PART ONE

Scientific and Technological Communities

CHAPTER 1

Introduction

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What is Science, Technology and Society, and why should anyone want to study it? In particular, why should science students have an interest in the subject? Many science degrees have a unit or two concerned with it, and some have several. It is natural for students to wonder why. Would it not be more sensible for, say, chemistry students to study as much chemistry as possible? There are many reasons why students, whether scientists or not, should study science and technology in their social aspects. First, we need some background and understanding of the significance of science and technology in the recent past, and their importance in the modern world.

The importance of science and technology

Most people would agree that science and technology are of great importance in the world today. Some highly developed countries, such as Sweden and Switzerland, spend 2 or 3 per cent of their gross domestic product (i.e. the total wealth a country produces) on science and technology. As we shall see in the next chapter, Australia spends about $5 billion a year (about 1.34 per cent of its gross domestic product), but is not considered a big investor in the area. These large sums tell us that decision-makers in government and industry are strongly convinced of the importance of developing science and technology.

It is equally clear that science can alter our entire conception of ourselves and our place in the universe. The most famous instance of this was the series of events known as the Scientific Revolution. During this turbulent time in the sixteenth and seventeenth centuries, Galileo and other scientists began to argue that the Earth was not at the centre of the universe, but whirled on its own axis, and orbited around the Sun.

Later, Darwin argued that humans arose as the product of natural processes, not divinely wrought miracles.

This century, the surprises have kept coming. Physicists now believe that, at base, the universe is probabilistic, and that it arose as the result of a huge explosion, the Big Bang. Also, plate tectonics has revealed that the continents upon which we live are not stable, but drift across the Earth and crash into each other. As we write this text, it seems possible (though not certain) that the remains of simple life have been discovered from the planet Mars. Whatever the future holds, it seems certain that science will play a major part in shaping our view of the universe—and of ourselves.

It is in conjunction with technology, though, that science has had its most dramatic effects. In the nineteenth century, science-based technology began to transform whole industries. In this century, it has made warfare far more dangerous—indeed, a major nuclear war could wipe out all human life—and has changed virtually all aspects of our lives. We have seen the rapid onslaught of computerisation and telecommunications. This has created a world-wide net of communication, and also wiped out employment for many millions of people throughout the world. Modern pharmaceuticals can cure diseases which terrified our forefathers, and yet other diseases arise, sometimes from the effects of the drugs themselves.

Clearly, these changes are important, and the workings of the science and technology which produce them must be understood. However, it is dangerously easy to take notice of only one aspect of what is happening: to enjoy computers and their games and ignore the unemployment created by computers; or to take antibiotics for infections and neglect the evolution of 'super-bugs' which are resistant to them. More important, perhaps, it is easy to overlook the fact that science is always the product of human activity. This is one reason why it is important to study Science, Technology and Society. We are all familiar with terms such as the 'progress of science' or the 'onward march of technology', and we tend to forget that all scientific knowledge has been produced by people thinking, believing, arguing, and sometimes making mistakes. It follows that human beings can always decide what research is done, and what is done with the results: science and technology are not the product of some unstoppable force, but are human products which both shape, and are shaped by, the society from which they emerge. For this reason, we all need to have some understanding of the links between science, technology and society, whether we are practising scientists or simply people who, every day and in many ways, experience the effects of science and technology.

For young people undergoing a university education, there are other reasons why the study of Science, Technology and Society can be valuable. As we noted earlier, the advent of modern technology has transformed whole industries and has even changed our ideas of work. The familiar situation of receiving an occupational training that would last a whole lifetime has now passed, and it is expected that many people will have to train and re-train several times in a working life in order to maintain their level of skills and their employment. In this rapidly changing work environment, flexibility and adaptability are important attributes, and science students with some background in Science, Technology and Society are often valued because of their broader view and their capacity to locate their scientific work in a wider context. This might be important, for example, when attempting to evaluate the social impacts of a project, or when applying for funds for a research proposal which has to demonstrate some social benefit as well as scientific originality.

In addition, many science graduates follow careers which do not require a detailed scientific understanding. Within a few years of graduation, many are working in areas such as local government, business and retail work. Their scientific training has not been wasted, because it can be useful in a wide range of work. Employers can make more of graduates with a broad range of skills and knowledge, and the flexibility and breadth gained from studies in Science, Technology and Society can be of great assistance as students seek work.

Finally, we believe that there is a responsibility for all people to have some awareness of how science and technology work, for the reasons we have discussed already. Science and technology are changing every aspect of our lives, all the time. No one in the contemporary world is untouched, and the greater our understanding of what is happening, the greater our ability to ensure that science and technology are used in ways which benefit the human race, rather than leading to our destruction.

Some basic terms

As with other words describing human activity, the basic terms *science* and *technology* cannot easily be defined. H. G. Wells once said that, with the aid of a good joiner, he would undertake to defeat any definition of a chair offered to him. In the same way, any definition of science or technology is likely to come adrift somewhere. Therefore, we will not offer hard and fast definitions, but will instead make some straightforward points which we understand about science and technology.

Science is our most effective way of understanding the natural world. All science involves some form of observation or experiment, and some sort of theorising about how to explain the evidence collected. The *Concise Oxford Dictionary* defines *science* as 'systematic, organised knowledge', and this systematic nature sets science apart from other types of understanding. In addition, science is concerned with evidence and with theory. Scientific evidence often comes from experiments, though some sciences, such as astronomy and geology, do not do experiments. To explain the evidence, theories are put forward, and further evidence is often sought, to see whether the theory accords with additional observations. The exact relationship between theory and evidence is extremely complex, and at this stage we simply note that science involves both. For those interested in the nature of science, Alan Chalmers (1982) has written a good introduction, dealing with the ideas of important philosophers of science such as Popper, Kuhn and Feyerabend.

Technology is even more difficult to outline than science. Many people regard technology as simply applied science. In their view, scientists produce knowledge and then technologists turn it into important products and devices, such as computers and spacecraft. In our view, this approach is too narrow. As we shall see in this book, science did not begin to be systematically incorporated into our production systems until the middle of the nineteenth century. If technology is simply 'applied science', we would have to conclude that there was no technology before that. In fact, quite complex and sophisticated technologies were needed to build the pyramids of Egypt, the Great Wall of China, and the ancient irrigation systems of India and Sri Lanka (Ceylon). Such knowledge was based on craft rather than science, with knowledge being slowly accumulated and applied (often through trial and error) and passed on from one generation to the next.

Broadly, we regard technology as a body of skills and knowledge by which we control and modify the world. More and more, technology is being influenced by scientific knowledge, with spectacular results. Technology has always been important in human affairs. Military technology, such as the bow and arrow and the armour worn by knights, has enabled kings to carve out huge empires. The technology of shipbuilding and navigation enabled Britain to conquer a quarter of the world. We should also notice that, from this viewpoint, medicine is a technology. It enables doctors to intervene in the human body through drugs or surgery.

An important term, cropping up again and again in the literature, is R&D. This stands for 'research and development'. Defining it is complex, and there is at least one manual on the topic (OECD 1970). Broadly, however, it refers to all activity concerned with developing new scientific knowledge, and new products and processes. For nations, it is a measure of the effort being put into science and technology.

A key point in Science, Technology and Society studies is that these activities are not isolated. They are all carried out in social, political and economic contexts. Therefore, if we are to understand what is happening in the modern world, we must understand how science influences the larger society. We must also understand how the larger society influences science.

In addition, there is another way in which the word *society* can be applied to science and technology. Scientists and technologists do not work in isolation. They work in universities, firms or research groups, and the functioning of these groupings is also a legitimate focus of study. Questions about ethics and conduct within these groupings, how they should be financed and how they are best organised, are also matters which researchers in Science, Technology and Society can ask about. You will notice this division in the book: Part One deals with matters pertaining to scientific and technological communities, the second part with relationships between science and technology and the wider society.

The origins of Science, Technology and Society studies

Any discipline has a history, involving founders and important scholars, and Science, Technology and Society is no exception. Although most work has been done since World War II, views of the relationships between science, technology and society go back for many centuries. Some of these are only incidental. For example, Plato, in the fourth century BC in the *Gorgias*, recognised the value of engineers, but went on to protest about their low status in ancient Greek society (Salomon 1973:6). Probably the first attempt to outline the ideal relationships between science, technology and society, though, was published in 1527 by the British lawyer and thinker Francis Bacon, in his book *The New Atlantis*. Bacon told of an imaginary voyage to a small island in the South Seas, where a civilisation was based upon science and technology. 'The end [i.e. goal] of our foundation is the knowledge of causes, and secret motions of things; and the enlarging of the bounds of human empire, to the effecting of all things possible' (quoted in Salomon 1973:7). In Bacon's imagination, scientists are accorded the same honours as royalty, and carry out their work in an organisation (called 'Solomon's House'), making scientific discoveries, and turning these discoveries into technology. This was a remarkable vision, long before science had demonstrated that it could influence technology in major ways (see Chapter 7 for more details). It is not surprising, therefore, that the vision had some important omissions. For example, Bacon did not provide any finance for his scientists and technologists. In modern terms, the R&D budget was zero!

It took many centuries for events to catch up with Bacon's vision. Thinkers in the Enlightenment, during the eighteenth century, laid out a program for extending knowledge and repelling superstition (Goodman and Russell 1991). Scientific academies were founded in Europe, many with the aim of promoting the useful advancement of knowledge (e.g. Merton 1968). During the French Revolution, the philosopher Condorcet advocated the realising of Bacon's vision on democratic lines (Salomon 1973:13). However, it was not until the present century, under the stimulus of war and political upheaval, that the discipline of Science, Technology and Society was launched.

Politics has played a crucial part in the Science, Technology and Society movement. One of the earliest efforts arose out of the experience of the 1917 revolution in Russia and the establishment of a (supposedly) socialist state. Marx and Lenin argued that a socialist state like the Soviet Union represented a higher stage in social development than the liberal democracies of the West. One part of this theory was the materialist interpretation of history, which held that all significant social and intellectual change is caused by change in the productive forces of the economy. Of course, this places technology at the very heart of historical change.

This approach was also applied to science, and the Marxist view of science became known to scholars in the West through a conference on the history of science, called Science at the Crossroads, which was held in London in 1931. Notable among the Soviet delegation was a historian named Boris Hessen, who gave a paper entitled 'The Social and Economic Roots of Newton's *Principia*' (Hessen 1931). The *Principia* is Sir Isaac Newton's famous book, in which he put forward his three laws of motion, his law of gravity and much more. Hessen argued that Newton was led to address certain sorts of problems because their solution would lead to advances in technologies that were important to the dominant social forces of the time. These technologies included advances in navigation, mining, and the development of weaponry.

Although the Soviet Union collapsed in 1992, for a long time many Western thinkers were impressed by the communist experiment. In particular, it was noted that science and technology were an important part of communism: the state financed large scientific and technological projects and did not leave developments to chance.

Perhaps the most influential of these thinkers was the physical chemist J. D. Bernal, of London University. After visiting the Soviet Union in 1934, he concluded that science in Britain should be organised, like that in the Soviet Union, to solve pressing economic problems. He wrote a book called *The Social Function of Science*, which appeared in 1939. The key point of this book is that science is not primarily a search for the understanding of the universe; rather, it has a social function. This function is the improvement of the lot of humanity. Much of the book—naturally, with many references to the Soviet Union—is a plan for the direction and use of science in the national interest. There was a fierce reaction to this: many scientists felt strongly that science could not be directed, and in the United Kingdom after World War II (1939–45) the Society for Freedom in Science was formed to combat what they called 'Bernalism'.

War has also had a major impact on the analysis of the role of science and technology in society. Of particular importance was the development of the atomic bomb. As Chapter 3 recounts, the American Manhattan Project was set up in 1942, in conditions of complete secrecy, with the aim of making the first atomic bombs. Late in the war, the Japanese cities of Hiroshima and Nagasaki were destroyed by these bombs, forcing Japan to surrender. Many scientists who were engaged on the project later expressed regret at their involvement in the Manhattan Project. For the next fifty years, too, the rest of the world saw the production of huge numbers of nuclear weapons in the Cold War arms race between the United States and the Soviet Union, and lived with the prospect of total destruction.

Thus, at the end of World War II, Bernal's argument was clearly true, at least in its essentials. Governments knew that, for their countries to progress, they had to support scientific research and technological development. As a result of this, governments began to plan for science and technology.

Perhaps the most dramatic of these developments took place in the United States. A distinguished scientist, Vannevar Bush, was asked to report on a suitable plan for science after World War II. Bush recommended the setting up of a National Research Foundation—which later became the National Science Foundation. He also wrote a report, *Science, The Endless Frontier* (Bush 1945), which advocated the setting up of a national policy concerned with science.

The development of government science policy (as it came to be called) was mainly concerned with the use of limited funds for the best effect. After the war, spending on science was growing exponentially, with the money spent doubling roughly every fifteen years. This could not continue, as eventually science would consume all of the government's budget. Governments had to make choices about what to fund and what not to fund, and they had to develop criteria to help them make choices. They also needed to be able to measure the effectiveness of their decisions. This has restarted the debate about the freedom of science which first surfaced as a response to 'Bernalism'. Two key questions are whether governments or scientists are best equipped to decide what should be funded in science, and how 'success' is to be judged.

More recently, Science, Technology and Society has come to embrace another area of study, known as technology assessment, and concerned with the impact of large-scale technologies on society. As technology becomes bigger and more complicated—with nuclear power stations, jumbo jets and supertankers—it follows that the impacts are felt far and wide if something goes wrong, even if it is only a minor problem. The nuclear disasters at Chernobyl (1986) and Three Mile Island (1979) are good examples. It is now clear that the likely impact of technologies should be assessed before they are introduced. Researchers in this field look at emerging technologies and try to ensure that positive outcomes are exploited and negative effects avoided. An extension of this is environmental impact assessment, which examines the effects of major developments on the physical environment.

From this brief discussion of how Science, Technology and Society arose, you will see that the discipline has emerged as a composite of a number of study areas. Some of these have been briefly discussed, and others, such as 'Ethics and Science' and 'Science and the Economy', are discussed elsewhere in this book. All the different approaches have some things in common: they are all concerned with science and technology in a social context, in which science and technology both shape, and are shaped by, the society in which they are performed. This basic approach is reflected throughout the book, and in the themes which arise from it.

Themes

This book is organised round two major themes. As you read each chapter, you should think about what has been said, and how it illustrates and extends the ideas implicit in the themes.

The first theme is this: *Science and technology are important in the world, and growing more so, and this presents both problems and opportunities to humanity*. The brief outline of Science, Technology and Society, above, shows how science has increased in importance. Chapter 6 on the Industrial Revolution discusses the importance of technology in this monumental event. The first part of Chapter 7 shows how science for the first time began to influence industrial technology. The discussion of science policy in Chapter 9 examines the ways in which governments have sought to use science.

The second theme is: *How we treat and use science and technology affects what is produced and what effects it has.* As Chapter 3 points out, research and development are organised in several different sectors, and these focus on producing different types of knowledge. In addition, as Chapter 8 argues, industrially useful innovations are taken up and used by industry: a useful invention which is not exploited has no economic consequences. You should find this theme appearing in other guises throughout the book as well.

Structure

We argued above that the term *society* can be considered as applying either to the scientific community, or to the wider society, which includes us all. Part One of the book adopts the former perspective. Chapter 2 is a guided tour of modern science. The main types of science—academic, industrial and government—are examined, and some explanation made of why each exists, and how they work. Then Chapter 3 takes up the issue of how far scientists are ethically responsible for the work they do. The conclusions lead on to Chapter 4, which examines a range of examples of dubious or unethical conduct in science.

Once we accept the obvious point that science is a human activity, then it is reasonable to ask: what happens when the inevitable disagreements arise? Chapter 5 investigates what sort of controversies arise within science, and how they may be settled. It also looks at how science becomes involved in larger controversies, and how these are resolved. Two quite different issues—continental drift and a medical research scandal—are examined in some detail.

Part Two of the book takes the broader view of the term *society*. In Chapter 6, John Forge examines the process of the Industrial Revolution. This event has transformed the world, and it is important to understand what happened and why.

Science and technology now take up a substantial part of the world's wealth, and are important factors in the future of all nations. Chapter 7 studies the impact of science upon industry, as it first occurred in the British alkali industry in the nineteenth century. Then the role of science and technology in the Australian economy is considered, and compared with two other advanced nations, Japan and Sweden.

Given this importance of science and technology to the economy, it is natural that economists have tried to understand exactly what is happening. Chapter 8 deals with the economics of science and technology. Some important questions are posed about how science and technology relate to modern economies, and some tentative answers given.