Science: an unnatural practice

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There is a certain ambivalence among non-scientists towards science, shown by this quotation from D H Lawrence: ‘The universe is dead for us, and how is it to come alive again? Knowledge has killed the sun, making it a ball of gas with spots. Knowledge has killed the moon; it is a dead little earth fretted with extinct craters as with smallpox. The machine has killed the earth for us. The world of reason and science, this is the dry and sterile world the abstracted mind inhabits.’ Not exactly a very positive attitude towards science! On the other hand, many people in the public domain regard science with great interest and look particularly to medical science to cure all diseases. Even so, there is more than a little hostility. The journalist Mary Kenny, when scientists at the Imperial Cancer Research Fund discovered the gene for sex determination in mice, compared them to the notorious doctor Mengele who did experiments on humans in Nazi concentration camps. While one can dismiss this as absurd, there is undoubtedly an anxiety about the nature of science and what scientists are up to; genetic engineering provides a good example. Mary Shelley was perhaps unintentionally the evil fairy godmother of science, since the image of the scientist as Frankenstein is all too pervasive.

There also remains a stereotyped image of science and scientists. In cartoons, for example, the scientist is male, slightly hunched, unattractive and obessional. There appear to be no cartoons of female scientists. These images vary from that of a nerdish Einstein to that of a dangerous Frankenstein and, even though the image of the scientist as presented by the media has recently extended the range, scientists, with few exceptions, remain personality-free. They are too often portrayed as cold, anonymous, uncaring technicians.

It is peculiar that scientists should be portrayed as such, for is not science the intellectual triumph of the 20th century? More than 30 years ago C P Snow suggested that there was a division in our culture between the sciences and the humanities. Considering the definition of culture as ‘the intellectual side of civilisation’, the neglect of science by the humanities is striking. As Max Perutz has said, the carriers of our civilisation are perceived to be those in the humanities whereas scientists and engineers are seen as its plumbers. Such attitudes may well have an origin in the class system where earning a living by using one’s hands—and scientists are seen as such—is treated with some disdain.

But there is another aspect to this anti-science view. As both the poet W H Auden and Lionel Trilling, an American literary critic, have confessed, they are embarrassed by their ignorance of what Trilling called the ‘characteristic achievement of the modern age’. The cause of some such attitudes is the peculiar nature of science and scientific thinking. Science is, ironically, unnatural; it goes against one’s natural expectations, requiring an unnatural mode of thought and leading to unnatural ideas. I strongly hold that, if an idea fits with common sense, then scientifically it is almost certain to be false. It is nobody’s fault that it is like this; it just so happens that the world, the universe, is not constructed on a common sense basis.

Unnatural thoughts

Let me offer a few examples. If you can see the sun during the day, it seems quite obvious that the sun goes round the earth, and that you would be a fool not to assume this to be true—the natural common sense explanation. Seventy per cent of the British population do believe it, and I do not blame them; it is quite against common sense to believe that the earth goes round the sun, and most people would find it hard to provide a good explanation of why it is so.

Quite a lot of our so-called common sense about science these days is really predicated by authority. Take the tides. We say with great confidence that the moon causes the tides; the moon attracts the water, so it is high tide on the side where the moon is. But why is it high tide also on the opposite side? There is a very complicated explanation for this, involving centripetal forces.

From the moment one is born, one is exposed to moving objects. Yet the laws governing motion once again confound common sense. Newton’s and Galileo’s ideas about moving bodies have been around for over 300 years, yet many people still find it difficult to predict how moving bodies actually behave. When an aeroplane is going to drop a heavy ball, where will it fall in relation to the aeroplane? Many students who have had courses in physics get it wrong; in fact it hits the ground directly below the plane. Again, if I throw a book into the air, what are the forces on it after it has
left my hand? Many people, even some trained in physics, think that after it has left my hand there is an impressed force on it which gets progressively less and that it then begins to return under gravity. The correct answer is, of course, that there is only one force acting on it all the time—gravity. If you hit a golf ball, at what stage is it travelling fastest? The answer is, at the moment it leaves the club—the velocity decreases from the moment you hit it. The reason why it is counter-intuitive may be that acceleration is a second derivative of motion, whereas speed is a first derivative, and it is very difficult to be intuitive about second derivatives. A great deal of science depends on mathematics and, unfortunately, mathematics is not an intuitive subject.

Let me give a few more examples. Imagine that I am in a flat field and I have two bullets, one in a gun and one in my hand. If I shoot one bullet horizontally at exactly the same time as I drop the other, which bullet hits the ground first? Most people’s common sense view is that the one shot horizontally will get there after the other one. In fact they both get there at the same time. The rate of fall is independent of horizontal motion.

Most sensible people, when asked why ice makes their drink cold, would think that it is the cold going from the ice to the liquid, whereas it is due to heat leaving the water to warm, then melt, the ice. No wonder children at school have difficulty with science. It may be that if one told people that the world is built on a non-common sense basis, then when they come to understand science they might be slightly more relaxed about it and will not necessarily expect it to fit with common sense.

With really difficult things like quantum mechanics everyday analogies break down. The ‘big bang’, ‘black holes’ and so forth, require complex mathematical equations, and there are no everyday metaphors. Even biological ideas like the theory of evolution do not fit with common sense. Do people really believe that humankind has been achieved by random changes and natural selection? I do but I am still surprised by it, and I certainly do not think it is intuitively obvious.

The idea that cancer was essentially an inflammation caused by an excess of black bile persisted until the 18th century. Only with the beginning of microscopic pathology and cell theory did any real insights develop. Cell theory itself provides a good example of how difficult it was to understand what we now accept as common sense. Even though cells were observed by Hooke in 1665, it took much debate and ingenuity before it was accepted that cells were the basic units of life and that they do not arise de novo but only by cell division. It is hard now to realise how difficult it was to understand the behaviour of chromosomes at mitosis, or that there is an invisible membrane bounding the cell.

After I had given a lecture on a related topic in Cambridge, James Meade*, Britain’s Nobel Laureate in economics, said he would like to tell me the words he wanted on his tombstone; they were: ‘He tried to understand economics all his life but common sense kept on getting in the way.’

To be a scientist requires a particular mindset, a particular way of thinking about the world. Probability, for example, which scientists use a great deal, does not fit with common sense. Many people who are not familiar with it believe that if you toss an evenly weighted coin, six heads in succession is less probable than alternate heads, tails, heads, tails, heads, tails. In fact they are equally probable. How many people in a room do you require in order to have probability of 1/2—that is, evens, of two of them having the same birthday? The answer is 23. Once again it is counter-intuitive.

Problems of scale in science are also difficult. There is a story about a Science Minister, who shall be nameless, who spent a whole day going round the molecular biology laboratory in Cambridge and as he was leaving, said to the head of the laboratory: ‘Tell me, how big is a molecule? Could I hold one in my hand?’ Molecules are indeed very small. There are more molecules in a glass of water than there are glasses of water in all the seas. Even quite simple puzzles involving quantitation do not fit easily with common sense. If you tie a piece of string tightly around the equator, 20,000 miles, and then increase its length by 36 inches, so that it is now 20,000 miles plus 36 inches long, how big is the gap between the string and the earth all the way round? The answer is about 6 inches. I used to find that so counter-intuitive that I had to check it before each lecture.

Kaneman and Tversky, two psychologists, have put forward an interesting idea in relation to how people make judgments when they do not have total information; they call it representativeness, meaning that people tend to give undue weight to the most recently acquired information, or to the information they know best. If I ask whether more words in English begin with ‘r’ than in which ‘r’ is the third letter, most people opt for the first choice, but they are wrong. There are more words with ‘r’ as the third letter than with ‘r’ as the first. Another example illustrates the same point. If you ask one group of people to estimate quickly the total of 8 × 7 × 6 ×...× 2 × 1 and another group to estimate 1 × 2 × 3, up to 8, the first group will give a much higher estimate than the second. Both groups’ estimates will be far too low; the answer is 40,320.

One of the ironies about science is that you can lead a perfectly good life without knowing any science whatsoever. You may not be able to mend things or take part in any of the major debates related to genetic engineering, nuclear power and so forth, but you can survive perfectly well. Science involves rigour and quantitativeness not related to common sense. The rigour is the requirement to be internally consistent. Everybody seems capable of holding simultaneously

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*Professor Meade died in December 1995.
two completely contradictory ideas or beliefs. Unfortunately, this is not possible in science. It may be necessary to give up some of your common sense views, and that is quite difficult. I have never met anyone at a medical school who was not absolutely convinced that he or she knew how to choose the best medical students. All the evidence says that we are very bad at such judgments. Many clinicians will say 'Well, the trials show that this drug doesn't work, but in my experience...'. It is all too easy to convince oneself of the efficacy of a particular activity in all walks of life.

Clinical trials, with the exception of James Lind's trial in 1747 of lime juice for the prevention of scurvy, are a rather recent invention. It was not until the 1830s, with Pierre Louis' statistical studies, that science began seriously to question Galenic science. He told his critics: 'It is precisely because of the impossibility of judging each individual case with any sort of mathematical accuracy that it is necessary to count.' But his critics argued that no two cases are alike and that numbers threatened their clinical judgment. It took till as recently as 1946 for Bradford Hill to provide the first double-blind clinical trial on the effects of streptomycin.

People seem to have a natural preference for believing that their lives are determined by outside forces, to identify causes for which there is no evidence; astrology is an obvious example. Moreover it is ironic that the aspects of science that do attract them are those that are the most magical or mystical. It is not Newtonian mechanics nor chemistry that excites public attention, but the Uncertainty Principle, Chaos theory and the weirdness of quantum mechanics. It is as if uncertainty, or ignorance, is more thrilling than knowledge. People more often seem to prefer mystery to understanding, and I have the suspicion that beliefs in the mystical remain more or less constant over long periods; it is just its nature that changes. Witchcraft has been replaced by, for example, New Age beliefs, astrology and psychoanalysis.

The widespread use of alternative medicine testifies to the difficulty people have in coming to terms with science. It is perhaps a distaste for materialism and a longing for vital forces—an aching for spirituality. The founder of homoeopathy, Hahnemann, was a typical holist who viewed disease as an ensemble of deranged vital forces. This view essentially underpins most alternative therapies. It is also worth noting that in non-Western societies the idea that illness is inflicted by some human or superhuman agency is widespread.

**Technology**

Science is not the same as technology. Doctors are not necessarily scientists any more than engineers are. It is all too easy to conflate science and technology. The distinction is important when considering ethical issues in relation to the applications of science. Much of what we would think of as technology, such as metal-making and agriculture, goes back several thousand years, but that sort of technology owes absolutely nothing to science. The French anthropologist Claude Levi-Strauss writes that 'Each of these techniques assumes centuries of active and methodical observation, of bold hypothesis, tested by means of endlessly repeated experiments.' Reading that, one could think that technology involves understanding. However, I would argue that until the 19th century, or the late 18th century, science—by which I mean understanding in some mechanistic and causal way, rigorous and usually quantitative—played no role in advancing technology, with the possible exception of navigation. Metal-making and agriculture are all trial and error, and require insight of the same kind that chimpanzees use when they join rods together to bring down bananas from a tree. I do not disparage it; on the contrary, one of the characteristics of human beings is technology, whereas science is not a necessary human characteristic. One could be a good cook yet understand absolutely nothing about what is going on. A recipe for pot-making dating from several thousand years BC reads like a cooking recipe: 'Dip the pot in this glaze, then lift it out, fire it and leave it to cool, inspect the result of the glaze, put it back in the kiln, and so on.' The great Chinese inventions—gunpowder, the compass, printing—required no understanding of science. The great mediaeval buildings and churches were built with no understanding of mechanics. They were built on what Professor Hayman calls the 'five-minute theorem', that is, you put up one of these buildings, then take away the props and wait for 5 minutes; if it lasts those 5 minutes you can assume it will last for ever. It is a very good principle of statics. It has been argued that the Greeks could have invented the steam engine, since it did not require any science; the thermodynamicists came along later to explain why it worked.

My strongest argument that it is possible for amazing technology to arise without any understanding comes from evolution. No one would deny that the elephant is an amazing machine, yet it has arrived by natural selection, by random change, and evolution understands no science whatsoever.

I also have Galileo on my side: 'We are certain that the first inventor of the telescope was a simple spectacle maker who, handling by chance different forms of glass, looked also by chance through two of them, one convex, one concave, held at different distances from the eye, saw and noted the unexpected result, and thus found the instrument'. Things changed dramatically in the 19th century, but even in today's society there is an enormous difference between knowing how to do something and actually doing it.

The claim that science had no impact on technology until the 19th century is not true for medicine. Physical methods of treatment from Greek times, blood letting in particular, were based on humoralism. In a way it was an extension of Thales' watery
universalism. The four humours were blood, phlegm, bile and water. Even today many people think of illness in terms with which Galen would have felt at home, eg. repressed emotions. A doctor’s aim was to restore humoral balance by removing excesses. Letting blood was a way of reducing the amount of at least one humour. With Galen the concept of balance was strongly promoted and he advocated blood-letting as a major treatment. As his rationale he used an analogy with water irrigating fields: too much and there is swamping, so a breach may be necessary. Blood-letting continued as a therapeutic method well into the 19th century; in spite of his discoveries, Harvey never doubted its efficacy. In fact, Harvey’s discovery of the circulation of the blood had little relevance to cardiology until the 19th century.

**Origin of science**

It is highly relevant that science had only one origin, and that was in Greece; no other society ever developed a scientific approach to the world. The fact that it happened only once supports my argument that science is an unnatural mode of thought. The first recognised scientist in recorded history was a Greek called Thales who lived around 600 BC. Thales said that the world was made of water in different forms. According to the historian G Lloyd, Thales was the first person in recorded history to stand back from the world, take a detached view of it and try to understand the physical world in a non-mythical way.

Moreover, it was a personal view. Later other Greeks came along and said that the world was made of air in different forms, and the debate started. Why science should have started in Greece is not understood. It was Thales, too, who started geometry; he said that all circles were bisected by their diameters. He moved measurement to mathematics, making general statements about all circles in the universe, which was a very important step.

The greatest Greek scientist was Aristotle, but he believed the world was built on a common sense basis. Therefore most of his ideas about the world are wrong. His strength lay in logic and internal consistency. He had two genius ‘descendants’: one was Euclid who, although not the founder of geometry, formalised it, setting up a system of postulates from which to deduce theorems. The other was my hero Archimedes; I consider him to be as great as Newton and Galileo, because he was the first person to apply mathematics to understanding the world, and in a way he was the world’s first physicist. When he lay in his bath and worked out the loss of weight of a body when submerged, and then leapt out naked and shouted ‘Eureka!’, he had made a monumental discovery. His ideas about levers, to which he applied geometry, were also astonishing. Just look at the way he writes: ‘Let it be granted that bodies which are forced upwards in a fluid are forced upwards along the perpendicular to the surface.’ It reads like a first-year physics text-book. When Galileo, my other hero, says that he could never really have got anywhere without reading Archimedes, I believe him. The astonishing thing is that Archimedes’ ideas took so long to flourish, and it was only 1,800 years later, with Galileo, that they really took off.

I would argue that all science as we know it comes from the Greeks; Islam makes an enormous contribution, and, of course, there was the flowering in the Renaissance. What about the Chinese? Joseph Needham has written many volumes on science and civilisation in China. He makes it quite clear that the Chinese had very little science. They were wonderful engineers, but they had no geometry and had a rather magical approach to science. Albert Einstein when asked why it was only in Greece and Europe that science flourished, replied: ‘The development of modern science has been based on two great achievements—the invention of the formal logical system in Euclidian geometry by the Greek philosophers, and the discovery of the possibility of finding out causal relationships by systematic experiments at the Renaissance. In my opinion, one need not be astonished that the Chinese sages did not make these steps; the astonishing thing is that these discoveries were made at all.’ If it had not been for the Greeks there need never have been science, because science did not help anybody until the 19th century. Francis Bacon, when he forecast the benefits of science, was rather like a politician making promises, for it took another 200 years for any of the applications to be of practical use. Why was it in the West that science flourished? Without wanting to over-praise the Church, it is possible to assert that Christianity’s concept of a Creator, of laws, of internal consistency, really did play an important role. In about the 3rd and 4th centuries there was a theological dispute, the so-called Arian heresy, the question about the material relationship between Christ’s body and God’s body. The very fact that Christians wanted to have an internally consistent argument in this was a step towards science. St Thomas Aquinas even tried to turn religion into a science; he tried to marry Aristotelianism with religion. Taoism, the dominant Chinese religion, is very different. For example, a quotation from the Tao says: ‘Don’t meditate, don’t cogitate, follow no school, follow no way, and then you will attain to Tao.’ It may be the right way to spiritual liberation but not the way to do science!

Aristotle said that heavy bodies fell faster than light bodies. The story about Galileo who went to the top of the Tower of Pisa and dropped two bodies, one heavy and one light, and observed they reached the ground at the same time, is well known. In fact, the experiment had been done about 1,000 years earlier. The point about Galileo is that he suggested that it was not necessary to do the experiment since there was a logical contradiction in Aristotle’s statement.
'Imagine', he suggested, ‘that from the top of the tower we drop these two bodies, one ten times heavier than the other, and that Aristotle is correct. The heavy one gets there faster. Let us do the experiment again, but now we join them together. What will happen? The light one slows down and the heavy one speeds up. But together they weigh more than either, so according to Aristotle they should have fallen even faster!’ It took something like 1,800 years for someone to realise this internal contradiction, which strongly supports my argument that science is not built on common sense.

Creativity

Jacob Bronowski has written: ‘The discoveries of science, the works of art, are explorations—more, they are explosions of a hidden likeness. The discoverer or the artist presents them in two aspects of nature and fuses them into one. This is the act of creation in which an original thought is born, and it is the same act in original science and original art.’ It is a widely held view among scientists, and maybe among some artists, that the act of creation in science is very similar to that in arts. This is a somewhat romantic view; there are certainly similarities between creativity in any field but I have never heard any scientist say that his creativity in science is just like that of a creative accountant. By conflating the two, one loses the important differences between the arts and the sciences. Science is progressive; science approaches closer and closer to understanding the nature of the world. You cannot talk about art being progressive; art is about change. But there are many other differences. A work of art has a high emotional content; the original production is the crucial thing, and it has multiple interpretations. Compare that with Newton’s discovery of the calculus; nobody, except perhaps historians, would go back and read his description of the calculus—it is very difficult. The ideas have been incorporated into mathematics in a much more accessible form.

David Hilbert pointed out that the measure of a good scientific paper is how many other scientific papers it makes irrelevant. When Tom Stoppard wrote the play *Arcadia*, it did not in any way do away with *Hamlet*. Moreover, if there had been no Shakespeare, nobody would have written *Hamlet*. Ultimately, however, all scientists are anonymous and irrelevant; had it not been Faraday, someone else would have made the same discoveries in electricity. With the DNA story, if it had not been Watson and Crick, we know it would have been Franklin and Klug within a year. There are many instances of simultaneous discovery in science; there can be no simultaneous novels or simultaneous paintings. It is good to see the similarities between art and science, but not to see the differences confuses the issue. Of course, there is a great deal of creativity in science, but it is of a rather different kind from that in the arts.

I dislike the concept of serendipity. It is sometimes used to disparage science. When Fleming discovered penicillin, some said ‘Isn’t he lucky!’, yet he had spent most of his life looking for an antibiotic. When Pasteur was told that he had been very lucky, his famous, and probably irritable, reply was: ‘In the field of observation in science, fortune only favours the prepared mind.’

Philosophy and sociology

Having recognised that science is peculiar, one might have thought that either the philosophers of science or the sociologists of science, those professionals who devote their time not to doing science but thinking about science, may have illuminated its nature. The 20th century philosophers of science, including Karl Popper, have made virtually no contribution to our understanding of science. I think Popper’s idea that the only way science progresses is by falsification is itself flawed, and the reason why is contained in this quotation from Francis Crick: ‘A theory that fits all the facts is bound to be wrong, as some of the facts will be wrong.’ How does one know a falsification is correct? Moreover, the whole idea fails to deal with discovery. Science is a very complicated process; there is no algorithm for doing science, no general scientific method. Peter Medawar made it very clear: ‘If the purpose of scientific methodology is to prescribe or expound a system of inquiry, or even a code of practice for scientific behaviour, then scientists seem to be able to get on very well without it.’

The sociologists of science are a somewhat different group. There is a group who support what is called the Strong Programme in the Sociology of Science, who really do believe that all science is a social construct and that the natural world has a small or non-existent role in the construction of scientific knowledge. Their argument now is that the universalism of scientific truth is a myth, that we should abandon the idea of science as privileged or even a separate domain of activity and enquiry. Such ideas are widely taught at British universities by sociologists of science in courses on science studies. Relativism is rampant among sociologists of science. I recently wrote in the *Times Literary Supplement* that there is nothing that comes from the Strong programme which is not obvious, trivial or wrong, and I still hold this view.

Morality and science

Leo Tolstoy wrote: ‘Science is meaningless because it gives no answer to our question, the only question important for us: “What shall we do and how shall we be?”’ I agree with Tolstoy. Science has severe limitations; it does not tell us how to live our life, and it has nothing to say about ethics and moral issues. Once you know what you want to do you can apply science, and that can help you. I would also argue that religion and science are totally incompatible. However, individuals
can be deeply religious and outstanding scientists at the same time. This may be because religion is a natural mode of thought and science an unnatural mode of thought, and the two can live happily together. Faraday, a genius scientist, was a deeply religious man, and it is likely that a survey of scientists in this country would reveal that more than half of them are religious. My position, following David Hume, is that science is about reason and religion is about faith.

But what about scientists and their social responsibility? The big issues are nuclear energy, weapons and genetic engineering. I suggest that the scientists' only social responsibility, because of their access to privileged knowledge, is to explain to the public the implications of that knowledge and how reliable that knowledge is. It is not up to them to make the decisions. For instance, in relation to the atomic bomb, the scientists behaved with great moral responsibility. Robert Oppenheimer made the position very clear: 'The scientist is not responsible for the laws of nature, but it is the scientist's job to find out how these laws operate. It is the scientist's job to find the ways in which these laws can serve the human will. However, it is not the scientist's responsibility to determine whether a hydrogen bomb should be used. That responsibility rests with the American people and their chosen representatives.' On the other hand, I consider that the scientists committed to eugenics in the early part of this century behaved badly. They not only did not make the social implications of their work clear, and discuss its reliability, they actually perverted their science in order to put forward a particular social programme. Konrad Lorenz even drew an analogy between on the one hand, bodies and malignant tumours, and on the other a nation and individuals within it who have become asocial because of their defective constitution.

Where do we stand today with issues relating to genetic engineering? People have always had a fear of chimeras, and Frankenstein and his monster really pervade a great many discussions. In relation to genetic engineering, the fears are grossly overrated. As a cyclist in London, I claim that potholes are a much greater social danger than genetic engineering, because the danger is imminent, whereas genetic engineering and the whole human genome project has as yet harmed no one, and is in principle no more dangerous than any other medical treatment. This is not to say that there are no problems. Understanding people's genetic constitution does carry with it the problem of privacy, particularly in relation to insurance, and this is one problem that people will have to deal with.

Some people say that there is a tyranny of knowledge that comes with genetic engineering. For example, prenatal diagnosis is said to put enormous stress on people who must decide whether to terminate a pregnancy or not. With knowledge comes responsibility. You can decide not to have the test. Life is filled with difficult decisions. It is now possible to have a test for Huntington's chorea, which will enable young people to find out whether they will actually get the illness. Surveys show that not everyone wants to take the test but that people want the test to be available. My own position is that the decision on most of those things must be left to the individual, not to the doctors and not to the scientists. The scientists' social responsibility is to make the implications clear and to point out the test's level of reliability.

In the House of Commons Dame Jill Knight MP recently attached a clause to the Criminal Justice Bill which outlawed the use of eggs from aborted fetuses. I do not think it is her right to do that without bringing it first into the public domain for wide discussion. Then if parliament wishes to take a decision it can do so. I object to any expert, or anyone with a particularly strong personal view, making the decisions for us. I strongly support the following quotation from Thomas Jefferson in relation to the public understanding of science: 'I know no safe depository of the ultimate powers of the society but the people themselves, and if we think them not enlightened enough to exercise that control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion.'

I end with the words of Einstein, which again reflect on the peculiarity of science: 'The greatest mystery of all is the partial intelligibility of the world.'

Further reading

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Address for correspondence: Professor L Wolpert, University College London Medical School, Dept of Anatomy and Development, The Windleyer Building, Cleveland Street, LONDON W1P 6DB.