

BETRAND RUSSELL
ESTRATTI DA
“ANALYSIS OF MATTER”



XIII — MATTER AND SPACE

COMMON sense starts with the notion that there is matter where we can get sensations of touch, but not elsewhere. Then it gets puzzled by wind, breath, clouds, etc., whence it is led to the conception of “spirit” — I speak etymologically. After “spirit” has been replaced by “gas,” there is a further stage, that of the ether. Assuming the continuity of physical processes, there must be things happening between the earth and the sun when light travels from the sun to the earth; assuming the medieval metaphysic of “substance,” as all physicists did until recently, what is happening between the earth and the sun must be happening “in” or “to” a substance, which is called the ether.

Apart from metaphysical interpretations, what we may be said to know (using this word somewhat liberally) is that processes occur

where there is no gross matter, and that these processes proceed, at least approximately, in accordance with Maxwell's equations. There does not seem any necessity to interpret these processes in terms of substance; indeed, I shall argue that processes associated with gross matter should also be interpreted so as not to involve substance. There must, however, remain a difference, expressible in physical terms, between regions where there is matter and other regions. In fact, we know the difference. The law of gravitation is different, and the laws of electromagnetism suffer a discontinuity when we reach the surface of an electron or proton. These differences, however, are not of a metaphysical kind. To the philosopher, the difference between matter and empty space is, I believe, merely a difference as to the causal laws governing successions of events, not a difference expressible as that between the presence or absence of substance, or as that between one kind of substance and another.

Physics, as such, should be satisfied when it has ascertained the

equations according to which a process takes place, with just enough interpretation to know what experimental evidence confirms or confutes the equations. It is not necessary to the physicist to speculate as to the concrete character of the processes with which he deals, though hypotheses (false as well as true) on this subject may sometimes be a help to further valid generalizations. For the present, we are confining ourselves to the standpoint of physics. Whether anything further can be known or fruitfully conjectured is a matter which we shall discuss at a later stage. We want, therefore, to consider the difference in physical formula which is described as that between the presence and absence of matter, and also to consider briefly the difficulties as to the interchanges of energy between matter and empty space. I say empty space or ether indifferently; the difference seems to be merely one of words.

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XIII — THE ABSTRACTNESS OF PHYSICS

Let us take **space, time, light and matter** as illustrative of the gradually increasing abstractness of physics. **These four notions are all extracted from common sense.** We see objects spread out in space, we can feel their shapes with our fingers; we know what it is to walk to a neighbouring town or travel to a neighbouring country. **All this makes space seem something familiar and easy,** until, in the course of education, we learn the puzzles to which it has given rise. **Time seems equally obvious:** we remember past events in a time-order we notice day and night, summer and winter, youth and age, we know that history relates events of previous epochs, we insure our lives in the confident expectation that we shall die in the future. **Light,** again, **seemed in no way mysterious to the author of Genesis,** as, indeed, how should it to anyone who had experienced the difference between night and day? **Matter was equally obvious:** it was pri-

marily anything that we could touch, though the first step towards mystification was taken when Empedocles included air. However, we are conscious of air in the form of wind and as something that fills our lungs, so that less effort was required to admit air among the elements than to exclude fire.

From this happy familiarity with the everyday world physics has been gradually driven by its own triumphs, like a monarch who has grown too grand to converse with his subjects. The space-time of relativity is very far removed from the space and time of our unscientific experience; yet even space-time is nearer to common sense than the conceptions towards which physics is tending.

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The view of Locke, that the secondary qualities are subjective but

not the primary qualities, was more or less compatible with physics until very recent times. There are spaces and times in our immediate experience, and there seemed no insuperable obstacle to identifying them with the spaces and times of the physical world. In regard to time, at least, practically no one doubted the rightness of this identification. There were doubts as regards space, but they came from psychologists rather than physicists. Now, however, both space and time, as they occur in immediate experience, are recognized by writers on relativity as something quite different from the space-time which physics requires. Locke's half-way house has therefore been definitely abandoned. I come now to the relation of light as experienced to light in physics. Here the cleavage is older than in the case of space and time; indeed, it is already admitted in Locke's theory. It is impossible to exaggerate the importance of this cleavage in separating the world of physics from the world of common sense. With the exception of parts of our own body and bodies with which our own body is in contact, the objects which, according to common

sense, we perceive, are known by means of light, sound, or odour. The last of these, though important to many species of animals, is relatively subordinate in the perceptions of human beings. Sound is less important than light, and in any case raises exactly the same problems in the present connection. We may therefore concentrate on light as a source of our knowledge concerning the external world.

When we “see” an object, we seem to have immediate knowledge of something external to our own body. **But physics says that a complicated process starts from the external object, travels across the intervening region, and at last reaches the eye.** What goes on between the eye and the brain is a question for the physiologists, and what finally happens when we “see” is a question for the psychologist. But without troubling ourselves about what happens after the light reaches the eye, it is evident that what the physicist has to say is destructive of the common-sense notion of “seeing.” It makes no difference, in this matter, which of the possible theories

we adopt as to the physical character of light, since all equally make it something utterly different from what we see. The data of sight, analyzed as much as possible, resolve themselves into coloured shapes. But the physical analogue of a colour is a periodic process of a certain frequency relative to the eye of the observer. The physical world, it seems natural to infer, is destitute of colour. Moreover, the correspondence between colours and their physical counterparts is peculiar: Colours are qualities, which are static while they last, whereas their counterparts are periodic processes, which are in the medium between the eye and the object which we say we “see.”

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XXII — THE BELIEF IN GENERAL LAWS

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Evidence in favour of a particular law is evidence that a certain class of phenomena are subject to a rule which we have succeeded in discovering. If so, they are sure to be also subject to other rules sensibly indistinguishable from the one for which we have evidence; but these will in general be more complicated than the rule which we adopt. **Complication may be of two kinds:** it may be in the **formula**, or in the **amount of hypothetical matter needed to make the rule work**. The great merit of **Newtonian gravitation** was that it **was simple in both respects**. But clearly any set of observations on planetary motions could have been fitted into the Newtonian formula by postulating a sufficient number of invisible bodies or a sufficient complication in the law of attraction. For any given set

of observations, there would have been many such possible methods of bringing harmony between observation and theory; most of these would not have been compatible with a fresh set of observations, but some of them would have been, given sufficient mathematical ingenuity. What is remarkable, therefore, is not the reign of law, but the reign of simple laws.

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XXIII — SUBSTANCE

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 formula in terms of permanent entities with changing states and relations**? The third concerns the special topics with which we are concerned in Part 11 — namely, the relation of perception to the physical world. The first and second problems really belong to other portions of the philosophy of matter, but I shall discuss them here in order to obtain a unified discussion of the problem of substance. 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, ...

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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 define as the existence of a first-order differential law connecting successive events along a linear route. 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, ...

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XXVII — PARTICULAR AND EVENTS

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When we wish to describe a **structure**, we have to do so by means of **terms and relations**. It may turn out that the terms themselves have a structure, as, e.g., in arithmetic, when cardinal integers are defined as classes of similar classes. In the technique of mathematical physics, there is a considerable apparatus which belongs to the formal method, and would not be regarded by most physicists as having any physical reality. Such is **the manifold of space-time points**.

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But what shall we say of **electrons**? Are they physical realities, or are they **mathematical conveniences**, like points? Or are they something intermediate between these two extremes? We think of a light-ray as a series of events; is an electron perhaps something similar? But the light-ray also raises problems: it has a certain assigned mathematical structure, but it is difficult to say what we are to think of the mathematical terms of this structure. ... This **illustrates a necessity in describing a structure: the terms are as important as the relations, and we cannot rest content with terms which we believe to be fictitious.**

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I shall give the name “**particulars**” to the **ultimate terms of the physical structure**—ultimate, I mean, **in relation to the whole of our present knowledge**. A “particular,” that is to say, will be something

which is concerned in the physical world merely through its qualities or its relations to other things, never through its own structure, if any. The difference between a transverse wave and a longitudinal wave is a difference of structure; therefore neither can be a “particular”: the technical sense in which I mean it. An atom is a structure of electrons and protons; therefore an atom is not “particular.” But when I call something a “particular,” I do not mean to assert that it certainly has no structure; I assert only that nothing in the known laws of its behaviour and relations gives us reason to infer a structure. From the standpoint of logic, a particular fulfils the definition of “substance” which we gave in Chapter XXIII. But it fulfils this definition only in the existing state of knowledge; further discoveries may require us to recognize structure within it, and it will then cease to fulfil the definition of substance.

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The word “particular,” as above defined is, therefore, a word relative to our knowledge, not an absolute metaphysical term.

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On all these grounds, persistent units of matter, though still convenient, have no longer the metaphysical status that they were formerly supposed to have.

This conclusion is reinforced by arguments of economy. We perceive events, not substances; that is to say, what we perceive occupies a volume of space-time which is small in all four dimensions, not indefinitely extended in one dimension (time). And what we can primarily infer from percepts are groups of events, again not substances. It is a mere linguistic convenience to regard a group of events as states of a “thing,” or “substance” or “piece of matter.”

This inference was originally made on the ground of the logic which philosophers inherited from common sense. But the logic was faulty, and the inference is unnecessary. By defining a “thing” as the group of what would formerly have been its “states,” we alter nothing in the detail of physics, and avoid an inference as precarious as it is useless.

What, then, shall we say about the analysis of water into hydrogen and oxygen? We shall say something of this sort: Water has, for common sense, a certain amount of permanence: although puddles dry up, the sea is always there. This permanence, interpreted without the use of “substance,” means certain intrinsic causal laws: the behaviour of the sea can, to a considerable extent, be discovered by observing only the sea, without taking account of other things. Similarity on different occasions is the most obvious of these approximate causal laws. But water can change into ice or snow or steam: here we can observe the gradual transformation, and continuity ta-

kes the place of likeness for common sense. In all changes, we find, on examination, that there is some continuity like that between water and ice; we thus trace a casual chain, more less separable from other causal chains, and having enough intrinsic unity to be regarded as successive states of one “substance.” When we throw over “substance,” we preserve the causal chain, substituting the unity of a causal process for material identity. Thus the persistence of substance is replaced by the persistence of causal laws, which was, in fact, the criterion by which the supposed material identity was recognized. We thus preserve everything that there was reason to suppose true, and reject only a piece of unfruitful metaphysics.

The analysis of water into hydrogen and oxygen represents, therefore, the analysis of one approximate causal law into two more nearly accurate causal laws. If you infer that where there was water yesterday there is water to-day, you are employing a causal law which is not always correct. If you infer that where there was hydrogen and

oxygen there is hydrogen and oxygen (or at least that there is hydrogen and oxygen in places connected by a continuous route with where they were yesterday), you are very unlikely to be wrong, unless the place is in the neighbourhood of Sir Ernest Rutherford. It is assumed (what is only partially true at present) that the properties of water can be inferred from those of oxygen and hydrogen together with the manner in which they are combined in the molecules of water. Thus by means of analysis you have obtained causal laws which are at once more true and more powerful than those which common sense could obtain by supposing that all the parts of water were water.

We may say that this is the characteristic merit of analysis as practised in science: it enables us to arrive at a structure such that the properties of the complex can be inferred from those of the parts.¹

¹Dr C. D. Broad, in *The Mind and its Place in Nature*, lays stress upon what he calls “emergent” properties of complexes—i.e. such as cannot be inferred from the properties

And it enables us to arrive at laws which are permanent, not merely temporary and approximate. This is an ideal, only partially verified as yet; but the degree of verification is abundantly sufficient to justify science in constructing the world out of minute units.

From what has been said about substance, I draw the conclusion that science is concerned with group of “events” rather than with things that have changing “states.” This is also the natural conclusion to draw from the substitution of space-time for space and time. The old notion of substance had a certain appropriateness so long as we could believe in one cosmic time and one cosmic space; but it does not fit in so easily when we adopt the four-dimensional space-time framework. I shall therefore assume henceforth that the

and relations of the parts. I believe that “emergent” properties represent merely scientific incompleteness, which would not exist in the ideal physics. It is difficult to advance any conclusive argument on either side as to the ultimate character of apparently “emergent” properties, but I think my view is supported by such examples as the explanation of chemistry in terms of physics by means of the Rutherford-Bohr theory of atomic structure.

physical world is constructed out of “events,” by which I mean practically, structures occupying a region of space-time which is small in all four dimensions. “Events” may have a structure, but it is convenient to use the word “event,” in the strict sense, to mean something which, if it has a structure, has no space-time structure, i.e. it does not have parts which are external to each other in space-time.

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XXX — CAUSAL LINES

If the electron is a point, it is a material point, and thus differs from points in empty space. The difference does not consist in anything characteristic of the electron at an instant, but in its causal laws. What distinguishes a material point from a point of empty space-time is that we recognize a series of earlier and later material points as all parts of the history of one electron. In the Newtonian theory, one could say the same of a point of absolute space; but with the abandonment of absolute space we have become unable to regard a point at one time as in any sense the same as a point at another time, except in the case of a material point. The existence of this connection may be taken as the definition of “matter,” and obviously the connection is causal.

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XXXVII — PHYSICS AND NEUTRAL MONISM

There will thus remain a certain sphere which will be outside physics. To take a simple instance; physics might, ideally, be able to predict that at such a time my eye would receive a stimulus of a certain sort; it might be able to trace the physical properties of the resulting events in the eye and the brain, one of which is, in fact a visual percept; but it could not itself give us knowledge that one of them is a visual percept. It is obvious that a man who can see knows things which a blind man cannot; but a blind man can know the whole of physics. Thus the knowledge that other men have and he has not is not part of physics.

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B. RUSSELL, “AN OUTLINE OF PHILOSOPHY”

Physics is mathematical, not because we know so much about the physical world, but because we know so little: it is only its mathematical properties that we can discover. For the rest our knowledge is negative.