Science and anti-science
The Lloyd-Roberts lecture 1986

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And The Lord God commanded the man, saying, Of every tree of the garden thou mayest freely eat: But of the tree of the knowledge of good and evil, thou shalt not eat of it. . . .

Most of our anxieties, problems, and unhappiness today, stem from a lack of purpose which was rare a century ago and which can be fairly blamed on the consequences of scientific enquiry' [1].

These two quotations, though separated by several thousand years, give some sense of the fear of knowledge and the idea that science corrupts. The second quotation is from a letter to The Times in 1975, from the now President of the Royal Society.

Current attitudes to science seem to me to indicate both ambivalence and polarisation. While there is much interest and admiration for science—some would say a religious devotion [2]—there is also, for some, a deep seated fear and hostility, and several lines of criticism [3]. Science is perceived as materialist and of having caused, not only the loss of purpose referred to, but also the threat of nuclear warfare, and the general disenchantment with modern industrial society which pollutes and dehumanises. Science is seen by the relativists as just another faith; and by others as a discipline whose practitioners are cold, unfeeling technicians whose conservatism is highly suspect. The fear of genetic manipulation of embryos looms large. By contrast, belief in the paranormal, astrology and fringe medicine seems to be on the increase.

Some of these ideas are not new. The biblical tree of knowledge, for the tasting of which man was expelled from Eden, was not only about the knowledge of good and evil. Milton, in Paradise Lost, has the serpent addressing the tree:

O sacred, wise, and wisdom giving plant,
Mother of science, now I feel thy power
Within me clear, not only to discern
Things in their causes, but to trace the ways
Of higher agents, deemed however wise

Milton, whose sentiments reflect quite a lot of today's feeling, also advised against too much curiosity. When Adam tells the Archangel Raphael that whilst his thirst for knowledge has been largely satisfied by what Raphael had told him about the Creation . . .

Something yet of doubt remains,
Which only thy solution can resolve
When I behold this goodly frame, this World,
Of Heaven and Earth consisting, and compute
Their magnitudes—this Earth, a spot, a grain,
An atom, . . .

. . . I oft admire,
How Nature, wise and frugal, could commit
Such disproportions . . .

Raphael's response is rather patronising. He doesn't blame Adam for asking, but

. . . the Great Architect
Did wisely to conceal and not divulge
His secrets, to be scanned by them who ought
Rather admire.

God is rather amused by their 'quaint opinions'. What, Raphael asks, does it matter if the Sun be the centre of the World? His advice is:

Solicit not thy thoughts with matters and:
. . . Be lowly wise
Think only what concerns thee and thy being

But that was not the predominant tone of the 17th, and, particularly, the 18th century. In the 17th century, as Willey has described [4], interest began to be directed at questions of how and not at why, and less was asked of final causes. The two types of explanation are of quite a different kind. Traditional scholasticism was a major obstacle to truth because it discouraged enquiry and relied on Aristotle and the Scriptures. The new age of inquiry removed all that. But some commentators trace our present chaos to the loss of God-consciousness. The Renaissance to them is akin to a second Fall of Man. For example, Dawson [5] wrote:

'The Western mind has turned away from the contemplation of the Absolute and Eternal to the knowledge of the particular and contingent. It has made man the measure of all things and has sought to emancipate human life from its dependence on the supernatural'. Willey perceived the nature of explanation as the desire to be rid of mystery, and as removing fear and dependence. But in so far as science succeeds in just this way, it
dehumanises. While this sounds very plausible, its validity is suspect. Is science really responsible for the decline in the power of religion?

The trial of Galileo is usually taken to illustrate the conflict between science and religion. But Galileo took great pains to determine the theological status of the incorruptibility of the heavens. In his letter to Castelli (1614) he asked why Holy Writ should be used to support false science. A devout Catholic, he never wished to oppose the Church and always respected its authority. How then can we reconcile his ability to be a great scientist with his deeply moral sense of value and religious belief. But, on Galileo’s victory, Willey wrote:

‘In so far as it lead to any undue elevation of empirical truth and an attribution to it of a special privilege to represent reality, it was a disaster.’ Here are the seeds of relativism, to be discussed later. Galileo’s attachment to empirical truth seemed to have very little effect on his faith; this is true of many other great scientists. Newton—the giant—was deeply religious. Bacon, who more than anyone attacked scholasticism, Aristotle and abstract speculation, made every attempt to keep science and religion separate, keeping his own faith and humility. The arch-sceptic, David Hume, claimed that ‘Our most holy religion is founded on Faith, not on reason’. In fact, Robert Merton argued that there is a positive relation between science and religion, particularly Puritanism [6].

One should be very cautious in assuming a radical decline in recent years of religious beliefs, or that it is due to science. According to Bryan Wilson [7], sociologists perceive secularisation in terms of the shift of power from elites with access to supernatural ordinances, to other bases of power, a shift dictated by economic forces in which technology makes a major contribution. Much of the change is due to industrialisation, not to science. It is just worth remembering that while there is a trend towards secularisation in Poland, churches are full and more are being built. This has nothing to do with science.

It is interesting to see how sociologists perceive industrialisation [8]. Industrial technology uniquely substitutes inanimate power for that derived from human effort and this allows a much greater scope in the location of places of work. This in turn leads to the progressive separation of the household budget from the industrial enterprise and results in a major break with past traditions. A characteristic of large-scale production is the essential use of ‘rational calculation’ and this calculation is extended over all realms of society. All this, rather than science, leads to an awareness of alternatives to the established tenets; the difference between ‘closed’ and ‘open’ cultures. The latter are scientifically orientated. Max Weber wrote: ‘... every economic rationalisation of a barter economy has the weakening effect on the traditions which support the authority of a sacred law.’ And on rationalisation, ‘It means that there are no mysterious incalculable forces that come into play, but that one can, in principle, master all things by calculation [9].

The idea of rationalisation is at the core of Weber’s concept of industrialisation [10]. While the concept is complex, a key aspect is the ‘... substitution of the unthinking acceptance of ancient custom, of deliberate adaptation to situation in terms of self-interest’. Perhaps it is this self-interest that drives science, for that is the best road to understanding, rather than vice-versa. All this is intimately bound up with the development of Capitalism. But, Weber argues, it was not just the capitalist spirit that drove science. It was also the change in ethical outlook brought about by the Reformation that was essential. So perhaps it was religion that was the driving force of science, and not the other way round.

I wish to draw a sharp distinction between science and technology. As Hall [11] said, science is knowledge of our natural environment and technology is the exercise of a working control over it; and in the 18th century natural philosophy grew by increasing knowledge, whereas invention sprang from ingenuity. He summed up the period 1660–1760 with respect to technological change: ‘We have not much reason to believe that in the early stage, at any rate, learning or literacy had anything to do with it, on the contrary, it seems likely that virtually all the techniques of civilisation up to a couple of hundred years ago were the work of men as uneducated as they were anonymous.’ Even the steam engine depended more on the blacksmith’s world than on the Royal Society. But it is not possible to analyse historical events in terms of linear cause and effect. As Mathias [12] puts it, ‘it is a banal, but I would argue valid, argument to think that science and technology moved forward together and they should be seen as characteristics of that society and not one being simply consequential upon the other.’ We should not reify science, and should hesitate in blaming science for complex social events.

But has magical and religious belief really declined or just become less overt? David Martin [13] pointed out that it is necessary to examine more than just the figures for church attendance. Superstition is still strongly with us. On secularisation in the so-called age of science, Martin wrote,

‘... far from being secular our culture wobbles from being a partially absorbed Christianity, biased towards comfort and the need for confidence, to belief in fate, luck and moral governance incongruously joined together. If we add to these layers of folk religiosity the attraction of Freudianism and Marxist mechanics for segments of the intelligentsia, it is clear that whatever the difficulties of institutional religion they have little connection with any atrophy of the capacity for belief.’

In Martin’s view vast numbers of people work on two basic principles: one is the rule of chance—fate, the other is a moral balance in which wicked deeds are punished. I believe that many of us subscribe to this magical image of the world.

One of the characteristic features of magical thought that makes it so different from science, was made clear by Keith Thomas [14]: ‘Once their initial premises are accepted, no subsequent discovery will break the believer’s faith, for he can explain it away in terms of the existing system.’ This is an important statement of what science is not. A Greek poem by Agathias (582–536 BC) about a farmer, Kalligiones, who consults an astrologer about his crops [39], illustrates this nicely.
The astrologer cast his stones across the board, studied them, wiggled his fingers and said: ‘If Kalligenes, there is rain enough on enough of your land, and if the weeds don’t take over, nor frost wreck the lot, if a hailstorm doesn’t knock it all flat if the deer don’t nibble, if no calamity up from the earth or down from the sky. Occurs, the signs show a good harvest. Unless there’s a plague of grasshoppers.’

Thomas accepts that the decline in magic was accompanied by—not necessarily caused by—the growth of science. While magic was seldom invoked when a technical solution was available, the contrary was not true. The mere absence of understanding did not in itself generate magic. Moreover, the sociological theories emphasise that changes in the structure of society precede changes in belief. But even this area has problems. Magic, according to Thomas, was on the decline before the rise of science and technology. How, for example, can one account for the 14th century Lollards, a religious sect, who denounced the church’s supernatural protection against disease or infertility, yet had nothing with which to replace it. Even in the 17th century the decline of magic in relation to medicine was not due to improvement in treatment. Harvey did nothing practical for medicine. It can be argued that medical innovations based on science did little to prolong life until the late 19th century.

Perhaps for most people it is authority that determines most of the population’s basic assumptions about science and religion and magic. As Ernest Jones [15] said, ‘The average man of today does not hesitate to reject the same evidence of witchcraft that was so convincing three centuries ago, though he usually knows no more about the true explanation than the latter did.’

The origin of some of our current anti-science movement is clearly seen in the work of the romantic poets, particularly Wordsworth and Coleridge. Wordsworth regarded the mechanical philosophy as yielding a ‘Universe of death’. The 19th century origins of the romantic anti-science movement is more clearly seen in Coleridge’s work. He was also an early anti-reductionist and obsessed with the difference between the living whole organism and the idea of the mechanical juxtaposition of parts.

‘My mind feels as if it aches to behold and know something great, something one and indivisible.’ And, ‘We have purchased a few brilliant inventions at the loss of all communion with life and the spirit of nature.’ This can be compared with D. H. Lawrence, [16] the more modern representative:

‘Give me the mystery and let the world live again for me.’ Or, even more explicitly:

‘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.’

Dostoyevsky [17] felt that science had removed freewill:

‘Therefore all there is left to do is to discover these laws and man will no longer be responsible for his acts. Life will be really easy for him then. All human acts will be listed on something like logarithm tables, say up to 108,000 and transferred to a time-table . . . They will carry detailed calculation and exact forecasts of everything to come, and so no adventure and no action will remain possible in this world.’

There are many other quotations: Mary Shelley’s Dr Frankenstein, and Huxley’s Brave New World give evidence of a powerfully emotive anti-science movement. Science is dangerous, so the message goes—it dehumanises, takes away freewill, is materialistic and arrogant, and removes mysticism [18]. These ideas did not come from the evidence of history or the studies of sociologists. They came from the creative artists who have moulded science in their image. It was Mary Shelley who created the monster, not science. In the face of this hostility one cannot help recalling the remark of American literary critic, Lionel Trilling [19], on the difficulty non-scientists have in understanding science:

‘This exclusion of most of us from the mode of thought which is habitually said to be the characteristic achievement of the modern age is bound to be experienced as a wound to our intellectual self-esteem.’

This could be an important clue. However, if these ideas are so widely held, we must try to understand the desire for mysticism and the hostility to science, we must find out how correct is David Martin’s statement that, though religious institutions may have been weakened, there is no evidence for atrophy in belief. Magic and superstition are still with us, witness the success of astrology. It is claimed that two-thirds of all people read their horoscope, if only occasionally, and that in 1968 there were 10,000 full-time and 175,000 part-time astrologers in the USA. In this country, 75 per cent believe astrology to be scientific. While we may conduct our public lives with little reference to magic and superstition, our private lives give a different picture. Even in public there are some striking examples. When the queen visited Germany in 1965 one of the houses she was to visit had its number altered from 13 to 12A. The press and television show an unusual interest in anything that might be regarded as outside science—ghosts, telepathy, miracle cures, and Uri Geller. On the whole, these are so silly that they do not merit serious attention, but some, like Sheldrake’s ideas of morphic resonance, are so widely publicised that it is necessary to give them the attention they do not deserve.

I am frankly hostile to the paranormal, partly because it deals with such apparently trivial phenomena, but mainly because it is anti-science in that it stops serious thinking about the world. One of my objections to pseudo-science and the paranormal is that these are ways of getting knowledge on the cheap. Whereas conventional scientific knowledge is obtained in a very tedious and painstaking way, with breakthroughs and flashes of insight being rare events, it is characteristic of the paranormal that major knowledge is easily obtained without any special knowledge. Anyone can do it. Almost no training is necessary. I have only to compare how hard it is to
establish in my field even a very simple piece of knowledge—such as when the cells in the developing arm make the decision to become a humerus—and the case with which levitation and psychokinesis can be established. Whereas my tiny bit of information takes many man-years, levitation, even though it invokes unmeasured forces and challenges the basis of physics, can be established and apparently accepted in man-seconds. In this sense the paranormal makes anyone an expert because it is personal experience that matters and the wound to self-esteem given by not understanding science is healed.

It is this lack of requirement for scientific knowledge, together with vitalism, that links so much of the paranormal and fringe medicine. Vitalism is an idea that gives man and life a special quality outside science. Vitalism is, in some ways associated with an anti-reductionist stance. The view is that life cannot be reduced to physics and chemistry and a more holistic approach is required. There is a genuine problem about how to relate different levels of organisation to each other, and which is the more appropriate for a particular set of problems, but that is not what the anti-reductionists and vitalists have in mind. For them, it effectively restores the soul and makes an after-life possible. It also provides humans with magical forces to directly control their environment.

The strong similarity between the mode of thought of those involved in the paranormal and those who support holistic medicine can be seen in the British Holistic Medical Association's [20] comments on the BMA's report on holistic medicine. The arguments put forward are a nice example of the anti-science movement, though they are not overtly meant to be so. The holists and paranormalists are closet scientists longing for the respectability that science might give their magic. The holists are strongly relativist in their position: knowledge is seen as a social product. 'The fallacy of clinical trials is that, when rigidly applied, they remove the factor of interaction between the subject and researcher.' This makes disproof of ideas almost impossible and reminds one of the Greek poem and how capricious paranormal events are supposed to be. Worse still, a reductionist approach cannot study wholes and 'orthodox scientific enquiry is inadequate for the study of human beings who cannot be reduced to mechanical and chemical machines.' Here we have Coleridge and vitalism again. Finally, science, it is argued, is 'driven as much by passion and bias as by careful and systematic observation', a point which is about the image of science, to which I shall return.

There is considerable sympathy with the paranormal, and vitalism is deepseated. Perhaps this is due to a desire to cling to the soul and immortality. Perhaps the scientific mode of thought is unnatural. Another viewpoint comes from the work of psychologists on judgement under uncertainty [21]. Experimental work shows that people rely on a limited number of principles which reduce the complex task of assessing probabilities to simpler judgemental operations [22]. To take a very simple example, people expect that a sequence of random events like tossing a coin is more likely to yield H-T-H-T-H-T than H-H-H-H-H-H, which is in fact not the case. The studies show that people find it quite difficult to think scientifically in everyday situations. A particularly interesting approach to understanding how people assign causes to events is the attributions theory of Kelly. Several features are of great interest to us here. The theory claims that 'preference for simple rather than complex explanations not only is characteristic of children but also persists into adulthood' and that 'the role of a given cause in producing a given effect is discounted if other possible causes are also present.' Surprisingly, there is evidence that one of the very reasonable assumptions made by attribution theory [23] is not valid—namely, that people are influenced in the causal attributions by knowledge of the behaviour of others. Part or all of this irrationality may stem from our difficulty in dealing with dry data, particularly of a statistical nature, and our tendency to rely on information that carries a greater clout—a point not missed by the advertising industry. As Bertrand Russell pointed out [24], 'popular induction depends on the emotional interest of the instances, not upon their number.' Scientific validation of our ideas is very hard work, not least because we have to behave in what begins to appear to be an atypical manner. We have to give up basic beliefs and perhaps accept that there is no simple linear cause; it is this again that makes the facile theories of fringe medicine so attractive. Magic can be seen as a means of defending the self against the hostile world, a concept not easily given up. Scientific modes of thought may be psychologically uncomfortable. Knowledge can be very painful. An example is evolution—it is counter-intuitive and for many emotionally unattractive. It is not surprising that it generates so many attacks.

I cannot help being struck by the similarity between certain paranormal beliefs and the magical practices of children so well described by Piaget [25]. In many cases the child is under the impression that reality can be modified by a thought and has the animistic belief that the will of one object can act on itself and on that of others. There is a magical causality according to which all things resolve about the self. A lovely example of such feelings comes from Edmund Gosse who was brought up in a most unmagical environment. But by the age of five or six he had: 'formed strange superstitions, which I can only render intelligible by naming some concrete examples. I persuaded myself that if I could only discover the proper words to say, or the proper passes to make I could induce the gorgeous birds and butterflies in my Father's illustrated manuals to come to life, and fly out of the book, leaving holes behind them.'

Perhaps we find it hard to escape from such modes of thought.

It may be illuminating to look at how we think about illness, where our ideas have a strong cultural bias [26]. There are a whole series of 'logics' about illness which relate to degeneration and mechanics—such as blockage, balance and invasion. As Kleinman points out, 'laymen are not as concerned with the theoretical rigour of their beliefs as the treatment options they give rise to.' For example, one popular model of illness and health perceives the body as struggling to maintain its integrity in the face of threats from toxins, germs, anxiety and stress.
Disease results from the failure to live according to nature’s laws [27], which is just what Thomas and Martin said in relation to magic and belief. Or consider the widely held view that upper respiratory infections come from cold air or water entering vulnerable areas such as the feet. Coldness can migrate from the head to the nose; from the feet to the stomach. They can be treated by counteracting the coldness with warmth. I do not mock, for such ideas are part of my own upbringing and I find it very hard to abandon such beliefs. It is on such basic misconceptions that fringe medicine unconsciously trades. I also wonder how many clinical treatments are based on irrational conceptions.

The criticism that scientists work with a passion and bias which must invalidate their work is based on the false image of science which implies that it is essentially cold, logical and impersonal. While the final results may be, the process is not. I do not wish to try to define scientific method but would argue that it is not all that different from that of the historians: a search for explanation, connections, the process of validation and verification, and falsification of ideas. What makes the study of history different is less the approach than the subject matter. The false image of science leads to the view that there is a scientific method, and fails to appreciate the variety of styles with which different scientists work and how different ecology may be from particle physics. There is even surprise that scientists should disagree; after all, the evidence is there and agreement should be easy.

One of the accusations made against science is that it is highly conservative and rejects new ideas that do not fit with current views. A recent Horizon programme went so far as to claim that, in science, there was no refutation by experiment and things became true because they were powerful. One begins to get an image of the neglected brilliant scientist levitating in his basement, rather like the starving artist in his garret. I am amazed at a sociologist’s claim that the ‘history of suicides and cases of mental breakdowns among scientists whose ideas have not been accepted’ remains to be written [28]. That such an image is false is shown by the transformation of biology by molecular genetics which occurred over just a few years around 1950 and met with very little resistance. Sangers’ sequencing of insulin, and the solving of the structure of DNA were decisive. By contrast, the acceptance of continental drift took a long time. It was put forward by Wegener in the 1920s, and even in the 1950s was taken seriously by very few, yet by the 1960s the situation was completely reversed. Hallam [29] suggests that, in part, the reason was the discovery of new geophysical data, particularly new palaeomagnetic work, and that Wegener’s proposed forces for moving the continents were inadequate. But he concludes that the main resistance was innate conservatism; geology had almost to start all over again. But while we might, with hindsight, regret how slowly the new ideas were accepted, we must also accept, as Barnes [30] pointed out in relation to the acceptance of meteorites, that there must be much filtering, and this takes time. We need very good evidence before giving up established and apparently good ideas. Facts and ideas that undermine our current beliefs need, finally, to be very persuasive and a nice case is Hoyle’s view about bacteria from outer space. Thus, I might produce some evidence that the Queen is a Russian spy. It is not impossible, but amazingly persuasive evidence would be required. As with Hume’s treatment of miracles, ‘... no testimony is sufficient to establish a miracle, unless the testimony be of such a kind that its falsehood would be more miraculous than the fact which it endeavours to establish’. We should not be frightened to reject the absurd [31]. Popper’s falsification criterion is not enough to make an hypothesis part of science. Consider, for example, that tiny particles of meat are the source of the poetic muse. Should we investigate the effect of hamburgers on the ability to write poetry?

One of the recent attacks on science has recently come from diverse groups—sociologists, philosophers—under the guise of relativism. The basic idea is that knowledge is socially conditioned and culturally determined and there is no one truth about the external world. All beliefs become equally valid. Scientific truth is an illusion. It is even argued that any set of observations is compatible with any number of theories’ [30]. If it is the case that there are an infinite number of theories which will account for the observations of classic genetics or the genetic code, it would be helpful if those who believe this would, from that vast panoply, name just one or two. It is the essential nature of science to try to find just one theory that is both internally consistent and fits the facts. I cannot here counter this essentially philosophical argument about relativism which arises in part because of the difficulty in deciding just what is science and scientific method. A non-relativist view is given by Ernest Gellner [32]. Related to relativism is the idea that quantum mechanics and Heisenberg’s Uncertainty Principle have undermined science and destroyed reality. I am even further out of my depth here, but am assured by my physicist friends that extrapolation from the micro world of quantum theory to macroscopic phenomena is not simple. My own position is that I find it reasonable, from both a pragmatic and empirical point of view, to think that we have a coherent real world which is, within limits, understandable. As Freud [33] put it: ‘No, our science is not an illusion. But an illusion it would be to suppose what science cannot give us we can get elsewhere’. Science does not resolve our moral choices, it can make the choices more rational, explicit, and meaningful.

The core of hostility to science may spring from the failure of science to answer our main moral preoccupations—the meaning of life and death—and inevitably leads to disappointment and possibly rejection. For Tolstoy, ‘Science is meaningless because it gives no answer to our question, the only important question for us: “What shall we do and how shall we live?”’. Science has nothing to offer on matters such as whether life is worth living—but helps only when we know what we want to do. But what is seldom explicitly spelled out is that the problems facing any society are severe and solutions very difficult. There is a whiff of Utopian sentimentality; the image of the Noble Savage lurks in the undergrowth. Those who decry technology, must be asked what they are prepared to give up: the motor car, or electricity?
But more serious is the illusion of solvability. Not all problems are solvable by technology or by science. Arrow’s theorem shows that where there are conflicting demands for resources or life styles in a community it is in principle not possible to find a rational solution [30]. There is no optimum. I cannot overemphasise the importance of this result for the appreciation of problems of our society on both the large and small scale. One should also be aware that the behaviour of complex systems may be unpredictable, though causal [34]. It is an illusion that science can provide solutions to all problems. In fact, that idea has been grossly oversold not least in medical fields, such as cancer and heart disease, and has done science severe damage.

The modern relationship between science and technology is quite different from that up to 150 years ago. There is now a real fear of knowledge. Again, I draw a sharp distinction between science and technology. This distinction is illustrated by the inability to predict how scientific knowledge can be applied; as Paul Valery said, ‘We enter the future backwards’. In 1892, Pearson regarded radio waves as having no useful application. Again, the basis of genetic engineering could not have been foreseen. A key tool is restriction enzymes that cut DNA at specific sites. Their discovery arose from the study of a particular problem related to the behaviour of certain bacteria with respect to viral infection. This unexpectedness is a characteristic feature of science. It is quite impossible to predict what will or will not be discovered, except in the cruelest terms.

George Steiner failed to recognise these points in his 1978 Bronowski Memorial Lecture, and exemplified the current fear of knowledge. He asked for example, ‘Should cloning be allowed; should research into and experimentation with recombinant DNA be pursued or stopped?’ Steiner considered that the search for pure truth may be of the highest intellectual fascination but the understanding given us may be of a kind which society cannot handle ‘...certain orders of truth would infect the marrow of politics and would poison beyond cure the already tense relations between social classes and ethnic communities. In short, there are doors immediately in front of current research which are marked ‘too dangerous to open . . .’. He is, for example, thinking about possible ethnic differences with respect to intellectual abilities.

This does raise real problems but these are less about the social implications than about being correct. Scientists have a major social responsibility not to make claims for the reliability of their work in socially sensitive areas beyond that which they can really demonstrate.

The distinction between pure and applied science has to be emphasised. The boundary is not sharp but the distinction is important. Thus, I do not necessarily regard doctors and engineers as scientists. It is a distinction between knowledge and its application. No one blames the massacres of World War I on science, even though the killing was done with guns. Why then should science be blamed for nuclear weapons and pollution? It is, as Medawar says, to commit the elementary blunder of blaming the weapon for the crime. It is all too convenient to shift responsibility from ourselves to science. It is we who are responsible. For example, as Michael Berry pointed out, a steel worker can work out what fraction of his output will be used for guns, knives and bombs. Some of his output will be used for purposes he does not approve of. The same is true of our taxes and it is true of physics too. When physicists create something it becomes public property, part of our culture. They have no control of it, other than through the standard means within a democratic society—which involves all of us.

Scientists have no more or no less responsibility to society than anyone else. With respect to knowledge they have the same responsibilities as any other workers—decency, honesty, safety and so on. They have a responsibility to their field and colleagues but no special social responsibility as scientists. There is good and bad science, important and trivial science, but these are not issues of social responsibility. As for the applications of science, the scientist has no particular responsibility. Robert Oppenheimer said ‘The scientist is not responsible for the laws of nature, but it is a 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 job to determine whether a hydrogen bomb should be used. This responsibility rests with the American people and their chosen representatives.’ Those who call the American scientists irresponsible for building the bomb should consider their verdict if the scientists had refused and the bomb had been built by Germans or Russians. With the terrible exception of the Nazi scientists [35], history has not shown scientists to be irresponsible.

Marx was essentially against the ecology movement and was for transforming nature with technology. He did not see a harmonious unity in nature. He saw not the beauty of the forest, but the bitterest competition among plants and animals and how the tall and stately oaks, like tall and stately capitalists, consume the nutrients of the tiny shrubs [36].

Great care should be taken by those who wish scientists to be more socially responsible. Do they really believe that scientists have special skills which will enable them to make, what are, in essence, ethical and social decisions? Do they really wish to give up to the scientists their right to participate in the decision-making process? Would they be prepared to leave to scientists decisions as to what defence systems to build? To make the scientist so powerful would be a mistake.

But there is clearly considerable anxiety about genetic engineering. I have asked many people what is their worst fear of the outcome of genetic engineering and, while responses vary considerably, there is undoubtedly considerable distaste for tampering with nature together with a fear of monsters being created. The image of Dr Frankenstein looms large. I think this reflects the ignorance of the nature of the science involved. For the further these fantasies are explored the less likely they become. If we are a society that restricts abortion, bans euthanasia, and is very sensitive about vivisection, how is it conceivable that we will breed a race of apelike slaves? Who would bear clones? Each case followed in detail turns out, I believe, to be implausible. Whereas problems of abor-
tion and euthanasia are low-level technology, the very term genetic engineering makes for alienation and implies a technology which most people think they cannot understand.

Some of these problems have been analysed by Jonathan Glover [37]. In considering how far we should adopt policies that change human nature he asks how different genetic engineering is from what we already do by means of church, school, mate selection and genetic counselling. Genetic engineering raises new moral problems but they are essentially similar to the old. They are obfuscated by the wrong images of science. Also, the idea of the chimera is a very old one and touches our psyche deeply. This may reflect that many of our taboos are, as Mary Douglas [38] showed, often related to boundaries. Crossing species is just the sort of boundary that may be expected to create the prohibitions which are currently being invoked. May be our vitalistic soul-demanding impulses are being threatened. Thus, it is striking that Enoch Powell, in introducing his bill to ban experiments on human embryos, refers to the repugnance being '. . . an instinct implanted in human society.' He recognises that the prohibition is of the acquisition of 'useful and beneficial knowledge'. His position is that the research is to be banned as it 'outrages the instincts'. This is a frightening stance which we must resist. It is the epitome of anti-science and anti-knowledge.

There is a marked ambivalence towards science and, if we fail to recognise it and analyse it, we will not be able to combat it. Better public understanding of science, as recommended by the Royal Society, will help but will not resolve the problem. I offer no simple solution. Science is difficult and an unnatural mode of thought. I am aware of many defects in the scientific community and of science's limitations. But, as an attempt at true knowledge of the world, science, like liberty, needs defending.

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