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Narratives and Paradigms: The nature of scientific thinking

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> 'Rebecca made clear, by concrete illustrations, by her own self, the two wholly different, wholly separate forms of thought and mind, *paradigmatic* and *narrative* … And though equally natural and native to the expanding human mind, the narrative comes first, has spiritual priority. Very young children love and demand stories, and can understand complex matters presented as stories, when their powers of comprehending general concepts, paradigms, are almost non-existent. It is this narrative or symbolic power which gives *a sense of the world*—a concrete reality in the imaginative form of symbol or story—when abstract thought can provide nothing at all. A child follows the Bible before he follows Euclid. Not because the Bible is simpler (the reverse might be said), but because it is cast in a symbolic and narrative mode.' (1)

Oliver Sacks (1) describes the case of a young woman, Rebecca, who seemed unable to comprehend or relate to the world around her. Almost by chance he discovered that while she was perfectly intelligent she was quite unable to understand the world when presented to her in the form of paradigms or rules about how the world functions but was perfectly able to understand the world when presented to her in the form of narratives. Sacks not only draws a distinction between narrative and paradigmatic forms of thought, but suggests that these two ways of understanding the world reflect, at a deep level, the way in which our brains function. My interest is in the relationship between narrative and paradigmatic thinking in doing and teaching science for it seems to me that, at least in the world of natural philosophy and natural history, this distinction is crucial but seldom explicitly stated and rarely understood.

I contend that creativity in science lies primarily in the narrative mode of thinking and it is here that new discoveries are made and new ideas are formed. But by formulating our narrative accounts of the world in terms of paradigmatic laws and theories we are able to do much more. First of all, we can constrain our narrative description in a logical framework which enables us to test the consistency of the narrative. Second, by quantifying and measuring our observations on the world we can make precise predictions that we can test. Finally, we can use our paradigms to make predictions about what will happen in other situations and by testing these we can hope to discover both the extent of their applicability and the areas in which they break down and require further elaboration. When they do break down we revert to a looser, narrative form of thinking, and the cycle repeats.

It is sometimes argued that the study of history involves only narrative, that history never repeats itself and that the most that can be done is to provide a consistent description of particular historical events and episodes. But as Diamond has shown the social history of our species is severely constrained by biogeography (2). At the other extreme some may argue that mathematics is essentially paradigmatic and that it proceeds by the formulation of axioms and rules from which everything else is shown to follow. Euclid is the archetypal example for this approach to mathematics but Euclid formalized the then accepted geometrical thinking with its roots in practical problems of surveying and mensuration. In modern science, physics is often held up as the model which other sciences, especially the social sciences, should follow and the paradigmatic presentation of modern physics is then held as the ideal to which other nascent sciences should aspire. However, it is easily forgotten that the paradigms of modern physics are the product of millennia of essentially narrative thought and argument and that modern physicists do not simply write down equations and then solve them. When they invent new theories they are doing a great deal more than simply elaborate the accepted paradigms.

Einstein (3) has remarked that 'the object of all science, whether natural science or psychology, is to co-ordinate our experiences into a logical system'. But what is the nature of this system or framework and how are we to arrive at it? We are confronted with a world that seems complicated, confusing and contradictory. In order to survive in this world we have to develop mental models of how it works and how the events that occur relate one to another. This mental model must be a simplification of the reality or it would be as confusing as the reality itself. Even the lower orders of animals have developed perceptual maps of their world so that bees, for example, are able to store a map of the relative positions of the hive and the flowers in relation to the direction of the sun and to convey this information to other bees in their search for nectar (4).

The problem of induction

When we examine the grand theories that have been developed in the natural sciences over the last few hundred years, Newton's theory of gravity, Maxwell's theory of electromagnetism, Einstein's theories of space and time (special relativity) and gravity (general relativity), Planck and his successors theory of quantum mechanics, Darwin's theory of evolution in its modern formulation, we are presented with theories which, provided we grant their premises, enable us to make precise and testable deductions as to the way in which the world behaves. Having developed and tested our theories we can then apply them to the actual world and make predictions about the future. The problem, however, lies in the reverse process. Starting from observations as to how the world behaves, how can we deduce the laws which, by a process of deduction, we can use to explain the world around us? Einstein (5) states the problem quite explicitly… 'I am convinced that ... the concepts which arise in our thought and in our linguistic expression are all—when viewed logically—the free creations of thought which cannot inductively be gained from sense experiences.' Nevertheless, he acknowledges (6) that such freely invented theories must be constrained if we are not to be swamped by a multitude of competing theories, and continues: 'The justification (truth content) of the system rests in the proof of usefulness of the resulting theorems on the basis of the sense experiences, where the relations of the latter to the former can only be comprehended intuitively.' If we agree with Einstein that there is no well-defined inductive method that can lead us to the formulation of our laws and theories, but rather that these are 'the free creations of thought which cannot inductively be gained from sense experiences' how then shall we go about inventing our theories and developing our paradigms?

Narrative thinking

The distinctive feature of *Homo sapiens* lies in our ability to develop, change and, where necessary, discard mental models of the way in which the world functions. Indeed, given this flexibility and power, it is almost inevitable that we have in our genes not only the ability to construct such models but a compulsion to do so. This is seen directly and clearly not only in the Book of Genesis, for example, but in the myths and fables of all pre-literate societies. Einstein (7) describes the drive to understand the world in the following words. 'Man seeks to form for himself in whatever manner is suitable for him, a simplified and lucid image of the world, and so to overcome the world of experience by striving to replace it to some extent by this image. This is what the painter does, and the poet, the speculative philosopher, the natural scientist, each in his own way. Into this image and its formation, he places the centre of gravity of his emotional life, in order to attain the peace and serenity that he cannot find within the narrow confines of swirling personal experience.'

Very young children delight in stories and in imaginative play which enables them to construct their own models of the world. Education for very young children reinforces this narrative mode of thought; it is only later that paradigmatic thinking is formally introduced and perhaps the unnecessarily abrupt switch from one to the other is the cause of many of the problems that children face in their later school years.

Popper (8) is quite explicit about the importance of narrative thinking in the development of scientific theories: 'It is one of the novelties of human language that it encourages story telling and thus *creative imagination*. Scientific discovery is akin to explanatory storytelling, to myth making and to poetic imagination.' Einstein (9) describing the process of scientific discovery says: 'In every true searcher of Nature there is a kind of religious reverence; for he finds it impossible to imagine that he is the first to have thought out the exceedingly delicate threads that connect his perceptions. The aspect of knowledge which has not yet been laid bare gives the investigator a feeling akin to that experienced by a child who seeks to grasp the masterly way in which elders manipulate things.'

It seems clear that when we attempt to develop our models of the world, these start as narrative descriptions within which our imagination is allowed to range freely and widely over many possibilities. We can illustrate this with reference to Darwin's theory of the evolution. When Darwin sailed on the Beagle the idea that the natural world had evolved was widely accepted (10). The problem was to provide a theory for this process of evolution. In the tropical world the fauna and flora were quite different from those in the temperate regions and this impressed itself greatly on Darwin, reinforcing in his mind the extraordinary diversity of the natural world. Visiting the Galapagos Islands he discovered many new species of finches, now named in his honour, and believing, correctly, that in spite of their diversity in form and function they must have originally evolved from the same species that colonized the island in remote past times, he began to develop a narrative theory to account for the process by which they evolved. After many years of reflection and observation he arrived at his now celebrated theory in which a combination of random variation and survival of the best adapted individuals leads to selection for particular traits and eventually the separation into new species (11).

As a second example we might consider Einstein's General Theory of Relativity. The theory seeks to explain the nature of the force of gravity whose mathematical formulation, in the hands of Newton, became one of the cornerstones of 19th century physics. The problem was
that Newton's theory, while providing a set of mathematical laws whose solutions could be used to describe the motion of planets around the sun or the speed at which an apple falls to the ground, gave no hint as to the essential nature of the gravitational force. It does not tell us what is this 'thing' that binds the earth to the sun, the apple to the earth. Feynman expresses it thus: 'Yes, you told us what happens, but what is gravity? Where does it come from? Do you mean to tell me that a planet looks at the sun, sees how far it is, calculates the inverse square of the distance and then decides to move in accordance with that law?' (12).

The key to the development of General Relativity lay in the realization that gravitational forces and the apparent forces that are produced when a body is accelerated are in a specific, but profound, sense equivalent. For our present discussion, however, it is of interest to note how he came to this realization: 'I was sitting in a chair in the patent office at Bern when all of a sudden a thought occurred to me: *If a person falls freely he will not feel his own weight*. I was startled. This simple thought made a deep impression on me. It impelled me toward a theory of gravitation' (13). The theory was borne not out of the solution of complex equations but out of a reflection on what would happen if one was falling freely in space.

The importance of paradigms

On its own, narrative thinking does not provide what we now regard as scientific theories. The Book of Genesis would not be called scientific in the modern sense and we need to progress beyond the purely narrative. Nevertheless, I contend that narratives of the kind found in Genesis and other religious texts were a necessary prerequisite for the development of modern scientific theories of the universe.

Darwin's theory illustrates this well. The 'Origin of Species', first published in 1859 (11), laid the foundations for a paradigmatic theory of evolution but was firmly rooted in its essentially narrative structure. Although Mendel's work on the inheritance of discrete characters in peas was published in 1866 (14), shortly after the 'Origin of Species', it took another 30 years before Mendel's work was rediscovered by de Vries, Bateson and others (15), and genetics in its modern paradigmatic form was developed. We are now able to quantify, in measurable terms, the various features of Darwin's theory such as fitness, heritability, rates of mutation, population growth rates and explain such unlikely events as the evolution of altruism (16). We can say that if a certain trait in an individual has a certain heritability and produces individuals with a certain degree of fitness relative to others, it will, in a predictable period of time, become the dominant trait in that population. In other words, we can subject Darwin's theory to much more stringent tests than were previously possible. We can now do more than simply argue, as Darwin did, [i] that the validity of his theory follows from its consistent explanation of a very large class of facts but can make precise and testable predictions based on the theory.

Many years elapsed between Einstein's reflections in the patent office in Berne and the development of his field equations and the general theory of relativity which explains the nature of gravity in terms of the curvature of space-time brought about by the presence of massive bodies. However, in both cases, the narrative description was a necessary prelude to the formulation of the quantitative theory. Medawar (17) expresses this connection between the two modes of thought as follows: 'Scientific theories ... begin as imaginative constructions. They begin, if you like, as stories, and the purpose of the critical or rectifying episode in scientific reasoning is precisely to find out whether or not these stories are stories about real life.'

The role then of paradigms is to take our diverse narratives, identify the common features that run through them, synthesize our many explanations into a few more powerful explanations. In the words of Whitehead: 'To see what is general in what is particular and what is permanent in what is transitory is the aim of scientific thought. In the eye of science, the fall of an apple, the motion of a planet round a sun, and the clinging of the atmosphere to the earth are all seen as examples of the law of gravity. This possibility of disentangling the most complex evanescent circumstances into various examples of permanent laws is the controlling idea of modern thought.' (18)

Models

In most of our research we are not developing grand theories of the kind mentioned above. Rather we are trying to develop limited models about particular aspects of the world of our experience. Nevertheless, the general principles still apply. Baran and Sweezy (19) describe the role of models in economics as follows: 'Scientific understanding proceeds by way of constructing and analysing 'models' of the segments

or aspects of reality under study. The purpose of these models is not to give a mirror image of reality, not to include all its elements in their exact sizes and proportions, but rather to single out and make available for intensive investigation those elements which are decisive. We abstract from nonessentials,
we blot out the unimportant to get an unobstructed view of the important, and we magnify in
order to improve the range and accuracy of our observation. A model is, and must be, unrealistic in the sense in which the word is most commonly used. Nevertheless, and in a sense paradoxically, if it is a good model it provides the key to understanding reality.' This is an excellent description of the nature and role of models in helping us to understand the world. What it perhaps omits to say is that in the process of deciding what to include and what to exclude, which aspects are important and which are not, we start by constructing a narrative account of what we regard as the essential features of the process that is under investigation. We use our narrative description to help us to formulate hypotheses from which we are able to draw conclusions which we hope to be able to test. If the tests fail, we might retain our narrative and reformulate our hypothesis or we might go further and try to construct a new narrative.

Further observations

There seem to me to be many areas in which a better understanding of the roles of narrative and paradigmatic thinking would be of great value. In the teaching of natural philosophy, especially physics in which I was trained, the very best students find the paradigmatic formulation of the subject easy and almost intuitive while others find it almost incomprehensible. The problem is this. Almost all undergraduate text books present physics as a purely paradigmatic exercise. One starts from the laws of Newton, Maxwell or Einstein or the laws of thermodynamics or quantum mechanics or relativity and then we proceed to prove that the earth travels around the sun in an ellipse, that the speed of light can be expressed in terms of the electric and magnetic permittivity of free space, that light is bent as it passes close to the sun, that there is an arrow to time, or that the energy levels of the hydrogen atom are quantized. As a student of physics the realization that these extraordinarily diverse phenomena can all be derived by a process of logical thinking from a few basic axioms and rules is extraordinarily exciting. But when one starts to do research it collapses and the attempt to derive everything from first principles becomes a hindrance. The first few years of research are often spent escaping from this rigorous way of viewing the world and learning to think in a much looser, more creative and essentially narrative way. To compound the error, research papers are presented in much the same way. It is commonly noted that the end product of a research project bears little relation to the original plan which was outlined in the application for funding. When the work is written up it is presented as a carefully planned exercise which starts from the assumption that what you have shown is what you wanted to show and you then argue clearly, convincingly and paradigmatically that this is in fact the case.

The situation in the biological sciences is somewhat different. Especially in ecology strict paradigmatic thinking is often simply not possible and the world has to be presented in a narrative context. However, this has led to a division of the world of biological sciences into natural historians and quantitative (usually laboratory or, these days, computer based) biologists, molecular biologists and immunologists. The quantitative scientists look down on the natural historians as being a relic of an earlier, pre-scientific age. The natural historians are scornful of the quantitative biologists as being people whose work is too simplistic to capture the essence of the natural world. Especially in relation to molecular biology this has led to a deep schism between the two with the ecologists looking enviously at the large grants received by the molecular biologists and waiting for them to get their come-uppance when their much vaunted techniques fail to deliver the goods.

Immunology is at a particularly interesting juncture. In spite of its basis in precise and carefully conducted laboratory studies, immunology is now in the position of ecology at the turn of the century. We know a great deal about B-cells and T-cells, helper cells, memory cells, antibodies, macrophages and the myriad of other kinds of cells. But what we know is essentially a description of the function of these various cell types and molecules in relation to the immune system. When one approaches immunologists as a mathematical modeller, the response is generally that what they are studying is far too complex to be captured in a few simple equations. What this means of course is that immunology is still in the narrative stage of theory and there is no doubt that it will eventually develop paradigmatic roots. What immunology requires is that the people engaged in constructing narratives about the immune system recognize the importance of developing the subject paradigmatically while the mathematicians and general theorists recognize the value and importance of the narrative basis that has been so painstakingly built up.

Another field, of personal interest to me, in which I think the distinction between the two ways of thinking is important, is in the role of science in development. I believe that science has failed in its objective of bringing successful development to Africa and the problems of malaria, trypanosomiasis, measles and many other diseases bear witness to this. The essential reason for the failure is in part that scientists come to Africa with readymade solutions, vaccines, insecticides, bed nets or whatever, for which they try to find appropriate problems. What they do not do is to first of all address and identify the problem clearly and then look for ways in which science might be used to alleviate these problems. In other words, they arrive with their paradigmatic baggage intact (usually derived from an understanding of the temperate and developed world) and find it almost impossible to address the complex and difficult problems of the African narrative, in the first instance. Of course, it might be argued that the anthropologists and sociologists do see the world in narrative terms but because neither side is willing to recognize the validity of the others thinking this deepens the rift between them and leads nowhere.

The 1960s and 70s were a time in which many social scientists were striving to develop a sound methodological basis for their work. Especially for the more behaviourally oriented scientists this lead to the notion that since physics was demonstrably successful, social scientists should develop an equivalent methodology. There are many obvious criticisms that one can make of this approach and the kind of work to which it led. But perhaps the most severe criticism is not that the exercise was doomed from the start but that it was based on a misconception of the nature of discovery in the physical sciences. It was based on the assumption that physics starts from the paradigmatic formulation of the problems to be addressed and so misses missed the more fundamental question of the role of narrative thinking in developing and creating new theories.

Where does this leave us?

We must recognize the importance of narrative and paradigmatic thinking. We must teach our students to tell stories about the world. While we should give precedence to the narrative we must ensure that our students develop the necessary skills to manipulate the paradigms. If you want to play Bach you will have to spend a lot of time practicing scales; but if you only learn to play scales you will never play great music.

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[i] It can hardly be supposed that a false theory would explain, in so satisfactory a manner as does the theory of natural selection, the several large classes of facts above specified. It has recently been objected that this is an unsafe method of arguing; but it is a method used in judging of the common events of life, and has often been used by the greatest natural philosophers. The undulatory theory of light has thus been arrived at; and the belief in the revolution of the earth on its own axis was until lately supported by hardly any direct evidence. It is no valid objection that science as yet throws no light on the far higher problem of the essence or origin of life. Who can explain what is the essence of the attraction of gravity? No one now objects to following out the results consequent on this unknown element of attraction; not withstanding that Leibniz formerly accused Newton of introducing ‘occult qualities and miracles into philosophy’. (Darwin, 1906)