-level theory of masses tailored to deal with masses that are logical constructions or processes. No more can be said about the upper tiers of the theory of masses until we have decided which multiple-category theory is best—or which is best for which sorts of constituted thing.

Philosophers actively attacking both temporal parts and relative identity are legion; but the defenders of the logical construction and "disturbance" approaches to constitution can be counted on

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<sup>70</sup>For one thing, the constitution relation holding between two masses-*qua*-sets-of-functions or two masses-*qua*-processes will be very different from the constitution relation holding between a mass of one of these sorts and an ultimate constituting mass. For example, the way in which a mass of furniture-*qua*-set-of-functions is constituted by, say, a mass of wood-*qua*-set-of-functions (assuming that masses of wood are also logical constructions) can be modeled on (D11). Given the logical construction account in terms of functions from times to ultimate masses, the constitution-relation between masses-*qua*-sets-of-functions will look something like this: one set of functions *X* constitutes another such set *Y* at a given time *t* if and only if either (1)  $X = Y$ , or (2)  $X \neq Y$ , in which case: (a) for every *v* such that *v* is the value of a member of *X* for *t*, every part of *v* has a part in common with some *u* such that *u* is the value of a member of *Y* for *t*, and vice versa; and (b) every *v* such that *v* is the value of a member of *Y* for *t* is decomposable into a set *S* all of whose members are values of one or another member of *X* for *t*. But the constitution relation between a homeomerous mass and a constituted mass-*qua*-set-of-functions will be very different: in this case, the ultimate mass *x* constitutes the set of functions *X* at *t* if and only if the set *S* of every *v* such that *v* is the value of one or another member of *X* for *t* is a *decomposition* of *x*.

Similar differences crop up in the case of masses-*qua*-processes. For instance, a mass of cellular tissue construed as a disturbance will constitute another mass-*qua*-disturbance—for example, some skin—just in case the presently existing stages of both the cellular tissue and the skin share a complete decomposition, and every part of the present stage of the skin that is itself a stage of some skin is decomposable into parts each of which is a stage of some cellular tissue. But a very different approach has to be taken to constitution relationships between ultimate masses and masses-*qua*-disturbances. An ultimate mass will constitute the large disturbance that is the mass of cellular tissue in my body, for instance, just in case the ultimate mass is the smallest object to which this large disturbance is presently occurring.

one hand. If my results are correct, however, anyone who persists in enmity toward temporal parts and friendship for absolute identity has little choice but to regard ships and human bodies as processes, functions, or even mere fictions.<sup>71</sup>

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