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978-1-107-63062-8 - New Pathways in Science: Messenger Lectures 1934

Sir Arthur Eddington

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CHAPTER I

SCIENCE AND EXPERIENCE

Does the harmony which human intelligence thinks it discovers in Nature exist apart from such intelligence? Assuredly no. A reality completely independent of the spirit that conceives it, sees it or feels it, is an impossibility. A world so external as that, even if it existed, would be for ever inaccessible to us. What we call “objective reality” is, strictly speaking, that which is common to several thinking beings and might be common to all; this common part, we shall see, can only be the harmony expressed by mathematical laws.

POINCARÉ, *The Value of Science*.

I

As a conscious being I am involved in a story. The perceiving part of my mind tells me a story of a world around me. The story tells of familiar objects. It tells of colours, sounds, scents belonging to these objects; of boundless space in which they have their existence, and of an ever-rolling stream of time bringing change and incident. It tells of other life than mine busy about its own purposes.

As a scientist I have become mistrustful of this story. In many instances it has become clear that things are not what they seem to be. According to the story teller I have now in front of me a substantial desk; but I have learned from physics that the desk is not at all the continuous substance that it is supposed to be in the story. It is a host of tiny electric charges darting hither and thither with inconceivable velocity. Instead of being solid substance my desk is more like a swarm of gnats.

So I have come to realise that I must not put overmuch confidence in the story teller who lives in my mind. On the other hand, it would not do to ignore him altogether, since his story generally has some foundation of truth more

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especially in those anecdotes that concern me intimately. For I am given a part in the story, and if I do not take my cue with the other actors it is the worse for me. For example, there suddenly enters into the story a motor car coming rapidly towards the actor identified with myself. As a scientist I cavil at many of the particulars given by the story teller—the substantiality, the colour, the rapidly increasing size of the object approaching—but I accept his suggestion that it is wisest to jump out of the way.

There are ponderous treatises on my shelves which tell another story of the world around me. We call this the scientific story. One of our first tasks must be to try to understand the relation between the familiar story and the scientific story of what is happening around us.

At one time there was no very profound difference between the two versions. The scientist accepted the familiar story in its main outline; only he corrected a few facts here and there, and elaborated a few details. But latterly the familiar story and the scientific story have diverged more and more widely—until it has become hard to recognise that they have anything in common. Not content with upsetting fundamentally our ideas of material substance, physics has played strange pranks with our conceptions of space and time. Even causality has undergone transformation. Physical science now deliberately aims at presenting a new version of the story of our experience from the very beginning, rejecting the familiar story as too erratic a foundation.

But although we try to make a clean start, rejecting instinctive or traditional interpretations of experience and accepting only the kind of knowledge which can be inferred by strictly scientific methods, we cannot cut ourselves loose altogether from the familiar story teller. We lay down the principle that he is always to be mistrusted; but we cannot do without him in science. What I mean is this: we rig up some delicate physical experiment with galvanometers,

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micrometers, etc., specially designed to eliminate the fallibility of human perceptions; but in the end we must trust to our perceptions to tell us the result of the experiment. Even if the apparatus is self-recording we employ our senses to read the records. So, having set the experiment going, we turn to the familiar story teller and say "Now put *that* into your story". He has perhaps just been telling us that the moon is about the size of a dinner plate, or something equally crude and unscientific; but at our interruption he breaks off to inform us that there is a spot of light coinciding with division No. 53 on the scale of our galvanometer. And this time we believe him—more or less. At any rate we use this information as the basis of our scientific conclusions. If we are to begin actually at the beginning we must inquire why we trust the story teller's information about galvanometers in spite of his general untrustworthiness. For presumably his fertile invention is quite capable of "embroidering" even a galvanometer.

I do not want to spend time over points which no scientifically-minded person disputes; so I will assume that you agree that the only channel of communication between the story teller who lives in your mind and the external world which his story professes to describe is the nervous system in your body. In so far as your familiar conception or picture of what is going on around you is founded on your sense of sight, it depends on impulses transmitted along the optic nerves which connect the retina with the brain. Similarly for your other sense organs. You do not, of course, perceive the impulses themselves; the story teller has worked them up into a vivid story. The inside of your head must be rather like a newspaper office. It is connected with the outside world by nerves which play the part of telegraph wires. Messages from the outside world arrive in code along these wires; the whole substratum of fact is contained in these code messages. Within the office they are made up into a pre-

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sentable story, partly by legitimate use of accumulated experience but also with an admixture of journalistic imagination; and it is this free translation of the original messages that our consciousness becomes aware of.

If we had a complete record of the impulses transmitted along the nerves we should have all the material which the story teller can have had as a foundation for his story—in so far as his story relates to the external world. And it is to this material that we must appeal if we wish to discover the truth behind the story. To appreciate the task of physical science let us then suppose that we are in possession of these data—the dots and dashes, or whatever the signals are, that arrive at the brain cells at the terminations of the nerves. All that physical science can assert about the external world must be inferable from these. If there is any part of our conception of the physical universe which cannot have come to us in the form of nerve signals we must cut it out. As in a beleaguered city there spread circumstantial rumours of happenings in the world outside which cannot have been received from without, so in our minds there arise all sorts of conceptions of entities and phenomena in the external world which cannot have been transmitted to us from outside. They do not conform to the type of message which the narrow threads of communication will bear. We are continually making the mistake of the man who, on receiving a telegram, thinks that the handwriting is that of the sender. The messages as we become aware of them in consciousness are dressed up with conceptions of colour, spatiuousness, substance. This dress is no part of the message as it was handed in by the external universe. It is assumed after the message arrives; for the transmitting mechanism is by its very nature incapable of conveying such forms of conception.

This limitation of the transmitting mechanism is strikingly illustrated when we talk with a colour-blind person. We know from his amazing mistakes that there is a big difference

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between his perception of his surroundings and ours. But he is quite unable to convey to us how his perception differs. When he confuses red with green, does he see both colours as red or both as green or as some hue unknown to us? He has no means of telling us. The intrinsic nature of his perception is trapped in his mind. It cannot flow out along his nerves; nor could it travel up our nervous system if it reached it. Similarly the sensory qualities of colour, sound and scent cannot have been transmitted to us from the object in the external world to which we attribute the colour, sound and scent; for even if we suppose the object itself to be endowed with such qualities it would be as impotent as the colour-blind person to convey to us their character. The part played by the external object is to condition directly or indirectly the signals which pass along the nerves. The story which arises in our consciousness is a consequence of these signals, but it contains much that does not belong to the external message.

The inference of any kind of knowledge of the physical objects which lie at the far end of these lines of communication must evidently be very indirect. In this respect it differs from the knowledge constituted by the mind's immediate awareness of its own sensations, thoughts, emotions. I have elsewhere expressed this in the words: "Let us not forget that mind is the first and most direct thing in our experience; all else is remote inference".^{*} That is a statement which, I believe, physicists accept almost as a truism, and philosophers generally condemn as a hoary fallacy. It is difficult to understand why there should be such a difference between us. I had thought that, like many other differences, it might arise because we do not talk the same language; but some recent writings seem to show that the cleavage may be deeper, and that there is a tendency in modern philosophy to adopt a view which is scientifically untenable.[†]

^{*} *Science and the Unseen World*, p. 24.

[†] See pp. 280–288.

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Scientific thinkers generally agree that the channel of communication between the external world and man's consciousness is severely limited in this way; but, whilst giving intellectual assent, they do not always adjust their scientific outlook to correspond. They are strangely reluctant to doubt the assertions of the familiar story teller even when it is evident that he is talking through his hat. The feeling that many of the conclusions of relativity theory and quantum theory are contrary to common sense is largely due to this tenacity. We cling to certain features in the familiar picture of the external world, almost as though we were persuaded that some part of our percipient selves had been projected outside the body, and had entered into external things and become aware of their ultimate nature in the same direct way that the mind is aware of its thoughts and sensations. We uphold the familiar conceptions of space in the external world as assuredly as if the spirit of man could enter into space and feel what it is like to be large or small. But when an external object raps on the door at the extremity of a nerve, you cannot put your head outside to see what is rapping. You cannot know more of its nature than that it must be such as to account for the delivery of the raps in their sequence. A scientific theory which accounts for the raps is none the worse because it runs counter to the story teller's habitual but unwarranted picture of what lies beyond the ever-sealed door.

II

Broadly speaking the task of physical science is to infer knowledge of external objects from a set of signals passing along our nerves. But that rather underrates the difficulty of the problem. The material from which we have to make our inferences is not the signals themselves, but a fanciful story which has been in some way based on them. It is as though we were asked to decode a cipher message and were

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given, not the cipher itself, but a mistranslation of it made by a clumsy amateur.

It is true that the physiologist nowadays is able to tap the messages as they pass along a nerve. He can record the changes of electrical potential that occur when a nerve is stimulated, and the record shows a series of oscillations which are presumably the physical foundation for the perception that arises in the mind. But we cannot begin the study of the external world with these records. In order to utilise them a rather advanced scientific knowledge of the nature of the human body and the functions of the various nerves is presupposed. All that the physiologist has done is to tap the messages on the way to one brain and divert them into another brain—his own. That is not fundamentally different from the method of the physicist who intercepts the messages emanating from physical objects before they reach any nerve, and, for example, causes them to record themselves on a photographic plate. By one route or another the messages must ultimately be conducted to a seat of consciousness if they are to be translated into knowledge.

It is the inexorable law of our acquaintance with the external world that that which is presented for knowing becomes transformed in the process of knowing.

Thus in saying that the initial data of physics are nerve signals, we must not be confused by the fact that nerve signals are pictured by us as known processes in the external world. This identification of our initial data is not itself an initial datum; it is one of our indirect inferences. It all emphasises the difficulty of tracing our knowledge of the physical world to its beginning. We detect it stealing into our minds through our nerves; but our knowledge of the physical world had to be considerably advanced before we discovered that we possessed a nervous system.

More by the exigencies of its own development than by the considerations that we have been discussing, modern

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physics has been forced to recognise the gulf between the external world which appears in the familiar story of perception and the external world which presents its messages at the door of the mind. It is for this reason that the scientific story is no longer a tinkering of the familiar story but follows its own plan. I think the modern view can best be expressed by saying that we treat the familiar story as a cryptogram.

Our sensory experience forms a cryptogram, and the scientist is a Baconian enthusiast engaged in deciphering the cryptogram. The story teller in our consciousness relates a drama—let us say, the *Tragedy of Hamlet*. So far as the drama is concerned the scientist is a bored spectator; he knows the unreliability of these play-writers. Nevertheless he follows the play attentively, keenly alert for the scraps of cipher that it contains; for this cipher, if he can unravel it, will reveal a real historical truth. Perhaps the parallel is closer than I originally intended. Perhaps the *Tragedy of Hamlet* is not solely a device for concealing a cryptogram. I would admit—nay, rather I would insist—that consciousness with its strange imaginings has some business in hand beyond the comprehension of the cipher expert. In the truest sense the cipher is secondary to the play, not the play to the cipher. But it is not our business here to contemplate those attributes of the human spirit which transcend the material world. We are discussing the external world of physics whose influences only reach us by signals along the nerve fibres; and so we have to deal with the story after the manner of a cryptogram.

The solution of a cryptogram is found by studying the *recurrency* of the various signs and indications. I do not think we should ever have made progress with the problem of inference from our sensory experience, and theoretical physics would never have originated, if it were not that certain regularities and recurrences are noticeable in sensory experience. We call these regularities of experience laws of Nature. When such a law has been established it becomes also

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a rule of inference, so that it helps us in further decipherment just as in solving an ordinary cryptogram.

I do not know how a logician would classify the process of solving a cryptogram. The decoded message is inferred from the cryptogram, but the method of inference can scarcely be described as logical deduction. In saying that the scientific description of the external world is inferred from our sensory experience, and that the entities of the physical world are *inferences*, I use the word inference in this broad sense.

Our task then is to discover a scheme revealed by the regularities and recurrences in our sensory experience. Since these regularities occur in the sensory experience of all men the scheme is presented as an *external* world linking together the experiences of different individual consciousnesses. In thus defining the object of our search we determine to a certain extent the nature of that which we shall find. The universe of physics must by its very definition have the two characteristics of regularity (or partial regularity) and externality. We do not contest the right of anyone who is interested in other aspects of sense data, or of the consciousness in which they reside, to pursue his investigations in his own way; but so far as physical science is concerned we drop everything that is inessential to the elucidation of regularities and recurrences.

I must also emphasise the significance of the term “external”. The familiar world of my perception seems to be external; but, in the courts of science, what the familiar story teller says is not evidence. The world of my dreams also seems to be external, but it has no existence outside my mind. The argument that the world containing the entities of physics is external is quite independent. When I examine the content of my consciousness with a view to formulating the recurrences of my sensory experience, there are two possible ways of treating the data—two ways in which I

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might attempt to solve the cryptogram. Among the data are certain auditory sensations “spoken words” and certain visual sensations “printed words” which admit of alternative treatment. I might study their recurrences and regularities without discriminating them from other auditory and visual sensations. Then all the recurrences are of data within my own consciousness and the study of them never takes me outside the region of my own mind; the solution of the cryptogram, if any, reached by this treatment will be an internal egocentric world. But such a treatment of the problem of experience is not often promulgated—if only because a lecturer cannot deny himself the hope that his “spoken words” will be treated by his audience as on a different epistemological footing from the beating of a tin can. Therefore in science and in most philosophies spoken and printed words are treated, not only as immediate sensory data of our own consciousness, but as communicating to us data existing in other consciousnesses.

Thus our first intimation of externality has no direct connection with physical science. It comes from the recognition that the problem of experience is concerned with data distributed among many different individual consciousnesses. The synthesis of experience then necessarily leads to the contemplation of a neutral domain not coextensive with any individual mind. Thus although we start from individual mental data, as soon as we commit ourselves to the recognition of other minds than our own, we are led to the conception of an external domain (physical space and time) to contain the inferential objects of our combined knowledge. Among these inferential objects are the nerve fibres and brain cells where (as the decipherment of the cryptogram progresses) the sources of communication between the objects of this external world and an individual consciousness are found to be located.

We asked why the story teller should be believed when he