XIII.—THE PRINCIPLE OF RELATIVITY AND ITS IMPORTANCE FOR PHILOSOPHY.

By H. WILDON CARR.

SUPPOSE that Gulliver when shipwrecked on Lilliput, instead of waking up in his old proportions, had undergone during his sleep a shrinkage to Lilliputian proportions, he would not have been able to discover that anything unusual had happened to him. It would have been impossible for him to know either that he himself or that the physical world had undergone a change. Yet he would have passed into a world in which all reality, spatial and temporal, with all the standards of measurement and all the clocks, had shrunk to one-twelfth of the proportions of the world in which till then he had been living. Compared with the former world feet would now be inches, and an hour would be five minutes. But as he himself would have shrunk to one-twelfth of his physical proportions he would be, and would continue to be, unconscious of any change of condition in his world. Physical reality would have suffered a complete snap, but psychical continuity would have been uninterrupted. Suppose now that, having remained one year, reckoned by his former system—twelve Lilliputian years—in Lilliput, he had returned to his former world, and that in returning he had been restored to his old proportions. He would still, as before, be psychically continuous, unaware and unable to be aware of the new change in his spatial and temporal universe. But now suppose he returned to his family and friends, he would discover a strange discrepancy. He would have been absent one year but would have aged twelve years and would find his old world eleven years younger, for he would

have been twelve years in Lilliput. If therefore a great change were to take place in physical reality, altering spatial proportions, altering temporal rate of flow, deforming the material universe, so long as we the observers continued ourselves to undergo the corresponding change we could not discover the fact; however great the alteration—the world would remain for us the same world. And there is only one way in which in such case we could become aware of the change, and that would be if we were able to compare our experience with that of an observer who had not like us undergone the change, but had remained in the system we had left and returned to. Suppose now we ask ourselves what is the relation of Lilliputian space to our space and of Lilliputian time to our time? It is clear that we can give no answer, or rather that the only answer we can give is that on the objective side there is no relation. They are not reconcilable with our ordinary notions of the conditions of the physical world. The Lilliputian space is not contained within our twelve times greater space, the Lilliputian time is not part of our twelve times slower time; if they are, there will be a remainder, and there is no remainder. There is a one-one relation between the two systems, but only for an observer who is able to pass out of the one into the other without himself changing with the change.

According to the Principle of Relativity a change in our physical conditions precisely of this kind is taking place at every moment. Space and time and matter are not absolute for all systems of reference, but absolute within each system of reference, and our system of reference is never for two moments the same. Our psychical continuity makes experience uniform. The movement of the earth on its axis and in its orbit, the acceleration of the earth's movement, and the movement of the solar system in the stellar universe and its acceleration, are to us a continual to-and-fro journey from Lilliput to Brobdingnag, which we do not become aware of only because our proportions change with every change in the proportions of our universe.

And we never could have made the discovery had we not been able to compare the propagation of ethereal states with the motion of material systems.

The Principle of Relativity affirms that neither space, nor time, nor matter, nor ether (if there is ether) is absolute, that no one of these is one and the same identical reality for every observer, but each is particular to the observer. The uniformity we observe in physical relations is a function of the system of relative movement to which we are bound. In the account I am about to give of this principle, I make no pretence to be able to appreciate the evidence on which it is based. I am neither a mathematician nor a physicist, my interest is a philosopher's interest. I shall not therefore criticise the principle with a view to determining how far its formulation is provisional and in need of modification. Whatever disagreement there is among those able to form a judgment from direct experiment, we may take it to be universally admitted that the old mechanical theory, however well it may still hold good for the measurement of comparatively low velocities, fails completely when applied to the immense velocities we meet with, and are now able to deal with, in electro-magnetic, and more especially optical, phenomena. It is the relation of this new kinematics to pure metaphysical theory to which I desire to direct attention.

The Principle of Relativity is that the laws of physical phenomena are, under equal conditions, presented under exactly the same form to different groups of observers in movement of uniform translation in relation to one another. And the corollary of the principle is that electro-magnetic phenomena are propagated in all directions at a uniform velocity, of about 185,000 miles a second, for all observers, to whatever system of relative movement of translation they are bound. This velocity of light is a critical velocity which cannot be exceeded. It is the sole velocity that is preserved when we pass from one system to another.

We may state these two grounds of the theory concisely thus—

1. It is impossible to discover the motion of a system relatively to other systems by means of experiments performed entirely within the system. (For instance, to discover the motion of the earth relatively to the sun or stars by means of purely terrestrial experiments.)

2. The velocity of light is a universal constant, independent of the motion of the source.

The Principle of Relativity rests on an experimental basis. It has been formulated to express the result,—the uniformly negative result,—of the experiments made to detect the acceleration of a system of movement by observations taken within it. Details of these experiments, of which there have not been many (three or four only), are given in the textbooks, and are familiar to all students of the recent development of physical theory. There are various opinions as to their interpretation, but no doubt of their accuracy has been suggested. The first and the best known is the Michelson and Morley experiment, which utilised the movement of the earth in its orbit. In this movement we have a velocity of translation immensely greater than any velocity we can produce directly, and yet far below, only $1/10,000$ part of, the velocity of light. If, as was supposed, light is propagated in a medium at rest in relation to the earth's translation, its apparent velocity will undergo an increase or a decrease for an observer on the earth dependent on the velocity and direction of that translation in relation to it. An experiment was therefore contrived to show a variation as small as $1/100,000,000$ of a difference in the velocity of light, taken in two directions at right angles, that is to say, one direction parallel to the translation and one direction perpendicular to it. The experiment would have revealed

a variation 100 times greater than this had it existed. The result was negative.

An illustration will make clear the paradox involved in this conclusion. Suppose we are observing the propagation of a light wave and also the movement of the source of the light wave; we should expect to observe the effect of the movement of the source in the velocity of the light, but we do not; on the contrary, we observe the light propagated at a constant velocity uninterfered with by the direction or velocity of the movement of the source. Suppose, again, we observe the propagation of a light wave and also an observer moving in the same direction with any velocity in relation to ourselves, the principle declares that he observes the light propagated at the same velocity, 185,000 miles a second, at which we observe it and not, as we should suppose, at a lower velocity.

The acceptance of this fact involves important modifications of some fundamental conceptions. We may single out a few:—
(a) The ether, if there is ether, cannot be absolute and at rest, it must be attached to and carried with every system of movement of translation; it must vary with every variation in the velocity of the observer's movement. (b) Neither space nor time is original or absolute, each is relative and correlative to the observer's system of reference. (c) Simultaneity, here, now, before and after, refer to no absolute standard of reference, they are not the same for all observers, they relate to events whose distance and interval are co-ordinated independently for every system of movement of translation, with the limiting velocity. This velocity cannot be overpassed by any movement of translation. (d) There is no mass independent of velocity; the mass of any body depends on its velocity and on the angle this velocity makes with the force acting on it. (e) There is no experience which can decide for us whether a body is at rest or in movement, whether in relation to a supposed absolute space or to a supposed fixed ether. There are many other results even

more disconcerting to ordinary notions, which are the subject of controversy, as for instance, the question of the nature of gravitation and the continuity or discreteness of energy. In the latest development even the old principle *Natura non facit saltus* is called in question.

The formulation of the Principle of Relativity is associated with the names of H. A. Lorentz, Albert Einstein, and the late H. Minkowski. The actual formulation was the work of Einstein, its general application the work of Minkowski. The first attempt to meet the facts revealed by the negative results of the experiments was what is known as the shrinkage theory of Lorentz, according to which it is held that there is a shrinkage of all matter in the direction of its motion. This hypothesis, I believe, still holds good, and has its place in the Principle of Relativity, but the shrinkage is no longer regarded as a physical reality, but as an appearance due to physical limits of observation. The principle, on the other hand, stands for a complete system of theoretical physics worked out on the basis of the independence of electro-magnetic phenomena of absolute motion.

A consequence of the theory is that the inertia of a body depends upon the energy contained in it, and this implies a fundamental identity of mass and energy, and from this it can be shown that radiation must have a "mass," and that consequently mass is a function of velocity. And instead of the old division of the universe into matter and energy we have a universe of radiant energy. And in connection with this problem the principle has led to the formulation of a new theory of radiation known as the theory of Quanta, a theory propounded by Professor Max Planck, according to which radiant energy is emitted in discrete quantities and not continuously. This is the theory that was opposed by Sir Oliver Lodge in his British Association address on "Continuity." Another problem of great difficulty which is a present subject of investigation is the nature of gravitation,

whether or not it is an electro-magnetic phenomenon, and, if not, what is its velocity? With controversial and unsettled problems, however, I do not propose to deal, but only with the philosophical problems to which this radical alteration in our ordinary notions of the fundamental realities of the physical universe give rise.

Let us examine first as a consequence of the Principle of Relativity the doctrine known as the abolition of the ether. The postulation of ether as the medium filling interstellar space was a necessary consequence of the undulatory theory. The notion of undulation or vibration involves as part of itself the notion of a medium which undulates or vibrates. There cannot be wave motion with nothing to support it. This necessity rests on the rejection by physics, as a fundamental axiom of the science, of the possibility of immediate action at a distance. Electric and magnetic actions therefore can only be transmitted from point to point through space by the interposition of a medium. There was no such medium known or that it was found possible to make evident to sense perception, and it had therefore to be hypothetically assumed. The argument still holds good, and physicists will no doubt continue to speak of ether in connection with undulation of light even though driven to deny to it every quality consistent with existence. The argument may be simply illustrated. It takes eight minutes for the light emitted by the sun to reach the earth—where is it during those eight minutes if there is no medium to transport it? And the negative argument based on the absence of any positive quality whatever which can reveal it to us is illustrated by the familiar fact that the existence of air could not be known had we no air pump. The ether pump awaits discovery. Sir Oliver Lodge further illustrates it by the impossibility of conceiving that deep-sea creatures, however advanced in intelligence, can be aware of water. But the notion of a luminiferous ether has had a strange and eventful history. At first a mere hypothetical x , it soon became a

physical reality constituted with regular attributes and calculable in its action, finally supposed to be the primordial substance of the universe out of which matter itself is generated. It is true it had strangely contradictory attributes—frictionless, solid, incompressible, immovable, fixed and yet strainable, enduring unaffected the translation through it of matter. Not that there is anything necessarily fatal to it in the fact that its attributes seem self-contradictory, the reconciliation may merely await fuller knowledge. The theory of atoms has survived and developed, although serious logical difficulties in the conception of the atom were obvious from the first. And, indeed, we are not free from logical contradictions. in any case, whether we hold that ultimate physical reality is continuous or whether we hold that energy and even time itself is atomic. The Principle of Relativity has deprived this hypothetical ether of every property but one, the absolute constancy of light propagation. But as this absolute constancy is for every observer, whatever his own system of relative movement, instead of one absolute ether filling space, at rest and unalterable in relation to all systems of movement, whatever, we must conceive the ether to be carried with and belong to every system of movement. Instead of one ether we must suppose infinite ethers, as many as there are systems of movement and one for every acceleration of a movement, and to suppose this is precisely the same thing as to suppose there is no ether. This can be shown in another way. If light moves at a constant velocity in an absolute ether, then to an observer in movement of translation relative to that ether, the velocity of light will appear greater or less by the amount of the observer's own velocity according to its direction. This is the expectation that experiment has falsified. It does not. The velocity is constant, therefore the ether is of no use and may be abolished.

It follows also from the Principle of Relativity that neither space nor time is absolute, each is a function of the observer's

system of reference. One and the same event occurring for observers in one system of reference at one moment and in one point, to observers in another system of reference occurs as two events separated by a distance in space and an interval in time. The familiar and simple illustration is that of objects dropped through the floor of a moving wagon. Two objects dropped in immediate succession is an event which to observers in the wagon occurs in one place at one time. To observers on the soil they are two events separated in space by the distance travelled by the wagon during the time of their occurrence. Also there is a time interval for the observers on the soil, for whom there is separation in space, which does not exist for observers in the wagon, for whom there is not. There are no two events separated to our observation in space for which it is not possible to conceive a system of movement of translation for observers in which they would occur in the same place, and likewise there is no one event which for us occurs in one place and might not for some system of reference be two events at different places. With this proviso, however, that if the velocity required in order that two events shall be observed in one place exceeds the velocity of light, it is not practically realisable, for a reason that will appear. It was at first thought that at least time must be absolute, but it is clear that by the principle the time interval is different for different observers; it must be shorter for observers to whom events occur in one place than for all other observers of those same events. Space and time therefore change and undergo alteration, when we pass from one system of reference to another: one thing alone remains constant, the velocity of light. This velocity therefore assumes of necessity a rôle of the first importance in the new kinematic theory.

This new conception of a finite critical velocity is also paradoxical when judged by ordinary notions. The velocity of light must be conceived as a constant finite velocity and also as a maximum velocity. And the Principle of Relativity

introduces a new meaning into the conception of simultaneity. Two events can only be simultaneous if they are in the same universe, and they are only in the same universe if the distance which divides them in space and the interval which separates them in time are co-ordinated with the velocity of light.

The Principle of Relativity therefore regards every observer as the centre of a universe in which all events are co-ordinated for his system of reference by four co-ordinates, three for space and one for time, all variable. These co-ordinates vary with every change from one system to another, with every change of acceleration, and the only constant is the velocity of light. Let us illustrate it by an extreme case, let us suppose that, from being an observer fixed to this system of reference we call our earth, one could be transferred to a system, say an atom, in which life as compared with our present life would pass in some thousand millionth of a second. Suppose now that from our new position on an electron we look out on to our new atomic system in place of our old solar system. One thing only will have remained constant, the velocity of light. Suppose then that our new system of reference is such that the light radiating from the centre of the atom takes eight minutes to reach our electron, then 90,000,000 miles will separate us from it in space. The relation between this new space and time of the atom and the old space and time of the solar system will have nothing in it that is absolute, each is a function of the relative velocity of the observer's system. Each observer will have eight minutes of time interval and 90,000,000 miles separating his light from its source, but there will be no standard for comparison of the space and time, the one will not be contained within the other. Five minutes of our old system may be a geological period of our new system. Einstein has calculated for example that were we to leave the earth in a system of translation moving at $1/20,000$ of the velocity of light and were to remain absent two years and then return we should come back to a world that had aged 200 years in our absence.

According to Einstein a velocity greater than that of light, though conceivable, is not physically realisable. The reason alleged is that a velocity greater than that of light would conflict with the notion of causality, which involves the necessary priority of cause to effect. The argument, though interesting and important, is open to criticism and is not now, I believe, generally followed. It is not a necessary part of the doctrine. Suppose two events to happen for an observer at a distance from one another greater than light can travel in the interval which separates them in time. It is clear that the one event can cause the other only if the influence (the cause) travels quicker than light. In that case there would be observers for whom the effect would occur before the cause, there would be systems of translation regressing in time. Consequently a velocity exceeding that of light would contradict our conception of the necessary priority of the cause to the effect. But if all movement falls short of the velocity of light, then for two such events as we have supposed there would exist systems of reference for which they would be simultaneous but there would be no system for which their distance would be annulled, for such a system would exceed the velocity of light. For us therefore two such events are independent, they do not belong to the same line of the universe. But though for two such events the distance at which they take place is not annulled for any observer, it is shorter for those for whom they are simultaneous than for any others.

The position is reversed for two events that take place at a distance less than that which light can travel in the interval of time. For two such events the time order cannot be annulled or reversed for any observers, but there might be systems for which the distance in space would not exist. And for such a system the time interval would be shorter than for any other.

This follows from the fact that for our physical universe one thing and one thing only is constant, the velocity of light propagation to our observation. For us there are two sorts of

relative movement, there is the relative movement of two material systems to one another and the relative movement of a material to an ethereal system. For the former kind the old conceptions suffice; for the latter, the failure to show any alteration in the ethereal system consequent on variation due to the translation of the material system, or to determine the velocity of the material system from the observation of the ethereal system, has necessitated the formulation of the Principle of Relativity.

What has all this to say to philosophy? So far as we are dealing with physical and mathematical problems, nothing whatever. Philosophy cannot decide for the physicist whether or not there is a movement which can exceed the velocity of light; whether, for example, gravitation is or is not such a movement; whether or not the ether is something really existing; whether if it is there may or may not be means of making it manifest; whether or not the hypothesis of an ether is necessary for the formation of an electro-magnetic field; whether energy is discrete and atomic, or continuous. These are all physical and not metaphysical problems, and metaphysics has no special means and makes no special claim to solve them. On the other hand a problem is undoubtedly and manifestly opened to philosophy in these speculations, because they deal with paradoxes, and paradoxes are conflicts between fundamental necessities of thought, and these conflicts can only be reconciled by a criticism of conscious experience itself.

There are three problems of philosophy which seem to be distinctly raised by the Principle of Relativity—

1. The problem of continuity. This is particularly concerned with the doctrine of the abolition of the ether.

2. The problem of the nature of real duration. This is concerned with the doctrine of the relativity of space and time to the observer's system of uniform movement of translation.

3. The problem of original movement. This is concerned with the doctrine that mass is a function of velocity.

1. An ultimate discontinuity is simply unthinkable. This fact may be illustrated in many ways. The simplest, perhaps, is to show the vanity of the attempt to represent in thought an absolute void. The supposed idea of an absolute nought is a false idea, it is the abstraction in thought of a certain order of reality, but it is not the idea of nothing, for there can be no such idea; it is the idea of an absence of something, which something is always present in idea, always in the mind of the person who has made the abstraction, and who himself is there to contemplate the void his abstraction has made. Even the conception of an ultimate discrete reality—atoms and the void—is unrealisable in thought. The void is not a real void but the potential place of an atom, even if the actual atoms are supposed to be completely closed systems without external relations. Yet it has always seemed as though continuity must depend on a physical principle. It appears absurd to suppose that the universe is not held together by some reality of which physical science can take hold. If it is not matter then it is ether, if it is not ether then it is geometrical space. Now what the Principle of Relativity has done, quite irrespectively of whether its formulation is final or is only an approximation, is this: It has shown the impossibility of regarding any physical fact, anything known to us in physical science, whether its existence is actual or hypothetical, as necessarily continuous. I think we might even go further and say that it shows us that any reality with which physical science is competent to deal is necessarily discrete, even space and time being no exception. Continuity, according to the Principle of Relativity, is not in anything which can be observed but in the observer.

There are two kinds of continuity—physical continuity and psychical continuity. The first is illustrated in the doctrine

of the ether. According to this doctrine, were there empty space or absolute void it would constitute a breach in the physical universe which would divide it into separate universes that could have no relations. If the universe is one it can only be because there is a medium holding it together, supporting the influences that radiate through it and which without it would be impossible. It is this consideration which makes Sir Oliver Lodge, Professor Marcel Brillouin and others cling to the affirmation of a real ether in spite of the formidable contradictions, logical, physical, and mathematical, which the notion involves. If the ether could undergo deformation, or could move in the way we suppose matter to deform and move, or if it could be one thing for one observer and another and totally different thing for another observer, it is clear it would not be the physical continuity which by the hypothesis it is. The reason why the notion of an existent ether persists in spite of the difficulties it involves (how, for example, its immobility is to be reconciled with its strain) is that finally it is itself the notion of absolute physical continuity.

When we consider psychical continuity we meet a complete contrast. Instead of something which has to be conceived as absolutely unchangeable and immobile, we have a change which is continuous, a reality which remains self-identical throughout continuous becoming.

I suggest, then, that we are forced by the scientific Principle of Relativity to find the continuity of the universe in a psychical principle. And I suggest, further, that philosophy can supply a complete reconciliation of the apparent paradox. We need no ether to support the universe. The reality is life, and the physical universe is for each living being the sphere of its action. The physical world is for us the externalisation of our life in action. We do not as separate individual personalities each create for himself his own physical environment, for a universal life impulse is behind

creative evolution, and individual personalities are realisations of it in present centres of activity. In creating our mode of activity the life impulse has selected the sphere of our activity. The one is relative to and correlative with the other. In vain, therefore, shall we ever look for continuity, in the absolute sense, in the physical world, for that world being external is spatial, and, therefore, in its very nature discrete and quantitative. Continuity can only be in what is essentially concrete and qualitative, that is, in life.

2. Let us now look at the philosophical aspect of the doctrine of the relativity of space and time to the observer's system of movement. In geometry space is regarded as absolute, but time is taken as an independent variable; in the old mechanics space and time are the homogeneous background of movements and events; in the new kinematics the three dimensions of space and the one dimension of time together are four axes by which every event is co-ordinated with other events in the universe which is the aggregate of events. The co-ordinates are not absolute and independent, but tied to the event, relative to the observer and his system of reference. The movement, for example, which provokes a contraction of the moving body parallel to its direction shortens the scales in proportion to the lengths measurable, alters the clock with the rate of flow of the system, so that continuity is maintained for the observer in the system.

It is much more easy to recognise the relativity of space than the relativity of time, at any rate if we have regard to the psychological origin of our ideas of these realities. An illustration used by Poincaré will explain my meaning in regard to space. Two points applied to the skin are felt as one or as two according to their distance from one another on the surface of the body; this distance varies for different parts of the skin, probably according to the disposition of nerve endings. But our skin is relatively fixed or itself varies in extension in narrow limits. Suppose, however, a mollusc to be dependent entirely

on such experience for its perception of space, how different to ours its space would be. Its extended and retracted skin would introduce an element to be co-ordinated in its experience entirely absent from ours. This is only one of many illustrations which show how relative space perception may be. But with time it is different. Time seems to have something necessarily absolute about it. The reason is two-fold. In the first place we confuse under the same term two quite distinct things, psychical time, the real duration of experience, and geometrical time. The real duration of psychical life is qualitative, in a sense it is pure quality, geometrical time on the other hand is quantitative simply, it is in fact in all respects analogous to a dimension of space, yet because we use the same term, the absoluteness of real duration seems to belong to geometrical time. The second reason is that time considered as a dimension, unlike the three recognised dimensions of space, has a direction which is irreversible. On this irreversible direction depends the relation of cause and effect, and therefore it appears to have something of an absolute nature which is absent from the notion of space.

It is perfectly easy in philosophy to reconcile the paradox that neither space nor time is absolute, but that a conception of space and a conception of time corresponds to every moment of our experience and to every degree of perfection of our knowledge. The perception of the nature of pure duration—that it is a quality and not a quantity—enables us to rationalise this empirical principle of the relativity of space and time. This is the philosophical principle which is the counterpart of the scientific principle. The source of all reality is duration, and duration is the life of the universe. In no other principle can we find the continuity which gives reality to the observer. It is this reality of the observer that is the centre from which the external universe is determined, and it is this determination of the universe for the observer that is the quality which belongs to his system of reference. This system of reference is the movement to which the observer is bound in relation to other movements. It is

therefore the observer's life, his psychical experience, qualitative and not quantitative, considered in its essential unity and individuality, which is the source and centre of all reality. Seen from within, it is the reality of a change that endures. Seen from without, it is pure quantity, a system of spatial and temporal relations to other systems. I suggest, therefore, that here again philosophy gives us a principle which accords completely with the new kinematic Principle of Relativity. It removes from it even the semblance of paradox.

3. Great as seems to be the paradox, however, in denying that there can be either a space or a time that is absolute, the supposed necessity of thought which affirms the contrary is not based on psychical experience but on mathematical and physical reasoning. It is a logical, not a psychological, postulate. Indeed, the notion of absolute space seems rather to be contradicted than to be confirmed by psychical experience. It is physical reality, not psychical reality, which demands a background of homogeneous space and time. But when we turn to the new theory of inertia, which depends on the doctrine that mass is a function of velocity, we seem to come up against a plain and glaring contradiction with ordinary experience and with what is really at the bottom the same thing, intelligible scientific theory. "It is to the self-induction of convection currents, produced by the movements of its electrons, that the atom, which is formed of them, owes its apparent inertia and what we call its mass."* That an immaterial particle should possess mass seems contrary to all our habits of thought. Indeed, mass and matter we commonly regard as one and the same thing. We ordinarily define mass as quantity of matter. Even when we recognise that weight is a relation of masses and that the weight of any mass tends to zero as it is removed from other masses, while the mass which thus loses weight yet itself may remain constant, it still seems a necessity of thought to

* Poincaré, *Dernières Pensées*, p. 201.

accord to mass priority over movement. We have, therefore in the electro-magnetic theory of the origin of matter the assertion of a reality more fundamental than material reality. This scientific doctrine is in entire accordance with the philosophical doctrine that change or movement is ultimate and original, and that things which change or are moved are views of the movement. This doctrine rests on the argument that movement is more and not less than immobility, and the more cannot be derived from the less. There is no way of deriving movement from immobility, but given an original movement, things are derived. Things are not parts of a movement but views of a movement.

What, then, is this original movement, where are we to look for it, and how are we to know that it is original? The answer is that there is only one reality which it can be, the reality we know as life or as consciousness. No other answer is possible, and it is the Principle of Relativity which shows us plainly why. The external universe, the world we look out upon and whose laws we study in physical science has no absolute standard of reference within it, no unit of absolute extension, no unit rate of time flow. It is ordered for each observer by axes which radiate from his centre and which are relative to the system of reference to which he is bound. Everything real in this universe, including the dimensions of space and the time rate of succession by which an event is co-ordinated with other events, is relative to the system of reference. And this system is to other systems a movement of relative translation. What then is left? What is there that is not relative in this universe of relations? Clearly the life itself. Life is a movement, or change, or duration which is not a quantity; it is not an aggregate; it is not divisible into parts external to one another; it is a pure quality. It manifests itself in individual centres of activity, centres from which it externalises itself in action. The physical world is the reflection outwards of what in itself, in its absolute nature, is psychical duration.