REITH LECTURES 1950: Doubt and Certainty in Science

John Zachary Young

Lecture 6: The Changing Symbols of Science

TRANSMISSION: 7 December 1950 - Home Service

It would be interesting to know how you would answer if I asked the question, 'Why do you listen to these lectures?' Perhaps many would reply that they want to understand things better, and feel that science can provide answers to many of their questions. As a biologist, I should prefer to put it the other way round, and to say that observation shows that year by year more and more people are using scientific ways of speaking and writing. The growing amount of science in broadcast programmes shows the widening use of this language.

To find out its advantages and limitations, I want to discuss the development of scientific systems of communication from the seventeenth century to the present day. The method I shall use will again be that of a biologist, and I shall be speaking mainly of physicists and chemists. I must say at once that I am not a physical scientist; my account is that of a biologist describing them. What do these physical scientists do for man to help him get his living on earth? We shall find their function to be very like that performed by those who, in earlier times, provided symbols and tools which enabled man to co-operate. As before, we shall find that, as man uses the new tools provided, his brain learns new models or symbols. Then, fitting its input to its new symbols, the brain, as we say, makes new observation possible, and produces a fresh output of further tools. The cycle of doubt and certainty continues in science as it did before.

The type of activity that we call scientific seemed to develop rather suddenly in the seventeenth century. There was a change then in men's habits of communication, and new ways of observing and speaking about observations were adopted. The rule with which brains had functioned in the western world in the Middle Ages was to describe everything that was observed in terms of religious symbols. By this convention of speech and writing all human experience and action was unified. It was an efficient brain system, producing a well-organised society and reasonably stable conditions, which allowed for development of techniques and tools. Invention of new engines and forms of social organisation proceeded, even though slowly. Each invention in turn provided new observations and fresh models that served as means of discussing the observations. Thus, the inventions of mills for obtaining help from use of wind and water were important not only for the work that they did. In addition, by separating the doing of work from the action of living bodies, they made it possible to begin to speak about energy in a new way. Henceforth, change began to be considered not as something produced essentially by living things only, but as the result of an outside agent—energy. This way of speaking about change remains a central feature of science today. The developments that interest us most, however, were in methods of observation and communication. The inventions of printing, of clockwork and of lenses, were especially potent factors in the change in the previous ways of observing and speaking that led to the growth of science.

The invention of printing during the fifteenth century was a landmark in the history of human communication, and was crucial for the development of scientific behaviour. The act of publication plays an essential part in the procedure of science. The so-called ‘true facts’ with which traditional science deals are observations that can be made by anybody who has the necessary apparatus and skill. For the medieval type of brain, making true statements depends on fitting sensory experience with the symbols of religion. Insistence on this correspondence ensured that all men agreed in their observations and all acted in the same way towards a common end. With the coming of printing it gradually became easier for people to achieve the same certainty about their communion with others by reading what those others said that they had observed. This was probably one of the main reasons for the changes that took place in the attitude to religious symbols. The Bible itself became the new symbol of communication.

As books became common men could look more directly at each other’s observations, with a very great increase in the accuracy and content of the information conveyed. This is a theme that suggests a variety of trains of thought; the only one I shall follow now is the connection between printing, measurement and mathematics. Science consists in exact description of one’s observations to other people. Therefore most of the exact sciences measure things—that is to say compare them with some standard and express the result as a number. Measuring was a habit that was greatly extended in the seventeenth century, because numbers provide us with one of the best ways of sending a lot of information to a distance in a small book. There are other ways of doing it, say by drawing or photography, but scientists are probably right in making something of a fetish, a symbol, of measuring. The manipulation of numbers by mathematics was a further technique that was greatly improved in Europe at this time. As scientists developed the practice of measuring they continually developed new ways of relating the measurements by mathematics.

The Significance of Clocks

Almost as important for the origins of science as printing was the perfection of the clock. The accurate division of time into equal intervals was a characteristic feature of late medieval development. It spread from the regular life of the monasteries into commerce; until finally the clock imposed itself as a burden upon man’s labour with the rise of industrial civilisation. Today we are so used to speaking of time as an even flow that we find it difficult to remember that this is only a convention. Professor Evans-Pritchard reports that among the tribes of the Upper Nile, time is reckoned by the needs of the cattle, milking time and so on, and the day is not divided into equal intervals of hours as with us. Seasons are reckoned from the migrations made necessary by the Nile floods. In our civilisation the emphasis on a steady flow of time developed mainly with the invention of good clocks. This conception provided an important part of the framework of the new view of a material world that man created in the seventeenth century. Moreover, natural events were compared with clocks. The heavens and the human body were said to function like clockwork. In fact, use of this model was largely responsible for the practice of speaking of the ‘working’ of any system—a practice still deeply ingrained in us.

The new world of the seventeenth century, besides having a new time, also had a new space. The vision of this was made possible by the fresh information obtained with the use of- glass and lenses. Lewis Mumford, among others, has pointed out the significance of the introduction of untinted glass windows in giving a freer view of the world and putting it in a frame. The Middle Ages used coloured glass to let light in, filtered through pictures of religious symbols. From the seventeenth century onwards men looked outwards through clear glass and saw a new world outside.

With improvement in glass manufacture lenses were made and used, at first for spectacles, which served to lengthen the reading life of the individual. But with telescopes and microscopes came the biggest shock of all, the sight of things that to the unaided eye simply are not there. Both instruments were discovered by Dutch opticians at the end of the sixteenth century. Galileo developed the telescope in the early seventeenth century. The motions of the planets that he saw with it could not be fitted into the idea that the sun goes round the earth. He therefore supported the seemingly ridiculous statement that the earth goes round the sun. The interpretation of astronomical observation that had been built up in the Middle Ages compared the universe with a series of spheres, carrying the heavenly bodies, with the earth at the centre. After Galileo's observations the whole model had to be abandoned. This was why the Church felt it necessary to make him recant.

The same sort of change came over other parts of science as reports of observations with the new instruments poured out. Description of earthly things had up to this time used the technique of describing 'matter' and its 'properties', a system we still largely use. It is often traced back to Aristotle, but is based essentially on the very ancient practice of speaking about anything as if it had some creature like a man inside it. In this language we might describe what a stone does when it falls by supposing it to be moved by a property of motion that we say 'resides' in it. Notice the significant word resides, suggesting comparison with a human house. If for each sort of observation we have to invent a new property we shall obviously soon have a great many of them, even for a simple body like a stone. We should have to describe also its properties of hardness, greyness, bitterness, noisiness and many more. Obviously it would take a long time to communicate information in this way and that was why medieval science did not develop very far.

Galileo and his successors simplified the description of observation by ceasing to study only the properties of each particular body. Instead of talking about the power of movement of a stone as due to the property of motion within it, scientists now directed their attention to motion as such. They postulated a force acting upon the stone from outside. Remember that the use of mills had led to a new way of speaking about force. Galileo made another great change by altering the whole method of making observations. The simple way of studying a subject, say motion, is to look at it where it occurs naturally, in this case in men walking, leaves in the wind or the sun in the sky. Galileo was not content with this. As Professor Dingle puts it, he took his experience in the form of experiment. He put spherical balls in grooves, watched them rolling down and made measurements of their movements. This is the process that I call doubting. The medieval way of behaving was to describe only those things that could be talked about with certainty—because they were like attributes of God. You used your rules to choose the right things to look at. Galileo's way was first to choose his vantage point for looking—to set up an experiment as we say—and then to describe as simply as he could what he saw. By choosing carefully arranged experimental situations he was able to make observations that were repeatable. From these he tried to see new laws of the relations between things so that he could forecast their behaviour: to make new laws from observations instead of only observations from laws.

Science has found this system of isolation of certain sorts of observation from others to be an enormous help in producing simple, exact and repeatable observations. It made possible the development of a special language for talking about each sort of observation—one set of terms for motion, another for light, another for chemical combination, and so on. Scientists have never been uninterested in trying to unify these different sorts of language; Newton, for example, tried hard to do it. But they have not made a fetish of doing so. They have preferred to describe some things exactly, even at the expense of leaving out others. Scientists are united in their endeavours, not by trying to force all observations into some preconceived system of law, but by insisting that the observations shall be freely available to all. Insistence upon this availability of knowledge is the central feature of the whole structure of science. It is, as it were, its central canon. It is important to notice that it contains the assumption that all people are equally able to observe. This is certainly not true, and therefore in defining science we must also define the varieties of man. I shall show later that this is not the unnecessary subtlety it may seem. In fact, consideration of it alters the whole structure. However, hitherto, scientists have certainly been very insistent about the free availability of their observations. Belief in this was expressed from earliest days in the growth of learned societies, devoted to discussion of the new discoveries. Such meetings have continued ever since and are active today. A biologist looking at scientists notes that each of them regards membership of learned societies as one of his most important activities. This is evidence that communication is an essential feature of science, as it was of the system in existence before. Publication and attendance at scientific meetings are as typical of the new behaviour as attendance at church is of religious behaviour.

Where Scientists have been Mistaken

The essence of the new method, then, was to pay attention to some features of a body—say, its motion—and to leave out all talk about other aspects, its colour and shape, its taste, its beauty, and its religious significance. The new science therefore seemed to many people, especially those in the ecclesiastical 'tradition, to be irrational and incomplete, indeed dull. So it was, and still is, except for certain purposes. The invention of the special scientific symbols and ways of observing, talking and writing provides a means of communication that has great practical value. But it is only one of the possible means available to men. The tragedy has been that its relation to the others has not been recognised. Some scientists, therefore, have been led to make the mistake of thinking that their ways of observing and speaking were the only proper ways. This is to make the very same mistake that science itself taught us how to avoid in the seventeenth century. Scientific symbolism provides ways of describing observation to others. This is just what all forms of symbolism do. The painter has his own way of communicating his observations. Original painters find new ways of doing this, new art forms. These literally enlarge the vision both of the artist himself and' of those who look at his paintings. Artists have discovered new aspects of space with one symbolism, just as physicists with another.

The fact that scientists began using a variety of symbols without reference to one central set is related to the general changes in society that occurred after the Middle Ages. What happened as these new verbal patterns developed was just what the biologist would expect: western humanity began to split up into a series of separate groups. As a result gradually thereafter there was a series of new arrangements of the behaviour patterns of the larger groups of men, in. the course of which, among other things, industrialism and modem nations were born. Since the new system looked away from man, and towards machines, it is not surprising that it neglected human values. This neglect is the chief practical defect of the systems of physical science. By a curious revenge it is now found to be also its chief theoretical deficiency—as I shall try to show presently. However, the varied new ways of acting did not produce the chaos in western society that might have been feared. They provided new and better means of communication. Men were bound into even larger and more compact groups as a result of the very techniques that ignored the men.

New Models

What the seventeenth-century scientists discovered, therefore, was the possibility of using new models and new signs for communication. Looking away from man, they began to form a picture or model of a completely new world, utterly strange to their predecessors. Space and time had hitherto been concepts considered purely relative to man and to God. By the use of the new exact ways of measuring time and distance the scientists built up a picture of a distinct world, the ‘real’ or ‘material’ world, as it came to be called, outside man and in a sense outside god, though the early scientists were devout and would have said that it was created by Him. This is the world that we are apt to feel so sure exists around us today: the plain, commonsense world of hard material facts, as some people would call it. What I am going to say is that the form we give to this world is a construct of our brains, using such observations as they have been able to make. Only in that sense does it exist. Before you give up trying to believe that there can be any sense in this, remember that your favourite ‘real’ world was only invented in the seventeenth century and seemed very far from commonsensical to the average man then.

Yet the new world invented by science was not described in symbols wholly different from those of the Middle Ages. The new ways of talking were a mixture of old and new symbols, as they are in most periods. The scientists tried to abolish animism in their descriptions of their new world of matter, space and time. As I shall show they were only partly successful in this and in describing their own relation to that world they retained the old models almost unchanged.

I shall have more to say in a later lecture about the system that Descartes adopted of treating man as composed of an entity mind set in another entity of a different sort, the body. In considering the origins of physical science the point is that the adoption of this technique made it seem as if the situation was that there is a fixed district or region, the material world, outside us. The business of the scientist, if this is true, is just to study and report on what happens in that world. I have shown already some reasons for believing that this is not a good description of the situation. In some sense we literally create the world we see. Therefore our physical science is not just a set of reports about an outside world. It is also a report about ourselves and our relations to that world, whatever the latter may be like. I want presently to indicate how physicists themselves have come to recognise this and have found themselves forced to adopt principles, as they say, of relativity and indeterminacy. The point to grasp is that we cannot speak simply as if there is a world around us of which our senses give true information. In trying to speak about what the world is like we must remember all the time that what we see and what we say depends on what we have learned; we ourselves come into the process. This should make us much more humble in believing that our present ways of speaking give a full revelation of what the world is like. As we expand our powers we should be able to observe and report more and more. This is what science has been gradually doing, and has enormously enlarged its vision. We may take a few examples of this enlargement from the development of the sciences of chemistry and physics.

Chemistry was built up around the system that med to describe its observations by saying that the world is made of something called matter, which can be divided into tiny pieces, or atoms. In the last century, chemists thought that they had found the indestructible atoms of which all matter is composed. We now see that this way. of describing our observations is not adequate. We no longer speak of atoms as pieces of matter at all. The change has come about largely as a result of study of the phenomena known as electrical. The various events known as electrical discharges, lightning flashes and electric currents occur under a variety of circumstances all involving special positions of two or more bodies. For example, movement of a piece of wire between the poles of a magnet (the essentials of a dynamo) produces what we call a flow of current in the wire. Similarly, when certain chemicals are placed together in suitable ways, we have a battery, which also gives a current between its poles.

Notice the words we still use to speak about these new discoveries— ‘a current’, ‘flowing’ (like water); a ‘battery’ sending out ‘discharges’ (like guns). For a long time the use of these primitive models made it difficult to relate our knowledge of electrical phenomena to others. Many of you may still feel the need to answer the question: ‘What is electricity?’ But that is to speak about it in terms of a primitive materialistic model. We have now learned how to avoid doing this. What we do instead is to find a language which will more directly describe our observations. In this case, electricity is that which results when there are certain spatial relations between things—when a wire is moved near a magnet, when chemicals are properly .arranged in a battery. You see, we find that we can talk about electricity quite easily without asking what it is or whether its flow is like water. In fact, we can do much better without the old models, provided we can accurately describe the conditions and relations in which electrical phenomena occur. This is done by mathematics. We get rid of the materialist model and replace it by a mathematical one.

With the development of electrical tools it became possible to make measurements of very large and very small quantities. The results of these measurements have given further evidence that our naive way of talking about a world distinct from man and divisible into pieces of matter enduring in time is simply not adequate. This has produced, among other things, a surprising revelation of the extent to which physics in the nineteenth century had been using, all unobserved, animistic ways of talking. Physicists have been forced by their own data to a further extension of .the principles laid down in the seventeenth century—namely, that the business of science is the simple description of observations, without postulating ‘occult qualities’, as Newton called them, as the causes of their observations. What are these further newly revealed occult qualities? Take the example of measuring. When I tell you that a stick is a foot long, I am saying essentially that I have taken a standard object, namely a foot rule, laid it alongside the stick and found that they match. But do I simply tell you that I have done this? No, I say 'The stick has a "length" of one foot'. I interpose the occult quality, length, I use it as my model in my description of what I did. 'But how can that matter so much' you might say. 'Surely we both understand what we mean by length; there is no harm in speaking in this way'.

Einstein's Contribution
It has been a great part of Einstein's contribution to show that there is a great deal of harm in this, that in fact our talking about entities such as length and velocity and motion, deceives us into ignoring certain fundamental features of our methods of observation. For example, it leads us to suppose that the length of a body is independent of time and of where it is in relation to ourselves and how it is moving. In practice it is found that this is very nearly true for ordinary terrestrial distances. It is not true for very large or very small distances. We understand pretty well what we mean by speaking of the length of a stick on earth. We deceive ourselves if we suppose that the same assumptions apply when we try to measure the vast distances of the stars. However Einstein showed that the way to avoid all such difficulties is not to speak of length, but always to describe simply and exactly what the observer does when he is measuring and then try to work out simple relations between the observations. That is why his theory is called that of relativity.

Something similar has happened as physicists have devised ways of measuring very small distances. It has been found no longer possible to use the old model of supposing that what was being done was to divide up something called matter into a series of bits, each with definite properties called size, weight or position. Physicists do not now say that matter is made of bodies called atoms, protons, electrons and so on. What they have done is to give up the materialist game of describing their observations in terms of something made as by a human process of manufacture, like a cake. The word atom or electron is not used as the name of a piece. Itis used as part of the description of the observations of physicists. It has no meaning except as used by people who know the experiments by which it is revealed. And the results of these experiments are nothing more than relations between measurements, expressed in mathematical formulae. I know that this may seem difficult to grasp, but what has happened has been simply that with new instruments new observations have been made and new ways of describing the results have been invented.

However, it is important to realise that great changes in ways of ordinary human speaking and acting are bound up with the adoption of new instruments. Some at least of the old animistic ways of speaking have been banished from the new language of science. We no longer speak of a world of matter, nor of particles, properties or forces. Physics is no longer materialist. Instead it speaks of what we may call a man-world of observers and the relations between them and the reports of what they observe. Since observers came into it a new phase is at hand in which a common science of physics and biology will be possible. I shall try to show how the models of each can be used to help the other. Physical science has so far provided a most ingenious set of symbols for improving human communication, and wonderful new tools have been produced as a result. The method has been so powerful because it freed man from the attempt to organise all communication round one set of symbols only. Presumably the change involved new ways of brain acting, though we can only dimly see what these were. They involved adding to the old linear, circular and animistic models the complicated ways of brain action that we call mathematical. We may be able to build a still more powerful science if we can fit the brain actions of the physicist together with those of the biologist. Science, like earlier human systems, has gradually changed the use of its symbols and further changes surely lie ahead.