

## SUBSTANCE <sup>1</sup>

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THE question of substance in the philosophy of physics has three branches: logical, physical, and epistemological. The first is a problem in pure philosophy: is the notion of "substance" in any sense a "category," i.e. forced upon us by the general nature either of facts or of knowledge? The second is a question of the interpretation of mathematical physics: is it (*a*) necessary, or (*b*) convenient to interpret our formulæ in terms of permanent entities with changing states and relations? The third concerns the relation of perception to the physical world.

Logically, "substance" has played a very important part in the past, and is still perhaps less obsolete than might be supposed. A substance may be defined in purely logical terms as "that which can only enter into a proposition as subject, never as predicate or relation." This definition is practically that of Leibniz, except that he does not mention relations, since he held them to be unreal. We shall do well, however, to include them, because the logical position of substance is not much affected thereby, and it may, I hope, be now taken for granted that relations are as "real" as predicates.

Metaphysically, substances have generally been held to be indestructible. But this opinion is not justified by the logical definition, though many philosophers have supposed that it was. When I wish to discuss a substance having this further attribute, I shall speak of it as a "permanent substance"; when I use the word "substance" without qualification, I shall mean only substance in the logical sense, leaving the question of duration open.

It is extraordinarily difficult, in considering substance from the point of view of logic, to avoid being unduly influenced by the structure of language. All languages commonly known to civilized people consist of sentences which can be analysed into subject and predicate, two subjects and a dyadic relation, three subjects and a triadic relation, etc., together with relations between such units, expressed by "or" or "if" or some analogous word. I do not know whether the same can be said of African, Australian, or other uncivilized languages. But certainly it can be said of all the languages that philosophers have known. Logic, as ordinarily

<sup>1</sup> The following article is a chapter in a forthcoming work, *The Analysis of Matter*, to be published shortly by Messrs. Kegan Paul.

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conceived, takes over this linguistic scheme, and is inclined to attribute metaphysical importance to it. We can hardly resist the belief that the structure of the sentence reproduces the structure of the fact which it asserts, or, in the case of false sentences, of the fact which would exist if the assertion were true. This belief, natural as it is, seems very unpalatable when explicitly stated. Nevertheless, I believe that it has some element of truth, though it is very hard to disentangle this element. An attempt was made by Wittgenstein,<sup>1</sup> and I have been much influenced by his point of view.

If we admit, as it seems natural to do, that some sentences, taken in their usual meaning, correspond to facts, while others do not, we must suppose that the structure of sentences is related, in some way, to the structure of facts, since otherwise such correspondence would be impossible. Moreover, a sentence is a physical fact, and may therefore be expected to be capable of correspondence with other physical facts. These two arguments come from quite different intellectual regions, the one being logical, the other physical. If we are discussing anything other than physics, they work in opposite directions, and tend to show that we cannot understand (at least verbally) anything having a structure radically different from that of events in space-time. For physical purposes, however, the two arguments are concurrent.

Let us, for a moment, consider a sentence as a physical occurrence. We must distinguish between spoken and written sentences, since the former are evanescent events, while the latter are pieces of matter. We must also distinguish between a sentence in the sense in which it is unique on each occasion when it is uttered or written, and a sentence in the sense in which the same sentence occurs at a given place in each copy of the same book. E.g. Jeremiah xvii. 9 is a sentence in the latter sense: in the former sense, the particular series of shapes at that point in my Bible constitutes a sentence, while those in yours constitutes another (similar) sentence. The former sense comes first when we are considering a sentence as a physical occurrence; the latter, when we are considering it as having "meaning."

A spoken sentence, considered physically, is a series of noises from the point of view of the hearer, and a series of movements in the mouth and throat from the point of view of the speaker. The "meaning" of the sentence depends upon the causes of the spoken words and the effects of the heard words.<sup>2</sup> But for the moment let us ignore "meaning." Then we find that the sentence consists essentially of noises in order; the order is as essential as

<sup>1</sup> *Tractatus Logico-Philosophicus* (Kegan Paul).

<sup>2</sup> Cf. *Analysis of Mind*, Chap. X.

the character of the noises. (In a language like Latin this is not so true of the separate words as in a modern language, but it is just as true of the parts of words: "Roma" is a different word from "amor.") Considered as physical occurrences, the words expressing different parts of speech are indistinguishable; nevertheless there are relations which are symbolized by relations among words, not by words. Consider "Brutus killed Cæsar" and "Cæsar killed Brutus." The difference between these two statements is indicated, in an uninflected language, not by a word, but by a relation among words. Thus a spoken sentence consists of certain noises in a certain temporal order. In the sentence we can distinguish terms and relations; the terms are the words (or, more strictly, the elementary noises which, in a phonetic system, would each be represented by a separate letter), and the relations are temporal relations among events. According to our definition, the elementary noises composing the sentence may count as "substances," in spite of the fact that they are evanescent.

In the case of written words, the sentence is no longer a temporal series of events, but a spatial series of material structures. It is not essential to a written sentence that its parts should stand for sounds; in some languages (e.g. Chinese) this is not the case, and there is some reason to think that writing developed from pictures, not from the attempt to symbolize speech. We may therefore treat the written language as an independent method of conveying meaning. It is obvious that its efficacy in this respect depends upon its capacity for causing visual perceptions (or tactual perceptions in the case of "Braille"). Written words, even Chinese ideograms, consist essentially of parts with a structure, and the structure is essential to the meaning. This is equally the case with a sentence, even in Latin. Take "Cæsar amat Brutum" and "Cæsarem amat Brutus." Here the case-endings may be regarded as separate words (which they probably were originally), whose position relative to the stem "Brut" or "Cæsar" indicates the "sense" of the relation asserted.

The written language depends upon the causal theory of perception and the existence of physical objects; the spoken language involves the former, but not the latter. Thus in the written language the "substantial" elements have a permanence (throughout some finite time) which they do not have in the spoken language. Their permanence, however, is not metaphysical or absolute; it is only like that of houses or trees. It depends upon the fact that matter arranged in certain patterns will often retain those patterns for a long time, though not for ever. And the essential thing about writing is its capacity for causing visual events.

So far, we have seen no reason to suppose that the suggestions

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of language are misleading where the physical world is concerned, since language is a physical phenomenon, and must share whatever structure all such phenomena have in common. But the philosophy which has been based on language—or, perhaps, has moulded language—has further elements which are more dubious. These are derived from the distinctions between parts of speech. Philosophers have, as a rule, failed to notice more than two types of sentence, exemplified by the two statements “this is yellow” and “buttercups are yellow.” They mistakenly supposed that these two were one and the same type, and also that all propositions were of this type. The former error was exposed by Frege and Peano; the latter was found to make the explanation of order impossible. Consequently the traditional view that all propositions ascribe a predicate to a subject collapsed, and with it the metaphysical systems which were based upon it, consciously or unconsciously. This did away with the objections to pluralism as a metaphysic.

But there remain certain linguistic distinctions which *may* have metaphysical importance. There are proper names, adjectives, verbs, prepositions, and conjunctions. It is natural to hold that, in an ideal language, proper names would indicate substances, adjectives would indicate the properties by means of which substances are collected into classes, verbs and prepositions would indicate relations, and conjunctions would indicate the relations between propositions by means of which we build up what are called “truth-functions.”<sup>1</sup> If there really are these categories in the world, it is desirable that language should symbolize them, and metaphysical errors are likely to result if language performs this task inaccurately. For my part, I believe that there are such categories, except, perhaps, conjunctions. But I will not argue the question at this point, since I wish as far as possible to avoid metaphysics.

One point in which language tends to mislead is that the words which symbolize relations are themselves just as substantial as other words. If we say “Cæsar loves Brutus,” the word “loves,” considered as a physical event, is of exactly the same kind as the words “Cæsar” and “Brutus,” but is supposed to mean something of a totally different kind. It follows that the relation of a word to its meaning must be different according to the category to which the meaning belongs. There *is* in the above sentence a relation which is symbolized by a relation, not by a word; this is the three-term relation of love to Cæsar and Brutus. This is symbolized by the order of the words, i.e. by a three-term relation. But in order to mention this relation, it is necessary to treat “love” grammatically as a substantive, which tends to confuse the

<sup>1</sup> See *Principia Mathematica*, vol. i, Introduction to Second Edition.

distinction between a substance and a relation. However, it is not very difficult to avoid the false suggestions due to this peculiarity of language, when once the danger of them has been pointed out.

I come now to the second part of our inquiry concerning substance. Assuming that the physical world consists of substances with qualities and relations, are these substances to be taken as permanent bits of matter, or as brief events? Common sense holds the former view, though its "things" are only quasi-permanent. But science has found means of resolving "things" into groups of electrons and protons, each of which *may* be quite permanent. There are some who think that an electron and a proton can annihilate each other, so that even they are not quite permanent. But the question of permanence is not the one which most concerns us. The question is: Are electrons and protons part of the ultimate stuff of the world, or are they groups of events, or causal laws of events?

We have already seen that the physical object, as inferred from perception, is a group of events arranged about a centre. There *may* be a substance in the centre, but there can be no reason to think so, since the group of events will produce exactly the same percepts; therefore the substance at the centre, if there is one, is irrelevant to science, and belongs to the realm of mere abstract possibility. If we can reach the same conclusion as regards matter in physics, we have diminished the difficulty involved in building a bridge from perception to physics.

The substitution of space-time for space and time has made it much more natural than formerly to conceive a piece of matter as a group of events. Physics starts, nowadays, from a four-dimensional manifold of events, not, as formerly, from a temporal series of three-dimensional manifolds, connected with each other by the conception of matter in motion. Instead of a permanent piece of matter, we have now the conception of a "world-line," which is a series of events connected with each other in a certain way. The parts of one light-ray are connected with each other in a manner which enables us to consider them as forming, together, one light-ray; but we do not conceive a light-ray as a substance moving with the velocity of light. Just the same kind of connection may be held to constitute the unity of an electron. We have a series of events connected together by causal laws; these may be taken to *be* the electron, since anything further is a rash inference which is theoretically useless.

What is peculiar about a string of events which physics takes as belonging to one electron is a character which is present approximately in the common sense "thing," a character which I should

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define as the existence of a first-order differential law connecting successive events. That is to say, given an event belonging to an electron at one place in space-time, there will be other events at certain neighbouring regions of space-time, separated from the first and from each other by small time-like intervals, such that, when the intervals are taken small enough, if  $a, b, c$  are three such events, and the interval between  $a$  and  $b$  is equal to that between  $b$  and  $c$ , then the difference between  $a$  and  $b$  tends towards equality with the difference between  $b$  and  $c$  in certain measurable respects. This is a way of saying that accelerations are always finite; or, where they are not (as perhaps in quantum phenomena), there are other characteristics involved which are subject to a condition analogous to finite acceleration. Let us take first the common-sense "thing." If I watch a moving object, I have a series of percepts which change gradually, both as regards position and as regards qualities—colour, shape, etc. The gradualness of the change is the criterion by which I am led to regard the percepts as all belonging to one "thing." But on a common-sense basis there are exceptions, such as explosions. Science deals with these as rapid, but not instantaneous, changes, and thus removes the exceptions. We thus arrive at the conclusion that, given an event  $x$  at a time  $t$ , there will be closely analogous events at neighbouring times. We may symbolize this by saying that, if there is an event  $x$  at time  $t$ , there will be, at any neighbouring time  $t + dt$ , an event

$$x + f_1(x)dt + f_2(x)dt^2$$

where  $f_1(x)$  is a continuous function of the time, while  $f_2(x)$  is determined by the second-order differential equations of physics. The string of events so connected is called one piece of matter. In the case of the sudden changes contemplated by the quantum-theory, there is still continuity in everything except spatial position, and the spatial position undergoes a change which is one of a small number of possible changes. Thus in this case also the new occurrences can be causally connected with the old, though the laws of the connection are somewhat different from what they are in the usual case.

Thus the string of events constituting one material unit is distinguished from others by the existence of an intrinsic causal law, though this law is only differential. A light-ray, in this respect, is analogous to a material unit; from a philosophical point of view, there is no very important difference between the two.

It will be seen that, if a piece of matter is a string of events, the distinction between motion and other continuous changes is not so simple as it seemed. We could form continuous series of

events which would not all belong to one piece of matter ; therefore the change from one to another would not be a "motion." A "motion" is a string of events connected with each other according to the laws of motion. This might seem like a vicious circle, but in fact it is not. What we assert is : strings of events exist which are connected with each other according to the laws of motion ; one such string is called one piece of matter, and the transition from one event in the string to another is called a motion. This contains as much as can be verifiable in physics, since every percept is an event. There is no mathematical advantage in asserting more, and to assert more is to go beyond the evidence. Therefore it is prudent, in physics, to regard an electron as a group of events connected together in a certain way. An electron *may* be a "thing," but it is absolutely impossible to obtain any evidence for or against this possibility, which is scientifically unimportant, because the group of events has all the requisite properties.

The light thrown on the notion of substance by the connection between physics and perception, which was the third branch of our problem, has already been touched upon. The physical object to be inferred from perception is a group of events, rather than a single "thing." Percepts are always events, and common sense is rash when it refers them to "things" with changing states. There is therefore every reason, from the standpoint of perception, to desire an interpretation of physics which dispenses with permanent substance. As we have seen that such an interpretation is possible, we shall henceforth adopt it.

There is, however, a view not uncommon in philosophy, and perhaps nearer to common sense than the view which I have adopted. This view is, I think, that of Dr. Whitehead. It holds that the different events which constitute a group—whether those which make up a physical object at one time, or those which make up the history of a physical object—are not *logically* self-subsistent, but are mere "aspects," implying other aspects in some sense which is not merely causal or inductively derived from observed correlations. I consider this view impossible on purely logical grounds, and have so argued elsewhere. But at the moment I prefer to argue that it is empirically useless. Given a group of events, the evidence that they are "aspects" of one "thing" must be inductive evidence derived from perception, and must be exactly the same as the evidence upon which we have relied in collecting them into causal groups. The supposed logical implications, if they exist, cannot be discovered by logic, but only by observation ; no one, by mere reasoning, could avoid being deceived by the three-card trick. Moreover, in calling two events "aspects" of one "thing," we imply that their likeness is more important than

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their difference ; but for science both are facts, and of exactly the same importance. One may say that the theory of relativity has grown up by paying attention to small differences between "aspects." I conclude, therefore, that the "thing" with "aspects" is as useless as permanent substance, and represents an inference which is as unwarrantable as it is unnecessary.