
Opening Extract from...

Bad Ideas?

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BAD IDEAS?

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An arresting history of our inventions

ROBERT WINSTON

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To Kathy Sykes,
Professor of Sciences and Society at the University of Bristol,
who has been an inspiration to so many people

'It is not thy duty to complete the work,
But neither art thou free to desist from it.'
R. TARFON. *Aboth:* 2,15 (*c.*70 CE)

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Preface and Acknowledgements

> 'Science becomes dangerous only when it imagines that it has reached its goal.'
>
> GEORGE BERNARD SHAW, 'Preface on Doctors' (1909) to *The Doctor's Dilemma*

During the late 1990s I had the privilege of chairing the House of Lords Science and Technology Committee. During the three years of my chairmanship, we set up a number of inquiries into scientific issues, from the disposal of nuclear waste to the medicinal uses of cannabis. But the one closest to my heart was the inquiry into science and society, which lasted for most of 1999 and part of 2000. The inquiry was launched because it seemed that the scientific community had an uneasy relationship with many members of the public, with policy-makers, with journalists and to some extent with government.

Among various concerns about public mistrust of science, there had been a major debacle over the use of genetically modified crops, and there had been the unedifying photograph of a cabinet minister feeding his little daughter a beefburger in an effort to persuade people that British beef was free of bovine spongiform encephalopathy. It seemed that human embryo research was almost the only scientific issue on which the public appeared to trust the scientists and the information those scientists were giving them, and to recognize its value for healthcare.

So, having taken copious evidence, we argued in our report that there needed to be much better public engagement with science; that merely attempting to increase 'public understanding of science' was really inappropriate. And since then a number of colleagues have become much more involved with thinking about and responding to the difficult issues raised by implementing advancing human technology. But until quite recently, the idea of listening to the public and responding to public concerns seemed almost anathema to many scientists. So various far-thinking people, and notably my friend and colleague Professor Kathy Sykes of Bristol University, raised the idea of dialogue with the public on these complex issues.

The thesis behind this book – namely, that the key to successful living in a society dominated by advancing technology lies in better public engagement with science and technology – will seem strange to many people. Yet it seems increasingly obvious that if we are to avoid harm from the increasingly powerful tools we have, we need to have much better methods of control. This control cannot be exercised solely by governments: history shows, as this book recounts, that governments do not always use scientific knowledge wisely. Nor can control simply be left to my community – the scientists – even though it is clear that most scientists are strongly altruistic and genuinely committed to improving the health and welfare of the society in which they live. So in my view, people from all sections of the community have a responsibility to learn and understand more about science in order that, in democratic societies at least, they will have a more powerful say in how science is used.

This book has been difficult to write, and in the first place I am deeply in debt to my publishers, Transworld, and particularly Sally Gaminara, who had sufficient faith in me to delay publication by a whole year while I struggled to make a very imperfect text into something slightly less imperfect.

My old friend Matt Baylis has as usual been a tower of strength and energy in seeking out so many matters of interest in the research for this book. We had been discussing the ideas behind the book for some years and had even pitched it as the theme for a television series. Matt's wide knowledge, his remarkable enthusiasm for all things scientific and historical, and his wonderful sense of humour have meant it has been a continued joy to work with him on this difficult project.

It is my very good fortune to have had Gillian Somerscales as an editor for another of my books. Her intelligence and clarity of thought have made a massive difference to my imperfect text, and as usual her input has been made with tact and with great insight.

Lira, my wife, has been, as ever, remarkable. She has been forbearing and tolerant when I am preoccupied by writing and thinking, and always deeply encouraging. Her wisdom in suggesting improvements for the text has helped make this a better book. Rachel Ward, my assistant and secretary, has been amazingly supportive. Her invaluable interest in and enthusiasm for this project was hugely helpful in persuading me to continue with it in the usual moments of depression.

Other colleagues and friends have read bits of the draft manuscript and made most helpful suggestions. Many others have helped in detailed conversations about its focus and its argument and about crystallization of my ideas in general. I am indebted to Carol Readhead, James Wilsdon, Sheba Jarvis, Brian Wynne, Anne Cooke, Jacqui Roche, the late Lord Porter of Luddenham, and various members of the Societal Issues Panel, and particularly Peter Ferris, of the Engineering and Physical Science Research Council.

Finally, I am so grateful to my old friend and agent, Maggie Pearlstine, who has always taken such a strong interest in my various projects and without whom this book would never have been published.

Introduction

Too Clever by Half?

HUMANS ARE CLEVER. Our cleverness and our ability to design and use tools have led to our increasing domination over the planet on which we live – though ultimately, as most of us realize, we cannot control or regulate it. As humans have developed more and more complex ideas, more and more sophisticated mechanisms, we have improved our lives in a multitude of ways and have increased our influence over much of our environment. But nearly all technologies are increasingly threatening. The achievements we rightly celebrate could also be bringing us closer to our own destruction – and not only our destruction, but also the demise of many species of animals and plants that share the planet with us. One obvious concern is the frightening threat of significant climate change and the alarming consequences of global warming. The great majority of scientists now agree on the basis of the evidence that this impending crisis is of human making. It may well have been started by our implementation of the technology of farming, but the data now strongly support the view that it is being brought about progressively by technologies which increase our recent dependence on fossil fuels.

I have set out in this book to present, chapter by chapter, a thematic history of human inventiveness and an account of its positive and negative aspects. By way of introduction to some of my themes, I start with stone.

Stones – our use of them – are what separate us from all other species. The earliest stone implements fashioned by hominids are perhaps more than 2 million years old. A flint fractured by chance in the right place, and others more deliberately worked into sharpened stones with a hard cutting edge, gave humans their unique power and led ultimately to their domination over the planet. Human technology, which enabled humankind to control its environment – even to the point of modifying the evolution of its own species – stemmed essentially from the development of the stone hand-axe. With the worked edge of this implement our hominid ancestors could deflesh the bones of animals they scavenged and, when they were lucky and hunting in groups, even occasionally kill their prey. Early man, hunting on his own, would have had few chances to kill a large animal for food. But hunting in groups, with its need for rapid communication between individuals, is thought to have been a powerful driver for the development of the human brain. Moreover, nearly 80 per cent of that brain consists of fatty substances called lipids, and an enriched diet containing plenty of animal fats and proteins would have supplied the vital fuel allowing the large brain of *Homo sapiens* to evolve. What I find remarkable is that the unique intellectual prowess of human beings was gained as a result of the earliest technology we invented. Humans are surely the only species that have changed their own evolution in this way.

Of course, the sharp hand-tool was not only a means of gaining sustenance, but could also be used as a weapon. With it, aggressive members of our species could gain power over other members of the same species. And those with a better weapon, improved technology, and the skills and cunning to use it, would tend to be the individuals who survived to pass on their genes so that their descendants could achieve greater mastery of the environment around them.

One surprising thought is how long each initial advance in our earliest technology took. Crafted, sharpened hand-tools have been around for over 2 million years. The earliest spears that have been dug up, excavated from a site in Schöningen, Germany, are 400,000 years old and show a beautifully worked wooden point.[1] Yet it seems that for a very long time nobody thought how vastly the power of either implement could be increased with a most simple device. Attach a sharp stone to the end of a stout piece of wood, and with this lever you can hugely increase the speed, force, effectiveness and safety with which the axe can be wielded. Fix a stone, sharpened with a deadly edge, at the end of a carefully weighted stick, and you have a weapon – a dart, arrow or a spear – that could be lethal at a considerable distance. Yet it seems that our ancestors did not get around to this critical refinement for around a million years after the first stone hand-tools were crafted. And when this major technological advance did finally occur, it may well have been developed in different parts of the globe more or less simultaneously, during the same period of our existence.

ATLATL AND AXE: WHAT SCIENCE TEACHES US ABOUT ITS BEGINNINGS

At first glance, an atlatl hardly looks like a major advance in any history of technology. Yet this rather unprepossessing – indeed, now largely forgotten – object gave humans even greater power over their environment. In itself the delicate-looking atlatl is not really a weapon at all. In its simplest form it is merely a notched stick, or a piece of bone or carved antler, into which the actual weapon – a stone-tipped spear or a dart – fits. When the atlatl is swung hard in an overhand arc, the dart is given huge momentum on its rapid journey through the air to hit its target.

Atlatls, in various forms, have probably been around for longer than bows and arrows. Atlatls made of finely carved reindeer antlers sculpted into animal shapes have been dug up in France and dated by archaeologists to be as much as 17,000 years old. In America they are associated with the Clovis culture, from about 14,000 BP. Note that I use the abbreviation 'BP', which stands for 'before present'. The 'present' in 'before present' does not refer to the year 2009, when I am writing, but to the year 1950. There's a reason for this.

All living things on this planet constantly take up carbon, and this process stops only at death. So any substance that has once been living tissue, such as a piece of bone or in this case an antler, contains carbon which has been acquired from the environment. It so happens that carbon has several forms or 'isotopes'. The two most common isotopes are carbon-12 and carbon-14. Carbon-14 is radioactive and that radioactivity is lost over time at a predictable rate – its half-life (the time it takes for half the atoms in any quantity of the substance to decay into another element) is about 5,700 years. Carbon-12 is not radioactive: it remains carbon. So chemists can measure the ratio of carbon-14 to carbon-12 in a biological artefact and by doing so get a very accurate assessment of its age.[2]

Why 1950, then? That was the year when humans started to contaminate the global environment significantly with their numerous attempts to manufacture the most powerful weapon ever devised. Repeated detonations of atom bombs and hydrogen bombs tested in isolated parts of the world altered the ratio of the radioactive isotopes globally, including isotopes of carbon – so we can no longer confidently say in what proportion carbon-12 and carbon-14 exist. For many decades now we have lived with the threat of nuclear weaponry and the risk that an irresponsible government (or indeed other forces) might use such devices recklessly. Remarkably, recent news from North Korea confirms that human beings are still exploding these terrible weapons. Because the effects of all these explosions have persisted, and will continue to do so for a very long time, for biological dating purposes we define 'the present' as 1950.

Well before humans mastered farming, early hunter-gatherers made a series of incremental improvements to the atlatl technology. One significant technical advance was, to my mind, quite counter-intuitive. It turns out that if the stick from which the dart is made is not rigid but whippy, it is more lethal. As the darts tend to be 2 metres or more in length, they store considerable kinetic energy when they bend as they leave the notch in the atlatl. At first thought it seems that an arrow which bends significantly as it flies through the air would be inaccurate and likely to miss its target. But it turns out that as the stored energy is released from such supple sticks, their momentum is increased as they hit their victim. And the accuracy can be astonishing, with the power to kill at well over 40 metres from the thrower's arm. Even a child using an atlatl can throw a dart a considerable distance with surprising precision. So, with time, early humans also learned that a flexible atlatl, like a flexible dart, could give added impetus to the launch.

An intuitive appreciation of physics led to another technological advance: the development of a weight, attached to the middle of the atlatl. Such a weight, provided the launcher is carefully balanced, adds considerably to the thrust that the human thrower gives. With a properly balanced and weighted atlatl of the right length, it is possible for an averagely built man to propel a substantial dart more than 120 metres. The position and size of the weight are important, and no doubt our ancestors experimented – science is not a new skill and they must have used considerable trial and error to optimize this physical system. It is interesting that the weight may have had other advantages. Swinging an atlatl through the air causes a substantial noise from its vibration, and a weight roughly halfway along the haft dampens this effect, allowing the hunter the great advantage of stealth. And the obvious material for the weight, of course? Stones of varying sizes have always been freely available.

How do we know that early humans used a machine like a bow, or a lever like an atlatl, to propel a projectile so forcibly? Much Palaeolithic cave art shows pictures of humans repeatedly pierced by thin whippy sticks. Jean Clotte, the French cave specialist about whom I have written in *The Human Mind*,[3] describes some revealing drawings in the Cosquer Cave.[4] Here, as in other caves in the Pyrenees, the human figures are pierced by very thin, crooked sticks much longer than the bodies of their human victims. Such long sticks would be quite unsuitable for use as arrows, and their thinness and curvature would have made them useless as hand-held spears. The most likely way of launching them would have been with an atlatl.

Dr L. Bachechi from the University of Pisa points out that the age of the origin of such weapons is very difficult to guess but nevertheless suggests some clues.[5] Together with his colleagues he made an interesting finding when examining the bones of a young adult woman which had been excavated from a cave in Messina in Italy in 1942, during the Second World War. She was about 1.6 metres in height and experts have dated her skeleton to around 13,760 BP. The most interesting feature of these bones is what is deeply embedded in her hip. Stuck into the pelvic bone is a very thin, sharp stone flake, about 5 centimetres long. This projectile would have entered the woman's buttock from behind – possibly she was running away when she was hit. The hipbone around the stone flint has undergone typical thickening and sinuses have formed, so it is clear that she did not die as a result of this injury and that the flake led to a chronic abscess. This caused bone inflammation – osteomyelitis – a painful injury from which pus would have drained almost certainly for some months, probably longer. There is, of course, no way that a hand-held spear could have entered the solid bone of this part of the hip and then been broken off. A sliver of flint this delicate and sharp must have had considerable momentum to burrow so deep through the fleshy buttock and then the tough pelvic bone. Such momentum could have only been produced at the projectile's launch – either with a bow or, more probably, with a spear-thrower of some kind.

Much information can be gained from osteology – the study of bones – and the skeletons of early humans are revealing. Persistent use of a hand-held spear, for example, led hunter-gatherers to develop prominent muscles in their upper arms, usually on the right side. As all the muscles in our arms and wrist are attached to bones at some point, we can see the extent of this hypertrophy by examining the bones from the shoulder, upper arm and forearm. Living bone is dynamic and responds to pressures on it by thickening and growing stronger. So where strong muscles have repeatedly pulled, an elevated ridge where the muscle was attached develops; and this remains long after death and after the muscle has decomposed.

From such observations, the osteologist can suggest what kind of weapon a particular skeletal arm is likely to have used. Dr Thor Gjerdrum, of the University of California at Santa Barbara, has examined thickening of the ulna (the larger bone) of the right forearm.[6] This is where the supinator muscle, which gives a twisting movement needed for throwing, is attached. He reports that many early hunter-gatherers had considerable hypertrophy of this region, amounting to an asymmetry between the right and left forearms so marked that it is now only seen in professional baseball players. It is interesting that the extreme torsion of the forearm required to use an atlatl most effectively is very comparable to the action involved in pitching a baseball. Later humans who did not throw spears or use an atlatl, but preferred the bow and arrow as a weapon, do not show this marked thickening of the ulna.

From reading bones, osteologists can also make an intelligent guess as to the position in which the spear was habitually held. An overarm position might be most suitable for hunting or killing an animal, but a spear held underarm, pointing upwards, would be more effective when facing a human enemy – and it seems likely that ancient man used this position. It is remarkable to consider that the technology of the spear has persisted until the modern day. British troops, going over the top on the Somme in the First World War, marched steadily towards the German lines with their bayonets held underarm, pointing upwards. The advantages of this position are several. It allows repeated thrusts to ensure the permanent immobilization of an opponent; it also makes the weapon's withdrawal physically easier, partly because the human attacker can use his naturally powerful back muscles and biceps to maximum effect and partly because, by contracting his abdominal muscles and rotating his trunk, he can lean back in preparation for the next thrust. An underarm position is also better defensively. A grip with the spear held above the shoulder exposes the attacker's chest and abdomen, making him very vulnerable if his blow is parried. To this day, infantrymen are still taught to fix their bayonets and trained to thrust them repeatedly upwards as they encounter their foe. Were Palaeolithic men any different? It seems unlikely that they would have exposed their soft parts willingly.

Towards a scientific citizenry

Various themes, then, run through this book. One is a concern about the threat that lies latent in many of our discoveries and increases as our technology becomes more powerful and more widely used. Ever since the hand-axe human progress has, in one sense, been downhill. The hand-axe led to the battle-axe, and the atlatl led to the catapult with which the boy David propelled a stone with sufficient velocity to kill the Philistine giant Goliath. Although iron replaced stone in most human societies long ago, the ancient arrow led to the Battle of Crécy where Edward III and his tiny force of archers destroyed the mighty ironclad horseman and infantry of France. Virtually every major idea that we have had – be it to do with farming, living in cities, writing, communications, the uses of fire, transport, weapons, even medicine – has at one level at least made humankind more vulnerable. As with the stone hand-axe, nearly all the wonderful technological advances that have enabled us to live in difficult and dangerous environments also have their threatening or negative aspects – hardly ever fully recognized at the time of their invention. So, as we shall see, farming resulted in human diseases that had not afflicted humankind previously, as well as loss of genetic diversity and threats to the environment of the planet. City-dwelling greatly increased the vulnerability of humans to infection: when people first lived in cities they had a shorter lifespan and were almost certainly less healthy than when they had maintained themselves as hunter-gatherers. Writing, one of the greatest gifts ever granted to humans, has spawned some communications that debase our thinking, promote political instability and threaten our privacy. We do not need the menace of advances in weapons technology to remind ourselves how precarious our existence on the planet is, because peaceful technologies like transport are damaging our environment just as effectively, and perhaps irreversibly. Scientific advances in nanotechnology and synthetic biology could risk the uncontrolled production of poisonous substances or infectious organisms against which we may have little or no defence. The development of robotics carries the risk of dehumanizing our relationships, and advances in genetics may see a time when manipulations of the human genome require us to redefine the very essence of what it is to be a human being.

Another issue concerns the regulation of science and who controls this work and the knowledge it generates. In chapter 2, I recount in some detail the career and fate of Nikolai Vavilov, the great Russian plant geneticist. His story epitomizes several themes which run through this book: in particular, how scientific knowledge may be abused by scientists themselves who are consumed by ambition and working in a very competitive environment; and how governments grasp science to use it for their own purposes and not necessarily for the good of their citizens. Vavilov, of course, lived in a country ruled by one of the most malign totalitarian regimes of modern times. But unfortunately, as we shall see, even democratically elected governments cannot always be trusted to use science wisely, or even necessarily for the betterment of their citizens.

A more encouraging theme that recurs throughout the book is that a very large proportion of discoveries and inventions have all kinds of beneficial applications that were not remotely envisaged when they were first made. We sometimes think that stone tools were abandoned after the Stone Age technology. But the ancient Egyptians refined the technology to make extremely elegant knives. Discoveries of beautiful razors made of chert – a very hard crystalline silicate – have been found at Giza; these date from the Old Kingdom of Egypt (2575–2134 BCE). And presumably no early hominid thought, when he or she fashioned a hand-axe, that the cutting edge might be used for engraving the artwork that has been seen on prehistoric bone atlatls.

It is also important to understand – indeed, it is axiomatic – that many human technological advances are made in unconnected places around the globe, independently and more or less simultaneously. This certainly seems true of hand-axe technology, archaeological finds from far-flung places suggesting that as the hominid brain developed, pre-humans developed the manufacture and mapping of stone implements independently. The design, certainly, may vary in different parts of the world, but the technology is essentially the same. And this is undoubtedly the case for much of modern technology. Scientists are human and like to congratulate themselves (and occasionally each other) that they have been first with a revolutionary idea which has changed the world. But most of the time, once human knowledge develops in a particular field or area, scientists everywhere are in a position to make the next leap forward. This is undoubtedly true in my own field of in vitro fertilization. Although we British pride ourselves on having been the first to produce a 'test-tube baby', that first birth could have easily occurred in Melbourne, or Montreal, or even possibly Baltimore. Perhaps one key factor in its happening in Manchester was the serendipity with which Robert Edwards timed the transfer of the embryo that led to the birth of Louise Brown.

As our world becomes more sophisticated, we are becoming more concerned about the dangers human societies may face from our inventiveness. *Homo sapiens* has existed on the planet for no more than about 100,000 years, and during that time the genes which help to define the capability of our brain have not significantly changed. But in the last 400 years, a tiny fraction of that time, the human mind has expanded extraordinarily.

It is exactly 400 years since William Shakespeare's collection of sonnets was published in 1609. Since then we have invented the telescope, the microscope, the steam engine, vaccination, the telephone, aircraft, television and the computer. Humans have also produced the H-bomb and landed on the moon. Now, using the techniques of synthetic biology, we are trying to create new life forms – a technology which holds great promise but may also be very threatening to life on this planet. No doubt William Shakespeare could have leaned over the parapet of London Bridge 400 years ago, speculating with a fair degree of certainty that the city would be likely to look pretty much the same over the next few decades. Now it is a foolish 'expert' who attempts to predict what the technological capability of our society will be even in five years' time because our knowledge is growing exponentially.

This massive growth in human knowledge is truly awe-inspiring but also, understandably, seems quite frightening to many people. Humans do not find it easy to live with uncertainty and there is a growing perception, particularly in more sophisticated societies, that our pursuit of scientific knowledge and its practical application may be very dangerous. In the last ten years or so we in Britain have seen public suspicion of genetic engineering expressed in vehement protests by ordinary people about genetically modified crops. We see increasing anxiety about using nuclear power, and government is undecided over whether we should develop our nuclear industry further and what we should do with the nuclear waste we have already accumulated. There has been considerable press hysteria over human cloning, many parents have rejected the triple vaccine against measles, mumps and rubella, and mishandling of bovine spongiform encephalopathy and foot-and-mouth disease have made people doubt the integrity of the foods they eat. Attacks on humane animal experimentation have taken little or no account of the value of this important use of biology to the health and welfare of our fellow citizens – as well as the animals we keep for domestic purposes.

I do not quite take the view of Lord Rees, recent President of the Royal Society, that we are necessarily facing Armageddon.[7] We surely have at our disposal sufficient mechanisms to ensure that our technology can be controlled and sufficient ability to harness our resources successfully. As the distinguished Cambridge engineer Alec Broers asserted during his recent Reith Lectures,

> Technology too can provide solutions to these problems but only if people choose to implement them . . . Technology can solve our problems but only if the public engage with it . . . Now we are at risk of permanently endangering our planet. Our aim for this century should be to make comparable progress in protecting our environment. Technology will truly triumph if we succeed.[8]

I am no Luddite, and I most certainly am not pessimistic about the future of humanity. Overall, we live longer, more fulfilled and probably much happier lives now than at any time in humanity's past, and our use of technology has been a key factor in attaining those levels of welfare. Our inventiveness and the knowledge it has brought us are remarkable gifts – but we need to develop them and exploit them with wisdom. We also need to recognize that the technology we develop and control has a huge effect on all our fellow citizens and that we must be responsible for trying to ensure it does not do harm to human society and to the planet on which we live. Scientists have a major role to play in all this, and this book, though written in the hope of reaching the widest possible audience, is at least in part a call to my fellow scientists.

The problems, dilemmas and dangers produced by technology are not ultimately, in my view, always going to be solved only by further technological innovation. In this respect, I both agree and disagree with what Lord Broers hinted at in his Reith Lectures. It is insufficient for scientists to state that 'Technology can solve our problems but only if the public engage with it.' Scientists need to be equally engaged, and in the last chapter of this book I suggest ways in which lay people – members of the public – and scientists may engage more closely with each other. I include a manifesto for scientists, and a number of aphorisms about science for non-scientists. Better understanding of these issues on both sides, I believe, may help ensure that we use our science and our technological prowess more wisely and for long-term good.

Scientists such as myself, I feel, may need to consider that the science we pursue is not *our* science. Our new knowledge is gained in the name of society and mostly is paid for by various members of the public. It is as much their science as ours. Its application may have beneficial effects, but people who are not scientists will have to bear the consequences when the effects of what we have established are harmful. Of course, we have to facilitate the engagement of the public to which Alec Broers refers. But we need to be more effective at communicating with the public so that they understand better what we are doing; and, most importantly, we also need to learn to listen to the public when they voice their fears and reservations about science. Moreover, mere listening is not enough. The majority of scientists are not yet ready to accept that the public should have greater involvement in decisions involving scientific research. But if we are to be good citizens, we need to recognize that by listening and responding better we are likely to make our science more relevant to the societies in which we live. We may even find that public dialogue may actually increase the quality of our work.

I am suggesting that every citizen has a part to play in understanding scientific achievement and ensuring it is used for good. Indeed, responsible citizenship implies that non-scientists have an obligation to learn and understand more about science and technology. This understanding, I believe, is one of modern humanity's most powerful weapons in ensuring our continued welfare. So this book is not merely about the negative aspects of our technology – it is a celebration of our extraordinary ingenuity. And if we are to ensure the health and welfare of generations to come, this ingenuity must be focused in part on making wise choices about how we promote, protect and use our ideas.