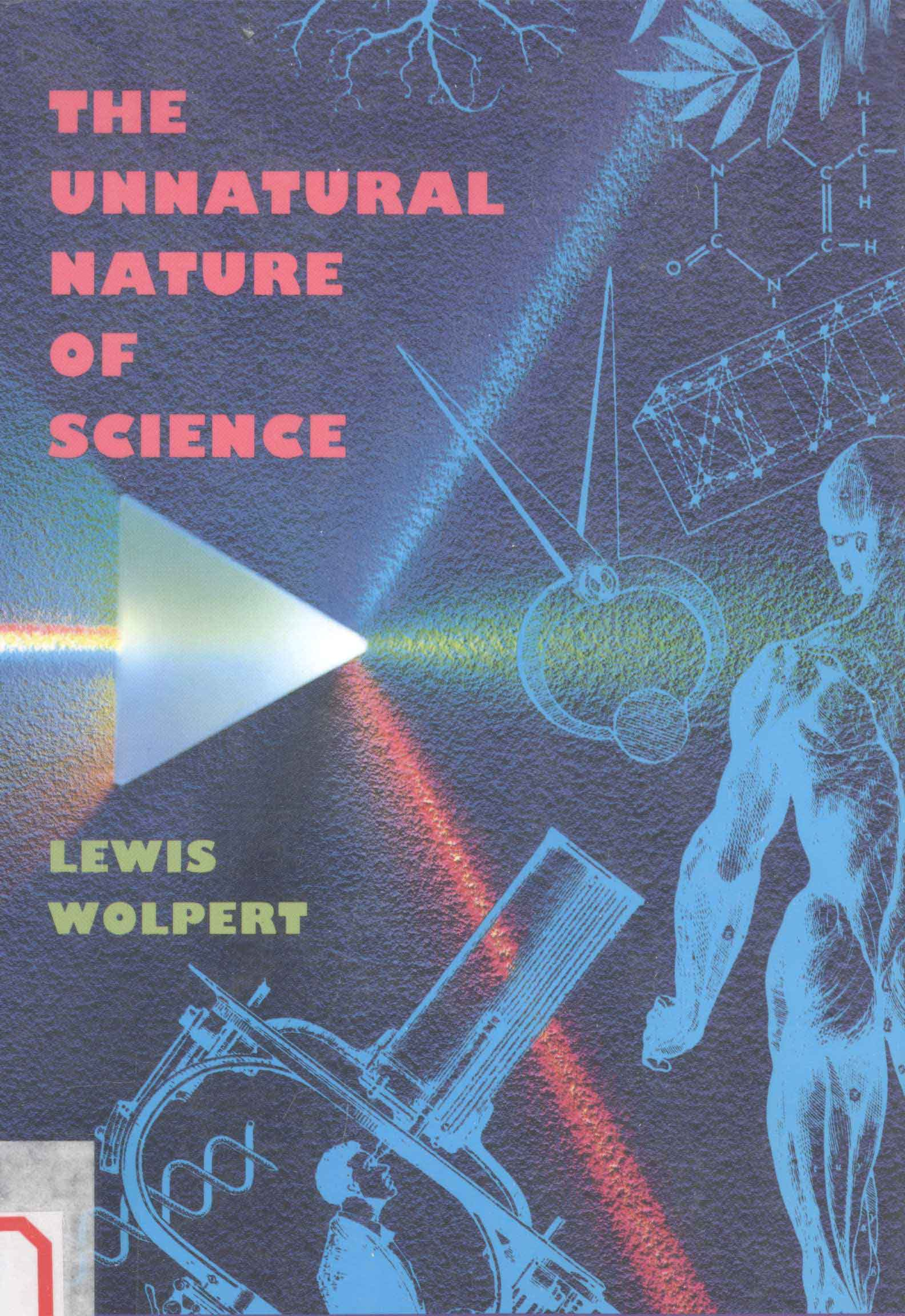
THE UNNATURAL NATURE OF SCIENCE



LEWIS WOLPERT

hy science does not make (common) sense

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HARVARD UNIVERSITY PRESS
CAMBRIDGE, MASSACHUSETTS

Printed in the United States of America
This book has been digitally reprinted. The content remains identical to that of previous printings.
Published by agreement with
Faber and Faber Limited, London

First Harvard University Press paperback edition, 1994

Library of Congress Cataloging-in-Publication Data

Wolpert, L. (Lewis)
The unnatural nature of science / Lewis Wolpert.
p. cm.
Includes bibliographical references and index.
ISBN 0-674-92980-2 (cloth)
ISBN 0-674-92981-0 (pbk.)
1. Science—Philosophy. 2. Science—Social aspects. I. Title.
Q175.W737 1993 92-40510
501—dc20 CIP

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Preface

This book has its origin in dissatisfaction and a puzzle. The dissatisfaction is with the public image of science and with much of the writing about science in the media as well as that by academics including philosophers and sociologists. The puzzle is why the nature of science should be so misunderstood and why non-scientists have so much difficulty understanding scientific ideas. This lack of understanding seemed to be linked to a certain fear of and even hostility to science itself.

So I have tried to present science in a new light, which I hope will help to resolve some of these problems. By dealing with so broad a topic as the nature of science, I have inevitably touched on areas in which I have no formal training such as philosophy, psychology and history. I am by profession a research biologist in the field of embryology, and my approach can best be characterized as that used in natural history. I have therefore sought much advice, some of which is acknowledged below, and I am very grateful to everyone who has helped me. I am also indebted to Warwick University for inviting me to give the 1990 Radcliffe Lectures on 'Science: An Unnatural History', which laid the foundations for what is presented here.

I thank Percy Cohen, Stephen Cang, Patricia Farrar, Christopher Gardner, Jonathan Glover, Mary and Jack Herberg, Judy Hicklin, Frank James, Jonckheere, Roger Jowell, Michael Kidron, Roland Littlewood, Lauro Martines, Arthur Miller, Timothy McDermott and Mary Tuck.

Maureen Maloney needs special thanks for her patience in preparing the manuscript.

I am also specially indebted to my editors, Bob Davenport and, foremost, Susanne McDadd.

Introduction

> Knowledge has killed the sun, making it a ball of gas with spots . . . The world of reason and science . . . this is the dry and sterile world the abstracted mind inhabits. *D. H. Lawrence*

> Modern science . . . abolishes as mere fiction the innermost foundations of our natural world: it kills God and takes his place on the vacant throne so henceforth it would be science that would hold the order of being in its hand as its sole legitimate guardian and so be the legitimate arbiter of all relevant truth . . . People thought they could explain and conquer nature – yet the outcome is that they destroyed it and disinherited themselves from it.
> *Václav Havel*

> A public that does not understand how science works can, all too easily, fall prey to those ignoramuses . . . who make fun of what they do not understand, or to the sloganeers who proclaim scientists to be the mercenary warriors of today, and the tools of the military. The difference . . . between . . . understanding and not understanding . . . is also the difference between respect and admiration on the one side, and hate and fear on the other. *Isaac Asimov*

Science is arguably the defining feature of our age; it characterizes Western civilization. Science has never been more successful nor its impact on our lives greater, yet the ideas of science are alien to most people's thoughts. It is striking that about half the population of the United States does not believe in evolution by natural selection and that a significant proportion of British citizens does not think the earth goes round the sun. And I doubt that of those who do believe the earth moves round the sun, even one person in 100,000 could give sound reasons for their conviction (the evidence and the arguments for such a belief are in fact quite complex). Indeed, many people accept the ideas of science because they have been told that these ideas are true rather than because they understand them. No wonder the nature of science is so poorly understood. Instead it is viewed with a mixture of admiration and fear, hope and despair, seen both as the source of many of the ills of modern industrial society and as the source from which cures for these ills will come.

Some of the anti-science attitudes are not new: Mary Shelley's Dr Frankenstein, H. G. Wells's Dr Moreau and Aldous Huxley's *Brave New World*, for example, are evidence of a powerfully emotive anti-science movement. Science is dangerous, so the message goes – it dehumanizes; it takes away free will; it is materialistic and arrogant. It removes magic from the world and makes it prosaic. But note where these ideas come from – not from the evidence of history, but from creative artists who have moulded science by their own imagination. It was Mary Shelley who created Frankenstein's monster, not science, but its image is so powerful that it has fuelled fears about genetic engineering that are very hard to remove.

Current attitudes to science indicate both ambivalence and polarization. Surveys confirm that there is much interest in, and admiration for, science, coupled with an unrealistic belief that it can cure all problems; but there is also, for some, a deep-seated fear and hostility, with several lines of criticism. Science is perceived as materialist and as destructive of any sense of spiritual purpose or awareness; it is held responsible for the threat of nuclear warfare and for the general disenchantment with a modern industrial society that pollutes and dehumanizes. The practitioners of science are seen as cold, anonymous and uncaring technicians. The fear of genetic engineering and the manipulation of embryos looms large, and the image of Dr Frankenstein is increasingly embellished. The image of scientists themselves remains as stereotyped and inaccurate as ever: when not crazy, they appear bedecked in a white coat, wearing spectacles, and wielding a test-tube. The media usually present scientists as totally anonymous and character-free and give little insight into the way in which they work. Scientists are still widely perceived as being like Mr Gradgrind in Charles Dickens's *Hard Times*, interested only in facts and yet more facts, the collection of which is the hallmark of the scientific enterprise, and the overwhelming burden of which seems to drive them into increasingly obscure specializations. Almost as misleading is the idea that there is a 'scientific method' that provides a formula which, if faithfully followed, will lead to discovery. Any idea of creativity in science – which is rare – is linked, romantically and falsely, with that of artistic creativity.

Thirty years ago, C. P. Snow suggested that there were two separate cultures: one relating to science and the other to the arts and humanities. He was criticized for his use of the term 'culture'. Some people even argue that science is not part of culture at all: following Nietzsche's claim that science, with its reductionism and materialism, has deprived man of his special status, it seems to some that only an idea of culture that actually excludes science can restore man's dignity. Whatever the definition of culture, however, Snow was right in emphasizing that the 'culture' of science was different. What he did not do was to give any insight into why this should be.

Some of the hostility to science may be explained by the American literary critic Lionel Trilling's comment 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.'

The central theme presented in this book is that many of the misunderstandings about the nature of science might be corrected once it is realized just how 'unnatural' science is. I will argue that science involves a special mode of thought and is unnatural for two main reasons, which are developed in Chapter 1. Firstly, the world just is not constructed on a common-sensical basis. This means that 'natural' thinking – ordinary, day-to-day common sense – will never give an understanding about the nature of science. Scientific ideas are, with rare exceptions, counter-intuitive: they cannot be acquired by simple inspection of phenomena and are often outside everyday experience. Secondly, doing science requires a conscious awareness of the pitfalls of 'natural' thinking. For common sense is prone to error when applied to problems requiring rigorous and quantitative thinking; lay theories are highly unreliable.

In establishing the unnatural nature of science, it is essential to distinguish between science and technology, particularly since the two are so often confused. The evidence for the distinction, discussed in Chapter 2, comes largely from history. Technology is very much older than science, and most of its achievements – from primitive agriculture to the building of great churches and the invention of the steam engine – have in no way been dependent on science. Even the mode of thought in technology is very different from that of science.

Once the distinction between science and technology is recognized then the origins of science in Greece take on a special significance, which is the subject of Chapter 3. The peculiar nature of science is responsible for science having arisen only once. Even though most, if not all, of Aristotle's science was wrong – he can be thought of as the scientist of common sense – he established the basis of a system for explaining the world based on postulates and logical deduction. This was brilliantly exploited by Euclid and Archimedes. By contrast the Chinese, often thought of as scientists, were expert engineers but made negligible contributions to science. Their philosophies were essentially mystical, and it may have been rationality and a concept of laws governing nature that allowed science to develop in the West.

Since science is unique, it is to be expected that scientific creativity has its own special characteristics quite different from those of the arts, as we shall see in Chapter 4. Scientific genius is often characterized by a 'psychic courage' which requires scientists to include in their ideas assumptions for which they have very little evidence. Scientific creativity is, of course, not understood, and one should be sceptical both of the suggestion that it involves merely a sort of problem-solving that can be done by computers and of the theory that it is heavily dependent on chance, characterized under the rubric of serendipity.

Because any scientific discovery can be made only once, scientific research generates intense competition, even though in the long term most scientists are anonymous, or their names are recorded only in a historical context. But the essential social nature of science, discussed in Chapter 5, engenders cooperation too. New ideas have to be accepted by consensus of the scientific community – and because there is often a reluctance to surrender current views, scientists may be unwise to abandon their ideas at the first indication they have been falsified. Scientists also judge theories on their explanatory value, simplicity and fruitfulness.

It might be thought that either philosophers or sociologists would have been able to illuminate the nature of science and why it has been so successful. Alas, not only have they failed to do so but some have instead provided what they regard as good reasons for doubting whether science really does provide an understanding of the way in which the world works, as we shall see in Chapter 6. Fortunately for science, these philosophical claims have no relevance to science and can be ignored. There are numerous 'styles' for doing science: the only constant is the need to measure one's ideas against the real world.

But it must be admitted that it is not always easy to explain the confidence with which one can distinguish science from non-science. One approach, discussed in Chapter 7, is to recognize that some areas are premature or too primitive for scientific investigation. Just as in the seventeenth and eighteenth centuries the great debate about the nature of the development of the embryo – whether all organs were preformed or actually were made during development – could not be resolved until other advances in biology had been made, so the claims made for the scientific nature of psychoanalysis may be premature given the current state of knowledge about the brain, particularly since the mechanisms that psychoanalysis proposes are little different from the phenomena they attempt to explain, as was also the case in early embryology. Claims for paranormal phenomena are easily dealt with because the evidence is so poor, but a special problem is raised by religion: while religious belief is incompatible with science, many scientists are deeply religious. An explanation of this paradox is the difference between natural and unnatural thinking.

There remains the major problem that scientific knowledge is perceived as being dangerous. Was it not responsible for nuclear warfare and the current unease about genetic engineering? Using the history of the atomic bomb and of eugenics as examples, Chapter 8 discusses the social obligations of science and argues that many of the so-called new ethical problems are merely reflections of a failure to understand the nature of science.

While science provides our best hope for solving many major problems such as environmental pollution and genetic diseases, it does have its limits, and these and the need for a more accurate public perception of science's nature and processes are discussed in Chapter 9.

Science can be quite uncomfortable to live with – at least for some people. It offers no hope for an afterlife, it tolerates no magic and it doesn't tell us how to live. But there is no good reason to believe, with D. H. Lawrence, that scientific understanding creates a 'dry and sterile world' by apparently removing all mystery. To quote Einstein, 'the greatest mystery of all is the (partial) intelligibility of the world.' And science itself can be very beautiful.

Contents

I
Unnatural Thoughts

It is often held that science and common sense are closely linked. Thomas Henry Huxley, Darwin's brilliant colleague, spoke of science as being nothing more than trained common sense. 'Science is rooted in the whole apparatus of common-sense thought' was the optimistic claim of the philosopher and mathematician Alfred North Whitehead. However reasonable they may sound, such views are, alas, quite misleading. In fact, both the ideas that science generates and the way in which science is carried out are entirely counter-intuitive and against common sense – by which I mean that scientific ideas cannot be acquired by simple inspection of phenomena and that they are very often outside everyday experience. Science does not fit with our natural expectations.

Common sense is not a simple thing: it reflects an enormous amount of information that one has gained about the world and provides a large number of practical rules – many of them quite logical – for dealing with day-to-day life. It is so much a part of everyday life that one seldom thinks about it. It will be considered shortly.

An immediate problem in comparing common sense with science is, of course, defining what is meant by 'science'. Providing a rigorous definition is far from easy, and the best way to advance at this stage is by example.

Physics is probably a good way of showing what is meant by science: it tries to provide an explanation of nature – the world we live in – at the most fundamental level. It aims to find explanations for an enormous variety of phenomena – the movement of all objects; the nature of light and sound, heat and electricity; the fundamental constitution of matter – in terms of as few principles as possible. Rigorous theories are constructed which explain observed phenomena, and these theories must be capable of being tested by both confirmation and attempts to falsify them. It is also an absolute requirement that theories must be capable of modification, or even abandonment, when evidence demands it. In this process, all the phenomena must be capable of observation by independent observers, for scientific knowledge is public knowledge.

Science always relates to the outside world, and its success depends on how well its theories correspond with reality. Criteria for a good theory – in addition to explaining observations and predicting new ones – include relative simplicity and elegance, and as scientists themselves repeatedly point out, a good theory should raise interesting new questions.

For Einstein, the object of all science was 'to coordinate our experiments and bring them into a logical system'. In this endeavour, mathematics plays a fundamental role for expressing scientific ideas in quantitative terms: for the nineteenth-century physicist Lord Kelvin, one could only really claim to know something if one could measure what one was speaking about and express it in numbers. While his was an extreme view, and can certainly be shown to be wrong, the attempt to express ideas with mathematical rigour underlies much of scientific endeavour. Newton's laws of motion provide a wonderful triumph of this approach: with a few basic laws of motion together with mathematics it is possible to explain an enormous range of movements – from those of the planets to those of billiard and tennis balls.

The physics of motion provides one of the clearest examples of the counter-intuitive and unexpected nature of science. Most people not trained in physics have some sort of vague ideas about motion and use these to predict how an object will move. For example, when students are presented with problems requiring them to predict where an object – a bomb, say – will land if dropped from an aircraft, they often get the answer wrong. The correct answer – that the bomb will hit that point on the ground more or less directly below the point at which the aircraft has arrived at the moment of impact – is often rejected. The underlying confusion partly comes from not recognizing that the bomb continues to move forward when released and this is not affected by its downwards fall. This point is made even more dramatically by another example. Imagine being in the centre of a very large flat field. If one bullet is dropped from your hand and another is fired horizontally from a gun at exactly the same time, which will hit the ground first? They will, in fact, hit the ground at the same time, because the bullet's rate of fall is quite independent of its horizontal motion. That the bullet which is fired is travelling horizontally has no effect on how fast it falls under the action of gravity.

Another surprising feature of motion is that the most natural state for an object is movement at constant speed – not, as most of us think, being stationary. A body in motion will continue to move forever unless there is a force that stops it. This was a revolutionary idea first proposed by Galileo in the early seventeenth century and was quite different from Aristotle's more common-sense view, from the fourth century BC, that the motion of an object required the continuous action of a force. Galileo's argument is as follows. Imagine a perfectly flat plane and a perfectly round ball. If the plane is slightly inclined the ball will roll down it and go on and on and on. But a ball going up a slope with a slight incline will have its velocity retarded. From this it follows that motion along a horizontal plane is perpetual, 'for if the velocity be uniform it cannot be diminished or slackened, much less destroyed.' So, on a flat slope, with no resistance, an initial impetus will keep the ball moving forever, even though there is no force. Thus the natural state of a physical object is motion along a straight line at constant speed, and this has come to be known as Newton's first law of motion. That a real ball will in fact stop is due to the opposing force provided by friction between a real ball and a real plane. The enormous conceptual change that the thinking of Galileo required shows that science is not just about accounting for the 'unfamiliar' in terms of the familiar. Quite the contrary: *science often explains the familiar in terms of the unfamiliar.*

Aristotle's idea of motion – that it requires the constant application of a force – is familiar to us in a way that Galileo's and Newton's never can be. So it is not surprising that, when asked to indicate the forces on a ball thrown up, many students imagine an upward force to be present after the ball leaves the hand, whereas the truth is that at all stages after the ball leaves the hand it experiences only a downward force due to gravity. This is no simple problem and even Galileo got it wrong, though he did recognize that there was a problem. Newton's second law provides the explanation. Forces acting on a body cause it to accelerate, so forces can either increase or decrease its speed. When a ball is thrown up, it would continue upwards forever if there were no forces like friction or gravity to slow it down. The force of gravity acts to accelerate the ball *towards* the earth – which is equivalent to a retardation in the ball's movement *away from* the earth – so the ball is slowed down and eventually reverses its upwards motion.

The naïve views held by the students are very similar to the 'impetus' theory put forward by Philoponus in the sixth century and by John Buridan in the fourteenth century. This theory assumes that the act of setting an object in motion impresses on that object a force or impetus that keeps it in motion. Persistence of thinking in terms of impetus over the three hundred years since Newton shows how difficult it is to assimilate a counter-intuitive scientific idea.

The nature of white light is another counter-intuitive example from physics which was also discovered by Newton. Newton showed that ordinary white light is a mixture of different kinds of light, each of which we see as coloured. When all the colours of the rainbow are combined, the result is white.

Yet another example is provided by the phlogiston theory in the eighteenth century, which addressed the problem of what happens when an object burns. In Aristotelian terms, and common sense, when anything burns, something clearly leaves the burning object. This something was thought to be phlogiston. Again common sense is misleading, for an essential feature of burning is that oxygen is taken up rather than something being released.

Even something as simple as the mechanism involved in the spread of a dye in water does not accord with common sense. Consider placing a drop of ink, or a dye, at one end of a trough of water. In time, the dye will spread across all of the water. Why does it spread? It might seem that there is something about the high concentration at one end 'driving' the dye away. In fact, on the contrary, the spread is all due to the random motion of the dye molecules; if one could follow the movement of any single molecule, one would not be able to determine the direction in which the dye spreads. Again, is it intuitive that temperature, hot and cold, reflects a similar underlying property related to the vibration of molecules?

Science also deals with enormous differences in scale and time compared with everyday experience. Molecules, for example, are so small that it is not easy to imagine them. If one took a glass of water, each of whose molecules were tagged in some way, went down to the sea, completely emptied the glass, allowed the water to disperse through all the oceans, and then filled the glass from the sea, then almost certainly some of the original water molecules would be found in the glass. What this means is that there are many more molecules in a glass of water than there are glasses of water in the sea. There are also, to give another example, more cells in one finger than there are people in the world. Again, geological time is so vast – millions and millions of years – that it was one of the triumphs of nineteenth-century geology to recognize that the great mountain ranges, deep ravines and valleys could be accounted for by the operation of forces no different from those operating at present but operating over enormous periods of time. It was not necessary to postulate catastrophes.

A further example of where intuition usually fails, probably because of the scale, is provided by imagining a smooth globe as big as the earth, round whose equator – 25,000 miles long – is a string that just fits. If the length of the string is increased by 36 inches, how far from the surface of the globe will the string stand out? The answer is about 6 inches, and is independent of whether the globe's equator is 25,000 or 25 million miles long.

There are rare exceptions to the rule that all scientific ideas are contrary to common sense. Ohm's law is the best example: the greater the resistance of an electric circuit, the