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An Ethical Career in Science and Technology?

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Foreword

The Social Conscience of Scientists*?

Joseph Rotblat, 1995 Nobel Peace Prize Laureate

Should scientists be concerned with the social impact of their work and the ethical issues it raises? Should they accept responsibility for the human and environmental consequences of scientific research?

An ivory-tower mentality was perhaps tenable in the past when a scientific finding and its practical application were well separated in time and space. The tremendous advances in pure science during the 20th Century – particularly in physics during the first half and in biology in the second half – have completely changed the relationship between science and society. Science has become a dominant element in our lives. It has brought enormous improvements to the quality of life, but has also created grave perils. These include pollution of the environment, the squandering of natural resources, increases in transmittable diseases and, above all, a threat to the very existence of the human species through the development of weapons of mass destruction. Scientists can no longer claim that their work has nothing to do with the welfare of the individual or with state politics.

Amazingly, many scientists still cling to the ivory-tower mentality, advocating a laissez-faire policy. Their logic rests mainly upon the distinction between pure and applied science. It is the application of science that can be harmful, they claim. As far as pure science is concerned, the only obligation that scientists should fulfil is to make the results of research known to the public.

However, the distinction between pure and applied science is largely non-existent. And for scientists to adopt an amoral attitude is unacceptable and, in my opinion, immoral, because it eschews personal responsibility for the consequences of one's actions.

We live in a world community with ever-greater interdependence, due largely due to technical advancement arising from scientific research. An interdependent community offers great benefits to its members, but by the same token it imposes responsibility upon them. This responsibility weighs particularly heavily upon scientists because of the dominant role played by science in modern society. The mathematician Michael Atiyah, who is currently president of the Pugwash Council for World Affairs, explained the reasons for the special responsibility of scientists in his 1997 Schrödinger lecture: "If you create something, you should be concerned with the consequences. This should apply as much to scientific research as it does to having children."

Atiyah outlined four reasons why scientists should take responsibility for the consequences of their work:

- Scientists will understand the technical problems better than the average politician or citizen, and knowledge brings with it responsibility.
- Scientists can provide technical advice and assistance in solving the incidental problems that may emerge.
- Scientists can warn of future dangers that may arise from current discoveries.
- Scientists form an international fraternity that transcends natural boundaries, so they are well placed to take a global view in the interests of the human race.

Atiyah also stressed that scientists should take responsibility for their work for another reason: the consequences of having a bad public image. The public does hold scientists responsible for the dangers arising from scientific advance: nuclear weapons are a menace and the public rightly blames the scientists; human cloning is distasteful and is viewed by the public as immoral. Through elected governments, the public has the means to control science, either by withholding the purse or by imposing restrictive regulations harmful to science.

Clearly it is important that science improves its public image, that it regains the respect of the community for its integrity, and that it recaptures public trust in its pronouncements. Scientists must show by their conduct that it is possible to combine creativity with compassion, by caring for their fellow creatures as they let their imaginations roam, and by being fully accountable for their actions as they venture into the unknown. ■

*Edited version of an article first published in Physics World, December 1999, pp.65-66.

Introduction

An Ethical Career in Science and Technology?

Stuart Parkinson

Science and technology have had a profound effect on society, particularly over the past century. We've seen massive increases in the supply of food allowing the human population to grow to 6 billion. We've seen once-virulent diseases such as bubonic plague and smallpox all but conquered. And we've even managed to put a man on the Moon. And if it were only consequences like those that resulted from our use of science and technology, this booklet would end here. But this is not the case. There are a whole other set of effects.

For a start, we have caused unprecedented damage to the environment on which we depend. Extinctions of animal and plant species are happening at a rate several hundred times greater than the natural level, whilst holes are appearing in the protective ozone layer around the Earth. Toxic chemicals are being released in huge quantities, whilst the climate is changing faster than at any time since the transition from the last ice age. These are all due to our careless use of science and technology.

But this is only one side of the problem. Historically, the main source of funding for scientific research has been the military. Such an emphasis has helped to start two world wars and, worst of all, create weapons so destructive that they could wipe out virtually all life on Earth within hours of their use. Many of these weapons, eg nuclear missiles, are still armed and ready for use across the world.

And then there is emerging science and technology. Will genetically modified crops help feed the world, or will they lead to 'super-weeds' and new diseases? Will the advent of cloning lead to designer babies or cures for new diseases? Will the increasing emphasis on commercially-driven science lead to technologies that are more profitable but less environmentally and socially beneficial?

The aim of this careers guide is to give scientists and engineers an introduction to the some of the wider issues and ethical dilemmas related to the areas that they may find themselves working in. The guide is divided into two main parts. The first, based on a small survey of scientists and engineers, explores the ethical issues that commonly occur across science and give ideas and advice for coping with them. The second part then discusses a number of important scientific areas where ethical issues are to the fore, including:

- Genetics
- Climate change
- Arms
- Militarisation of space
- Animal experiments
- Cleaner technology
- Information technology
- Science funding

This booklet is a summary of work which Scientists for Global Responsibility will be publishing as a book in 2002.

Science and technology can be used for the good of human society and the wider environment or they may not. Whilst it may be government or industry that takes the final decision on whether to use or not use a particular technology, it is we, as the scientists and engineers, that give them these technologies in the first place. It is therefore the ethical decisions we take in our work (whether consciously or unconsciously) that are critical in shaping the society of the future. We should not take such decisions lightly. ■

Part 1: General Issues

Yes, but is it ethical? Practical experience in dealing with science and ethics

Barry Rubin and Stuart Parkinson

Most people, when asked, would consider it important to act in an ethical manner - to do the 'right' thing. Scientists and engineers are no different. But their decisions can have consequences that are less predictable and have greater impacts upon society and the wider environment. In the worst case if you don't keep a close eye on the wider ethical issues, you may find yourself with no option but to resign to preserve your conscience. But there are many situations where the ethical dilemmas are more complex, the solutions more subtle. This section addresses how a range of scientists and engineers have dealt with ethical questions in their scientific career and asks them what advice they would give and whether they think that education for scientists needs to change.

The information given here comes from a survey carried out by Scientists for Global Responsibility during the period 1999-2000. The survey was carried out in two stages: the first was to fill in a questionnaire and the second consisted of interviews. 43 scientists completed the questionnaire and 21 were interviewed. The respondents encompassed a range of disciplines and ages.

1. Learning ethics

The first part of the survey was devoted to finding out how our respondents learnt about wider social and environmental issues, how this affected their ethical views, and what they thought about the teaching of such issues for scientists.

Early influences

There were many different factors that influenced the development of respondents' ethical viewpoints. For some, the strongest influences were early in their life, for others it came later, for example from an ethics course at university.

For some, a religious upbringing seemed particularly influential, whilst others had parents who were quite political. Carsten Rohr (physicist), for example, vividly remembers having political discussions at home during his childhood. Stephen Cox (engineer), on the other hand, became involved in ethical discussions whilst at school.

For others in our survey, the influence seemed to be particular events. For example, Rachel Burroughs (environmental chemist) remembers going to a local nature conservation group as a youngster and becoming involved in a discussion about how barn owls were declining in the area due to the increased use of metallic 'easy-build' barns. Cecile Le Duff (chemist) has a strong recollection of being repulsed by a biology class at school when she realised she might have to dissect a cow's eye. For Thomas Connolley (materials scientist), the most influential event was the fall of the Berlin Wall when he was 17. Up until then, he had wanted to be a fighter pilot. After that event he was not so sure.

A number of our survey mentioned the importance of travel and how this helped them to get a wider perspective on the world. Dr Sarah Cornell (environmental scientist), for example, spent much of her early life in Brazil. She lived in an area where the electricity supply had been cut off to be redirected to local gold mines, and hence began working towards a career in environmental science. Dr Dorothee Bakker (environmental scientist), who was brought up in The Netherlands, remarked how much environmental awareness on day-to-day issues, such as transport and recycling of materials, differs between neighbouring European countries.

However, several in our survey just felt they 'were going with the flow' – simply fitting in with what convention dictated was ethical, rather than thinking deeply for themselves. It was not until they were confronted with an ethical dilemma in their job that they actually thought about such issues. We will go into these dilemmas in section 2, but first we look at the perspectives of our respondents on the teaching of ethics.

Experiences of ethics courses

Of the 43 scientists and engineers who took part in our survey, 13 had taken a course that dealt in some way with wider issues, including some discussion of ethics . Most who had taken such courses were environmental scientists. Few in other disciplines had had the option of such a course.

The courses taken obviously varied according to the degree in question but covered issues such as science and society, philosophy of science, history of science, social effects of engineering projects, sustainable development, environmental impacts of petroleum/chemicals, responsibilities of professional practice, and doctor-patient relations.

Several of those who had taken such a course mentioned how significant it was for them. These individuals described how they found it particularly useful and helpful in clarifying what they wanted from their career. Thomas Connolley, for example, did a course on 'Environment and Development' which influenced how he plans to use his degree in materials science:

> *"A few years after completing a science degree, I took an Open University diploma in Environment and Development, because I was thinking about undertaking voluntary work in a developing country but felt that I poorly understood the issues involved. The course did a great deal to broaden my understanding of ethical issues in world development, particularly the relationships between politics, economics, cultural factors and the use of technology. The course also challenged some of my preconceptions about world development and highlighted the harm that can be done by well-meaning but poorly-planned development projects. I didn't take the voluntary post abroad, but it is something I am still considering for the future when I hope to have more appropriate skills and experience to offer."*

Paula Jacobs found her 'Science, Values and Ethics' module in her Environmental Science degree *"extremely interesting and thought provoking"*. She felt it was unfortunate that it was only an optional course.

Others, however, felt that, even when a course in wider issues or ethics was offered, it was not taken seriously, either as part of the degree (because it was not examined) or, as Neil Morris (electronic engineer) relates, by some of the students who took the course:

> *"I have often heard engineers complain about having to take compulsory classes in 'Engineering and Society' ".*

Cecile Le Duff offers an interesting perspective:

> *"In my last year at school, we had to take this compulsory philosophy course, which included quite a substantial part on science. Looking back, this was indeed very useful, although I didn't think much of it at the time..."*

How would you teach ethics?

This question provoked a lot of discussion, and a range of views. Virtually all of our survey believed that there should be some teaching of ethics to science students during their degree, and that this should include background information from other disciplines like sociology, environmental science and history. Dr Bevis Miller's (veterinary scientist) view was typical:

> *"If we believe that all scientists and engineers should be aware of the social implications of their work then clearly examining the ethical aspect of science and engineering should be part of their training."*

Some, like Dr John Devaney (engineer), believed that a separate ethics module should be compulsory in all science degrees, eg on moral philosophy. Dr Don Syme (computer scientist) felt that such a course should include discussion of the political pressures on science, from vested interests such as government, business and campaign groups.

Others thought that a course entitled 'ethics' could sound *"presumptuous and off-putting"* to scientists, or *"be seen as propaganda"*. John Stirling (sociologist) argued that to get around such resistance, controversial issues in science and technology could be introduced via a series of debates or role-playing exercises integrated into existing teaching modules. Sarah Cornell agrees:

> *"It would be nice to see it integrated into a range of courses, where - just like a certain basic knowledge of mathematics is assumed - everyone would be expected to have learnt a bit about ethical functioning and processes."*

Dr Ivan Long (environmental scientist) thinks that:

> *"A good scientific education should encourage the person to ask questions about what they are doing, think everything through carefully and not to be afraid to question the establishment."*

If this is the case, then he argues that the explicit teaching of ethics would not probably be necessary. Some thought that ethical issues should be considered much earlier in the people's lives. Cecile Le Duff argued that an introduction to ethics should accompany A-levels, and then the issues could be taken further and discussed in more depth at university. Dr David Cromwell (oceanographer) argued that:

> *"The whole educational system, right from primary school onwards, needs an overhaul."*

Some people were concerned about how much bias might creep into an ethics course. Thomas Connolley recommended that:

> *"Care must be taken to ensure that the course is not biased towards one particular ethical or cultural point of view. Instead, the emphasis should be on equipping young*

scientists with the necessary intellectual and communication skills required to actively participate in the ethical debates that will arise in whatever career they choose."

Dr John Stevens (climate scientist) took this point further, warning against the imposition on students of a *"pre-defined ethical standard"*.

So, in general, the respondents to our survey felt that teaching of wider issues relating to the practice and use of science and technology was necessary for all science students, and that this should include a discussion of ethical perspectives. Some felt a separate course was necessary whilst others preferred integration with other courses. Care was recommended with the teaching of such a course to prevent imposing a particular ethical viewpoint.

2. Experience in dealing with ethical dilemmas in your career

Trying to assess whether a particular job or career path is ethical can be very difficult. The issues that affect ethics in science and technology can be diverse. There may be some themes that occur repeatedly across a variety of disciplines, while others are more specific to one subject area. In this section, we look at how our survey respondents dealt with a range of ethical issues: involvement with the military; impact on the environment; animal experiments; and corporate responsibility.

Involvement with the military

The most common areas where our respondents found problems with links to the military were in computer science, electronics and physics, although, as we shall see below, other disciplines may also have connections. One electronic engineer, Neil Morris, told of how he worked on weapons-related projects for the Ministry of Defence and then began to feel that his work was unethical. He decided to leave and found non-military work. Several others in our survey had similar experiences.

But sometimes the decisions are not always so clear-cut, as the case of Kate Malkovich (computer scientist) shows:

"I had to decide whether or not to work for a company which made weapons systems. The project I worked on put up satellites for the military but did not directly kill anyone. In the end, after a long and agonizing process, I decided it was okay. The products I made were able (unlike something like Agent Orange) to be used in an ethical manner and I decided that I did believe in justified war. No formal mechanism for resolution of these issues existed, but I know that many other engineers in the department had thought about it."

Stephen Cox (engineer) also points out another ethical problem related to military projects:

"A distasteful aspect of the arms industry is its secrecy, ostensibly to keep military secrets secure, but sometimes also to conveniently cover up the spending of large amounts of taxpayers' money on projects of often dubious utility. Whilst readily admitting that it is essential to keep some important matters secret for military reasons, I think we should be more inquisitive and more critical about what our money is spent on and ask ourselves whether we want to spend it on this. This points to the need for debate and democracy in making decisions that were traditionally taken in secret on our behalf."

As ethical issues come to fore, some organisations are beginning to ask about such views at the interview stage to try to avoid problems later. The case of John Devaney (engineer) shows how important it is to be prepared:

"In being interviewed for work with a major aerospace company (on military aircraft) I was asked if I would have any problems working with nuclear weapons or in related areas. I was unable to answer."

But it is not always clear from the job application whether the candidate will be required to work on military projects. Rachel Burroughs (environmental chemist) applied for a job working on gas detectors:

"Before the interview they could not give details of the exact nature of the job - it turned out to be sensing of gas emissions from explosives. The science would have been interesting but the implications were not at all appealing."

Thomas Connolley (materials scientist) chose to tackle such issues by being direct at the interview:

"I made clear my reluctance to work on military/defence related projects. It was explained to me that it could affect my employment prospects."

He did not get the job. On asking why, the company replied that, since they had some projects with military involvement, they thought it would be better not to take him on. He was glad he had raised the issue at this early stage and avoided problems later.

However sometimes it may not be so easy to that honest. One physicist, Dr Philippa Browning, had the misfortune to find that virtually all the jobs she was recommended through her student careers service had military or nuclear power links. She now works as a senior lecturer in academia.

Sometimes the ethical dilemma may not arise with the company you work for, but a third party that you are contracted to. Dr W Arthur Chapman (physicist) became involved in such a situation:

> *"At the time we were engaged in some basic IT training on a consultancy basis. We had a request from a defence-related company for training. I refused to take part. I think we did not take up the training contract. However there was no formal mechanism as far as I can remember."*

But employers may not always be so understanding. It is important to consider what you would do if your employer gave you a choice between carrying out the work you consider unethical or leaving the organisation. A further issue is the work your colleagues are involved in. One case that arose was when a biologist won funding from the Ministry of Defence. As Dr Bevis Miller, a veterinary scientist in the research centre at the time, explains, it *"resulted in a severe internal departmental dispute with one of my colleagues resigning over the issue"*. On completion of the project, the department chose not to apply for funding to extend the work.

And of course, there is the issue of what happens to the research once it leaves the organisation, as Dr Don Syme (computer scientist) explains:

> *"The research I do (formal verification of computer systems) has the potential to be applied by military groups, because it is concerned with safety critical systems. Of course I do not engage in military work myself. However, it has many non-military applications, and indeed I think by doing the work I am doing I am helping to ensure that regular companies can apply modern verification techniques."*

This issue is something we will return to in the corporate responsibility section below.

Impacts on the environment

Another concern expressed by many of the respondents was the way in which their work may cause adverse environmental effects. Dr David Cromwell (oceanographer) worked for a major oil company for five years before resigning over concern for the way in which the company was contributing to global climate change. He believes that:

> *"the apparent 'greening' of oil companies is superficial - the core practices remain unchanged. What we need from the oil company giants is a fundamental shift to a truly ecological outlook and practice. But perhaps such large corporate structures are actually beyond reform."*

Environmental concerns were also expressed in working in the electronics sector, as John Devaney highlights:

> *"I see my present work as having a negative social and environmental impact – linked to unsustainable growth in production and energy use, use of toxic chemicals, and practices of built-in obsolescence. Lip service is given to sustainability issues by my employers."*

He has decided to look for work elsewhere.

And what of the direct environmental impacts of carrying out scientific research? Dr Dorothee Bakker (environmental scientist) is bothered by the use of potential pollutants as environmental tracers. Dr Mark Jones (ecologist), on the other hand, is concerned about the damage done by scientists researching the deep ocean ecosystems which form around hydrothermal vents.

As in the military section above, some scientists were concerned about how their work may be used in an unethical way. Dorothee Bakker was concerned about the use of some of her work to develop possible 'climate engineering' technologies (ie, intentional modification of the climate system - see the climate section).

Of course the opposite is also true, and some felt that by doing environmentally-related research they were contributing to solving major problems. Dr John Stevens, for example, felt his research on climate change was valuable work.

However, some reservations were expressed. For example, George Chester (air pollution scientist) is cynical that the air pollution work he does for local government makes much difference:

> *"More research is fruitless because there is no will to do anything about the problems caused by cars and so all research is targeted at tampering with symptoms and not at sorting out the cause or finding alternatives. The problem is completely institutionalised from government to university department."*

Edward Milner (science journalist) gave an example of when expensive scientific research was used unnecessarily. He described how a complex biological research project was carried out to look at agricultural pest control in East Africa, when the solution was simply educating the local farmers in particular weeding methods.

A further point made by several respondents was that, by doing environmental research, you become more aware of your own personal environmental impacts. Dr Andrew Park, in particular, expressed concern about the how flying to scientific conferences has, on a personal level, a proportionately large environmental effect. Again, some problems were encountered at the job application stage, as Paula Jacobs (transport researcher) explains:

> *"I am an active member of the Green Party and was in several cases advised to hide that fact on my application as it might make me seem biased and somehow extreme."*

A novel problem was raised by John Stirling, who translates scientific research papers:

> *"I have occasionally had misgivings with the hidden aims/agendas of the subject matter – especially regarding geological texts which dealt with the mining of precious metals."*

Animal experiments

Animal-based research is another area where ethical dilemmas are very much in evidence. However, in contrast with some of the other ethical issues raised above, there seems to be more formal recognition of the dilemmas involved. More university courses (eg in veterinary science) raise these ethical issues. Ethical committees have been set up within some research establishments to allow the discussion of issues such as animal suffering. Some respondents like Dr Geoffrey Hayes (veterinary scientist) felt these measures, coupled with legislation on the use of animals, adequately dealt with the issue.

Others were less certain. Biology student, Peter Benfell, expressed concern that he had not been made aware of any formal process for dealing with an ethical problem with a laboratory experiment (eg the use of animals or animal parts). And others, like Cecile Le Duff, felt that not enough was being done to reduce the use of animal experiments.

Sometimes there are particular personal issues which scientists working within the biological sciences face. For example Cecile Le Duff felt that:

> *"Working with animals would not be a career choice. But at the same time, I would rather see someone like me in the job than someone that has little respect for animals."*

Meera Singh (biologist) mentioned a more unusual dilemma:

> *"I have a personal discomfort in the killing of animals for research. The research is valuable, no doubt, I just had to talk it over and deal with it within myself. I've got the added dimension of being a vegetarian..."*

A further issue, raised by those involved in vivisection, was the concern that if they more openly discussed their work they would become targets for animal rights activists, as Ben Scot (biochemist) describes:

> *"It is often not possible to discuss work in detail with colleagues or members of the public for reasons of personal security."*

Geoffrey Hayes felt that, despite these pressures, the profession should still be more open: *"Not to be transparent is even more dangerous."*

Corporate responsibility

A concern that was raised by most of the survey respondents, regardless of what area of science and technology they worked in, was the growing influence of large corporations. Whether the respondents worked in the public sector (eg universities) or for the companies themselves, all questioned whether the work they did was always being used in the best interests of society. David Anthony (physicist) sums up the concerns of many:

> *"Science seems to be increasingly geared towards creating more wealth for already rich corporations. I do not believe this to be beneficial to humankind or the environment – the two entities that, in my opinion, should be the main beneficiaries of scientific effort."*

Dr Don Syme, a computer scientist working for a large software corporation, notes:

> *"The main ethical issues faced in working for major corporations are about the systemic nature of the corporation. A lot of what the corporation wants to achieve may be very positive, and the technology in general quite benign, but certain parts of the corporation are bound to be doing something they shouldn't be doing. There seems almost no way to avoid this – the whole system is set up from top to bottom to stop the individual asking ethical questions. When it comes to technical input at the personal level, individual engineers have little control over how their designs are deployed by marketing, sales or by customers."*

Thomas Connolley (materials scientist) highlights a particular dilemma faced by a scientist contemplating working in the commercial sector:

> *"In a world of multi-national corporations, frequent take-overs, mergers and joint ventures, a company with apparently impeccable ethical credentials may be part of a larger organisation whose moral position is open to question. For example, a small company manufacturing solar panels for use in developing countries may be owned by a parent company which is a major weapons manufacturer. Choosing to work for the small company raises a number of moral issues: is it ethically justifiable to contribute to the success of the parent company by working for the subsidiary? Do the environmental and social benefits of the solar power technology outweigh one's personal objections to weapons manufacture? Are the solar panels a spin-off from military technology? Could some of*

the solar power technology be used for military applications by the parent company?"

The particular concerns about the activities of individual companies vary widely. Dr Sarah Cornell (environmental scientist), for example, was worried about the activity of a particular major food company:

"I was offered a research post in the food industry, where I felt uneasy about the extent of the company's influence on the economy and environment of the island nation where the crops were produced. Discussion at and following the interview left me with a stronger sense that the company was less scrupulous than I would like."

In order to avoid the ethical problems involved in working for a large corporation, some of the scientists we interviewed chose to work in universities. But, as Dr Cornell highlights, the pressure to work with large corporations is still there:

"Because of the structure of university research council research, I expect a certain autonomy in deciding what work I do and what techniques I use, but I also have tremendous job insecurity, with short term contracts and occasional gaps between them. We may often find we take whatever work we're given. In practice, I think that if some work were offered that was ethically unsound, we'd only have the 'take-it-or-leave-it' choice."

Edward Milner (science journalist) is also worried:

"Because of budgetary constraints, much research (eg in agriculture) has to be orientated towards the corporate sector, so that patenting, restricting, and censoring of scientific publishing are now quite entrenched within the scientific community. Many scientists now have to gain approval before they can speak to journalists or even other researchers. In the end I can't see how true scientists can serve two masters: the search for truth and pursuit of profit. Most scientific research should be publicly funded, nationally or internationally."

Dr Geoffrey Hayes (veterinary scientist) refused funding for a project concerning the response of an animal's immune system to being fed with mother's milk because he was concerned about how the funder, a large corporation, would use the results. The corporation in question had been widely criticised for irresponsible marketing of baby milk in developing countries.

Edward Milner makes a similar point from the perspective of making documentaries on science-related issues. If a political point is being made in the documentary, he argues, it is much harder to secure funding from commercial sources. In particular, wildlife documentary-makers are regularly advised to steer clear of making political statements. And if a programme criticises a corporation's activities there is a significant threat of legal action.

David Anthony highlights another problem encountered when university researchers undertake commercially-funded work:

"Information is often rather restricted and papers containing potentially 'commercially sensitive' material have to be vetted by the interested parties before publication."

Jane Blake (meteorologist) pointed out a wider issue of ethics related to scientists and corporate responsibility. Many pension schemes, including the universities' own USS scheme, are invested in large corporations. Recent changes in UK law have meant that ethical issues are now more widely considered as investment criteria, but a given pension scheme may still not be consistent with an individual's personal views.

Being honest?

Some of the survey respondents highlighted the concern of scientific information being manipulated to suit a particular political or corporate agenda. Dr Paul Marchant (statistician) neatly sums up this concern:

"There is sometimes pressure to give the results that they want."

But in many cases, there is not an intention to deceive, simply a lack of appreciation of the complexities involved, as Dr Sarah Cornell explains:

"In the fuzzier disciplines, like environmental science, research quite often leads to complex or conditional types of outcome, and we get used to thinking in terms of multiple scenarios. It can sometimes be difficult to get information about these outcomes across to other people - 'hard' scientists may often be used to fixed, elegant relationships, and non-scientists (whether they are policy makers, the media or the public) also prefer to deal with short, snappy ideas rather than what they perceive as speculation. The risk is then of misrepresentation, ie that research results become over-simplified (or in the worst case, manipulated) summaries."

3. What advice would you give young scientists concerning ethics and career choice?

The survey asked the respondents what advice they would give to young scientists and engineers regarding the ethical dimension of career their choices. Here are their thoughts.

More education?

The first recommendation made was the need for scientists to try to understand the wider issues related to any work they might undertake. Dr Bevis Miller (veterinary scientist) summaries it thus:

> *"Consider the role of technology and science in a rapidly changing world. Clearly it has the potential to bring great advancement but potentially it also can bring about great destruction."*

John Stirling (sociologist) expands this point:

> *"The sort of science and engineering being done today impinges on the interconnectedness of the social and natural life of the planet in unpredictable ways. This means that any applied science or engineering project must be subjected to, and evaluated in terms of, multifaceted and inter-disciplinary scrutiny. Science and engineering can therefore not be done safely if they are done in isolation."*

Dr Mirna Dzamonja (mathematician) highlights the need even for theoretical scientists to become informed:

> *"Being involved in the ethical aspects of the scientific research is important even for those scientists who are not in the position to see or anticipate an immediate application of their work. Somebody else, now, or in the future, might be applying your research in a way you haven't thought of."*

And Dr Don Syme (computer scientist) goes on to remind us of current concerns about the effects of the global economy:

> *"Learn as much as you can about how science is regarded by non-scientists, and about how science is seen as a commodity by many of these people, and that your skills may effectively be bought, sold and controlled."*

Cecile Le Duff (chemist) points out a useful possible source of information:

> *"It might help to talk to people that are involved in the type of work that you are thinking of doing. Many people choose a career not knowing exactly what it involves."*

Rachel Burroughs (environmental chemist) has one further observation:

> *"Just because something is 'legal' does not make it 'ethical'."*

Deciding where you stand

After educating yourself about the wider issues, the obvious next step is to decide what your own view is. Dr Stephen Cox (engineer) gives a common example for someone looking at a career in electronics or computing:

> *"Ask yourself if you would feel comfortable designing a missile - how might it affect job satisfaction? How would you feel if it were used in anger to kill, which is nowadays not as uncommon as one might think. Mostly, in the computing and electronics business, there is a choice."*

But Thomas Connolley (materials scientist) sounds a note of caution:

> *"Question your own motives for taking a particular ethical position. Are you sure you understand all the issues involved?"*

Edward Milner (science journalist) points out the importance of thinking ahead:

> *"Learn to consider or confront the ethical dimension as early as possible in your scientific career, ie well before a situation arises where your career may be influenced by the outcome of a particular situation."*

Following your chosen career path

So now you've spent a bit of time finding out about the wider ethical issues in science technology, and decided how you feel about them. Now it's time to look for a job! But it is not as straightforward as that, as John Stirling, explains:

> *"By the time a young scientist or engineer comes to make a career choice, they will have already invested an enormous amount of their intellectual energy and creativity in acquiring the specialist knowledge of their field, and it's natural they should want to capitalise on this knowledge to make a good living. If current career opportunities in their specialism come disproportionately in an ethically 'at-risk' area, then they are faced with an agonising decision - go for money and prospects or risk their chances on the basis of ideals and seek to transfer their skills to a field which is less 'dangerous'. Another option may be to proceed in their specialist field and seek to influence decisions in their work according to their principles and ideals."*

But it should be remembered that trained scientists have a number of 'transferable skills', eg numerical skills, which can be applied by a wide range of scientific disciplines. Dr Andrew Park, for example, took an undergraduate degree in engineering and physics, but then studied environmental science at postgraduate level:

"Changing disciplines is often not as difficult as you might think. Engineers have switched to environmental science, physicists have become economists - I know of several individual cases besides myself. And scientists like these who have worked in more than one discipline can actually have an edge over their peers. A growing number of research centres are being set up, both in the UK and elsewhere, as the value of inter-disciplinary work is increasingly recognised."

So how should you approach job hunting? A number of the respondents believed that you should stick to your ethical principles (Dr John Devaney, engineer):

"Have strength in your convictions – don't be pressurised into taking a job which will compromise your principles."

But Dr John Stevens (environmental scientist) felt that that view was too idealistic, even working in a university:

"Research costs money and funding agencies will very rarely fund science for the sake of it. If you wish to have a rewarding career you will need to attract funding for research whose results have an application. This comes from a variety of sources and increasing in importance is the role of commercial or politically motivated non-governmental organisations. It is therefore becoming an increasing necessity for scientists to adopt a more flexible approach and there is a requirement to divorce one's professional ethical outlook from one's personal ethics. If you enter research starry-eyed and naive and expecting to put the world's wrongs to right you will be disappointed and you will have to compromise your personal ethical outlook to ensure continuity."

Thomas Connolley feels it is necessary to be straightforward about your own feelings:

"Be honest with yourself and potential employers about your ethical beliefs and be prepared to listen to other people who have views that differ from your own. Raising ethical matters at an early stage encourages debate and will help to identify any moral dilemmas that may arise during the course of your work."

Of course, sometimes it is not always clear what ethical problems may arise in a particular job, as Dr Ivan Long (environmental scientist) describes:

"You will rarely be faced with a big ethical dilemma in work. What is more likely is a series of very small steps which together add up to something much larger which is why one constantly has to think about what one is doing."

But despite all this, you still may find yourself involved in work that you consider unethical. At this point you may want to consider leaving the job. As we mentioned above, it can often be possible to find an alternative even if it means moving to a new discipline, and a number of our survey have done this (see section 2). But, of course, the final decision depends on the circumstances of the individual concerned. This is when the importance of 'support' comes to the fore.

Getting support

Many of our survey pointed out that trying to take an ethical stance within your scientific career can be a difficult and demanding thing to do. However, in general, they didn't think that this was a reason to give up on your beliefs, more that you should take care not to isolate yourself. As John Stirling explains:

"If you're faced with particularly intractable ethical problems at work, think about how you can get help and support - don't try to go it alone. Strive to establish a rich network of support so that you'll have somewhere to turn at such times."

He adds:

"Actively seek contact with specialists of other disciplines including non-scientific ones and also with 'ordinary', non-specialist people. Try to make sure you are constantly involved in discussion and debate not just about the detail of your work, but also about its wider context. Cultivate your ability to talk about your work and communicate it to people who know little or nothing about it, and listen to their reactions (this is also, arguably, essential to doing good science in today's world)."

Thomas Connolley suggests you also think about support from more formal directions:

"Is there a mentor or senior person within the company you can turn to when faced with a moral dilemma? Is there a union or professional organisation that can advise you on ethical issues in the workplace?"

4. Concluding comments

Looking at the advice given above, there seem to be four basic steps that need to be followed by scientists and engineers in the quest for an 'ethical' career:

1. Educate yourself about wider issues.
2. Decide where you stand – and think what you might do if your views were compromised.
3. Try to choose a career path consistent with these views – but be aware you may one day need to re-evaluate your views or even change job.
4. Get support.

We end this section with a couple of general thoughts:

> *"The choices you make will make a difference to the future. For most of us that difference may be small. But it matters. Think ahead to the day when you retire, and imagine that you are looking back on your career. Will you feel that you have made a contribution to society and that your effort had benefited other people? Will you think that the work you did during your career made the world a better place, or a worse one?"*

Neil Morris, electronic engineer

> *"Don't give up on a career in science because it's difficult to be true to your ethical beliefs. If all the scientists with strong ethical views gave up – who'd be left? Just the ones who didn't question at all – and where would science and society be then?"*

Dr Andrew Park, environmental scientist. ■

Note: many of the names were changed in this section in order to preserve the anonymity of the respondents.

Part 2: Key Issues by Subject

The Environment

Cleaner Technologies - why technology doesn't have to cost the Earth*

Tim Foxon

The development of 'cleaner' technologies offers the hope of providing people with the services that they want with reduced environmental and social impact. As the will to deal with these impacts increases, opportunities for employment related to the development and application of cleaner technologies are likely to increase dramatically.

The approach of clean technology is to find ways of satisfying people's demand for end-use services whilst using fewer resources and creating fewer wastes. This is often described as increasing the resource efficiency of providing those services. The need for dramatic increases in resource efficiency follows from the need to find ways to enable millions of people in poorer countries to meet their basic needs and aspirations.

Global population is likely to rise from the current level of 6 billion to 9 or 10 billion by 2050. At the same time, as developing countries industrialise and consumption levels in industrialised countries continue to grow, economic growth of 2-3% per year would lead to a quadrupling of consumption levels by 2050. This means that, unless consumption patterns change dramatically, the environmental impact per unit of consumption will need to decrease by a factor of 6 just to keep environmental impacts at current levels, and by substantially more to decrease impacts.

To achieve reductions of greenhouse gas emissions to combat climate change, whilst still enabling social and economic development of poorer countries, will require a massive switch to cleaner technologies for energy generation, in the form of more energy efficient technologies and practices and renewable energy generation. Similar arguments apply more generally across a range of technologies and practices, because of the wasteful nature of current, linear production and distribution processes. For example, it is estimated that, of products consumed, 90% of the material is discarded as waste (solid and gaseous) within six months of purchase.

Where will the employment opportunities lie in the new 'service provision' economy?

All products have some environmental impacts associated with the extraction, use and disposal of materials. This is the reason for favouring employers who take a responsible attitude towards reducing these life-cycle impacts, for example by selling services rather than products. The service idea can be applied in many sectors, including electrical goods, household services, transportation and energy services.

A clear need is for innovation in the design of product-service systems. This is often known as 'eco-design' and involves a combination of strategies to minimise total environmental impacts over the life cycle of a product. These include:

- selecting low-impact materials, e.g. renewable, recycled materials;
- reducing the weight or volume of materials in the product;
- using cleaner techniques for product manufacture, packaging and distribution;
- reducing environmental impacts arising from the use and maintenance of the product;
- optimising the life of the product, e.g. by creating durable products;
- designing for re-use, re-manufacture or recycling of the product.

Of course, technological changes, on their own, are unlikely to be sufficient to achieve sustainability. This is because at least some of the savings to customers resulting from resource efficiency improvements may be taken back in the form of increased consumption. For this reason, moves towards resource efficiency need to be complemented by moves towards ecological tax reform (taxing resource use and waste rather than jobs and income) and investments in maintaining natural capital - the living systems that provide the ecosystem services of freshwater, fertile soil and nutrient and resource cycles.

There is also a need for social and economic incentives for people to take up cleaner technologies and practices.

Thus, the move towards cleaner technologies will create employment opportunities not only in design and engineering, but also in business, marketing and policymaking. ■

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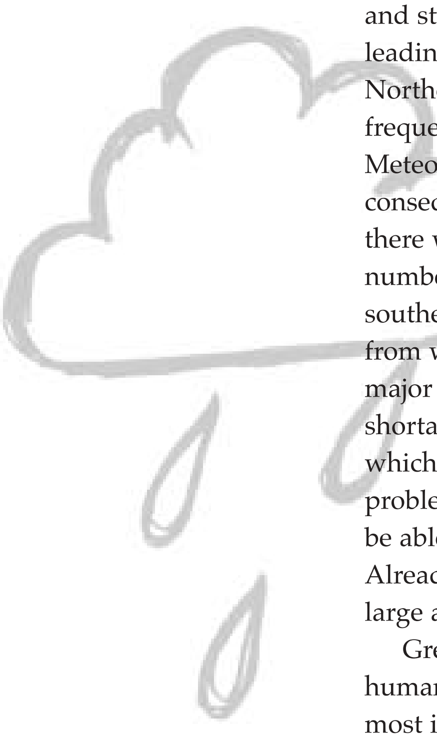

Tackling Climate Change*

Stuart Parkinson

Global climate change is one of the greatest environmental problems facing humankind. Due to the annual emission of billions of tonnes of greenhouse gases (GHGs) from activities such as the burning of fossil fuels, the globally averaged temperature is set to rise faster than at any time in the past 10,000 years (i.e. since the transition from the last ice-age). Over the last century, average temperature has risen by 0.6ºC, mainly due to the burning of coal, oil and gas and deforestation. In the next century it is set to rise by between 1.4ºC and 5.8ºC if no specific action to address climate change is taken. The range is due to uncertainty in both the science of the climate system and political and economic factors.

The consequences of climate change are likely to be devastating. The higher temperatures will lead to rising sea levels, due to the thermal expansion of sea water and the melting of ice. Coastal flooding will therefore become more common. These higher temperatures will also lead to a more severe 'hydrological cycle'. This means water will evaporate more quickly, leading to more droughts, and storms will become stronger and more common, leading again to more flooding. Continents in the Northern hemisphere are already experiencing more frequent storms and higher rainfall. The UK Meteorological Office has tried to estimate some of the consequences of this. Their conclusions are that globally there will be approximately a seven-fold increase in the number of people affected by flooding (mainly in southern Asia), and three billion extra people suffering from water shortages by 2080. There are also likely to be major impacts on agriculture, leading to local food shortages, and changes in disease patterns. The speed at which the climate is likely to change will create major problems for natural ecosystems. Many species will not be able to adapt fast enough and will become extinct. Already, with the recent small increase in temperature, large areas of coral reefs are dying.

Greenhouse gases are emitted by a vast array of human activities, but it is possible to summarise the most important sources. Carbon dioxide, the main GHG, is produced by the burning of coal, oil and gas to produce energy for use in industry (eg steel, chemicals, cement), homes (for heating, lighting etc), and transport (especially road vehicles and aircraft). It is also emitted during deforestation. Methane, the second most important GHG, comes from many sources including leaks in gas pipelines, livestock farming and rice cultivation. The third main GHG, nitrous oxide, comes from a variety of agricultural and industrial processes.

The employment opportunities for scientists and engineers wishing to help tackle climate change are as manifold as the causes. For example, there is a great need for environmental scientists to reduce the uncertainties associated with the climate system. One particular area is trying to predict 'climate surprises'. These are rapid changes in the climate system which may be highly damaging to humans and ecosystems. A major area for engineers is in the development of renewable energy technologies (eg solar, wind, hydro and biomass) and energy efficiency technologies, in buildings, industrial processes and transport (especially road transport). For social scientists, an important area is the investigation of how to encourage the adoption of environmentally friendly lifestyles. For economists and political scientists, important areas are ecological tax reform, environmental permit trading and ethical investment.

Climate change is one of the greatest environmental threats to humans and ecosystems. However, there is a wide range of ways in which scientists and engineers can help tackle the problem. ■

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The Environmental Impacts of Your Career*

Phil Webber

Almost every kind of career or activity has some kind of impact. This section outlines a widely-accepted methodology for assessing environmental, social and economic impact, sometimes called sustainability impact assessment or auditing.

This methodology can be applied to products or to specific well-defined projects and can also expose the impacts of the various elements of a career path, project or job and help reduce adverse effects.

The modern, developed-world lifestyle is based on high levels of consumption of raw materials and energy. High consumption levels are accompanied by high waste outputs. The collective consumption of resources due to human activity is rapidly reducing the levels of global resources and creating environmental impacts that exceed the recycling capacity of the ecosystem.

Sustainability assessment goes beyond accepted environmental, cost-benefit and social audit analyses and postulates a framework in which all three are considered holistically. The following list, extracted from a full check-list developed from several studies around the world, provides sets of criteria against which to assess the impacts of the issue, career path or activity in question.

Environment and natural resources

Are the global and local environment and natural resources conserved and protected? For example by:

- keeping emissions of greenhouse gases to within environmental capacity
- prudent use of natural resources to preserve sufficient stocks for the future
- conserving biodiversity
- avoiding processes that result in harmful bio-accumulative materials passing into the environment or food chain.

Social and community aspects

Does the local or global society/community benefit? For example by:

- introducing urban and transport design that is not dependent upon car or air travel.
- control of air pollution to safe levels
- providing health care that devotes as much resource to prevention of disease as to treatment
- empowering people to take part in a functioning local community

- providing appropriate learning resources to enable active participation in society
- eliminating unfair discrimination

Economy

Does the project benefit the local economy and create wealth? For example by:

- enabling good standards of living
- providing worthwhile jobs
- recognising and rewarding occupations supporting the community
- realising that wealth sharing is as important as wealth creation

Any list such as this will always be incomplete, and the terms themselves are not easy to define. But it can help form a framework by which to judge "sustainability", and it was endorsed – although not in this precise form – by the UK Government in 1999 in "A Better Quality of Life – a sustainability strategy for the UK".

The check-list can also be used to assess the sustainability of a project or occupation, by helping to establish the main impacts of a particular activity and to analyse those impacts in more detail, in order to establish their physical, social and economic scales and timescales. It should then be possible to see those impacts which tend to reduce or enhance sustainability opportunities, and, with good data, to establish whether key impacts are above or below the critical level at which the activity is deemed unsustainable. Ultimately the activity or product can be redesigned to minimise the impacts, or scrapped.

The role of scientists and engineers

As a scientist or engineer you are far more likely to be involved at the vital design stage of a project or activity, or in assessing the success or failure of work. Your role is crucial in helping bring about a more sustainable way of life.

Archimedes is attributed as saying "give me a lever long enough and a place to stand and I will move the world". Science and technology, combined with limitless exploitation of natural resources and the environment, have put us in the position of Archimedes in his vision. Together we are indeed moving and reshaping the world – ecologically and socially.

Scientists and engineers have given us this immense power and must take responsibility for helping us decide and plan for how to use it. To achieve sustainability according to the above list, engineers and technologists must start moving towards designs that reduce energy use by 90% and resource use by 80%. What is needed is a revolution in design and in the application of technology.

Sustainability appraisal is one tool that might help prevent continued environmental degradation, and widespread and irreversible damage to ecosystems that, if unchecked, will lead to a sharp decline in quality of life and living standards for most of the world's population during the first century of this Millennium. ■

*Based on an original article by the author.

Military Issues

Warfare and Technology

Stuart Parkinson

Historically, scientists and engineers have played a major role in developing technologies for military use. Even now a third of UK Government funding of science and technology is from the Ministry of Defence. The right of a nation to defend itself is enshrined in the United Nations Charter but the ethics of being involved in military projects is increasingly open to question.

Since the end of the Second World War, there have been at least 212 wars around the world, with 35 of them still being fought in 1999 - mostly in Africa and Asia. One estimate puts the average number of deaths at half a million a year. While some wars have been widely reported, such as those in the Middle East or former Yugoslavia, many have gone virtually unnoticed giving the impression that armed conflict is receding.

In fact what has been happening over recent decades is that the nature of armed conflict has changed. Historically, wars have tended to be fought between nations by their armed forces. Much more common now is warfare within a country, for example between government forces and ethnic militias or criminal organisations. This change, coupled with the availability of more powerful weapons, has meant that civilians are considerably more likely to suffer the consequences, both through being caught up in the fighting and also through indirect effects such as famine. It is now widely accepted that approximately 90% of the casualties of war are civilians, with half of those being children. Landmines have become a particular problem, killing 10,000 people a year and maiming another 20,000, with many of the deaths and injuries occurring after the end of the conflict. The scale of the problem led to the agreement in 1997 of a United Nations Convention banning the manufacture and export of landmines.

Apart from conventional arms, many nations have stockpiles of weapons of mass destruction, particularly nuclear weapons. Attempts to stop the spread of nuclear weapons have been made using the Nuclear Non-proliferation Treaty (1968), but these have failed largely because of the unwillingness of the five declared nuclear states (USA, Russia, China, UK and France) to take significant steps towards disarmament. Biological and chemical weapons are banned under the Biological and Toxic Weapons Convention (1972) and the Chemical Weapons Convention (1993). However, concern has grown recently that biological weapons in particular are being secretly developed following the discovery of such a programme in Iraq.

The UK is the world's second largest exporter of conventional arms after the USA. It is also home to the world's second largest defence company, BAE Systems, formed from the merger of British Aerospace and the defence subsidiaries of GEC. Arms exports, according to the Ministry of Defence, are worth £5 billion a year to the UK economy and support 90,000 jobs. Government rules prohibit the sale of arms if there is a 'clear risk that the proposed export might be used for internal repression or international aggression'. However, this policy has been called into question on a number of occasions, most recently with the sale of Hawk jets to Indonesia where eyewitnesses reported their use on the East Timorese. Further, it has been pointed out that the UK supplies arms to 30 of the 40 most oppressive regimes in the world, with British arms being used in most of the world's current conflicts.

So how might a scientist or engineer go about avoiding involvement in military projects? In some cases, of course, it will be obvious if a project has military applications. In others, however, it will not be so clear. Many defence companies now contract out components manufacture so it is worth checking if a chosen employer is a defence supplier. A safer bet is work on a project with a clear beneficial output, e.g. renewable energy generation.

In addition there are jobs that help prevent war, for example research on conflict avoidance or disarmament verification. The former looks at the roots of war and attempts to suggest means of finding a peaceful settlement before armed conflict begins. The latter is an essential part of disarmament treaties, providing a means for nations to ensure all parties are adhering to the treaty. A further possible job is in detecting and clearing landmines, under programmes co-ordinated by the UN Mine Action Service (UNMAS). ■

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The Militarisation and Nuclearisation of Space*

Dave Webb

The background

Military, commercial and scientific endeavours in space are closely linked. It is well known that the first explorative space missions employed hardware originally developed for military purposes, that the race to send astronauts to the moon was politically motivated and that military requirements often still provide the catalyst for space exploration.

This is despite the UN's Outer Space Treaty of 1967, agreed by 91 nations including the US, Russia and the UK, which reserves space for peaceful purposes. The treaty says *"the exploration and use of outer space shall be carried on for the benefit and in the interests of all countries and shall be the province of all mankind"*. It also bans nuclear weapons and weapons of mass destruction from space.

The Reagan administration presented the most severe threat to this agreement with, among other actions, the Strategic Defense Initiative (SDI) announced in Reagan's famous Star Wars Speech of 1983. At a Washington press conference in 1986, 3700 senior scientists and engineers publicly pledged not to take SDI funds.

Satellites are now commonly used for communications and surveillance. The information they provide helps military commanders to monitor battlefields, develop strategy, organise their forces and target their weapons. In November 1999 the UN General Assembly was asked to reaffirm the Outer Space Treaty. Some 138 nations voted for the motion entitled: "Prevention of an Arms Race in Outer Space". The United States, joined by Israel, abstained.

Creeping militarism

Space projects are often promoted to the public for one reason (e.g. spotting ecological disasters) but sold to the highest bidder (i.e. the military) as soon as the technology can be demonstrated.

The original European Space Agency (ESA) statute limits its activities to peaceful purposes. However, in November 2000 the ESA and the European Council issued a joint strategy paper stating that dual-use is inherent to all space technology and that space is important to a European defence system.

And, more than 30 years after SDI, Washington is saying it needs a missile defence system to safeguard against potential new threats from "rogue" states. The system is seen by many as less a deterrent, more as the initiator of an arms race in space.

Nuclearisation of space

In 1997, NASA launched the Cassini space probe carrying 72.3 pounds of plutonium on a Titan-4 military rocket. Cassini's sling-shot orbit brought it within 700 miles of Earth. It passed safely – but NASA said that if the probe had made an "inadvertent re-entry" into Earth's atmosphere, it would have broken up, released its plutonium and exposed approximately 5 billion of the population to radiation. NASA put the chance of failure at 1 in a million but others have calculated it at 10% – and the possible human death toll at up to several million.

According to a US General Accounting Office report, NASA is *"studying eight future space missions between 2000 and 2015 that will likely use nuclear-fueled electric generators."*

Both ESA and NASA have developed new, high-efficiency solar cells for space-use which can be substituted for nuclear sources. The ESA plans to deploy them in 2003 on the Rosetta probe. NASA insists on using nuclear power for probes to Jupiter and Saturn.

Justifying space missions – and jobs in space science At the 1999 conference "Space Use and Ethics" in Germany, it was suggested that the worthiness of any scientific project should be evaluated by considering the costs and resources needed; the goals and benefits expected; and the undesired consequences and risks. And in addition: who gains what; who pays the costs; and who takes the risk. Very often these are quite different groups of people.

Ideally, future space projects should exclude the possibility of severe catastrophe, avoid military use, violent conflict, and proliferation, minimize adverse effects on health and environment and justify projects in a public debate.

In space-related research it can be easy to convince yourself that your involvement in any project is acceptable and independent of the harmful technologies being developed by someone else. Of course, not all space projects are harmful. However, we must be careful to check who we associate with when choosing space-related work, and if necessary speak out against false representation. ■

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*Based on an original article by the author.

Ethical Issues in Biological Sciences

Ethics and Genetics*

Mae Wan Ho and Sue Mayer

The public and private sectors are pouring funding into genetics technologies and opening multitudes of opportunities for scientists; but the area is dogged by a host of ethical dilemmas. These are a few that you might consider when considering a career in this area (this is only a sample, not an exhaustive list). These moral questions need not rule out a career in genetics – but they may help put some boundaries around what you feel is acceptable or not.

Patenting

Patenting is one issue that cannot be avoided by any scientist in the public or private sector any more. Previously, patents (ie exclusive commercial rights) have been given only for inventions, ie new technologies. With the advent of genetics, however, patents can now be given for discoveries, thus considerably expanding the power of the corporate sector in this field. Is it right to patent the discovery of gene sequences and thereby have monopoly control over their commercial use for 20 years? Should plants and animals be patentable even though they reproduce naturally? And will patents hinder the use of genetics in the broader public interest? How will they affect the ability of developing countries to access the technologies? What of the rights of indigenous peoples, who sometimes supply raw materials and information that is then patented by a large company, resulting in the loss of the previous free access by those people to their own product?

Human Genetics

In human genetics there are questions about the morality of cloning. Whilst human cloning is banned in the UK, this is not true worldwide. Could knowledge gained here be wrongly applied elsewhere? And should embryos be used in genetic research? Does their use in research intended to produce organs change their status to one of being a commodity?

Another question is whether it is right to interfere in human germ lines – should we genetically engineer people in ways where the change will be passed on from generation to generation? Whilst it may be possible to correct genetic defects that cause certain serious diseases by genetically engineering an embryo, can we predict the outcomes for the child and subsequent generations? Many potential uses of genetic technologies will involve experimenting on babies (if engineered embryos are allowed to develop). Even if we do not do this, how far should genetic testing of embryos be allowed to go – what is the dividing line between disease and enhancement? And should we allow enhancement, ie allow parents to select favourable genetic traits such as beauty or intelligence which could have knock-on social effects?

Agricultural Genetics

In the field of agricultural genetics there are questions about whether it is morally justifiable to transfer genes between unrelated species. Can we predict the outcome with any accuracy and will the benefits outweigh the risks? For example, genetically modified (GM) arable crops such as soya and maize have been grown on a large scale particularly in the USA. Their attraction lies in the possible increases in yield to feed a growing human population, but so far there has been no overall increase in crop yields in practice. While some farmers have benefited in terms of easier management, potentials for negative effects on human health and the wider environment has emerged, with some research raising fears about possible increases in human allergies, and damage to beneficial insects and soil. Further, some GM crops have been specifically designed to be resistant to a herbicide which will lead to an increase in the use of that chemical (manufactured by the same company that developed the genetically engineered seeds).

There is also concern about the consequences of the uncontrolled spread of genetic material. The infectivity of viruses makes them useful in genetic engineering as carriers of foreign genes into a host species. Unintentional spread of alien genes to other plants or animals is then possible through the mechanism of horizontal gene transfer, i.e., direct gene transfer from one individual to another, in contrast with normal, vertical transfer from parent to offspring. Some geneticists cite strong evidence that the viral fragments in genetically engineered plants and animals may combine with other viral fragments already present in the host, resulting in the creation of new, highly infective hybrid viruses that could cause new and possibly virulent diseases in plants and animals, including human beings.

Some researchers argue that alternative routes to increasing food production are being neglected due to the commercial focus on GM crops (see also 'Where does the money come from?' on p?). For example, researchers from the University of Essex have highlighted how crop yields could be significantly improved in developing countries simply by minor changes in traditional farming methods. Other researchers have also pointed out that greater food production could be achieved if there was a reduction in the proportion of grain used as livestock feed (currently standing at 37% of the total grain production) as meat production is a much less efficient way of producing human food. It has also been pointed out that agricultural dependence on a small number of commercial crop varieties (which GM companies encourage) can leave farmers, particularly those in developing countries, vulnerable to disease.

There are also major concerns about the use of genetics in animal farming. When animals are used, is it right to engineer them to fit into intensive agricultural systems? Many genetic engineering experiments go wrong and there has been considerable animals suffering as a result.

A wider issue is the way in which patented GM crops can allow corporations to gain further control of how and what food is produced. Companies developing GM plants are exploring genetic means of restricting access to the technology. The result is that seeds produced will not germinate, or a characteristic such as flowering or disease resistance has to be switched on by the application of a chemical – both resulting in the farmer having to buy seed and/or chemicals each year from the company that produces the seed. Is this a morally defensible course of action in the developed and developing world, or is it right that people should not be able to 'steal' such developments? Is there a way to ensure that the government agencies responsible for making decisions about the safety of GM foods will be truly independent and will not ignore scientific evidence that undermines commercial interests?

Biological Weapons

Finally and most chillingly – could the knowledge be applied to make biological weapons? Genetic engineering could make biological weapons more attractive to aggressors by making them more rapid and effective at causing death or disease or by enabling weapons to be targeted at certain ethnic groups. Crops and animals may also be the targets of biological weapons. Military research in universities continues: how can you be sure knowledge is not abused in this way?

Conclusion

Genetics is a very complex research area, which throws up a whole range of ethical issues. Whilst some researchers believe that the technologies will yield benefits, others are much less certain questioning in particular the powerful influence of large corporations. Some also argue that the underlying science is far less certain than conventionally believed: that the assumption that a single gene (or small number of genes) is responsible for a single trait or illness (known as 'genetic determinism') is over-simplistic. The implication of this is that the results of genetics research are likely to be much less predictable, and hence promises of 'magic bullet' treatments for disease may well be flawed. It is important therefore that scientists consider both the uncertainties in genetics research and the way society may use or misuse such research. ■

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*Based on two original articles by the authors.

Ethics and Animal Experiments*

Gill Langley

Introduction

When human needs and desires conflict with animal interests, it is the human perspective which is normally considered to be paramount. Nowhere is this more apparent than when animals are used in scientific or medical research. The justification for this stance results from a view of the moral status of non-human animals which, in the world of research, is often based on the argument that while other animals have moral value they do not have moral equality with humans.

There are other views. Philosopher Tom Regan, for example, believes that since some non-human animals not only feel pain, but also have attributes such as thoughts, beliefs, memories and intentions, they should have equivalent rights. But the prevailing opinion where the use of animals in research and testing is concerned assumes that the animals' pain and distress count in the balance, but not as heavily as human interests. As a result, an estimated 100 million animals are used in scientific procedures every year worldwide, including about 2.6 million in the UK.

Different perspectives

The way animals are viewed, by scientists and by society, has been deeply influenced by the behaviourist school of psychology which allowed biomedical researchers to consider laboratory animals as insensitive to suffering. In contrast, animal ethology, psychology and modern evolutionary biology combine to suggest that a continuum of cognitive and emotional functions throughout the animal kingdom is more likely than a major discontinuity between humans and all other species.

Apart from organizations and individuals conducting animal research, many commercial sectors have an economic interest in its continuation, including manufacturers and suppliers of animals and equipment. Researchers and pro-vivisection groups fear that scientific progress and freedom of investigation will be damaged by stringent regulation of animal experiments.

Ranged against these interests are anti-vivisectionists who completely oppose animal experiments for ethical reasons and/or on scientific grounds.

Non-animal methods of research offer a way forward that can be supported by all sides of the vivisection debate. The concept of non-animal methods was developed in Britain in the late 1950s but replacement methods were not widely accepted as practical by the research community until the 1980s. Today, replacement techniques such as molecular research, cell culture and computer modelling are often perceived as beneficial to scientific standards as well as to animal welfare.

Change is also occurring at the regulatory and legislative levels and there is now stricter control of animal experiments. As a result, in Europe and the USA, the number of experiments on animals has been falling since the 1970s. However, scientists applying to mainstream funding bodies specifically to develop non-animal techniques are unlikely to find success, unless they couch their justification in terms of scientific rather than ethical benefits.

However there is a risk that these positive trends are about to reverse: animal genetic engineering, for example, has increased enormously over the last decade and multinationals threaten to evade Britain's control of animal experiments by moving their research overseas. Increasingly, science is being driven by commercial enterprises whose interests conflict with public opinion on animal experimentation.

Ethical employment paths?

The majority of biomedical research does not, in fact, involve laboratory animals. The focus of the following research areas is (or can be) primarily non-animal: clinical and human volunteer studies (including brain imaging), cell and tissue culture, molecular research, computer modelling and epidemiology.

There are also employment areas that address the negative impacts of animal experimentation: working for an animal welfare organisation, for example, is many people's dream. However, posts within them for scientists are few at present.

There are research opportunities for modifying or 'refining' traditional animal models or procedures to reduce suffering. There is as yet no established career path in refinement research, so finding suitable locations and funding remains ad hoc.

There is a field of research that seeks ways of improving the husbandry of laboratory animals, by identifying the needs of different species. There are also opportunities in research specifically aimed at developing alternatives to replace animal experiments.

As a self-confessed animal welfarist or even anti-vivisectionist you can still pursue a research career, but you may well come under fire from time to time. Even so, you would be influencing the future directions and character of biomedical research. ■

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*Based on an original article by the author.

Broader Issues in Science and Ethics

Politics and Ethical Dimensions in Science*

Alan Mayne

The political situation

Global politics needs a new holistic approach, which works for the interests of all, emphasises cooperation instead of confrontation, and provides a more participatory democracy. Here, scientists, like other citizens, have a wide range of responsibilities and much to contribute. Most global, national, and human problems are escalating into a cluster of interlocking crises that cannot be solved in isolation. They must be addressed together, taking account of their mutual interactions. Advances in science and technology have contributed to the problems, and could also help to provide the solutions.

Political and scientific paradigms

Citizens and politicians alike need to be made aware of existing and new political paradigms and thinking. Democratic paradigms, for example, need to go much further. A paradigm of multi-level worldwide democracy is emerging, based on the Principle of Subsidiarity.

New paradigms in other fields are also valuable. Ecological economics offers alternative paradigms to the present dominant, global capitalist paradigm. The ‘living systems paradigm’ applies biological principles to humanity. The Gaia hypothesis (also known as ‘Planetary medicine’), pioneered by James Lovelock (1991), applies biological and medical principles to the healing of Planet Earth. In the best of the new business paradigms, people matter most and environmentally sustainable policies and practices are sought and adopted.

Ideally, politics should be a holistic concept that draws on these new paradigms; where scientists are able, we should help promote these ideals. We should also try to take part in the political process by participating in public debates, submitting evidence to government consultations and so on.

Global ethics and spiritual values

Despite their diversity, the similarity between the basic moral principles of the great religions gives hope for the emergence of a global ethic. Much has been written on this subject.

Hans Küng’s (1992) book Global Responsibility argued for a consensus on basic ethical values among people of all religions. Its influence led to the Declaration Toward a Global Ethic, agreed by the 1993 Parliament of the World’s Religions. Its principles are based on a realisation that Earth cannot be changed for the better without transforming the consciousness of individuals and those in public life. Ideally, as many professions as possible should develop up-to-date codes of ethics.

The responsibilities of scientists

Effort is needed to think through the longer-term impacts of our jobs. Appropriate texts on how science can be practised ethically can help. Science for the Earth (Wakeford & Walters 1995), for example, advocates radical reform if science is to work effectively for the good. It recommends less ‘big science’ and more ‘little science’, new career structures and more encouragement of scientists’ originality and versatility, among other things.

We can also advocate the adoption of the Precautionary Principle, which says: "Where there are threats of serious or irreversible damage, uncertainty should not be a reason for postponing action to prevent that damage."

The start of a positive new stage of evolution for humankind and the planet will require radical changes to existing trends in many directions; a holistic approach; a dramatic raising of human consciousness and human morality; and a ‘critical mass’ of people transformed in these ways. ■

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*Based on an original article by the author.

Where Does the Money Come From? - The Funding of Science

Stuart Parkinson

The sources of funding for science and technology are critical in shaping the work that is carried out. In the UK, this funding comes from three main sources: government, business and charitable trusts. While each generally has different priorities, the distinction can often be misleading. For example, some businesses are narrowly focused on profit whilst others have strong social and environmental objectives. However, there are three particular ethical concerns about the current way in which UK science and technology are funded:

- Government funding heavily favours military projects;
- Overall science funding from government has fallen significantly, causing scientists to depend increasingly on business funding, which leads to greater emphasis on science geared towards narrow economic goals; and
- Increasingly government funding is linked to commercial funding, again leading to a narrowing of objectives.

The UK Government currently spends £6.3 billion a year on science and technology. Of this, one-third is spent by the Ministry of Defence. This proportion dwarfs spending by other government departments: for example, the Department for the Environment, Transport and the Regions (DETR), until it was restructured in 2001, was responsible for less than 3%. Further, since the UK is one of the world's largest exporters of arms, much commercial funding also goes into this area. This leads to an emphasis on projects with military applications within the UK science and technology sector.

Government funding for science and technology fell by 17% between 1987 and 1999. This shortfall has caused scientists to turn increasingly to business for funding. It could be argued that this is a positive development since applying new technologies could help boost the UK economy and provide jobs. However, such a path inevitably leads to a greater focus on work that adds to the profitability of UK industry, rather than looking at wider social and environmental concerns. One particular example illustrates the dangers of this approach. Current funding of research in UK universities concerned with oil and gas exploration and production is five times greater than that on cleaner renewable energy sources such as wind and solar.

The UK Government provides the main sources of funding for university-based research, mainly through the Higher Education Funding Council (HEFC) and the seven Research Councils. Again, however, the influence of industry is significant and, indeed, it is government policy to encourage this, as stated in 'Science and Innovation' the Government's recent White Paper on the subject. A growing number of the grants awarded by these bodies are on the condition that matching funding is found from industry. Further, the steering committees of each of these councils have significant representation from industry. Again, this leads to a bias in favour of the science and technology which suits the powerful industrial lobbies. For example, the government recently admitted that in 1999 it spent £52 million on research into the agricultural applications of genetic engineering compared with only £1.7 million on research on organic farming methods.

So where does this leave the 'ethical' scientist looking for a job? Probably the most important action is to do some research into the funding-providers for any jobs of interest. Whether it is a Research Council, private company or charitable trust, find out whether they have an environmental and social policy and investigate what sort of activities they have funded in the past – i.e. identify their ethical position. (The web-sites of organisations are often good places to start.) Only then will you be able to make a fully-informed decision about whether to work for them. ■

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Ethics and the World Wide Web*

Tim Berners-Lee

I designed the World Wide Web for a social effect, to help people work together, not as a technical toy. When technology evolves quickly, society can find itself left behind, trying to catch up on ethical, legal and social implications. This has certainly been the case for the Web.

It is essential that policy and technology be designed with a good understanding of the implications of each other. Technologists cannot simply leave the social and ethical questions to other people, because the technology directly affects these matters.

Ideally the Web should accommodate the maximum diversity of public policy choices. The kinds of tools we make available should ensure that individuals retain basic control over their online experience while also helping assure that national laws are effective in areas like freedom of expression, child protection, intellectual property and so on.

Issues such as information quality, bias, endorsement, privacy and trust – fundamental values in society but much misunderstood on the Web – need also to be considered, as they are highly susceptible to exploitation by those who can find a way.

Privacy

Agreements on privacy and confidentiality are part of the greatest prerequisite for a web-like society: trust. A key technology for implementing trust is public key cryptography (PKC), a scheme for encoding information so no one else can read it unless he or she has the key to decode it. However, it is not currently available, largely for political reasons.

Bias and the quality of information

Bias on the Web can be insidious and far-reaching. It can break the independence that exists among our suppliers of hardware, software, opinion and information, corrupting our society.

The Web's infrastructure can be thought of as composed of four horizontal layers: the transmission medium, the computer hardware, the software and the content. The independence of these layers is important. From the point of view of economics, it represents the separation of horizontal competitive markets from anti-competitive vertical integration. From the information point of view, think of editorial independence.

Companies that try to take a vertical slice through the layers are more worrying than those that create a monopoly in any one layer. Vertical integration – for example, between the medium and content – affects the quality of information, and can be insidious.

I want a Web browser that will show me any site, not one that keeps trying to send back to its host site. When I ask a search engine to find information on a topic, I don't expect it to return just the sites that happen to advertise with or make payments to the search-engine company. And imagine this: it could be possible for my internet service provider (ISP) to give me better connectivity to sites that have paid for it, and I would have no way of knowing this.

There should always to be a choice of the unbiased way, combined carefully with the freedom to make commercial partnerships. When other people are making a choice for me, I would like this to be made absolutely clear.

Endorsements

Strong concern about business standards has motivated some companies to make attempts to pre-empt outside imposition of ethical standards by trying to regulate themselves, primarily with endorsements.

The Netcheck Commerce Bureau, for example, is a site where companies can register their commitment to certain standards, and receive a corresponding endorsement.

Some larger companies are taking it upon themselves to establish a 'branding' of quality. IBM, for example, has developed what it calls an 'e-business mark' for companies that have shown a commitment to delivering a secure and reliable environment for e-commerce.

The e-business mark may be a harbinger of the way many endorsements will go, but, unlike regulation, endorsement can be done by anyone, of anything, according to any criteria. If 'self--regulation' simply becomes an industry version of government, managed by big business rather than by the electorate, we lose diversity and get a less democratic system.

As a consumer, I'd like to be made aware of the endorsements that have been given to a site - but without being distracted from the content. ■

Further Reading

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*This article is a summary of Chapter 10 of 'Weaving the Web' by Tim Berners-Lee.

And the Rest ... *

Alan Cottey

To have a career that 'did not cost the earth', but a lifestyle that did, would not make sense. This is obvious, but avoiding this contradiction is not so simple. ‘Not costing the earth’ applies to the whole of our activities. This includes what we consume and our relations with other people. When we review our life over, say, the past year, we find that we sometimes worried about unsustainable practices. We sometimes did (or abstained from) things which we now recall with satisfaction. But often we went with the flow. In this summary (and in more detail in an essay in the full guide), the focus is on ‘the individual in society’ and on offering some thoughts on the links between career/employment and the rest ...

The main concern, for those seeking a job that does not cost the earth, should be a generalised one - what can I do to minimise harmful ecological impact? This concern bears on our personal life, and it also bears on our occupation, no matter what the sphere of employment. In particular, the ideology of economic growth pervades nearly all employment, and not just ‘business’. Nearly all education professionals, for example, want their sector to grow and they assume this must take the form of economic growth.

"How?" rather than "for whom?"

It is natural for environmentally aware students to ask ‘where can I find a job that does not cost the earth?’ Of course, some employers and some areas of employment are greener than others and we can search them out. But it is also necessary to integrate this choice with our practice once in post and also with the rest of our lives. Even if we work for, say, an alternative energy company, we will need to be sympathetic to the company’s need to survive economically in the real world, which necessitates many compromises.

Similarly, a case can be made for light greens joining grey companies and helping them to become (as a first step) light green. Each instance requires separate investigation.

In any case, we may surprise ourselves by finding that we need to ask: ‘What shall I do with an income far in excess of what I need for a pleasant but environmentally sound lifestyle?’ Most people from rich countries travel a great deal by air. The goods they consume have also travelled many air-miles. Here are major sources of environmental harm, and ones that the individual can readily influence. These problems deserve high priority – in our personal lives and our professional practice.

And finally, a general suggestion for those attempting to effect change: don't go it alone. It is safer and more effective to find allies first. Constructive engagement can then follow. Some channels for engagement (in no particular order) follow.

- A professional society for your specialism: this will probably have some kind of ethical code, although it may be principally concerned with the self-interest of the profession. Those few members who, at an early stage of their careers, take a constructive, non-confrontational interest in the ethical code of their professional society can have a considerable effect: usually this is left to more senior members.
- A staff association or union: for the most part, it will probably attend rather narrowly to its members’ interests. But a small ginger group within it will usually be able to interest the association in issues regarding ‘not costing the earth’.
- An independent organisation concerned with ‘not costing the earth’: nowadays, communication between like-minded people is very easy.
- Reading - keep in touch with what others are thinking and doing in these areas. There is a constant trickle of new ideas and information in books, articles, discussion lists and web pages. ■

Further Reading

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*Based on an original article by the author.

About the Contributors

This booklet is a summary of the forthcoming report, *An Ethical Careers Guide in Science and Technology?*. The contributors to this report are listed below (in alphabetical order).

Dr Tim Berners-Lee, the inventor and principal architect of the World Wide Web, has taken the ethical and social responsibility aspects of this innovation seriously throughout its development. He carries these concerns forward in his current work on the Semantic Web. He is Director of the World Wide Web Consortium.

Dr Alan Cottey is a Fellow at the University of East Anglia, where he initiated and taught a course on Science and Ethics. He is currently working on a project known as Open Science. He is Secretary of the Martin Ryle Trust and a member of SGR's Coordinating Committee.

Dr Tim Foxon is a Research Associate at Imperial College's Centre for Energy Policy and Technology, and Secretary of SGR. He was a member of the student team which organised an influential series of conferences 'Science for the Earth' at Cambridge University. One of the recently completed projects on which he worked is an estimate of the ecological footprint of the Isle of Wight.

Dr Mae Wan Ho is Director of the Institute of Science in Society (I-SIS), visiting Professor of Biophysics in Catania University and Scientific Adivsor to the Third World Network. She has authored over 250 publications spanning several disciplines. Among these are ten books including *Genetic Engineering: Dream or Nightmare?*.

Dr Gill Langley is Scientific Adviser to the Dr Hadwen Trust for Humane Research. She is editor of the widely-used book 'Animal Experimentation - the Consensus Changes'. She opposed animal use in her undergraduate course at Cambridge University in the early 1970s, and later left academic research to work in the anti-vivisection movement.

Dr Sue Mayer is Executive Director of Genewatch UK, a trustee of Vetwork UK and a member of the Agriculture and Environment Biotechnology Commission. Formerly she was Director of Science at Greenpeace. Earlier, while employed at Bristol University's Veterinary School, she played a leading part in opposing the diversion of veterinary research towards biological warfare research.

The late *Alan Mayne* was a mathematician and consultant on science and technology issues. He was author of many books, notably 'From Politics Past to Politics Future', 'Resources for the Future' and (with B Burrows and P Newbury) 'Into the 21st Century: A Handbook for a Sustainable Future'.

Dr Stuart Parkinson is a Research Fellow at the University of Surrey's Centre for Environmental Strategy, and Chair of SGR. He is an expert reviewer for the Intergovernmental Panel on Climate Change and a co-author of the book 'Flexibility in Climate Policy: Making the Kyoto Mechanisms Work'. He used to work in the defence industry before his views on the ethics of science and technology led to a move to environmental work.

Professor Sir Joseph Rotblat was a member of the Manhattan Project. He resigned from it when it became clear that its original motivation - fear of Hitler getting an atomic bomb - was no longer relevant. He is a founder member the Pugwash Conferences on Science and World Affairs, and a signatory of the Einstein-Russell manifesto. He was for many years Secretary-General, and later President, of PCSWA. He and PCSWA are joint recipients of the 1995 Nobel Peace Prize.

Dr Barry Rubin is a physical chemist and director of the web consultancy Davis Rubin Associates Ltd. He is a co-author of 'Crisis Over Cruise' and of 'London After the Bomb'.

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Dr David Webb is a Principal Lecturer in the School of Engineering at Leeds Metropolitan University. After seven years of postgraduate and postdoctoral research in near-Earth magnetism, and needing secure employment, he worked briefly for the Ministry of Defence in an information gathering operation. Finding that defence and offence could not be separated, he resigned shortly thereafter, and has since been active in study and education on the militarisation of space.

Dr Philip Webber is a physicist and Head of the Kirklees Environment Unit, West Yorkshire. He has been responsible for developing an approach to sustainable development and Local Agenda 21 which has been recognised by many UK awards and European case studies. He is the author of 'New Defence Strategies for the 1990s: from confrontation to coexistence'. He is Vice-Chair (formerly Chair) of SGR, and Chair of the Martin Ryle Trust.

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SGR promotes the ethical practice and use of science and technology. Our work involves research, education, lobbying and providing a support network for ethically-concerned scientists.

SGR is a UK-based membership organisation and is affifilated to the International Network of Engineers and Scientists for Global Responsibility (INES).

You can become a member of SGR if you are a scientist in the broad meaning of the word. Our members include biologists, chemists, engineers, geographers, mathematicians, physicists, psychologists, sociologists, students, teachers and people working in electronics and computing.

If you agree with SGR's aims and want to support our work, but are not a scientist, you are invited to become an associate member.

Scientists for Global Responsibility

"Science has become a dominant element in our lives. It has brought enormous improvements to the quality of life, but has also created grave perils. These include pollution of the environment, the squandering of natural resources, increases in transmittable diseases and, above all, a threat to the very existence of the human species through the development of weapons of mass destruction. Scientists can no longer claim that their work has nothing to do with the welfare of the individual or with state politics."

From the Foreword by *Professor Sir Joseph Rotblat*,
1995 Nobel Peace Prize Laureate

'An Ethical Career in Science and Technology?' is intended to give scientists and engineers an introduction to some of the wider issues and ethical dilemmas in relation to their current and future career choices. The guide includes summaries of some of the major scientific controversies in today's world, and testimony from working scientists. Issues covered include genetics, climate change, arms, militarisation of space, animal experiments, cleaner technology, information technology, and science funding.

This booklet is a summary of a report produced by Scientists for Global Responsibility, which will be published as a book in 2002.