The Analysis of Matter

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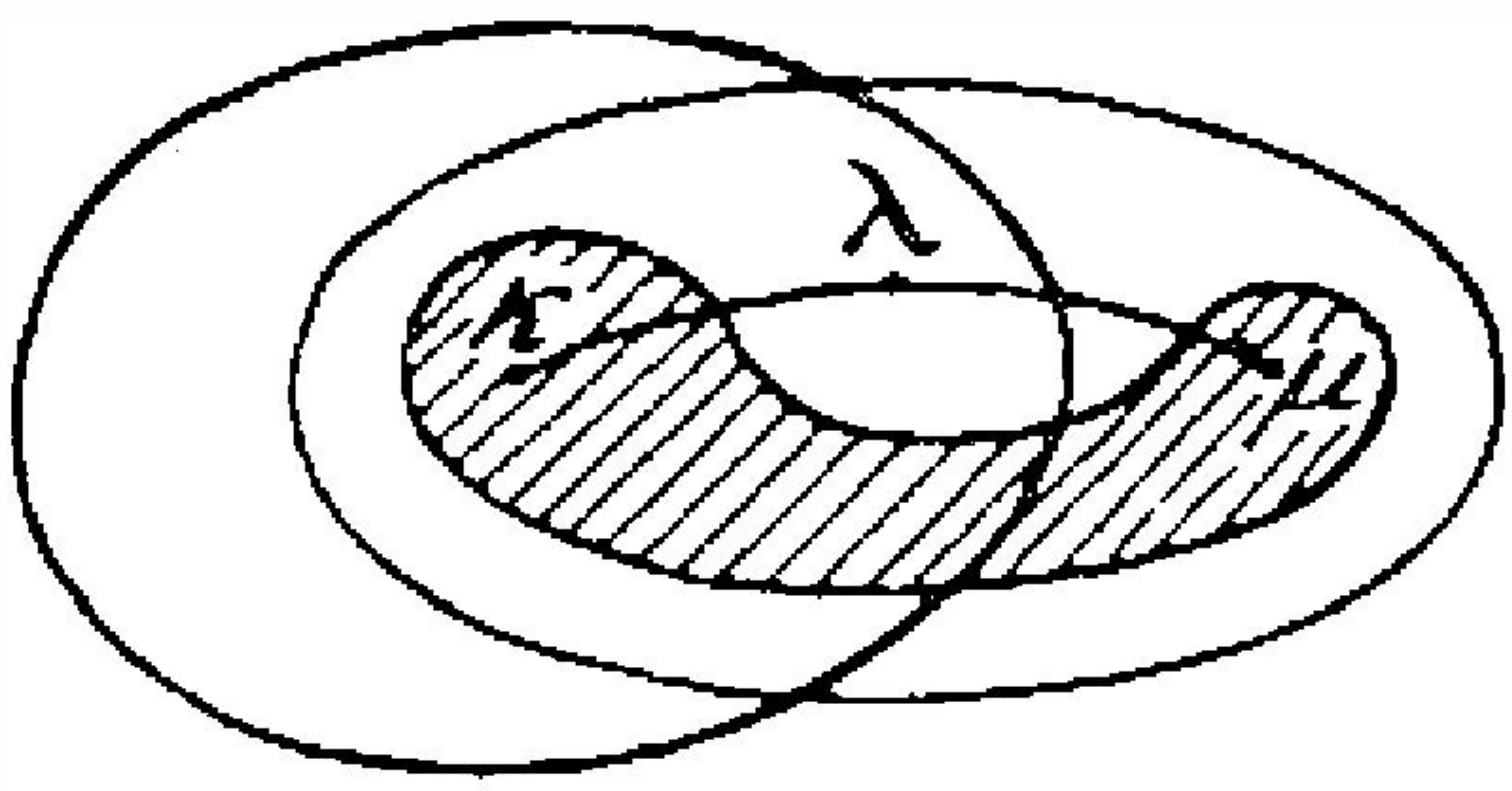
with a new Introduction by John G. Slater



ROUTLEDGE

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CHAPTER XVI

FROM COMMON SENSE TO PHYSICS

It was in the seventeenth century that the scientific outlook, as opposed to that of common sense, first became important. It had existed in individuals among the Greeks, but it had not been able to point to sufficiently great achievements to impress the general educated public. It was in the seventeenth century that science began to win spectacular victories, and to develop an outlook definitely different, in certain important respects, from that of common sense. The historical aspects of this change have been set forth by Dr Whitehead in his *Science and the Modern World*, particularly in the chapter on "The Century of Genius," so admirably that it would be foolish to attempt to cover the ground again. I shall therefore select only certain topics which are important in relation to subsequent chapters.

The chief thing that happened in the seventeenth century, from our point of view, was the divorce between perception and matter, which occupied all the philosophers from Descartes to Berkeley, leading the latter to deny matter, while it had, in effect, led Leibniz to deny perception.

Common sense believes that there is interaction between mind and matter: when a stone hits us our mind feels pain, and when we will to throw a stone it moves. The development of physics made matter seem causally self-contained: it appeared that there were always physical causes for the movements of matter, so that volitions must be otiose. Descartes, believing in the conservation of *vis viva*, but ignorant of the conservation of momentum, thought that the mind could influence the direction of the motion of the animal spirits, but not its amount. This half-way house had to be abandoned by his followers, owing to the discovery of the conservation of momentum. They therefore decided that mind can never influence matter. They also decided that matter can never influence mind. This latter view was not based directly upon science, but upon the metaphysic which had been invented to explain away the apparent influences of mind on matter. To suppose that the movement of my arm is not caused by my volition is to suppose something very odd; it is no odder to suppose that the perception of my arm is not caused by my arm. The view that there were two substances, mind and matter, and that neither could act upon the other, explained the causal independence of the physical world, and entailed that of the mental world. Thus mind and matter became very widely separated—much more so than they had been before the rise of modern physics.

All modern philosophy before Kant is dominated by this problem, for which a variety of solutions were offered. Spinoza held that there was only one substance, whose only *known* attributes were thought and extension, which ran parallel without interaction, like the two perfect clocks of the occasionalists. Leibniz believed in an immense number of substances, all causally independent of each other, but all running parallel in virtue of a pre-established harmony; these substances were all minds, more or less developed, and matter was only a confused way of "perceiving" a number of substances. The word "perceiving" has, in Leibniz's philosophy, a peculiar meaning, derived from parallelism and from the notion of "mirroring the universe." Without attempting to adhere closely to Leibniz's own words, we may set forth the view which is implied in his system, whether he held it in its entirety or not, as follows: Each monad, at each moment, is in an infinitely complex state, which is capable of a one-one correspondence with the state of each other monad at that moment. (This is the pre-established harmony.) The differences between the states of different monads are like the differences between the aspects of a given object from different places, and are compared by Leibniz to differences of perspective or point of view. These differences are capable of arrangement in a three-dimensional order, so that the monads form a pattern which changes with the time. In addition to the one-one correspondences between the monads, there is a one-one correspondence between the state of each monad and the pattern formed by all the monads (mirroring the world). It will be seen that the latter logically implies the former: if each monad always mirrors the world, each is always in harmony with every other. Let us take a mathematical analogy: suppose the states of the m^{th} monad at a given moment are represented by the numbers:

$$m - 1, m - 1/2, m - 1/3, \dots$$

then there is a one-one correspondence between these states and those of the n^{th} monad, which are:

$$n - 1, n - 1/2, n - 1/3, \dots$$

and there is also a one-one correspondence between the states of each monad and the series:

$$1, 2, 3, \dots m, \dots n, \dots$$

which may be taken to be the series of monads. Substitute three continuous co-ordinates for one discrete co-ordinate, and we get a mathematical representation of Leibniz's world.

The obvious difficulty in this system was that no conceivable reason could be given for supposing that a monad mirrored the world. Leibniz himself was one monad, and, on his own theory, would have had exactly the same life if he had been the only monad, since the monads were "windowless." He could not therefore give any grounds against solipsism except some rather far-fetched arguments derived from theology and God's "metaphysical perfection." This defect was due to his theory of causality, which was an outcome of the Cartesian denial that one substance could act upon another, which in turn was inspired by the success of physics in establishing purely physical causal laws which seemed to account for all the motions of matter. In spite of this glaring defect, I have lingered on Leibniz's system, because I believe that it contains hints for a metaphysic compatible with modern physics and with psychology, although of course it will require very serious modifications.

The problem of perception remained unsolved, although it was one of the main pre-occupations of philosophers. Locke, important as he was, did not contribute much on this question, except his theory that primary qualities are objective and secondary qualities subjective; but his *Essay* led others to theories which have remained important. Berkeley discarded the material world, though he need not have discarded physics, since the formulæ of physics may perfectly well be applicable to collections of mental events, as Leibniz supposed. Berkeley does not seem to have been influenced by the argument which affected the Cartesians—namely, the supposed impossibility of interaction between mind and matter. What influenced Berkeley was rather the epistemological argument, that everything with which we are acquainted is a mental event, and there is no valid reason for inferring that there are events of quite another kind. This type of argument is, I think, new in Berkeley, when regarded as a source of metaphysics; in another form, it achieved fame through Kant. Hume carried the same type of reasoning much further than Berkeley did, since he was content to remain sceptical, whereas Berkeley employed scepticism about matter as a support of religion, and therefore had to limit the scope of his criticism of what passed as knowledge. Hume's criticism of the notion of cause cut at the root of science, and demanded an answer imperatively. Of course innumerable answers were forthcoming, but I cannot persuade myself that any of them were in any degree valid, not even that of Kant. I do not wish, however, to discuss at this moment any philosophy which has still a more than historical interest, as is the case with Berkeley, Hume, and Kant. Let us therefore return from this excursus to topics more intimately connected with science.

The profound and lasting effect of Cartesianism upon the outlook of philosophers and men of science was to widen the gulf between mind and matter. Physicists were satisfied with the view that their science could be pursued independently of considerations concerned with mind, and contentedly left the philosophers to wrangle, under the impression that philosophy did not matter to them. For a time, from the point of view of the progress of science, there was much truth in this view; but in the long run science cannot shut its eyes to problems which are logically relevant to its investigations. It may be admitted that most of what has passed for philosophy would not have been very useful to the men of science; but that was chiefly because philosophy was no longer being created by men like Descartes and Leibniz, who were of supreme eminence in science as well. It may be hoped that this state of affairs is coming to an end.

The "matter" of the Cartesians, owing to their denial of interaction between mind and matter, should have been just as abstract, and just as purely mathematical, as in the most modern physics. But in fact this was not the case: the technique of the period still depended upon notions which had an immediate basis in our own experience. We may perhaps distinguish three sorts of physics, in relation to the sense-experiences from which their ideas are derived: I will call them muscular physics, touch physics, and sight physics respectively. Of course no one of them has ever existed in isolation: actual physics has always been a mixture of the three.

But it will be a help in analysis to imagine a separation of each from the others, and ask ourselves which elements in actual physics belong to the first, which to the second, and which to the third. Broadly we may say that sight-physics has more and more predominated, and has achieved an almost complete victory over the others in the theory of relativity.

Muscular physics is embodied in the idea of "force." Newton evidently thought of force as a *vera causa*, not as a mere term in a mathematical equation. This was natural; we all know the experience of "exerting force," and are aware that it is connected with setting bodies in motion. By a sort of unconscious animism, physicists supposed that something analogous occurs whenever one body sets another in motion. Unfortunately for dynamics we have the experience of "exerting force" when we merely cause a body to preserve a constant velocity, as in dragging a weight along a road; this misled Aristotle into thinking that force was to be regarded as the cause of velocity, not of acceleration, a mistake first corrected by Galileo—though Leonardo came very near seeing the truth. It may be said: if force is a mathematical fiction, how can it be more "true" to regard it as proportional to the acceleration than to regard it as proportional to the velocity? The reason is that laws can be found connecting force with the situation of a body relative to other bodies, if force is defined as Galileo defined it, but not if it is defined as Aristotle defined it. Galileo's discovery that falling bodies have a constant acceleration, which is the same for all (*in vacuo*), is a very simple instance. More generally we may say: The laws of physics are, as a rule, differential equations of the second order—with respect to time in Newtonian physics, and with respect to interval in the physics of Einstein. This is a very different notion from that of force as derived from experience of muscular exertion; yet the one has led to the other by an evolution containing many intermediate links.

Touch-physics has led to the passion for conceiving the world as composed of billiard balls—a passion which existed already in the Greek atomists. We know what it is to bump into people, or to have them bump into us; we know that when this happens motion is communicated without the exercise of volition. Billiard balls exhibit the phenomena concerned in the best form for elementary mathematical manipulation. The way billiard balls move when they hit each other is not at all surprising; on the contrary, in a general way it is such as everyone would expect. If all the world consisted of billiard balls, it would be what is called "intelligible"—*i.e.* it would never surprise us sufficiently to make us realize that we do not understand it. The conservation of momentum, which is exemplified in the impacts of billiard balls, seemed to give an admirably simple view of the whole occurrence. We can regard momentum as "quantity of motion," and say that in an impact a certain quantity of motion is interchanged between two bodies, just as nowadays electrons are exchanged when one body becomes positively electrified and another negatively. This view was preferable to that which used force, because it did not seem to demand of matter anything even remotely analogous to volition; it was therefore beloved of pre-Newtonian materialism. It has, however, completely disappeared from modern notions of the structure of matter. The "atoms" which are believed to exist—electrons and protons—never come into contact, but move as if they exerted attractions and repulsions at a distance; these, however, are explained as due to something transmitted through the intervening medium. What has remained from touch-physics is an objection to "action at a distance." But this objection can hardly be now attributed to an *a priori* prejudice; it is rather the outcome of experiment. We believe that, when one body seems to influence another at a distance, this is either capable of being explained away, or is attributed to the continuous passage of energy across the space between the two bodies; but we believe this because it is the view which fits best with known facts, not because it seems the only "intelligible" view. The latter opinion is no doubt widely held, but is not required to justify existing physical theories.

Sight-physics has inevitably been dominant in astronomy, owing to the fact that sight is the only sense by means of which we have cognizance of the heavenly bodies. So long as we only see a motion, we are not conscious of anything analogous to force. The fact that gravitation remained so long unexplained may have stimulated the desire of theoretical physicists to develop their subject without the notion of "force," since the "force" of gravitation remained totally obscure. Sight-physics also had the advantage that it dealt with a wider range of phenomena than were included in dynamics, since it included everything to do with light. Thus physics came more and more to use only such notions as were intelligible in terms of visual data. Mass, it is true, remained from another order of ideas. Obviously the sensational source of the idea of mass is the feeling of weight. But even mass has gradually yielded. On the one hand, it is less fundamental than it formerly seemed; on the other hand, it can be inferred from optical data, by the deflection from a straight line which a body suffers in a known field of force. (Consider methods of determining the apparent masses of α and β particles.) Sight-physics also makes the relativity of motion much more evident than either of the other kinds. A train exerts force, and a railway station does not, so that, from this point of view, it seems natural and right to say that the train is "really" moving while the station is "really" at rest. But from a visual point of view the appearance of the station from the train is exactly correlative to that of the train from the station.

In the visual world, quite independently of the velocity of light, a rapid movement can be produced by a very small "force"—for instance, by rotating a mirror which is reflecting a bright light. Rotating lighthouses at night send out beams which can be seen travelling with great rapidity. A beam is not a "thing," because it is not tangible, and yet, for common sense, it preserves its identity while it rotates. But common sense is not shocked when the beam is broken up into a series of events. A purely visual view of matter makes it much easier to regard all material things as series of events, like the rotating beam.

Of course I am not suggesting that the other senses should be ignored as sources of knowledge concerning the physical world. What I am saying is that physics has tended, more and more, to interpret the information derived from the other senses by means of an imaginative picture derived from sight. Perhaps there are reasons for this; indeed, two suggest themselves, one physical and one physiological. Anticipating later discussions, we may say that fairly accurate perception is only possible when there is a causal chain, leading from the object to the sense-organ, which is to a considerable extent independent of what is to be found in the intermediate regions. Whether this is the case or not is a question for physics. Touch is confined to bodies with which the observer is in contact; smell and sound are not diffused very far. But light-waves travel with extraordinarily little modification through empty space, and without very great modification through a clear atmosphere. If we were to accept Professor Lewis's theory mentioned in Chapter XIII., we could say that a light-quantum travels unchanged from a star to a human eye. Even if this theory is not true, the mere fact that it can be seriously proposed illustrates the causal "purity" (if I may use such a word) of the passage of light from one body to another. This is the physical merit of sight as a source of knowledge concerning the external world.

The other merit is physiological. One kind of physical stimulus is better than another, as a source of information, if less energy is required to produce a noticeable sensation, and smaller physical differences are required to produce noticeable differences of sensation. In both these respects, light is peculiarly excellent. The energy in the light from a just perceptible star is of the order of one quantum per cubic metre.* Very small differences of wave-length produce perceptible differences of colour, and stars are seen as separate even when the angle between the rays from them to the eye is very minute. In these respects, sight is markedly the best of the senses. It is therefore not surprising that physics has laid increasing stress upon visual data.

At the level of common sense, the most important merit of sight is that it makes us aware of objects at a distance. Sound and smell do this to some extent—smell, however, is much more important to certain species of animals than to us. But neither sound nor smell carry over great distances, and they do not enable us to locate their source at all accurately. If we accept the usual causal theory of perception—as I think we should—the proximate physical cause of the physiological occurrences leading to a visual perception is not something happening in the object which we say we see, but something happening at the surface of the eye. If this is to give us information about the distant object, it must be, in the main, causally determined by the object, without regard to anything intervening between the object and the eye. This is the physical merit of sight which we mentioned a moment ago. It has, of course, very distinct limitations. The colour of the light which reaches the eye will be different from that emitted by the object if there is intervening mist or coloured glass. The direction can be altered by a refracting medium. Mirrors deceive animals and young children. Then there are more subtle matters, such as the Doppler effect and aberration. But

* Jeans, *op. cit.*, p. 29.

after making all these allowances, sight remains supreme as a method of acquiring knowledge about distant objects.

In one respect, sight is defective—namely, in regard to distance. Some psychologists argue that depth can be, to a certain extent, perceived by sight alone, while others contend that it is wholly derived from other data. However that may be, it is certain that sight alone cannot judge any but very small distances. No one can distinguish between a hundred yards and a hundred miles by sight alone. Infants do not know at all, at first, which visual objects are within their grasp and which are not. For practical purposes, visual space has only two dimensions, even if this is not strictly correct in psychological theory. In practice, when we know the "real" size of a distant object, say a man or a cow, we can judge its distance by its apparent size.* But our initial experience of distance is derived from the amount of bodily movement required to establish contact. We may only have to stretch out an arm, we may have to lean the body, or we may have to walk for some time. An hour's walk is a natural measure of distance—in fact, it is a league. We cannot arrive at the common-sense idea of space without bringing in movement. And measurement with a measuring rod involves movement, if the distance to be measured is longer than the rod. Of course there is space in our own body, which is known without movement: we refer a headache to the head and a stomach-ache to the stomach. But this space is limited, and does not give spatial relations between our body and objects merely seen. To acquire a knowledge of these relations, bodily movement is indispensable. And this would never have been available for the purpose if there were not so many objects surrounding us which are motionless relatively to the earth.

* To show the depth of Dover cliff, Shakespeare says:

> "The crows and choughs that wing the midway air
> Show scarce so gross as beetles."

We can discover the distance of a house by walking to it, but not of a fox by the distance we have to gallop before reaching him.

Science cannot dispense wholly with postulates, but as it advances their number decreases. I mean by a postulate something not very different from a working hypothesis, except that it is more general: it is something which we assume without sufficient evidence, in the hope that, by its help, we shall be able to construct a theory which the facts will confirm. It is by no means essential to science to assume that its postulates are true always or necessarily; it is enough if they are often true. They ought to be so used that, when they are true, they yield verifiable theories, but, when they are not true, *no* theory can be framed which will fit the facts—until we find a way of working with different postulates.

The most important postulate of science is induction. This may be formulated in various ways, but, however formulated, it must yield the result that a correlation which has been found true in a number of cases, and has never been found false, has at least a certain assignable degree of probability of being always true. I propose to assume the validity of induction, not because I know of any conclusive grounds in its favour, but because it seems, in some form, essential to science and not deducible from anything very different from itself. I do not propose to discuss it, because the problem concerns empirical knowledge in general, not physics in particular; also because the subject is so complicated that a discussion is useless unless it is very lengthy. For the moment I must refer the reader to Mr Keynes and his critics.*

* *A Treatise on Probability.* By John Maynard Keynes. Macmillan, 1920.
Le Problème Logique de l'Induction. Par Jean Nicod. Paris, Alcan, 1924.
Review of the above by Braithwaite, *Mind*, 1925.
The Foundations of Probability. By R. H. Nisbet. *Mind*, January, 1926.

The other postulates which were at one time thought necessary have gradually been found to be superfluous. At one time, the indestructibility of matter would have been regarded as a postulate. Now, though electrons and protons are supposed to persist as a rule, it is seriously suggested that an electron and a proton may sometimes combine so as to annihilate each other; Eddington has advanced this as an important possible source of stellar energy.* It is true that, in this process, energy is supposed to be not destroyed; but the conservation of energy is no more than an empirical generalization, and is not thought to be strictly true.

Spatio-temporal continuity was, until lately, a postulate of science, but the quantum theory has called it in question without intellectual disaster. It *may* be true, but we cannot say that it *must* be.

The existence of causal laws perhaps deserves to rank as a postulate, or may perhaps be proved probable, on the existing evidence, if induction is assumed. Here our proviso is relevant, that a postulate need not be supposed to hold universally. We shall assume that there are causal laws, and try to discover them; but if none are found in a given region, that merely means that science cannot conquer that region. There are at present important regions of this kind. We do not know why a radio-active atom disintegrates at one moment rather than another, or why a planetary electron changes its orbit at one moment rather than another. We cannot be sure that these occurrences severally are governed by laws; but if they are not, science cannot deal with them individually, and is confined to statistical averages. Whether this will prove to be the case, we cannot yet say.

* *Nature*, May 1, 1926, supplement.

CHAPTER XX

THE CAUSAL THEORY OF PERCEPTION *

COMMON sense holds—though not very explicitly—that perception reveals external objects to us directly: when we "see the sun," it is the sun that we see. Science has adopted a different view, though without always realizing its implications. Science holds that, when we "see the sun," there is a process, starting from the sun, traversing the space between the sun and the eye, changing its character when it reaches the eye, changing its character again in the optic nerve and the brain, and finally producing the event which we call "seeing the sun." Our knowledge of the sun thus becomes inferential; our direct knowledge is of an event which is, in some sense, "in us." This theory has two parts. First, there is the rejection of the view that perception gives direct knowledge of external objects; secondly, there is the assertion that it has external causes as to which something can be inferred from it. The first of these tends towards scepticism; the second tends in the opposite direction. The first appears as certain as anything in science can hope to be; the second, on the contrary, depends upon postulates which have little more than a pragmatic justification. It has, however, all the merits of a good scientific theory—*i.e.* its verifiable consequences are never found to be false. Epistemologically, physics might be expected to collapse if perceptions have no external causes; therefore the matter must be examined before we can go further.

We must first give somewhat more precision to the common-

* On this subject, *cf.* chap. iv. of Dr Broad's *Perception, Physics, and Reality*, Cambridge, 1914.

sense view which is rejected by the causal theory. We have to ask what is meant by "external objects." One would naturally say "spatially external." But "space" is very ambiguous: in visual space, the objects which we see are mutually external, and objects other than the visual appearances of parts of our own body are spatially external to those appearances. In the space derived from the combination of touch and sight and bodily movement, which is the ordinary space of common sense, there is the same externality of visual appearances other than those of parts of our own body. Thus spatial externality, in the sense in which space can be derived from the relations of our own percepts, is not what is meant. I think we shall come nearer to what is meant if we say that two people can perceive the same object. In some sense, unless we reject testimony, we must of course admit that this is true: we can all see the sun unless we are blind. But this fact is differently interpreted by common sense and by the causal theory: for common sense, the percepts are identical when two people see the sun, whereas for the causal theory they are only similar and related by a common causal origin.

It would be a waste of time to recapitulate the arguments against the common-sense view. They are numerous and obvious and generally admitted. The laws of perspective may serve as an illustration: where one man sees a circle, another sees an ellipse, and so on. These differences are not due to anything "mental," since they appear equally in photographs from different points of view. Common sense thus becomes involved in contradictions. These do not exist for solipsism, but that is a desperate remedy. The alternative is the causal theory of perception.

We must not expect to find a *demonstration* that perceptions have external causes, which may produce perceptions in a number of people at the same time. The most that we can hope for is the usual ground for accepting a scientific theory—namely, that it links together a number of known facts, that it does not have any demonstrably false consequences, and that it sometimes enables us to make predictions which are subsequently verified. All these tests the causal theory fulfils; it must not be assumed, however, that no other theory could fulfil them. But let us examine the evidence.

First: there can be no question of logical proof. A certain collection of facts is known to me by perception and recollection; what else I believe about the physical world is either the effect of unreasoning habit or the conclusion of an inference. Now there cannot be any logical impossibility in a world consisting of just that medley of events which I perceive or remember, and nothing else. Such a world would be fragmentary, absurd, and lawless, but not self-contradictory.* I am aware that, according to many philosophers, such a world would be self-contradictory. I am aware also that, according to other philosophers, what we perceive is not fragmentary, but really embraces the whole universe—what is fragmentary is only what we perceive that we perceive. The first of these views is that of Hegel and his followers; the second is that of Bergson and (perhaps) of Dr Whitehead. The Hegelian view rests upon an elaborate logic, which I have controverted on former occasions; at present I am content to refer to what I have written before. The other view is traditionally associated with mysticism; my reasons for not accepting it are given in *Mysticism and Logic*. I say, therefore, on grounds given in former writings, that the world of perception and memory is fragmentary, but not self-contradictory. On grounds of logic, I hold that nothing existent can imply any other existent except a part of itself, if implication is taken in the sense of what Professor G. I. Lewis calls "strict implication," which is

* Perhaps it would notreally be lawless; I shall discuss this at a later stage.

the relevant sense for our present discussion. If this is true, it follows that any selection of the things in the world might be absent, so far as self-contradiction is concerned. Given a world consisting of particulars x, y, z, ... interrelated in various ways, the world which results from the obliteration of x must be logically possible. It follows that the world consisting only of what we perceive and recollect cannot be self-contradictory; if, therefore, we are to believe in the existence of things which we neither perceive nor recollect, it must be either on the ground that we have other non-inferential ways of knowing matters of fact, or on the basis of an argument which has not the type of cogency that we should demand in pure mathematics, in the sense that the conclusion is only probable. As for the fragmentary character of the perceived world, those who deny it have to introduce minute perceptions, like Leibniz, or unconscious perceptions, or vague perceptions, or something of the kind. Now it seems to me unnecessary to inquire whether there are perceptions of such kinds; I certainly am not prepared to deny them dogmatically. But I do say that, even if they exist, they are useless as a basis for physics. Perceptions of which we are not sufficiently conscious to express them in words are scientifically negligible as data; our premisses must be facts which we have explicitly noted. Vagueness, no doubt, is omnipresent and unavoidable; but it is only in proportion as we overcome it that exact science becomes possible. And we overcome it most by analysis and concentration, not by a diffused ecstatic mystical vision.

I return now to the question: What grounds have we for inferring that our percepts and what we recollect do not constitute the entire universe? I believe that at bottom our main ground is the desire to believe in simple causal laws. But proximately there are other arguments. When we speak to people, they behave more or less as we should if we heard such words, not as we do when we speak them. When I say that they behave in a similar manner, I mean that our perceptions of their bodies change in the same sort of way as our perceptions of our own bodies would in correlative circumstances. When an officer who has risen from the ranks gives the word of command, he sees his men doing what he used to do when he heard the same sounds as a private; it is therefore natural to suppose that they have heard the word of command. One may see a crowd of jackdaws in a newly-ploughed field all fly away at the moment when one hears a shot; again it is natural to suppose that the jackdaws heard the shot. Again: reading a book is a very different experience from composing one; yet, if I were a solipsist, I should have to suppose that I had composed the works of Shakespeare and Newton and Einstein, since they have entered into my experience. Seeing how much better they are than my own books, and how much less labour they have cost me, I have been foolish to spend so much time composing with the pen rather than with the eye. All this, however, would perhaps be the better for being set forth formally.

First, there is a preliminary labour of regularizing our own percepts. I spoke of seeing others do what we should do in similar circumstances; but the similarity is obvious only as a result of interpretation. We cannot see our face (except the nose, by squinting) or our head or our back; but tactually they are continuous with what we can see, so that we easily imagine what a movement of an invisible part of our body ought to look like. When we see another person frowning, we can imitate him; and I do not think the habit of seeing ourselves in the glass is indispensable for this. But probably this is explained by imitative impulses—*i.e.* when we see a bodily action, we tend to perform the same action, in virtue of a physiological mechanism. This of course is most noticeable in children. Thus we first do what someone else has done, and then realize that what we have done is what he did. However, this complication need not be pursued. What I am concerned with is the passage, by experience, from "apparent" shapes and motions to "real" shapes and motions. This process lies within the perceptual world: it is a process of becoming acquainted with congruent groups—*i.e.* to speak crudely, with groups of visual sensations which correspond to similar tactual sensations. All this has to be done before the analogy between the acts of others and our own acts becomes obvious. But as it lies within the perceptual world, we may take it for granted. The whole of it belongs to early infancy. As soon as it is completed, there is no difficulty in interpreting the analogy between what we perceive of others and what we perceive of ourselves.

The analogy is of two kinds. The simpler kind is when others do practically the same thing as we are doing—for instance, applaud when the curtain goes down, or say "Oh" when a rocket bursts. In such cases, we have a sharp stimulus, followed by a very definite act, and our perception of our own act is closely similar to a number of other perceptions which we have at the same time. These, moreover, are all associated with perceptions very like those which we call perceptions of our own bodies. We infer that all the other people have had perceptions analogous to that of the stimulus to our own act. The analogy is very good; the only question is: Why should not the very same event which was the cause of our own act have been the cause of the acts of the others? Why should we suppose that there had to be a separate seeing of the fall of the curtain for each spectator, and not only one seeing which caused all the appearances of bodies to appear to applaud? It may be said that this view is far-fetched. But I doubt if it would be unreasonable but for the second kind of analogy, which is incapable of a similar explanation.

In the second kind of analogy, we see others acting as we should act in response to a certain kind of stimulus which, however, we are not experiencing at the moment. Suppose, for example, that you are a rather short person in a crowd watching election returns being exhibited on a screen. You hear a burst of cheering, but can see nothing. By great efforts, you manage to perceive a very notable result which you could not perceive a few moments earlier. It is natural to suppose that the others cheered because they saw this result. In this case, their perceptions, if they occurred, were certainly not *identical* with yours, since they occurred earlier; hence, if the stimulus to their cheering was a perception analogous to your subsequent perception, they had perceptions which you could not perceive. I have chosen a rather extreme example, but the same kind of thing occurs constantly; someone says "There's Jones," and you look round and see Jones. It would seem odd to suppose that the words you heard were not caused by a perception analogous to what you had when you looked round. Or your friend says "Listen," and after he has said it you hear distant thunder. Such experiences lead irresistibly to the conclusion that the percepts you call other people are associated with percepts which you do not have, but which are like those you would have if you were in their place. The same principle is involved in the assumption that the words you hear express "thoughts."

The argument in favour of the view that there are percepts, connected with other people, which are not among our own percepts, is presupposed in the acceptance of testimony, and comes first in logical order when we are trying to establish the existence of things other than our own percepts, both because of its inherent strength, and because of the usefulness of testimony in the further stages. The argument for other people's percepts seems to common sense so obvious and compelling that it is difficult to make oneself examine it with the necessary detachment. Nevertheless it is important to do so. As we have seen, there are three stages. The first does not take us outside our own percepts, but consists merely in the arrangement of them in groups. One group consists of all the percepts which common sense believes to be those of an identical object by different senses and from different points of view. When we eliminate reference to an object, a group must be constituted by correlations, partly between one percept and another (touch and sight when an object is held in the hand), partly between one percept and the changes in another (bodily movement and changes of visual and tactual perceptions while we move). In assuming that these correlations will hold in untested cases, we are of course using induction; otherwise, the whole process is straightforward. The process enables us to speak of a "physical object" as a group of percepts, and to explain what we mean by saying that a near object and a distant object are "really" of the same size and shape. Also we can explain what we mean by saying that a physical object does not "really" change as we walk away from it (*i.e.* as we have the percepts which make us say we are walking). This is the first stage in the argument.

In the second stage, we note the likeness of the physical objects called other people's bodies to each other and to our own body; we also note the likeness of their behaviour to our behaviour. In the case of our own behaviour, we can observe a number of correlations between stimulus and reaction (both being percepts). For example, we feel hunger or thirst, and then we eat or drink; we hear a loud noise, and we jump; we see Jones, and we say "Hullo, Jones." The behaviour of the percepts we call other people's bodies is similar to that of our own body in response to this or that stimulus; sometimes we experience the stimulus, and behave just as others do, which is the second stage; sometimes we do not experience the stimulus, but suppose, from their behaviour, that other people have experienced it, which is the third stage. This is a particularly plausible supposition if we ourselves experience the stimulus in question very shortly after we have observed the behaviour which led us to infer it. The third stage is the more important, since in the second we *might* attribute the behaviour of others to the stimulus which we perceive, and thus escape inferring unperceived existents, while in the third stage this alternative is not open to us. It will be seen that, in the third stage, the argument is the usual causal-inductive type of argument upon which all empirical laws are based. We perceive *A* and *B* conjoined in a number of cases, and we then infer *A* and *B* in a case in which we do not know by perception whether *A* is present or not. Moreover, the argument for other people's perceptions is the same in form and cogency as the argument for the future truth of laws of correlation among our own percepts. We have exactly as good reason for believing that others perceive what we do not as we have for believing that we shall have a perception of touch if we stretch out our hand to an object which looks as if it were within reach.

The argument is not demonstrative, either in the one case or in the other. A conjuror might make a waxwork man with a gramophone inside, and arrange a series of little mishaps of which the gramophone would give the audience warning. In dreams, people give evidence of being alive which is similar in kind to that which they give when we are awake; yet the people we see in dreams are supposed to have no external existence. Descartes' malicious demon is a logical possibility. For these reasons, we may be mistaken in any given instance. But it seems highly improbable that we are *always* mistaken. From the observed correlation of *A* and *B* we may argue, as regards cases in which *B* is observed but we do not know whether *A* exists or not, either: (1) *A* is always present, or (2) *A* is generally present, or (3) *A* is sometimes present. Dreams suffice to show that we cannot assert (1). But dreams could be distinguished from waking life by a solipsist, unless his dreams were unusually rational and coherent. We may therefore exclude them before beginning our induction. Even then, it would be very rash to assert (1). But (2) is more probable, and (3) seems extremely probable. Now (3) is enough to allow us to infer a proposition of great philosophic importance, namely: there are existents which I do not perceive. This proposition, therefore, if induction is valid at all, may be taken as reasonably certain. And, if so, it increases the probability of other propositions which infer the existence of this or that unperceived existent. The argument, though not demonstrative, is as good as any of the fundamental inductions of science.

We have been considering hitherto, not the external world in general, but the percepts of other people. We might say that we have been trying to prove that other people are alive, and not mere phantoms like the people in dreams. The exact thing we have been trying to prove is this: Given an observed correlation among our own percepts, in which the second term is what one would naturally call a percept of our own bodily behaviour, and given a percept of similar behaviour in a physical object not our own body but similar to it, we infer that this behaviour was preceded by an event analogous to the earlier term in the observed correlation among our percepts. This inference assumes nothing as to the distinction of mind and body or as to the nature of either.

In virtue of the above argument, I shall now assume that we may enlarge our own experience by testimony—*i.e.* that the noises we hear when it seems to us that other people are talking do in fact express something analogous to what we should be expressing if we made similar noises. This is a particular case of the principle contained in the preceding paragraph. I think the evidence for other people's percepts is the strongest we have for anything that we do not perceive ourselves; therefore it seems right to establish this, so far as we can, before proceeding to consider our evidence for "matter" —*i.e.* for existents satisfying the equations of physics. This must be our next task; but it will be well to begin with common-sense material "things" conceived as the causes of perceptions.

Having now admitted the percepts of other people, we can greatly enlarge the group constituting one "physical object." Within the solipsistic world, we found means of collecting groups of percepts and calling the group one physical object; but we can now enrich our group enormously. A number of people sitting near each other can all draw what they see, and can compare the resulting pictures; there will be similarities and differences. A number of stenographers listening to a lecture can all take notes of it, and compare results. A number of people can be brought successively into a room full of hidden roses, and asked "What do you smell?" In this way it appears that the world of each person is partly private and partly common. In the part which is common, there is found to be not identity, but only a greater or less degree of similarity, between the percepts of different people. It is the absence of identity which makes us reject the naive realism of common sense; it is the similarity which makes us accept the theory of a common origin for similar simultaneous perceptions.

The argument here is, I think, not so good as the argument for other people's percepts. In that case, we were inferring something very similar to what we know in our own experience, whereas in this case we are inferring something which can never be experienced, and of whose nature we can know no more than the inference warrants. Nevertheless, the common-sense arguments for an external cause of perception are strong.

To begin with, we can, without assuming anything that no one perceives, establish a common space and time in which we all live. (Our discussion is necessarily confined to people on the surface of the earth, since other people, if they exist, have not succeeded in communicating with us; consequently the complications of relativity do not yet arise.) The usual methods of determining latitude and longitude can be applied, without assuming that the readings of clock and sextant have the physical meaning usually assigned to them. Altitudes, also, can be measured by the usual methods. By these means, observers can be arranged in a three-dimensional order. Of course the resulting space will not be a continuum, since it will contain only so many " points " as there are observers. But the motion of an observer can be sensibly continuous, so that we can construct " ideal " points of view with defined mathematical properties, and thus build up, for mathematical purposes, a continuous space. We can thus arrive at the laws of perspective, taken in a generalized sense; that is to say, we can correlate the differences between correlated perceptions with differences in the situations of the percipients. And in the space derived from " points of view " we can place physical objects. For, let *A* and *B* be two observers, *a* and *b* their correlated visual percepts, which, being correlated, are described as percepts of one physical object *O*. If the angular dimensions of *a* are larger than those of *b*, we shall say (as a definition) that *A* is nearer to *O* than *B* is. We can thus construct a number of routes converging on *O*. We shall construct our geometry so that they intersect, and shall define their intersection as the place where *O* is. If *O* happens to be a human body, we shall find that the place of *O*, so defined, is identical with the place of *O* as an observer in the space of points of view.*

The correlation of the times of different percipients offers no difficulty, since, as before observed, our percipients are all on the earth. The usual method of light-signals can be employed. But here we come upon one of the arguments for the causal theory of perception, as against both common sense

* On this subject, *cf.* my *Knowledge of the External World.*

and phenomenalism. (We may define phenomenalism, at least for the moment, as the view that there are only percepts.) Suppose a gun on a hilltop is fired every day at twelve o'clock: many people both see and hear it fired, but the further they are from it the longer is the interval between seeing and hearing. This makes it very difficult to accept a naively realistic view as to the hearing, since, if that view were correct, there would have to be a fixed interval of time (presumably zero) between the sight and the sound. It also makes it natural to adopt a causal view of sound, since the retardation of the sound depends upon the distance, not upon the number of intermediate percipients. But hitherto our space was purely "ideal" except where there were percipients; it seems odd, therefore, that it should have an actual influence. It is much more natural to suppose that the sound travels over the intervening space, in which case something must be happening even in places where there is no one with ears to hear. The argument is perhaps not very strong, but we cannot deny that it has *some* force.

Much stronger arguments, however, are derivable from other sources. Suppose a room arranged with a man concealed behind a curtain, and also a camera and a dictaphone. Suppose two men came into the room, converse, dine, and smoke. If the record of the dictaphone and the camera agrees with that of the man behind the curtain, it is impossible to resist the conclusion that something happened where they were which bore an intimate relation to what the hidden man perceived. For that matter, one might have two cameras and two dictaphones, and compare their records. Such correspondences, which are only more extreme forms of those with which primitive common sense is familiar, make it inconceivably complicated and unplausible to suppose that nothing happens where there is no percipient. If the dictaphone and the hidden man give the same report of the conversation, one must suppose some causal connection, since otherwise the coincidence is in the highest degree improbable. But the causal connection is found to depend upon the position of the dictaphone at the time of the conversation, not upon the person who hears its record. This seems very strange, if its record does not exist until it is heard, as we shall have to suppose if we confine the world to percepts. I will not emphasize the more obvious oddities of such a world, as, *e.g.*, the one once brought forward by Dr G. E. Moore, that a railway train would only have wheels when it is not going, since, while it is going, the passengers cannot see them.

Before accepting such arguments, however, we must see what could be said against them by a phenomenalist. Let us, therefore, proceed to state the case for phenomenalism.

It may be suggested that our argument is, after all, not so strong as it looks, since all the facts can be interpreted by means of "ideal" percipients. The doubt I have in mind is suggested by a certain kind of construction, of which a good example is the introduction of "ideal" points, lines, and planes in descriptive geometry.* For our purposes, "ideal" points will suffice. The process by which they are constructed is as follows. Take all the straight lines which pass through a given point; these form a group of lines having other notable properties besides that of all possessing a common point. These other properties belong also to certain groups of lines which have no point in common—*e.g.* in Euclidean geometry, to the group consisting of all lines parallel to a given line. We then define a group of lines possessing these properties as an "ideal" point.† Thus some "ideal" points correspond to

* See Dr Whitehead's tract on this subject (Cambridge University Press). Also Pasch, *Neuere Geometrie*, Leipzig, 1882.

† The definition of an "ideal" point is as follows. Let l, m be any two lines in one plane, A any point not in this plane. Then the planes Al, Am have a line in common, say n. The class of all such lines as n, when A is varied while l and m remain fixed, is the "ideal" point determined by the two lines l, m.

real points, while others do not. In this way, by proceeding to "ideal" lines and planes, we arrive at last at a projective geometry, in which any two planes have a common line, and any two lines in a plane a common point, which immensely simplifies the statement of our propositions.

The analogy with our problem is perhaps closer than might be thought. We have, in the first place, real percepts, collected into groups each of which is defined by the characteristic that common sense would call all its members percepts of one physical object. These real percepts, as we saw, vary from one percipient to another in such a way as to allow us to construct a space of percipients, and to locate physical objects in this space. Let us, for the moment, adopt the view that nothing exists except percepts, our own and other people's. We shall then observe that the percepts forming a given group can always be arranged about a centre in the space of percipients, and we can fill out the group by interpolating "ideal" percepts, continuous in quality with actual percepts, in regions where there are no actual percipients. (A region of space which is "ideal" at one moment may be actual at another owing to motion of a percipient. The successive positions of an observer watching Cleopatra's Needle from a passing tram form a sensibly continuous series.) If a number of people hear a gun fired, there are differences in the loudness and the time of their percepts; we can fill out the actual percepts by "ideal" noises varying continuously from one actual one to another. The same can be done with correlated visual percepts; also with smells. We will call a group thus extended by interpolation and extrapolation a "full" group: its members are partly real, partly ideal. Each group has a centre in the space of percipients; this centre is real if occupied by a percipient, while otherwise it is ideal. (Our space is not assumed to be a smooth geometrical space, and the centre may be a finite volume.) As a rule, even when the centre is occupied by a percipient, it nevertheless contains no member of the group, not even an ideal member: "the eye sees not itself." A group, that is to say, is hollow: when we get sufficiently near to its centre it ceases to have members. This is a purely empirical observation.

A full group which contains any real members will be called a "real" group; a group whose members are all ideal will be called "ideal." It remains to show how we are to define an ideal group.

In addition to the laws correlating percepts forming one group—which may be called, in an extended sense, laws of perspective—there are also laws as to the manner in which percepts succeed one another. These are causal laws in the ordinary sense; they are included in the usual laws of physics. When we know a certain number of members of a full group, we can infer the others by the laws of perspective; it is found that some exist and some do not, but all that do exist are members of the calculated full group. In like manner, when we are given a sufficient number of full groups, we can calculate other full groups at other times. It is found that some of the calculated full groups are real, some ideal, but that all real groups are included among those calculated. (I am assuming an impossible perfection of physics.) Two groups belonging to different times may, in virtue of causal relations which we shall explain when we come to discuss substance, be connected in the way which makes us regard them as successive states of one "thing" or "body." (The time of a full group, by the way, is not exactly the time at which its members occur, but slightly earlier than the earliest real member—or much earlier, in the case of a star. The time of a full group is the time at which physics places the occurrence supposed to be perceived.) The whole series of groups belonging to a given "thing" is called a "biography." The causal laws are such as to allow us sometimes to infer "things." A thing is "real" when its biography contains at least one group which is "real," *i.e.* contains at least one percept; otherwise a thing is "ideal." This construction is closely analogous to that of "ideal" points, lines, and planes in descriptive geometry. We have to ask ourselves whether there are any reasons for or against it.

The above construction preserves the whole of physics, at least formally; and it gives an interpretation, in terms of percepts and their laws, to every proposition of physics which there is any empirical reason to believe. "Ideal" percepts, groups, and things, in this theory, are really a shorthand for stating the laws of actual percepts, and all empirical evidence has to do with actual percepts. The above account, therefore, preserves the truth of physics with the bare minimum of hypothesis. Of course there should be also rules for determining when a calculated percept is real and when it is ideal; but this is difficult, since such rules would have to contain a science of human actions. It may be known that you will see certain things if you look through a telescope, but it is difficult to know whether you will look through it. This completion of our science is therefore not possible at present; but that is no argument against the truth of our science so far as it goes. It is obvious that the method might be extended so as to make all perceptions except one's own "ideal"; we should then have a completely solipsistic interpretation of physics. I shall, however, ignore this extension, and consider only that form of the theory in which all percepts are admitted.

The metaphysic which we have been developing is essentially Berkeley's: whatever is, is perceived. But our reasons are somewhat different from his. We do not suggest that there is any impossibility about unperceived existents, but only that no strong ground exists for believing in them. Berkeley believed that the grounds against them were conclusive; we only suggest that the grounds in their favour are inconclusive. I am not asserting this: I am proposing it as a view to be considered.

The great difficulty in the above theory of "ideal" elements is that it is hard to see how anything merely imaginary can be essential to the statement of a causal law. We have to explain the dictaphone which repeats the conversation. We will suppose that it was seen in place before and after the conversation, but not during it. Consequently, on the view we are examining, it did not exist at all during the conversation. Causal laws, stated without fictitious elements, will thus involve action at a distance in time and space. Moreover, our percepts are not sufficient to determine the course of nature: we derive causal laws from close observation, and preserve them in other cases by inventing "ideal" things. This would not be necessary if percepts sufficed for the causal determination of future percepts. Thus the view we are examining is incompatible with physical determinism, in fact though not in form. We could multiply difficulties of this kind indefinitely. No one of them is conclusive, but in the aggregate they suffice to account for the fact that it is almost impossible to compel oneself to believe such a theory. Perhaps continuity (not in a strict mathematical sense) is one of the strongest objections. We experience sensible continuity when we move our own body, and when we fixedly observe some object which does not explode. But if we repeatedly open and shut our eyes we experience visual discontinuity, which we find it impossible to attribute to the physical objects which we alternately see and do not see, the more so as, to another spectator, they remain unchanged all the time. Causation at a distance in time, though not logically impossible, is also repugnant to our notions of the physical world. Therefore, although it is logically possible to interpret the physical world in terms of ideal elements, I conclude that this interpretation is unplausible, and that it has no positive grounds in its favour.

Nevertheless the above construction remains valid and important, as a method of separating perceptual and non-perceptual elements of physics, and of showing how much can be achieved by the former alone. As such, I shall continue to utilize it in the sequel. The only thing rejected is the view that "ideal" elements are unreal.*

The matter would, of course, be otherwise in this last respect if we could accept the argument for idealism, whether of the Berkeleyan or the German variety. These arguments profess to prove that what exists *must* have a mental character, and therefore compel us to interpret physics accordingly. I reject such *a priori* argumentation, whatever conclusion it may be designed to prove. There is no difficulty in interpreting physics idealistically, but there is also, I should say, no necessity for such an interpretation. "Matter," I shall contend, is known only as regards certain very abstract characteristics, which might quite well belong to a manifold of mental events, but might also belong to a different manifold. In fact, the only manifolds known for certain to possess the mathematical properties of the physical world are built up out of numbers, and belong to pure mathematics. Our reason for not regarding "matter" as actually being an arithmetical structure derived from the finite integers is the connection of "matter" with perception; that is why our present discussion is necessary. But this connection, as I shall try to show, tells us extremely little about the character of the unperceived events in the physical world. Unlike idealists and materialists, I do not believe that there is any other source of knowledge from which this meagre result can be supplemented. Like other people, I allow myself to speculate; but that is an exercise of imagination, not a process of demonstrative reasoning.

I shall assume henceforth not only that there are percepts

* The character of the "ideal" elements, also, will be less similar to that of percepts than in the above construction, or at least cannot be known to be so similar.

which I do not perceive, connected with other people's bodies, but also that there are events causally connected with percepts, as to which we do not know whether they are perceived or not. I shall assume, *e.g.*, that if I am alone in a room and I shut my eyes, the objects in it which I no longer see (*i.e.* the causes of my visual percepts) continue to exist, and do not suddenly become resurrected when I re-open my eyes. This must be taken in conjunction with what was said earlier about perspective in a generalized sense, and about the common space in which we locate the physical objects which, for common sense, are perceived by several people at once. We collect correlated percepts into a group, and we suppose that there are other members of the group, corresponding to places where there is no percipient—or, to speak more guardedly, where there is not known to be a percipient. But we no longer assume, as when we were constructing "ideal" elements, that what is at such places is what we should perceive if we went to them. We think, *e.g.*, that light consists of waves of a certain kind, but becomes transformed, on contact with the eye, into a different physical process. Therefore what occurs before the light reaches an eye is presumably different from what occurs afterwards, and therefore different from a visual percept. But it is supposed to be causally continuous with the visual percept; and it is largely for the sake of this causal continuity that a certain reinterpretation of the physical world seems desirable.

In some ways, the language of causation is perhaps not the best for expressing what is intended. What is intended may be expressed as follows. Confining ourselves, to begin with, to the percepts of various observers, we can form groups of percepts connected approximately, though not exactly, by laws which may be called laws of "perspective." By means of these laws, together with the changes in our other percepts which are connected with the perception of bodily movement, we can form the conception of a space in which percipients are situated, and we find that in this space all the percepts belonging to one group (*i.e.* of the same physical object, from the standpoint of common sense) can be ordered about a centre, which we take to be the place where the physical object in question is. (For us, this is a *definition* of the place of a physical object.) The centre is not to be conceived as a point, but as a volume, which may be as small as an electron or as large as a star. The essential assumption for what is commonly called the causal theory is, that the group of percepts can be enlarged by the addition of other events, ranged in the same space about the same centre, and connected both with each other and with the group of percepts by laws which include the laws of perspective. The essential points are (1) the arrangement about a centre, (2) the continuity between percepts and correlated events in other parts of the space derived from percepts and locomotion. The first is a matter of observation; the second is a hypothesis designed to secure simplicity and continuity in the laws of correlation suggested by the grouping of percepts. It cannot be demonstrated, but its merits are of the same kind as those of any other scientific theory, and I shall therefore henceforth assume it.

CHAPTER XXI

PERCEPTION AND OBJECTIVITY

WHEN a number of people are, from the standpoint of common sense, observing the same object, there are both likenesses and differences among their percepts. For common sense, with its naive realism, the differences constitute a difficulty, since they render the percepts mutually inconsistent if taken to be each wholly a revelation of one and the same physical object. But to the causal theory of perception this difficulty is non-existent. We have now, however, an opposite difficulty—namely, that of deciding what elements in a percept can be used for inference as to the existence of something other than itself, and as to the nature of the inferences when they can be drawn. For the moment, I am not thinking of inferences involving motion, but only of inferences as to the present state of the physical object which is being observed.

We must be on our guard against a confusion which is difficult to avoid in such inquiries. Perception, as an event in our own history, is a recognizable occurrence; its psychoogical meaning is fairly definite. But it has also an epistemological meaning, and this is hardly capable of being made as definite as could be wished. Perception is interesting to us, in our present discussion, because it is a source of knowledge, not because it is an occurrence which a psychologist can recognize. So long as naive realism remained tenable, perception was knowledge of a physical object, obtained through the senses, not by inference. But in accepting the causal theory of perception we have committed ourselves to the view that perception gives no immediate knowledge of a physical object, but at best a datum for inference. A perception does, however, still give knowledge of something: if I perceive a round red patch, I know that there is a round red patch in the world now, and no account of the causes of my perception can destroy this knowledge. It may be conceded that, in saying this, I am using "perception" more narrowly than it might be used in psychology: I am confining it to cases where we notice explicitly what we are perceiving. For epistemological purposes, this restriction is essential. I am deliberately refraining from all analysis of "knowing," since that would take us too far from our subject.

The inferences to be primarily drawn from a perception are as to other members of the group to which the percept concerned belongs. This is done, in a confused way, by common sense, when it infers the "real" size or shape of an object from its "apparent" size or shape, *i.e.* from the real size or shape of the percept. The "real" size or shape is a norm, from which the percept of a spectator in a given relative situation can be inferred. Ordinarily, there is no conscious inference involved; but conscious inference can be used without invoking any fresh knowledge. For example, an architect can show the view of a proposed house from any angle when he knows its measurements, and for this purpose he uses only systematized common sense; and he can infer the measurements approximately when he has viewed an actual house from several angles. The "real" object, as opposed to its "appearances," is thus something of the nature of a formula by means of which all sufficiently near "appearances" can be determined. Given the measurements of a house, we can infer its apparent shape at a given distance in a given direction. If perception were perfectly accurate and regular, a few percepts belonging to a given group would enable us to determine all percepts, actual and possible, belonging to that group.

This is found to be not in fact the case. From seeing a drop of water with the naked eye, we cannot know that under the microscope it will be found to be full of bacilli. When we see a man a hundred yards away, we cannot tell whether he is handsome or plain. When we can only just distinguish a person's voice, we cannot tell what is being said. These are all cases of "vagueness," in a certain perfectly precise sense. In any group of percepts, those nearer the centre have a many-one relation to those farther off—*i.e.* two things which look alike from a distance look different when seen close to. In this sense, the more distant percepts are vaguer than the nearer ones: the former can be inferred from the latter, but not the latter from the former.

There is, however, a converse fact—namely, that what may be called the "regular" law for inferring distant from near appearances may be interfered with by intervening things. The sun may be visible from a great altitude when clouds make it invisible from the earth's surface. Sounds may be stopped by obstacles, and die away completely at a sufficient distance from their source. Smells die away still more quickly, and are even more dependent upon the wind. This set of facts interferes with the inference from near to distant appearances, just as the former set interfered with the inference from distant to near appearances.

There is, however, an important difference between the two sets of facts. The increasing vagueness of distant appearances is an intrinsic law of groups of percepts, whereas the uncertainty as to distant appearances when near appearances are given depends always upon outside interference. This distinction is of a kind which we shall find to be very important in various ways. Let us try to state it clearly in the case in question.

Suppose two persons to be both observing a given object which is stationary on the earth's surface, and suppose that one of the persons remains at rest while the other moves about. We will suppose that to the person who remains at rest there is no perceptible change in the object throughout the time concerned. To the other person there will be changes which, in general, are approximately according to the laws of perspective, especially for small changes in the observer's position. But sometimes, to take the most obvious example, the object in question becomes invisible when the observer takes up certain positions—those, namely, from which some opaque object is between the observer and the object which he had been seeing. As a rule, this happens gradually: at first both objects are visible, gradually their angular distance becomes less, and at last only the nearer object remains visible. The nearer object has thus had an effect upon the appearance of the farther object. Fog, smoke, glass, blue spectacles, etc., similarly modify the appearances of distant objects. That is to say, in calculating the appearance which a body will present in such and such a place, we have to take account, not only of the body's appearances elsewhere, but also of the bodies between it and the place in question. These intervening bodies are sometimes sensible, sometimes not; when they are not, they are inferred as being necessary in order to preserve the laws which have been found to hold when they were sensible. The principle is the following: If we compare neighbouring members of a group of percepts, we find, in a great many cases, that their first-order differences are in accordance with the laws of perspective, while their second-order differences are functions of groups with other centres; or rather, since the above statement is too precise for the facts, we may say simply that the differences between neighbouring positions are compounded of the laws of perspective together with functions of groups with other centres. Suppose, *e.g.*, that you are seeing an object through glass which is slightly distorting. The glass is a tactual group between you and the object; as you move, the distortions due to the glass change, and have to be compounded with the laws of perspective in order to calculate one member of a group from another. In other cases, by carefully comparing a number of members of a group, we can discover that their departure from perspective laws proceeds according to a law which is a function of a position not perceptibly occupied. The previous illustration will apply to this case also, if we have not touched the distorting glass. Human beings are superior to birds and insects in the fact that they can infer glass in such cases, without any scientific apparatus, whereas birds and insects repeatedly bump into it.

Like much of what has to be said in the transition from perception to science, the above statement is not capable of being made in an exact form. The methods by which we collect a number of percepts into one group are rough and ready, and become impossible if there is very great distortion by the intervening medium. But these methods are successful in a sufficient number of cases to give rise to the notion of events grouped about a centre, changing partly in accordance with the laws of perspective and partly in ways which are functions of groups with other centres. Having arrived at this notion, it is not very difficult to modify it in such a way that it shall become capable of scientific precision.

I come now to the question of "objectivity" in a perception. This is a matter of degree: the more correct are the inferences we can draw from a percept as to other events (whether percepts or not) belonging to the same group, the more "objective" is the perception. (I propose this as a definition.) A percept may not belong to a group at all; in that case it has no objectivity. Hallucinations and dreams come under this head. Or we may be mistaken as to the position of the centre of the group; this is the case with a mirage, or with a reflection not recognized as such. Or we may perceive a colour or shape which is erratic, say owing to intervening smoke, and thus misleads us as to the colour or shape which others will see. I should not regard a perception as failing in objectivity through mere vagueness. Vagueness diminishes the number of inferences that we can draw, but not their correctness. From a distance we perceive correctly that what is approaching is a man; when he gets near we perceive that he is Jones. But our previous perception did not fail in objectivity through failing to show that it was Jones. It would have failed of objectivity if, owing to intervening lenses, it had shown us a man standing on his head.

When two people simultaneously have percepts which they regard as belonging to one group, if the inferences of the one differ from those of the other, one of them at least must be drawing false inferences, and must therefore have an element of subjectivity in his perception. It is only where the inferences of the two observers agree that both perceptions may be objective. It will be seen that, according to this view, the objectivity of a perception does not depend only upon what it is in itself, but also upon the experience of the percipient. A man accustomed to being short-sighted can judge objects much more correctly than a man whose vision suddenly acquires the same defect. Fatigue as well as alcohol may make us see double, but fatigue will not deceive us when it does so.

Subjectivity in perceptions may be traced to three sources, physical, physiological, and psychological; or, better perhaps, physical, sensory, and cerebral. In all cases in which a percept is really a member of a group constituting a physical object, any element of subjectivity that it may possess is due to the distortions connected with intervening physical objects —that, at least, is the theory which has been found successful. When these objects are between the body of the percipient and the centre of the group to which the percept belongs, the subjectivity is physical; when they are in the body of the percipient but not in his brain, they are sensory; when they are in his brain, they are cerebral. The last of these, however, is usually purely hypothetical; the *discoverable* causes of the subjectivity which we are calling cerebral are as a rule psychological.

Physical subjectivity exists equally in a photograph or gramophone record; it is present already in the events, external to the percipient's body, which belong to the group in question and are very near to the sense-organ concerned in the perception. The stick that looks bent when it is half in water is an obvious example of physical subjectivity. So are many effects of reflexion, refraction, etc. The theory of relativity has brought to light a new kind of physical subjectivity, dependent upon relative motion. The prevention of mistaken inferences owing to physical subjectivity is part of the business of physics, and does not involve physiology or psychology.

Physiological (or sensory) subjectivity arises through defects of the sense-organs or afferent nerves; it may also be produced by drugs. We can discover such defects by the comparison of different people's perceptions in a given situation. It should be observed that the intrinsic quality of a percept is unimportant in this respect: if one person sees red where another sees green, and green where another sees red, the fact will be undiscoverable and harmless. But if, where one person sees two colours, red and green, another only sees one, we have a discoverable difference, which is correctly described as a defect in the vision of the person who only sees one. It is always assumed that if two stimuli produce noticeably different effects in a given percipient at a given time, there must be differences in the stimuli correlated with the differences in their effects; while if the effects are not noticeably different, there may nevertheless be differences in the stimuli. Consequently *A*'s senses are better than *B*'s if *A* perceives differences when *B* does not. For the same reason, the microscope and the telescope are better than the naked eye. But this has, as a rule, more to do with vagueness than with subjectivity. Subjectivity only enters in when we are led to make false inferences, not when we are merely unable to make inferences which another can make. A mere deficiency, such as blindness or deafness, does not amount to subjectivity, but seeing double does if it deceives us. It deceives us when it leads to false inferences—*e.g.* that there are two tactual objects, or that a person near us will see two objects.

Cerebral (or psychological) subjectivity arises as a result of past experience. An obvious example is a sensation which appears to be in a leg which has been amputated. We are liable to this kind of error whenever two things usually associated are for some reason dissociated. Certain sensations have, in the past, been generally associated with a stimulus in the leg; but they have had as intermediaries conditions of the nerves between the leg and the brain. If these previously intermediate conditions arise in a person who has lost his leg, he will interpret them as sensations in his leg, if he has momentarily forgotten that he has lost his leg—*e.g.* on waking from sleep. In all perception (except perhaps during the first weeks of life) there is a large element of interpretation due to past experience, and this element is subjective when the present situation does not contain the correlations whose past occurrence has caused the interpretation.

All these sources of error have to be guarded against if perception is not to mislead us. The ways of guarding against them are those suggested by common sense and perfected by science; they are all such as to substitute laws with few or no exceptions for laws with a comparatively large number of exceptions.

It will be seen that very little can be inferred with confidence from a single percept; we need observation from different points of view, and throughout a certain period of time. It is true that we shall *usually* be right in what we infer from a single percept, but that is because the objects that surround us mostly belong to familiar kinds—men, horses, motor-cars, etc. But it would not be difficult to construct situations which would deceive at the first glance, especially if we could be suddenly transported into a quite unfamiliar world, like Wells's Martians. Water, for example, would completely puzzle a person who had never seen a liquid, if such a person could exist. In this matter, as elsewhere, we proceed step by step from the easy but precarious inferences of common sense to the difficult but more reliable inferences of science.

Where the intervening medium is relevant in inferring other members of a group from a percept, it is obvious that the single percept is theoretically inadequate as a basis for inference, since, by a change in the medium, the same percept might be associated with a different group. In this case, the distorting element in the medium may be directly discovered by other percepts—*e.g.* glass may be touched—or it may be merely inferred by examining the way in which percepts belonging to one group change from place to place—*e.g.* refraction in air. When it has been inferred, the inference needs to be tested by examining whether it has further consequences which can be verified. All this is a commonplace.

It remains to say something about the inference from percepts to events which no one perceives. It is not its validity that I wish to examine now, but its scope—*i.e.* how much we can know about unperceived events, assuming the causal theory of perception. It is sometimes urged that an unperceived cause of a perception must be a mere *Ding-an-sich* or Spencerian Unknowable. This seems to me only very partially true, if we accept the usual canons of scientific inference. We assume that differences in percepts imply differences in stimuli—*i.e.* if a person hears two sounds at once, or sees two colours at once, two physically different stimuli have reached his ear or his eye. This principle, together with spatio-temporal continuity, suffices to give a great deal of knowledge as to the *structure* of stimuli. Their intrinsic characters, it is true, must remain unknown; but we may assume that the stimuli causing us to hear notes of different pitches form a series in respect of some character which corresponds causally with pitch, and we may make similar assumptions in regard to colour or any other character of sensations which is capable of serial arrangement. And we can without difficulty extend geometry to the world outside our perceptions, although the space of that world will only correspond to the space of perception in certain respects, and will be by no means identical with the space of perception.

What we assume is, formally, something like this: there is a roughly one-one relation between stimulus and percept—*i.e.* between the events just outside the sense-organ and the event which we call a perception. This enables us to infer certain mathematical properties of the stimulus when we know the percept, and conversely enables us to infer the percept when we know these mathematical properties of the stimulus. Consequently, except when we are studying physiology or psychology, we may suppose that what is happening in a place is what a person would perceive in that place, provided we use, in inference, only those properties of the percept which it shares with the stimulus. *E.g.* we must not use the blueness of blue, but we may use its difference from red or yellow. We cannot argue that because a picture looks beautiful, therefore there is beauty in the system of stimuli, because beauty may depend upon the actual qualities.* But nothing in physical science ever depends upon the actual qualities. Hence for practical purposes in physics the difference between percept and stimulus only compels us to confine ourselves to the structural properties of percepts; so long as we do this,

* If we accepted the theory that beauty depends only upon "significant form," we should have to say that a musical score is as beautiful as the music which it represents.

we need hardly trouble to remember that percept and stimulus are different. In physiology and psychology this does not hold, since we are concerned with the process intervening between stimulus and perception, or with perception itself.

Even in physics, it does not hold strictly, because the relation of stimulus and perception is not strictly one-one. It is only approximately so, even when we confine ourselves to stimuli to a given sense of a given person at a given time—*e.g.* two colours which I perceive side by side. Even here, vagueness comes in, so that slightly different stimuli may give indistinguishable perceptions. This constitutes an essential limitation to our knowledge, enshrined in the notion of "probable error." It can, however, be reduced to a minimum by the usual methods and constitutes, therefore, rather a practical difficulty than a theoretical problem.