CHAPTER XIV

SCIENTIFIC KNOWLEDGE

WILL the same features which we have found in everyday common knowledge be found also to characterize that kind of knowledge which is commonly called 'scientific'? Shall we be able to trace the same structure in the specialized kinds of knowledge associated with such names as those of Newton, Darwin, or Einstein, as we have traced in the knowledge of the common man and even of the savage?

We shall find—as might be expected—that knowledge is of a piece all through, that the same structure appears in the lowest kinds of knowledge and in the most advanced discoveries of science. This will accord with the common remark, the truth of which there seems no reason to doubt, that science is no more than an extension of common sense brought about by its more elaborate organization and increased efficiency.

It is naturally impossible for us to do more than touch the fringe of so vast a subject. A complete survey of the epistemology of science cannot be looked for here. All that I can attempt is very briefly to consider a few of the more famous scientific theories, selected partly because of their intrinsic importance and partly because of their epistemological interest.

1. EVOLUTION

I take the concept of evolution first because, however complex it may be considered as a scientific subject, it is epistemologically extremely simple.

It is important to understand the cause of this simplicity. We are not, of course, concerned with any of the details of the evolutionary theory, much less with any disputed points. In broad outline the concept of evolution may be taken to mean simply that organic species have developed from one another in time, beginning with elementary forms of life, advancing through intermediate species, and going on to such highly organized beings as men.

It is clear that we have here no more than a collection of alleged facts about animals and vegetables and about their changes. The theory purports to be no more than a statement of the facts which have occurred during the history of life on the planet. It is a story about 'things' and their changes. It thus involves nothing epistemologically different from what would be contained in any other history or statement of facts. It is on a par with the statements that Brutus murdered Caesar, that Jack and Jill went up the hill, or that my lawn-mower has just cut a worm in half. Only it is more complicated, remote, and vast, and instead of referring to two people or a worm it refers to billions of organic beings in all ages. These differences are irrelevant. The point is that the theory of evolution is a mere statement of alleged 'facts' about 'things'.

This being so, we have nothing here except concepts of kinds already studied, concepts of the given and concepts of things. The truth of such concepts means, chiefly, their 'correspondence' with the facts, or, more accurately, the correspondence of the concepts with the percepts. The concept contains, in conceptual form, the same substance of knowledge as is given in perception, or as it is supposed would have been given in perception if any mind had been present and watching on the earth throughout the ages. Nothing is added by the mind to these perceptions or possible perceptions. There is no constructive element.

There are, of course, the constructions of independent existence, of continuous public space and continuous public time, &c. These are taken for granted by all science and all common sense. They are the stage on which the whole drama of human knowledge is enacted. We have already settled our account with them. And it would clearly be wrong to describe evolution as a constructive concept on account of them. That would be to include them twice over in our accounts. The point is that there is in the theory of evolution no *new* construction. We shall be right to call evolution a *factual* concept.

Thus evolution presents no specially interesting features to the epistemologist. It is a straightforward factual concept which does not differ epistemologically from concepts of the given, such as 'red' or 'loud', or concepts of things, such as 'house' or 'steamer', except in the irrelevant fact that it is more complicated. The principle is the same. Its truth consists in the correspondence of the concept with the percept or with what it is believed would have been perceived if any mind had been suitably situated.

2. THE ATOMIC AND ELECTRIC THEORIES OF MATTER

Until recently the old atomic theory of matter held the field. Matter, it was thought, is not infinitely divisible. There must come a limit in the process of division when further division is impossible. You have then reached the atom, the ultimate indivisible constituent of matter. Each element has its own qualitatively peculiar atoms. An atom, therefore, was just a small lump of matter. And matter was entirely composed of these little indivisible lumps. This was the old atomic theory.

But the atom is no longer regarded as indivisible. The first change in outlook came with the view that the atom consists of a nucleus of protons and electrons and a number of electrons circling in orbits around it. The atom so conceived could be compared with perfect correctness to the solar system. The electrons were supposed to whiz round the nucleus just as the planets whiz round the sun.

There are two points to be noted here. Firstly, it was still possible at this stage to make, or at least to imagine, a *model* of the atom. The nucleus with its circling satellites could still quite easily be pictured in imagination. Secondly, we still had before us a theory of *particles.* The early electronic theory of physics still regarded matter as composed of ultimate little bits or particles of stuff. On both points these simple views have now disappeared. Newer and far less simple views hold the field. But it will be profitable for us first to consider the early stages of the atomic and electronic theories in which matter was still conceived as composed of picturable particles.

Now the question in which the epistemologist is interested is this. What is meant (or what was meant when the theory was in vogue) by saying that the theory of particles is 'true'? What, in the first place, did the theories actually mean to assert? Were atoms and electrons supposed to be really existent, or were they merely some kind of a scientific dodge?

If I correctly understand the physicists, they undoubtedly meant to assert that atoms and electrons really exist. And this is still, I believe, the position. The simple view of the electrons as a lot of little bullets or tiny pills has given way to more complicated theories. But I am not aware that physics has abandoned the view that the electron is an actual existent.

But what does it mean to say that atoms or electrons exist? They cannot be perceived. It is inconceivable that human senses will ever perceive them. Nor could any imaginable degree of magnification by the microscope ever bring them within view. No doubt we may be able to perceive their effects. Beautiful laboratory experiments have been devised by means of which it is possible to perceive the effects of a single moving electron. But this is not perceiving the electron itself.

To say that the atom exists unperceived is, for us, on exactly the same level as the assertion that the table exists when no one is aware of it. The latter statement can only mean that *if* some one were looking he would perceive the table. The belief in the existence of atoms can only mean that *if* the human senses could be rendered subtle enough, or instruments refined enough, the atoms would be perceived. Any assertion of existence must, on our view, be understood in terms of perception, and must refer to some perceptual experience conceived as possible. The fact that it is really inconceivable that any senses could ever perceive atoms or electrons proves nothing to the contrary. What it proves is that the existence of the atom is an existential construction. For it is characteristic of such constructions that they can only be exhibited by hypothetical propositions having antecedents expressing impossible conditions.

The existence of atoms is, for us as epistemologists, clearly a mental device for making the appearances of matter intelligible to us. On the other hand the existence of atoms is no more unreal than the existence of the table when no one is aware of it. The two are on exactly the same footing. In both cases it is assumed that something can exist unperceived. The lack of perception in one case is supposed to be due to the accident that one is not looking, and in the other to the essential infirmity of human senses. The difference between the two cases is thus unimportant.

Thus the physicist is apt to insist that the atoms are no device of his, no convention which happens to 'work' and to produce results, but that they 'really exist'. We may entirely agree that they really exist. But the question is: what does 'really exist' mean? This real existence is itself nothing but a device of the mind, not the mind of the physicist, but the mind of primordial man. There is no contradiction between our view and that of the physicist. Or if there is any difference, it is not as to the meaning of the theory of atoms (on which the physicist alone is competent to pronounce), but as to the meaning of 'existence'. Physicist and philosopher can both agree that the atom or the electron really exists. The physicist is perhaps apt to take the plain, unreflective man's view that existence is a given fact, whereas the philosopher will view it as a mental construction. But this is quite as it should be. It is the physicist's business, and not the philosopher's, to expound the atomic theory. And it is the philosopher's business, and not the physicist's, to expound the meaning of 'existence'.

The atomic and electronic theories carry the hypothesis of unperceived existence a little further than we have so far seen it carried in our studies of pre-scientific knowledge. The table, after all, is sometimes perceived. The atom never has been and never will be. The constructions which we studied in Chapter VI only went to the extent of assuming that the things which we see, hear, touch, &c., go on existing when no mind is perceiving them. Science now with the atom pushes this idea to the length of assuming that there are existences which never are or can be perceived. The atoms, the electrons, the ether, are examples of this. We have here, therefore, a *new* element of construction for which science, and not common knowledge, is responsible. We shall, therefore, be right to classify all such concepts as constructive, and not factual, concepts.

But an important principle comes to light at this point. When the mind supposes something to exist unperceived, of what materials does it construct this existence? Clearly, of materials taken from the given. It must always suppose that what is not given is constructed of the same materials and in a similar manner to what is given. The best example of this is that the time-gap between the two appearances of the same object, say the table, is filled up in imagination by the continuation of the same table across the gap. The green patch, when I am not looking, is supposed still to be green. Whenever and wherever the mind creates existence by constructive concepts it must necessarily conceive this created existence by means of analogies from actual perception. *For the mind has no other material at its disposal.* This is a universal rule regarding existential constructions.

How does this apply to the atomic theory? The table which is supposed to exist unseen is conceived as exactly like the seen table. But we cannot suppose that the unseen atoms are like seen ones, because atoms have never been seen. What do we do then? We think of them after the analogy of tiny pellets or pills. We think of them after the analogy of small pieces of matter which we have actually seen. This means that we construct for the mind a picture or model of the atom, and this was quite easy so long as the atom or electron was still thought of by physicists as a particle.

But recent developments of physics raise difficulties.

We are told that we must not expect the constitution of matter to be such that any model can conceivably or possibly be made of it. The electron is not a particle after all. In some respects it is now supposed to behave as if it were a particle, but in other respects as if it were a wave. For this new conception Eddington has invented the clever word 'wavicle'. We cannot form a picture of a 'wavicle' because the images of wave and particle cannot be combined, because in fact they possess *contradictory properties*.

This same self-contradictory character of the present-day atom is further brought out very vividly in what is known as Heisenberg's Principle of Indeterminacy. This principle lays it down that an electron may have a determinate position or a determinate velocity, *but not both*. If its velocity is determined, then it cannot be said to be present at any precise position in space. If its exact position is determined, then it cannot be said to have any determinate velocity.

It is clearly impossible to picture such an electron or to make a model of it. For the only materials we have for such a picture are the characters of *perceived* motions. But any perceived moving object must have both determinate position and velocity. The assertion that a particle is moving with a certain determinate velocity *means* that it moves from *this* determinate position to *that* determinate position in a given time. It therefore appears to be self-contradictory and *meaningless* to ascribe to a particle a determinate velocity and to deny it a determinate series of positions. Certainly no picture or model of such a motion can be framed, because no analogies from perceived motion will help us.

Now to say that anything exists of which no model or picture can possibly be made is a definite challenge to the whole philosophy which we are here advocating. The fundamental position of that philosophy is that all truth goes back in the end to what is given, i.e. to images seen, heard, felt, &c. To exist, for us, means nothing more than to be a possible object of perception. Whatever can be perceived, however, can be pictured in imagination, and a model could be made of it. To say that something is incapable of being pictured or modelled is to say that it is incapable of being perceived. And this is to say that it does not exist.

We must distinguish, of course, between the allegation that a thing cannot be perceived owing to some accidental circumstance and the allegation that it is inherently and in itself incapable of being perceived or pictured. The old particle-atom could not be perceived because it was too small. This was an accidental circumstance. We could easily picture the particle in imagination. This kind of imperceptibility is not incompatible with existence. The existence of the particle means that if our eyes were more powerful magnifiers (a physical impossibility, no doubt, but not a logical one) we should see it. But the statement of the modern physicist that no model of the 'wavicle' atom can be made seems to mean much more than this. It seems to mean that the inner nature of the atom is such that the framing of a model or picture would be inherently and logically impossible.

My contention is that this is inconsistent with the very meaning of existence. For to assert that anything exists unperceived can only mean that *if* certain conditions (perhaps impossible ones) were fulfilled, the thing would be perceived. And whatever could be perceived by the senses could be pictured or modelled.

There undoubtedly exist *concepts* the corresponding perceptual objects of which cannot be pictured or modelled. It will be helpful briefly to examine some of these. We will take as our examples the fourth dimension of space, the concept of colour in the mind of the man born blind, and the concept of a square circle.

By the fourth dimension of space I do not refer to the relativist conception of time as a fourth dimension of space-time. I refer to the notion of a fourth *spatial* dimension, i.e. to a supposed direction in space at right angles to the three known dimensions.

It is possible to form a concept of such a dimension. It is possible even to work out four-dimensional, five-dimensional, or *n*-dimensional geometries. But we cannot form a picture or model of the fourth dimension, much less of the fifth or *n*th.

The blind man's concept of colour is a more homely illustration of the same thing. Assuming that he was born blind, he may use the word colour, and attach some meaning to it, so that he must be considered as having a concept of it. But he has absolutely no *image* of it, and cannot possibly form one (except perhaps a wholly incorrect image based upon the data of the other senses).

But in both these cases the only reason why no picture can be formed is simply that the mind lacks the requisite perceptual experience. It has not the necessary sensuous materials, and it cannot make bricks without straw. There is nothing *self-contradictory* in the ideas of colour and the fourth dimension which prevents the formation of the image or model.

But now consider the case of the square circle. The reason why we cannot picture that, is that it is a flat self-contradiction. And this means, not merely that we cannot picture it, but that *we cannot believe in its existence.*

We must carefully distinguish, then, between these two kinds of cases. In some cases, such as the fourth dimension and the blind man's idea of colour, the reason why the mind is unable to form any picture is simply that it is without that particular kind of perceptual experience which is required as material for the image. The same is true of radiations outside the range of our senses. There is no reason why, in such a case, we should not believe in the existence of the object. But in other cases, such as that of the square circle, the reason why no picture can be formed is that the idea is self-contradictory. And in such cases we cannot believe in the existence of the object.

Now what do the physicists mean when they tell us that the atom is such that no model can be made of it? If they mean merely that we have not the requisite experience, then we need raise no objection. A mind which had the requisite experience could make the model. And the assertion that such an atom exists means only that *if* we had certain faculties which we do not possess, or *if* there actually are any minds with those faculties, then both we and those minds could both perceive and picture the atom. But I am very much afraid that the contention of the physicists involves more than this; involves that the 'wavicle' is like the square circle. And in that case we must pronounce their conceptions erroneous and due to confused thinking.

For the difficulty seems to be that the wave and the particle possess mutually inconsistent properties, like the square and the circle. If so, we must believe that the wavicle theory is not final, is due to a partial understanding of the problem, and that it will be replaced some day by a self-consistent theory. I think it must be clear to any impartial observer that the physics of the atom is to-day in a transitional state, and that it cannot be claimed that any satisfactory theory has been reached. New theories are succeeding each other with bewildering rapidity, and there seems not the slightest reason to suppose that the 'wavicle' theory will stay with us in its present form for very long. In these circumstances I do not think that physicists ought to dogmatize too much about whether a picture or model of the real atom will be possible when its nature is discovered.[1]

I do not think that anything in the present state of physics need deter us from holding to our main doctrine; which is that the assertion of the existence of atoms, whether particles or wavicles or whatever else, means only that *if* . . ., the mind would perceive atoms.

One of the lessons for epistemology here is this. If the 'wavicle' theory is really self-contradictory, it cannot be true. If it is true, it cannot really be self-contradictory, and further research is certain to result in a reconciliation

[1] How any one can dare to found upon the present uncertainty in physics such doctrines as free will and the spiritual nature of inner reality passes my comprehension. Philosophers have often been accused of building idle speculations upon insufficient data. But some of our men of science completely outdo the philosophers in this.

of the apparent contradiction. Truth cannot be self-contradictory. This is the lesson we learnt from the conclusion that logical laws possess necessity, and that truth is tied by these laws.

Present-day theories of the constitution of matter illustrate very well, then, the procedure of the mind in its search for knowledge. Knowledge is fixed at two points. It is tied by the given, and it is tied by the laws of logic. Its attachment to the given means (1) that the truth about the atom must be conceived in terms of perception, and (2) that no deduction from the theory must conflict with given facts. The condition that the atom must be conceived in terms of perception means that it must be possible to picture a model of it. Whatever theory is ultimately established will mean that *if* . . ., then we should perceive the atom in such and such a way, i.e. in accordance with such and such a picture or model. The 'if' clause will of course state an impossible condition, and therefore the concept will be that of an existential construction.

3. THE GEOLOGICAL AND ASTRONOMICAL PAST

The scientific concept which I wish to discuss in this section is that of a past which extends back millions of years before any minds were in existence to perceive anything. As regards its epistemological character there is no difficulty and very little to be said. It is concerned, like evolution, merely with facts which are said to have occurred. It is historical. It involves, of course, the fundamental construction of an independently existing world. But this construction belongs to common sense. Science adds nothing in principle. The concept, therefore, is factual.

But I bring up this subject here for another reason. The theory which is advocated in this book, when it comes to deal with the question of the past, is likely to find itself opposed by violent and obstinate popular prejudices. It will be said that the theory abolishes the past, or renders it a farce. And since the past in geological and astronomical ages, not to mention the past within human memory, is solid unshakable fact, our theory cannot be said to be even plausible. If our theory comes into opposition with the solid past, it is our theory, and not the past, which will look silly.

We shall find, however, that there is no such opposition. What is meant, on our theory, by the past? Let us consider first the recent past which is within human history. What do we mean, for example, by saying that Caesar was murdered two thousand years ago?

Now duration-spread is a quality of that which is given within the solitary solipsist mind. There exists, therefore, even for the solitary mind, a past. But that past will stretch back only so far as the private memory of the individual mind goes. This brief private past is not constructed, —except so far as explained in Chapter IX—but given.

Suppose that two such solitary minds get into communication and compare notes. Suppose that their pasts have run parallel, and that they have been to the same places, at the same times, have seen the same things, &c. They pursue comparison of notes backwards along these parallel private pasts. *A*'s earliest memory is the presentation *X*. But *B*, who is ten years older than *A*, remembers *X* and also a series of presentations *previous* to *X*. Now *A*'s series of memories were originally in a different world from *B*'s series. Each of the two minds had his own private world. But, with the development of a public external world, *A* identifies his series of memories with *B*'s. But *B*'s series goes back beyond *A*'s. Thereupon *A* discovers that there was, in the now established public world, *a past which existed before his own private world began*.

This would establish the idea of a past having existed so long as there was some mind to perceive it. The extension of this into a past which existed before there was any mind at all to perceive it is merely a deduction which follows as a matter of course from the general belief, the construction of which has been fully described, that things have an independent existence and persist when no one is perceiving them. So the remote past is constructed. The strands in the fabric of our common experience pass backwards out of sight. We naturally continue them and extend them indefinitely. The network of causal and other relations is also extended back into the unknown past.

On archaean sandstones we find pock-marks which look like the imprints of raindrops. We explain these marks by supposing that a rain storm passed over these sands hundreds of millions of years ago. There seems to be no doubt that this theory is *true*. That is what actually happened. Each of us finds in his own experience a series of causes and effects. This is projected into an independent and external world in which there is a series of causes and effects, public, external, and independent, existing whether any one is aware of it or not, and having existed before any mind was aware of anything. Into this causal series the rain drops of the Precambrian age fit with certainty. Leave them out, and there is an inexplicable gap in our world.

The story of the archaean raindrops is just as much true and solid fact as the existence of the atoms. And the meaning of truth is the same in both cases. The statement that atoms exist means that if suitably microscopic eyes could be developed, atoms would be seen. The statement that there was a storm of rain so many hundred million years ago means that if any mind had been present it would have perceived the storm.

And *why* need we assume that these marks on the rocks have been caused in this manner? Why should the mind make any assumption to explain them at all? In the last resort it will be found that the answer to such questions is always as follows. We have *begun* by constructing the world along certain lines. And now we are compelled by the laws of logic to carry on the same work. We are compelled to make new assumptions to fit in with the old. Even in the earliest stages of knowledge we saw how, when a construction had been set up, it came up against *facts* which rendered it necessary either to abandon the construction or to invent a new construction to make the old one square with the facts. This is how the game of knowledge is carried on.

We could have refused to construct a world at all. Each of us could have remained content in his private world of phantasms. Or at least, there would have been nothing *illogical* in doing so. But we did not do this. We began to build. And, having once begun, we cannot stop. It would be illogical to stop arbitrarily anywhere. Somehow or in some way, if we did so, we should come up against inconsistency and self-contradiction in our world-view, or against facts which contradict our world-view and have to be reconciled with it either by modifying our world-view or by adding to it new assumptions and constructions. We began by inventing a permanently existing world, independent of minds, which is 'there' even when we know nothing about it. Having invented this world we cannot control it. It persists in going back into an eternity in the past and forward into another eternity in the future. We invented the independent world. Next we discovered regular sequences in the given, and we set up the idea of causation. The marks on the rock, therefore, must have a cause, and it can only be this cause which geology asserts. Any other assumption will be in some way inconsistent with the world-picture which we have ourselves painted. Thus we go on spinning a network of knowledge across the void. Every strand leads to, and necessitates, the next.

We might have made similar reflections regarding the theories of atoms and electrons. We have a lump of matter before us. It is hard, coloured, shining, pungent-scented, &c. This is all that is actually *given* in experience. Why do we not leave it at that? What necessity is there to go beyond these plain announcements of experience? Why should we go and divide this up into atoms and electrons which we cannot possibly experience? What is the use of this proceeding? And the answer to these questions is as follows. If only we had remained in our private phantasmal world, we might have taken everything that appeared to us, the colour patches, the resistances, the sounds, at their face value and asked no questions. We might have led the simple life pasturing peacefully on floating colours and sounds. But we were not content to do this. We sought the society of other minds, and for purposes of our intercourse with them we built up a solid, permanent, public world. Now we have to pay the price. We are caught in a vast network of assumptions, hypotheses, and explanations, of which we can never free ourselves, and which goes on elaborating itself for ever. Originally logic compelled us to suppose that we could go on dividing up a piece of matter into invisible small bits. But then the idea of the infinitely divisible was supposed to lead to a contradiction and to break the laws of logic. So the indivisible particle, the atom, was assumed. Once that step was taken, all the rest had to follow down to the very latest hypotheses of physics.

But still the old question persists. Under the theory here advocated did the remote astronomical and geological past *really* exist or did it not? If it did not, then the philosophical theory here advocated had better put its head in a sack and drown itself. The reply is quite clear. Certainly the past really existed, and the assertions of geology and astronomy on the matter are true. But real existence is itself the mind's own construction, and the truth likewise. Nor is the universe, its past, its present, and its future, any less solid, real, and permanent on our theory than on any other. But solidity, reality, and permanence are themselves mental constructions.

4. EINSTEIN'S SPACE-TIME

We have seen that the common space and time of our everyday knowledge are themselves constructions. But they are solid constructs, completed long ago, and having become through many ages consolidated and taken for granted, have now the appearance of being given. Just as a platform constructed on the ground, if it is solidly built, may be treated, for the purposes of walking about, as if it were the ground, as if it had always been there; so I shall now, for the sake of shortness, treat time and space practically as if they were given. They are *there*. They are what we start with when we begin to elaborate the further construction of the space-time of modern relativity mechanics.

And we may, without danger, speak of them in this argument as if they were given in experience. They are *relatively* our starting-point. Thus do the constructions of the mind proceed in the manner of the building of a house—one story upon another.

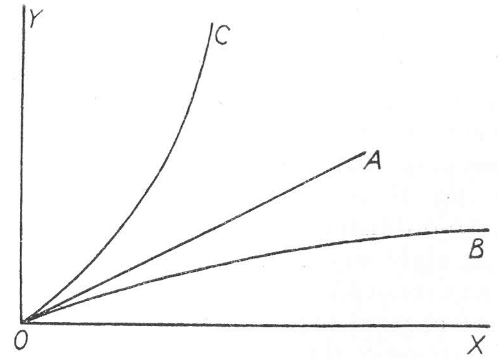
I do not propose to discuss relativity in general, but only the particular idea of space-time. That idea is arrived at as follows. We start with space and time as quite separate entities. It has always been evident, however, that they were closely connected, and indeed necessary to each other. For the apprehension of things in space is successive, i.e. involves time; and the measurement of time is primarily obtained through the perception of the changes of things in space. There seems at any rate sufficient ground for saying that time and space are closely interconnected.

The first discovery which led to the space-time theory was that space measures and time measures vary according to the circumstances of the observer; and that if we are given the variations in the one, the variations in the other can be predicted, so that they are connected by a law. Suppose that we are standing on the earth and regard ourselves as stationary. If an aeroplane, which we have previously measured while it lay on the ground and found to be forty feet long, flashes past; and if its speed is sufficiently enormous (we need not trouble about the figures, but the speed would have to be many thousands of miles per second to make the effect noticeable); then, if we could measure it as it passes us, i.e. if we measured the distance between two points on the earth which we judged to be opposite the two ends of the aeroplane, we should find that it has become shorter along the line of flight. The faster it goes the shorter it would appear to us; until, when it attains the velocity of light, its length disappears altogether and becomes equal to o. But this change of measures is relative. The man in the aeroplane is not aware of any change in his machine, and when he measures it while it is in motion he finds it still forty feet long. It is we, and the things around us on the earth, which have, in the opinion of the man in the aeroplane, changed our sizes. He can regard himself as stationary and us as moving past him. When he measures us he finds that *we* have contracted in the line of our flight past him.

Not only space measures vary according to relative motions in the manner described, but time measures also. What appears as one hour to one observer will be measured as half an hour by another observer, and as two hours by a third.

Thus neither the space-interval nor the time-interval between two events are—as was hitherto assumed—absolute or constant quantities. They vary according to the relative motions of the observers. It happens, however, that an absolute and invariable interval between the two events can be obtained if we combine the ideas of space and time and regard time as a fourth dimension of space-time.

Let us, first of all, imagine a space of only one dimension, a space consisting of a single straight line. Let us suppose that a particle is moving along it with uniform velocity. We can then represent the movement of the particle by means of a graph:



Let OX represent distance in the one-dimensional space, and let OY represent time. If the particle travels uniformly two units of space in one unit of time, the graph of its motion will be the straight line OA. Now suppose that its motion, instead of being uniform, is accelerated.

The graph will then have to be curved. If the acceleration is positive, i.e. if the velocity is increasing, the graph will bend towards the space co-ordinate as in the line *OB*. If the acceleration is negative, it will bend towards the time co-ordinate as in the line *OC*.

In this illustration the time line and the space line are placed at right angles to one another as if they were two dimensions in space; and the lines *OA*, *OB*, *OC*, are obtained representing the space *and* time measures of the motion of the particle. It will be realized that this is purely a mathematical device and nothing more. The time and the single space dimension which we have chosen for the illustration are not really at right angles to one another in nature, nor are there any lines in the actual world corresponding to *OA*, *OB*, and *OC*.

We can with equal ease make a graph showing how population increases with the years. We make *OY* represent years, while *OX* represents population. *OA* will then represent a population increasing at an even speed. The curved line *OB* will represent an accelerating increase of population. *OC* will represent a slowing down of the increase of population. This would be obviously only a device. No one would suppose that population and time are really at right angles to one another, since such a statement would be quite meaningless. It is exactly the same with the time line and the single-dimension space line in the original illustration.

Next suppose that instead of a single dimension of space we take three dimensions. We then have three Cartesian co-ordinates, i.e. three straight lines each of which is at right angles to both the other two. Now although we cannot *picture* a fourth dimension, i.e. a fourth straight line at right angles to all the previous three, yet the fourth-dimensional geometry which would result from supposing that there is such a straight line can easily be worked out by a mathematician. Let us then imagine a graph constructed exactly on the model of the one already given, except that instead of having a single co-ordinate representing a single space dimension we now introduce the three co-ordinates representing the three dimensions of space. And let us, in accordance with the rules of four-dimensional geometry, suppose a fourth straight line at right angles to all three of these co-ordinates. This fourth straight line may be made, for the purposes of our graph, to represent time. We shall by this means be able to get the motion of the particle we are studying represented as a line in a four-dimensional continuum. This line may be called the 'world-line' of the particle. The combination of space and time into a single four-dimensional continuum may be called space-time.

This is just as much a dodge as the graph of the increase of population. People are often puzzled by the idea of time as a fourth dimension which seems to be involved in relativity. This appears to them to be nonsense, because a fourth dimension means a fourth straight line at right angles to the three ordinary co-ordinates. And to say that time is at right angles to a line in space appears to be as meaningless as it would be to say that a scent or an emotion or the number three is at right angles to a line in space. It it true that we all of us think of time on the analogy of a straight line, and we tend to picture it as such. Why we do so is a big question. But it is at any rate certain that such thinking is purely metaphorical, and that in fact time is no more a line in space than a scent or an emotion is. It is for this reason that it appears, and in fact *is*, absurd and meaningless to suppose that time can be a fourth dimension in a continuum of which the other three dimensions are spatial.

The explanation is perfectly simple. The relativist is simply using the dodge with which we became familiar in our childhood as a graph. Time cannot be at right angles to a line in space any more than population can be. But a useful picture can be drawn of the relation of population to time by the graph method. The same can be done, as we have seen, for a moving particle, placing the time interval along one co-ordinate and the one-dimensional space-interval along the other. And there is no geometrical difficulty in making a graph with four co-ordinates instead of two, three being spatial and the fourth representing time (just as it might represent population or anything else). This is what the relativist does. And he does it because it happens to give certain very useful results.

Among these useful results is the following. We ordinarily measure two intervals between two events, namely, a time interval and a space interval. For example, suppose that the two events are (1) an earthquake which occurred in Calabria yesterday, and (2) the striking of a clock in London to-day. Then the space-interval between these two events is the distance between London and Calabria; the time-interval between them may be twenty-four hours. But these two intervals are not invariable for all observers. An observer on the earth may find the time-interval to be t and the space-interval s. But an observer situated on a body travelling at a high velocity relatively to the earth may find the time-interval to be t' and the space-interval s'. But it has been found that if we make a graph of the movement between event and event, in the manner above indicated, taking three co-ordinates to represent the three space dimensions and a fourth co-ordinate (which has, of course, to be imagined as in the fourth dimension) to represent time;[1] then the interval between the two events so obtained along this graph or 'world-line' is constant, i.e. the same for all observers. For example, the space-interval and the time-interval between the earthquake in Calabria and the striking of the clock in London vary according to the motions of the bodies from which they are measured. *But the interval along the 'world-line' in the four-dimensional continuum will be the same whatever the motions of the observer.* It is therefore called the 'absolute interval'.

Space-time, therefore, seems to represent an unchanging reality. Space and time measures fluctuate with the motions of different observers, but space-time measures remain always the same, and are independent of the

[1] This is not absolutely accurate because time enters into the equation with a minus instead of a plus sign. But this is neglected in the text because it does not affect our argument.

observers. Hence there is a tendency to hypostatize space-time as a *reality* of which space and time are only appearances or at best abstractions. This tendency, it may be remarked, is based upon the metaphysical view that what is independent of us is more real than what is dependent. It has no scientific value at all.

It is not entirely clear to me whether relativists mean to assert the real existence of space-time or not. From the strictly scientific point of view the question does not appear to be of any importance. It is ontological rather than physical. Physicists find that the conception of space-time gives results, and they therefore rightly use it. They need not concern themselves with anything further. But it would certainly seem, in spite of this, that there is a tendency among men of science to assert real existence of space-time. We may quote the well-known words of Minkowski: 'From now onwards space and time sink to the position of mere shadows, and only a sort of union of both can claim an independent or absolute existence.' In truth this statement goes beyond what physics has a right to declare. It introduces metaphysics, and even allows itself to be coloured by poetical feeling. But I think that passages which imply the real existence of space-time could be quoted from the majority of scientific writers on the subject.

Perhaps the sense of doubt and hesitation which we feel on this point at present is due to the fact that mind is now in process of creating a new existence. Before creation is complete there will be hesitancy. But in the future it may be that the existence of space-time will be taken for granted just as the existence of a public space and a public time, both constructions which must have given pause and hesitation to the mind in ages long past, are now taken for granted. At any rate it is clear that the existence of space-time, if it is asserted, is a creation or construction of the mind, a creation which rests upon the fiction involved in supposing that the mathematical device of the graph represents something real.

To assert the existence of space-time can only mean that space-time is a possible experience. Yet we have, and can have, no experience of it. We have experience only of space and of time, or more strictly of private extension-spreads and duration-spreads. And to suppose that we could ever experience space-time is as much a fiction as to suppose that we could experience time and increase of population at right angles to one another, or that we could perceive the table when it is not being perceived.

And yet the lesson we learn from our investigations is this. There is no reason why the existence of space-time should not be asserted, if the assertion of it seems necessary to science. And the assertion may prove to be 'true'. It will be true if it is found that the phenomena of nature cannot be explained without it, and if in the long run it fits in with the entire scheme of things which knowledge discloses, and if its results are in accordance with the given and do not contradict any other part of knowledge. The procedure of the mind here amounts to the erection of a fiction to the dignity of existence. But what we have learnt from the beginning of our studies is that 'independent existence' and 'reality' are themselves fictions. To erect the mathematical device of space-time into an independent entity is of a piece with the general procedure of knowledge, and is a perfectly justifiable work of mental construction.

Space-time is, of course, a construction of the existential type. It is not unificatory because it does not *identify* space with time, or abolish an unnecessary existence, as is always the case with unificatory constructions. It creates a new existence. It is therefore expressible in the hypothetical proposition. 'If . . ., we should perceive space-time.' The blank may be filled up how we please.

5. GRAVITATION—NEWTON AND EINSTEIN

Newton's theory of gravitation was that there exists an attractive *force* operating between all particles of matter, the force varying directly as the product of the masses and inversely as the square of the distance between them. If there were no forces acting on a body, then it was supposed that the body would move with uniform velocity in a straight line. That was Newton's first law of motion. But if a force, such as that supposed to be exerted by the sun on the planets, acted on the body, it would be deflected from the straight and its path would be deducible from the law stated in the first sentence of this paragraph, which we will call for short the law of the inverse square.

Einstein's theory of gravitation cannot be so simply formulated, but it may be said to be based on the notion that the movements of bodies, e.g. the planets, are governed, not by 'forces', but by the configuration of the space-time in which they move. The important point to get hold of is that the law of gravitation is thus reduced to a law of *geometry*.

In order to understand this we have, first of all, to replace Newton's first law of motion. Since our new view dispenses altogether with the idea of forces and explains motions by means of geometrical concepts, our first need will be a new law of motion. This law is as follows:

If a body is moving freely, and if X *and* Y *are two events in its history, then the series of events which constitutes its history between* X *and* Y *is such that the 'absolute interval' of* Y *from* X *measured along that path is a maximum.*

This means in effect that a body always takes the longest possible space-time path between two events. It follows that if you know *which* is the longest space-time path you can always predict the movements of any body. But in order to do this all that you require is to know the geometry of the space-time in which the body is moving. *Which* is the longest space-time path is obviously a purely geometrical question. Einstein's law of gravitation is simply a formula which tells us what kind of geometry to expect in different parts of space-time. When we know that, we can deduce which of all possible paths between two events is the longest, and that will be the path of our planet or other heavenly body.

The details of the geometrical formulae required are, of course, very complicated. But we may say at least that in portions of space very remote from any matter space-time has a Euclidean geometry; whereas near heavy masses such as the sun its geometry is non-Euclidean. In remote spaces the longest space-time path will be a straight line. Near the sun it will be a curved line. It will be in fact the orbit which the planet actually takes. Thus the reason why the planets move in the orbits they do is simply that those orbits represent the longest possible space-time paths in the particular kind of space-time which exists at that place. Elsewhere, in another kind of space-time, i.e. in a space-time with a different geometry, different paths would be followed. Thus the orbits chosen are determined solely by geometry.

Given (1) the law of motion as above stated, i.e. the law of the longest path, and (2) suitable formulae for the geometry of space-time, we can deduce the orbits, positions, and times of all bodies in space.

Now if any one finds all this very puzzling (as is the common experience) the reason probably is this. We have got into the habit of thinking that Newton's forces 'explained' the motions of the planets, i.e. gave us an intelligible reason *why* the planets move as they do. But Einstein's law does not seem to give us any reason. That motions should be governed by forces seems understandable. But that they should be governed by geometry seems unintelligible. Why for example should bodies take the longest space-time path? It seemed 'natural' that freely moving bodies acted on by no forces should move in straight lines. But why bodies should go zigzagging about in order to obey this eccentric new law of motion seems inexplicable.

But this supposed difference between Newton's and Einstein's laws in respect of intelligibility is solely the result of our greater familiarity with the former. In reality neither of them give any *reasons* why things move as they do. No explanation can be given of Einstein's law of motion. Neither Einstein nor any one else can tell you *why* bodies move in the way they do. They might, for all any one could tell to the contrary, move in any other way. But it happens that they move in this way. It is a brute fact, and there is no more to be said about it. It is a mistake, therefore, to think that it is difficult to understand. For beyond the fact that it *is* so there is nothing to understand.

Newton deduced the movements of bodies from his formula about forces. Einstein deduces them from formulae about the geometry of space-time. Both the forces and the space-time and its geometry are fictions which are adopted because they are useful for predicting the positions and movements of the heavenly bodies. But we falsely imagine that Newton's formula gives us a *reason why* bodies move as they do, whereas Einstein's does not. And we make this erroneous discrimination because we are more familiar with Newtonian ideas, and more especially because the notion of 'force', being of anthropomorphic origin, appeals to our incorrigible animism.

For a 'force' means primarily a *sensation* of pressure. When some one pushes me from behind I feel the pressure sensation of his hands on my back. When I hold between my fingers a piece of string with a weight hanging from the end of it, the force appears in my consciousness as a pressure sensation in my finger tips and a sense of muscular strain in my arm. Let us suppose a disembodied intelligence suspended in mid space, neither operating on bodies, nor in any way operated on by them. Its entire life consists in inactively watching the motions of the universe, while remaining itself motionless. Such a consciousness, because it would be without experience of sensations of pressure and strain, could not possibly frame or understand the notion of force. Suppose that this intelligence, looking down with telescope-like eyes upon our earth, watched a billiard match in progress. It would not think that one ball striking another 'pushes' it this way or that. But it could perfectly well conclude that when moving solid bodies meet at such and such angles and speeds, their directions and motions are altered in such and such ways. Watching the planets, it would neither suppose any force in existence nor see the necessity for any. It could, however, quite easily frame satisfactory laws of motion and gravitation. But they would be based solely upon the concept of *succession*, and not at all on the concept of *compulsion*. They would be of the form 'when *A* happens, *B* happens', not of the form '*A* exerts a force which makes *B* happen'. It would perceive that when bodies move in remote enough empty spaces they move in straight lines, but that when they move in the neighbourhood of other bodies their paths are functions of such factors as velocity, distance, and mass.

The notion of force is as completely otiose in science as that conception of causation which regards a cause as compelling its effect. Both notions, in fact, spring from the same anthropomorphic root; or, more accurately, the concept of force is a particular case of the concept of compulsory causation.

Now it is quite possible to restate the Newtonian law without using the concept of force at all. It then becomes simply a mathematical equation for calculating the paths of moving bodies. The position of the body at any moment will appear as a function of the three variables, velocity, mass, and distance. Such a law makes no pretence of *explaining* (by means of forces or any other anthropomorphic conceptions) why bodies *must* move in such and such a way. It merely states that as a matter of fact they do move in that way, and it provides a formula for the calculation of their positions at any moment.

Unfortunately, however, the Newtonian law, even when purged of the irrelevant concept of force, has not proved to be precisely correct. It is very nearly correct. But it fails to predict with sufficient accuracy certain well-known astronomical phenomena such as the curvature of starlight rays passing the limb of the sun, and the movements of the perihelion of Mercury. This means, of course, that it fails to predict with absolute accuracy the motions of *any* of the heavenly bodies. But it is only in a few cases, such as that of Mercury, that the difference between calculated and observed positions is large enough to be noticeable or important. It is not that the law is correct for other heavenly bodies and incorrect for Mercury. It is incorrect for all bodies in greater or less degree.

Now there would be no insuperable difficulty in working out, along Newtonian lines, on the assumptions of Euclidean geometry, without any reference to curved or humped spaces or to any of the familiar paraphernalia of Einsteinian mechanics, a corrected law of gravitation, a law which would correctly predict the movements of the perihelion of Mercury and all the other motions of bodies. It is true that among the factors of Newton's law are distances and times, which are assumed by Newton to be constants, whereas we now know them to vary with the motions of the observer. But allowance could be made for this in our corrected law. This law might be simply an equation or set of equations in terms of velocities, intervals, &c. Such a formula could be worked out. We will call it the corrected Newtonian law. The only trouble about it is that *to make it correct we have to make it enormously complicated.*

To work out such a law would have been one way of meeting the difficulties created by the inaccuracies of Newton's law. Einstein, however, found that a simpler procedure could be introduced by framing a set of formulae in terms of a four-dimensional geometry. These formulae constitute Einstein's law of gravitation.

Thus neither Newton's nor Einstein's laws 'explain' anything. To suppose that they do so would be exactly on a par with supposing that the nautical almanac 'explains' the movements of the stars. Newton's law, Einstein's law, and the nautical almanac are all alike no more than abbreviated statements of what happens, short memoranda or keys which we can apply to any particular case to ascertain the motions, positions, and times of any particular moving body.

There is at the present day a danger of the geometrical properties of space-time becoming an anthropomorphic superstition in the same way as 'force' did. This superstition is being created by those popular writers who talk about bent and curved spaces and who tell us, for example, that around the sun there is a hill or hump in space-time, so that the planets have to run around it instead of running straight. The truth which these metaphors represent is that, if we choose to adopt the assumptions of non-Euclidean geometry, we can deduce from them and from the new law of motion the movements of the planets. We need not adopt these assumptions, and if we adopt Euclidean axioms instead we can equally work out the motions of the planets. The only point is that our calculations are easier and simpler if we adopt a non-Euclidean geometry. Pure space itself, the space which is *given*, is neither Euclidean nor non-Euclidean. It has no geometry at all. It is nothing but the extension-spread of private sense-data. We invented Euclidean space. And the human mind has later invented various kinds of non-Euclidean spaces. And it is found more convenient to use the fiction of non-Euclidean space or space-time in the formula for working out the motions of the heavenly bodies than to use the fiction of Euclidean space. But these popular writers speak as if the hills and the humps in space-time were actual physical things which push the planets about. The image inevitably created in the mind by their metaphors is that of a planet being pushed out of a straight course by hitting up against a bump. This encourages the mind once more to believe that space-time in some mysterious way *compels* the planets in their courses.

But there no more exists any compulsion by the geometry of space-time than there exists any compulsion by 'forces'. All that scientific laws, if properly framed and understood, should ever attempt to do is to state in a generalized form *what as a matter of fact happens*. What they should above all avoid is to attempt to give *reasons* why things happen as they do, for all such reasons turn out to be errors and anthropomorphic superstitions. Newton's law was primarily a formula which enabled any one, given the necessary data, to work out the path of any freely moving body. But over and above this there was foisted in the conception of 'forces'. This was not essential to the law. The law merely stated how bodies move. The addition of 'forces' was supposed to explain *why* bodies move as they do. The ideas of pushing and pulling were supposed to make us understand the reasons why the planets do not move in straight lines. They were a pandering to the human mind which feels happier and more satisfied if the operations of the universe can be ascribed to anthropomorphically conceived agencies.

Einstein's law, if stated in purely mathematical terms, is merely a generalized statement of how bodies move, which turns out to be more accurate than Newton's. But the human craving for an answer, in anthropomorphic terms, to the question why they move as they do, causes popular writers to foist in the idea of compulsion by the humps and curves in space-time. Since we are not allowed to have forces to push the planets about we must have bumps in space-time. Such is the weakness of the human mind.

Newton's law is often credited with having given the 'explanation' of Kepler's laws. But in the light of what has been said it will be evident that it does not explain either Kepler's laws or anything else. The only superiority of Newton's law over Kepler's three laws resides in the facts that it reduces three laws to one and is therefore simpler, and that it is of wider application than Kepler's laws, extending as it does to the whole universe and not merely to the solar system.

It happens that Einstein's law is presented in terms of geometry. But it must not be supposed from this that geometry is the cause of anything. The law would be just as true if it were presented in terms of arithmetic, chemistry, eugenics, heraldry, or cookery, provided that it correctly predicted the positions of moving bodies. Geometry is not a cause, or explanation, or reason, why bodies move as they do. It is a mental construction which happens to provide a satisfactory method of procedure in predicting the facts of experience.

It follows also from what has been said that the corrected Newtonian law and the law of Einstein are both equally 'true'. They are *alternative truths*. Science chooses the law of Einstein purely because it is simpler and easier to manipulate. 'Forces' and non-Euclidean space-time are both alike existential constructions. Einstein has not discovered a single new *fact* about nature. For the only real facts are our experiences of the given, colour patches, sounds, and the like. What he has done is to invent a new fiction or construction which is superior to the Newtonian construction because it agrees better with the facts (e.g. our light sensations from Mercury), and is superior to the corrected Newtonian law because it is simpler.

This throws light upon the difference between valid and invalid constructions. The three requirements of a valid construction are (1) that it shall be internally self-consistent; (2) that it shall be consistent with all other constructions which form a permanent part of 'knowledge'; and (3) that it shall agree with the facts. The meaning of the last condition will be more fully discussed in the next chapter. Newton's uncorrected law fulfils the first two conditions, but not the third. It is therefore invalid. Newton's corrected law would fulfil all three conditions, and would therefore be valid. Einstein's law fulfils, so far as is at present known, all three conditions. It is therefore valid. Thus because they are both valid constructions Einstein's law and the corrected Newtonian law are both 'true'. They are, as we said, alternative truths. But Einstein's law is now being embodied into 'knowledge', and the corrected law of Newton rejected because the former is simpler than the latter.

6. PTOLEMAIC AND COPERNICAN ASTRONOMY

Both Ptolemaic and Copernican astronomy assumed, until the advent of Einstein, the truth of absolute rest and motion. In one sense, therefore, they have both been superseded and rendered untrue by Einstein's views. But it does not appear that the theory of absolute motion is essential to either of them. For, granted the truth of the relativist doctrine, we can work out the motions of the heavenly bodies either by taking the earth as relatively at rest and the sun and planets as revolving round it (the

Ptolemaic method of procedure), or by taking the sun as relatively at rest and the planets as revolving round it (the Copernican method of procedure).

Understood in this way the Copernican hypothesis is now generally supposed to be true and the Ptolemaic hypothesis false. But the more correct way of viewing the matter would appear to be to think of the two hypotheses as alternative *methodological assumptions*. Neither of them is, strictly speaking, true. It is false that the earth is at rest and that the sun and planets move round it. It is false that sun is at rest and that the planets revolve about it. The truth is that all these bodies move relatively to one another. But we may, for the purposes of calculation of their paths and positions, treat the facts either *as if* the sun were at rest or *as if* the earth were at rest. Either assumption will, if properly handled, lead to true predictions and correct results. But the Ptolemaic hypothesis with its cycles and epicycles is so complicated that it has been abandoned in favour of the other method which is simpler.

Thus the two hypotheses, properly understood, do not either of them now claim truth. They are not judgements which state any facts about the universe. What they affirm is simply that this method or that method will give us truths about the universe. Their subject-matter is not anything in the external world at all but only our *methods* of dealing with things. It is for that reason that they should be classed as methodological assumptions.

This is the first occasion on which we have come across the methodological assumption in the course of our inquiries. This is natural because such assumptions are mostly confined to that kind of knowledge which we commonly call scientific. And since we shall not, in the limited space now left at our disposal, be able to make any fuller study of them, it will be well forthwith to fix their epistemological character and determine their functions in knowledge.

A methodological assumption may be defined as *a proposition, not known to be true, and the truth or falsehood of which is, for the limited purposes for which the assumption is* *used in knowledge, a matter of indifference; but from which it is known that true propositions can be deduced within a limited area of knowledge.*

It must not be known to be true. For if it is, then it ceases to be purely methodological and becomes a substantive truth about the universe. For example, the concept of purpose may be used as a methodological assumption in biology. We may up to a certain point and with certain reservations treat the facts *as if* it were true that every organ has been designed by a mind seeking to adapt means to ends. Whether such a mind or such a purpose actually exists is, from the purely biological point of view, a matter of indifference. For the biologist, as such, it is unknown whether it is true or not, and it is for him, therefore, a methodological assumption. The theologian presumably will not regard it as merely a methodological assumption. For him it will be a substantive truth. Which shows, of course, that a proposition which is at one time a methodological assumption, treated as if true within certain limits but not known to be true, may in the light of advancing knowledge come to be recognized as substantive truth. On the other hand, propositions once regarded as true may be degraded to the level of methodological assumptions. This is what has now happened to the Copernican hypothesis.

The methodological assumption must not be known to be true, but it may be known to be false. Even if it were known to be false that there is a purposive mind governing the development of organisms, the teleological concept might still be used in biological researches exactly as if it were true, and with equally good results. The Ptolemaic and Copernican hypotheses in astronomy are actual examples of methodological assumptions which are known to be false. For, as we have already had occasion to point out, it is false that either the sun or the earth is absolutely at rest in space.

The existence and nature of methodological assumptions should not be surprising to any one who has learnt the lesson of the logic books that an hypothesis may lead to true deductions and yet be false. As is well known, there may be several hypotheses all of which cover the facts, and the problem of science then is to find a crucial experiment to decide between them. Any hypothesis which covers the facts within a certain area of knowledge, and which is not known to be true, may be used as a methodological assumption, provided there are proper safeguards against its misuse.

In fitting the methodological assumption into its proper place in the scheme of epistemology it may be felt that there is a difficulty in distinguishing it from certain kinds of construction. It is essential that they should be distinguished. For valid constructions, we have declared, are 'true', and give actual knowledge about the world. Methodological assumptions are propositions the truth of which is indifferent, and which may be definitely false. But now, take the case of our belief in the existence of a single public world. We have represented this as a construction, and therefore as essentially true. But is it not equally capable of being represented as a methodological assumption? And is there not, therefore, some confusion here? We believe in a single world. We believe, for example, that there is only one ink-pot on my table which I and any other persons who are in the room see. Might it not be said that the *truth* is that there are as many private ink-pots as there are people seeing them, and that the view that there is only one ink-pot is a methodological assumption? For it may be argued that it is strictly speaking untrue (the real truth being that there are many private ink-pots), but that it is an assumption which leads to true results. This, of course, would fit in with the definition of the methodological assumption but not with that of the construction. It is therefore necessary that we should make clear the difference between the two.

The nature of the difference is indicated in the wording of our definition of the methodological assumption. It is defined as a proposition 'from which it is known that true propositions can be deduced *within a limited area of knowledge*'. This implies that whereas the construction is true throughout the entire field of knowledge and all deductions made from it are true, the methodological assumption, on the other hand, only yields true deductions within a certain restricted area. If it is used outside that area it comes, or may come, into conflict with other parts of knowledge, and leads to false results. Thus the construction of the public external world yields results which are recognized as true over the whole field of knowledge. It is true for all purposes. To assume one universe instead of millions of private ones makes no difference to any of the facts in the universe. But the proposition that the sun is at rest and that the planets revolve round it can only be regarded as if it were true for the limited purpose of calculating the positions of the planets. If we try to treat it as always and unconditionally true it comes into conflict with the fundamental principles of modern mechanics which are relativistic. Again the teleological assumption in biology is valid as a method if confined within narrow limits. But if we extend it outside those limits, if we assume that it is true generally, and outside biology, then it will have to be taken as asserting an actual factual existence, namely the existence of an overruling mind. This may come into conflict with facts, and it will actually do so if there is in fact no such mind.

Thus an assumption is true if it is true for all purposes, unconditionally, in all branches of knowledge, and in all contexts. In that case we call it a construction. It yields substantive truth about the universe. An assumption which can be treated as if it were true within certain limited areas and within a limited context, but which would conflict with other propositions which are known to be true if it were asserted outside that area and that context, is methodological. It does not contain substantive truth about the universe, although the deductions which follow from it within its proper area will contain substantive truth.

If we now understand the nature of methodological assumptions we can see more clearly the fallacy, already exposed, of the pragmatist suggestion that the principle of 'the uniformity of nature' is a methodological assumption. An assumption it is, for its truth cannot be proved and no reason or ground can be given for it. But it is not methodological. If it is true at all it is unconditionally true in all contexts. For its absolute universality is its very essence, and if exceptions were allowed to it, it would cease to be the principle of the uniformity of nature. It is either a substantive truth about the universe or it is nothing.

7. THE ETHER OF SPACE

At the present day it appears that physicists are divided as to whether ether exists or not. The more recent view is that the ether is no longer necessary, that empty space or space-time is sufficient to explain the facts, and in fact that ether may be identified with empty space. The older view, of course, was that ether is a continuous something —are we to call it a substance?—pervading all space. We need not concern ourselves with the dispute as to which view is correct. The only question of interest to us is whether the concept of the ether—be it true or false— throws any light upon epistemological problems.

The assertion of the existence of ether—if it is asserted —means, of course, that *if* . . ., then we should perceive the ether. The conditions with which the blank in the antecedent clause might be filled in are inconceivable and unimaginable. The hypothesis of the ether deliberately robbed it of any qualities by means of which it could be perceived, since it was conceived as possessing only those qualities which would make it a wave bearer. But most minds, I imagine, must have helped themselves out with some kind of vague picture of a thin mist throughout space, or of something like the invisible air but infinitely finer. Of course the mind was well aware that these images were inadequate and even misleading if taken too seriously. But they show that the mind, in conceiving of any supposed existence, attempts to imagine how it could *perceive* that existence. The pictorial habit of the mind bears witness to the deep-seated feeling that whatever exists must be somehow or other perceptible, i.e. that existence must be conceived in terms of perception.

The ether hypothesis illustrates very well the procedure of the mind in filling up gaps in knowledge. To fill up gaps is one of the functions of the existential construction. We desire a continuous world in time and space and circumstance, and where we find holes and crevasses in the given we stop them up with new existences invented by ourselves. The gap between the two appearances of the table in perception is filled up by the fiction of the unperceived table. The ether performs a similar function. In the world which the mind has constructed out of the given it finds itself confronted by a number of truths of which the following are well-known examples: that the distance of the earth from the sun is about ninety-three million miles; that light travels with a velocity of about three hundred thousand kilometres per second; and that it travels in waves or vibrations. These truths are themselves, of course, not given. They are constructions out of far simpler elements of the given. This means that innumerable gaps have already been filled up. But there is obviously one left. Light is stated to consist of waves or vibrations which race across space at an enormous velocity. But waves or vibrations of *what*? Everything which is supposed to exist must be supposed to be in some way perceptible or picturable or conceived in terms of perception. Can we conceive or picture waves without their being waves either of water or of air or of some kind of substance? It was this necessity of the mind for thinking all existence in terms of perception which compelled us to insist that if there are waves they must be waves *of something*. Here then is the gap in knowledge. An existence has to be invented to stop it up. It has to be invented because it cannot be found. There is not the slightest trace of such a wave-bearing medium in space. It is not perceptible, and the subtlest experiments have failed to reveal its presence. There is thus no evidence of its existence whatever. But it is wanted to fill up a hole in our world-picture. The mind, therefore, asserted its existence.

But what are its qualities? It cannot be given such crass qualities as ponderability, colour, odour, and taste; for these would render it perceptible, and it is entirely imperceptible. It is therefore endowed with only those qualities which are the minimum required by the mathematician and the physicist for transmitting waves. These minimal properties were *assumed* by the physicists, without any positive evidence, solely because they fitted in with the wave theory.

Thus the ether bears everywhere the marks of being a creation of the mind, a stop-gap in a very literal sense, something made to fit into an awkward hole in knowledge. And now that, with relativity physics, it is apparently no longer needed by the mind which gave it birth, it is quietly being relegated to the limbo of non-existence, to the annoyance of Sir Oliver Lodge, who wants to retain it as the seat and special residence of spirits. Very clearly the question whether it exists or not is simply the question whether the mind has need of it. Existence is nothing else but what the mind needs to build its world.

8. THE SUBCONSCIOUS

Our examples of scientific knowledge have so far been taken from the sciences of external reality. I will take my final example from the science of internal reality or mind, namely psychology. The concept of the subconscious has of late years been specially emphasized by the psychoanalysts, though it was, of course, known to psychology long before their day. The essence of it is the assumption that mental phenomena can take place unknown to the mind in which they occur, that we may think, feel, and will without being conscious of our thoughts, feelings, and conations.

This, as is obvious, is a formal self-contradiction. An unconscious thought appears to be a contradiction in terms, since thought is a kind of consciousness. An unconscious feeling is similarly a contradiction, since it implies that we have a feeling which we do not feel. And yet the concept has been successfully introduced into the science of psychology and is used with telling effect. How is this?

The contradiction is resolved if we take the view that the assertion of the existence of the subconscious is a fiction, an assumption which the mind makes for the purpose of filling up gaps in its experience. Consider an unconscious train of thought or reasoning. Let us assume that there is a train of reasoning of which the consecutive steps are *a*, *b*, *c*, *d*, *e*, *f*, *g*. In order to get from *a* to *g* I have to pass through all the intermediate steps. This may be true both logically and psychologically. It will be true in the logical sense if all the steps are necessary to make the argument valid. It will be true psychologically if it is unlikely that the thought *g* would enter my mind unless led up to by the train of associated ideas *b*, *c*, *d*, &c. Now suppose I actually think the consecutive steps *a*, *b*, *c*, and that for the moment I can get no further with my problem. I give it up and think about other things or go to sleep for the night. Later on—on waking in the morning, it may be—the proposition *g* suddenly flashes into my mind as the solution of the problem set by the thoughts of the previous day *a*, *b*, *c*. My mind appears to have skipped the intermediate links *d*, *e*, *f*. We account for this by saying that the thoughts *d*, *e*, *f* have been worked through *unconsciously* during the night or during the period when I was thinking of other things.

But what is *given* in internal experience here is simply *a*, *b*, *c*, . . . *g*. We have the beginning and the end of the process and a gap between them. That is absolutely all that my experience contains. I have no warrant whatever for assuming that anything exists between *c* and *g*. The very fact that I am said to be unconscious of the intermediate links means that I have no warrant for postulating them. But I invent the concept of the subconscious (or unconscious, as the case may be) to fill up the gap.

The position of the subconscious links in a train of thought is exactly parallel to the position of the changing states of a material object when no one is aware of it. We assume that the material object projects itself unseen across the gap which lies between its appearances to mind. We assume that process, change, and causality continue in it when it is unperceived. Exactly the same assumption, when it is made in regard to mind instead of to matter, is the concept of the subconscious. In only one important respect is there a difference. The material world, both when perceived and when not perceived, is further assumed to be public. The world of mind remains always private.

The subconscious is, of course, an existential construction. And subconscious thoughts, emotions, and conations have a constructive, and not a factual, existence. This does not make them the less real. They really exist. They are, as the Freudians tell us, the causes of many of our conscious actions, of our dreams, &c.

Will it not follow that the mind itself, the very ego, has a factual existence only while it is conscious, and that its continued existence through periods of total unconsciousness (if there are any such periods) is a construction? In view of the purely empirical character of our undertaking, I have purposely avoided all such transcendental questions as the nature of the ego itself. Nor do I propose to discuss them now. But I see no reason why we should seek to avoid the inference just suggested. It is certainly important that the mind, while it is functioning, should be regarded as a factual existence. But I do not see any reason why we should insist that, if it is convenient to regard it as continuing to exist during unconsciousness, such existence must be anything more than a construction of the conscious mind. We like to regard ourselves as the 'same' persons to-day, yesterday, and throughout our lives. But this appears to be very little more than a convenience of speech. If it became the custom to regard ourselves as 'different' from day to day, and as having changed our egos after every period of unconsciousness, I think we should very soon adapt ourselves to the change so long as every one was treated alike.