Scientists for Global Responsibility

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Science and the corporate agenda

The detrimental effects of commercial influence on science and technology

Chris Langley and Stuart Parkinson

SGR

Promoting ethical science, design and technology

Science and the corporate agenda: The detrimental effects of commercial influence on science and technology

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Written by Chris Langley and Stuart Parkinson

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About Scientists for Global Responsibility (SGR)

SGR promotes ethical science, design and technology, based on the principles of openness, accountability, peace, social justice, and environmental sustainability. Our work involves research, education, advocacy and providing a support network for ethically concerned science, design and technology professionals. Founded in 1992, we are an independent UK-based non-profit organisation with over 1,000 members. SGR is affiliated to the International Network of Engineers and Scientists for Global Responsibility (INES).

SGR works with a range of individuals and organisations to pursue our goals, including academics, civil society organisations and ethically concerned businesses. We are funded through subscriptions and donations from our members, together with grants from trusts and other organisations that share our ethical concerns. Full details of SGR's ethical principles and funding policy, together with a current list of funders, can be found on our website at: http://www.sgr.org.uk/

About the authors

Chris Langley has degrees from University College London and the University of Cambridge. Following post-doctoral research in neurobiology at Cambridge, he has worked for more than 25 years in science policy and the communication of science, technology and medicine. At present he runs ScienceSources, an independent consultancy, which facilitates and widens access to science, technology and medicine, fostering a more publicly accountable, independent and open science. He has produced critiques of science, engineering and technology for a wide range of audiences, both lay and professional, and has given presentations and invited lectures on science communication, ethical science and the military influence on science, engineering and technology. He has authored or co-authored, for SGR, the publications: *Soldiers in the laboratory; Scientists or soldiers?; More soldiers in the laboratory;* and most recently *Behind closed doors.*

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Chris Langley and Stuart Parkinson

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Executive summary

Links between science, technology and business are numerous. It is no secret that these links are increasing in number and extent, a reflection of the growing role of science and technology in the drive for competitiveness between the leading economies. Both governments and business assert that this close relationship is generally positive for science and technology on the one hand and society on the other. However, there is growing evidence that this relationship brings with it a range of detrimental effects. This study examines how significant such effects are, how they manifest themselves and where their impact is felt.

We investigate these effects in five industrial sectors: pharmaceuticals; tobacco; military/defence; oil and gas; and biotechnology.

This study approaches the issue primarily from a UK perspective, while drawing on a wide range of sources. In particular, we critically examine the extensive range of government policy initiatives over the last 20 years that have driven much closer links between business and the universities in the UK. Given the transboundary nature of science and technology, we cast a wider net when examining the five industrial sectors, taking account of experiences in the USA – where commercial involvement in academia is more extensive – as well as in some other European countries. We make recommendations for tackling the problems that we identify.

The march of commercialisation

Over the past 20 years, in the UK (and other leading industrialised nations), there has been a concerted effort by policy-makers and commerce to increase the links between business and academic science. There have been numerous reviews, white papers and other policy documents arguing that these closer links will improve economic competitiveness and have broader benefits for society. This has led to a swathe of new initiatives, funding programmes and other measures to stimulate these links – from the 1993 White Paper, *Realising our potential*, to the ten-year science and innovation strategy launched in 2004, and most recently the creation of the Department for Business, Innovation and Skills whose responsibilities include science and universities. One recurring theme in these initiatives is the concerted attempt to encourage universities to behave like businesses themselves, and institute a 'corporate' mindset, undermining the traditional ethos of openness, objectivity and pursuit of knowledge.

The sectors

The five industrial sectors covered in this report are large-scale users of science and technology in the UK and internationally. Many of the leading companies in these sectors have strong links to universities. All five of the sectors have been the subject of at least some in-depth independent research of the effects of their activities.

The pharmaceutical industry is the largest private funder of R&D both in the UK and globally. Two of the world's top five companies in this sector are based in the UK. There are extensive links between the industry and academia. While the sector contributes important health benefits, there have been numerous criticisms about the problems associated with their involvement in the research process. These criticisms come from a range of sources, including peer-reviewed academic studies, medical practitioners, researchers and policy-makers.

Despite its apparently narrow product base, the tobacco industry is very large, not least because of the recent expansion of its markets in poorer countries. The leading companies in this sector include two based in the UK, British American Tobacco and Imperial Tobacco. The industry has a long and controversial association with health research. Documentary evidence spanning many decades – including company files recently made public – reveal that there have been some very serious detrimental effects due to commercial involvement.

The military/defence industry is a powerful player in science and technology. The UK is home to the world's second largest arms company, BAE Systems. The industry receives high levels of government funding to carry out R&D often in-house, but also within universities. UK government and commercial initiatives in recent years have led to an increase in military involvement in UK universities. The effects of this industry on the research process have only received limited attention from academics. However, studies by Scientists for Global Responsibility and others have revealed a range of problems related to the industry's involvement in science and technology.

The oil and gas sector is the world's largest industrial sector, with the top five companies earning revenues of nearly £1 trillion in 2008. The UK is home to two of the top five companies in this sector. There are strong links between oil companies and numerous universities in the UK, especially in disciplines relevant to fossil fuel extraction such as geology and chemical engineering. There has been limited academic research on problems related to the influence of the oil companies on R&D. Nevertheless, there is some strong evidence of detrimental effects, especially concerning ExxonMobil's promotion of 'climate scepticism' – the view that scientific research on the threat of climate change is flawed.

Biotechnology is a complex area which raises numerous ethical issues. The biotechnology industry has expanded rapidly in recent years, with the support of major pharmaceutical, chemical and agricultural companies. This has led to a strong focus within agricultural and health R&D on gene-based technologies, including most controversially genetically modified (GM) crops. A close relationship has developed between the industry and academics in the sector, leading to much criticism. Although there is dispute over the scale of the problems in this sector related to commercial involvement, there remains significant evidence of detrimental effects.

The detrimental effects of the commercial influence on science and technology

The main concerns about commercial influence on science and technology uncovered by this study and presented in detail in this report are:

1) There is clear evidence that large-scale, commercial involvement in university-based science, engineering and technology has impacts that can be very detrimental, such as the introduction of significant bias and the marginalisation of work with clear social and environmental benefits. These impacts occur at different levels, including during individual research studies, the agenda-setting process for R&D, and communication of findings to fellow professionals, policy-makers and the public. While academic examination of these impacts has so far been limited, there is nevertheless credible evidence of serious problems across all the five sectors examined in this study.

2) At the level of the individual research study, we found the following problems:

   (a) Direct commercial funding of a research study increases the likelihood that the results will be favourable to the funders. Evidence of this mainly came from academic research in the pharmaceutical and biotechnology sectors. One way in which this bias – known as sponsorship bias – happened in the cases under examination was that funders tended to choose scientists who were already sympathetic to their viewpoint. Intentional distortion or suppression of data was much less common, although it did occur, especially in pharmaceutical and the tobacco funded areas, and it may well be more prevalent.

   (b) Openness in research can be compromised through the use of commercial confidentiality agreements (including patents) and other intellectual property rights considerations. We found evidence for this in the pharmaceutical and biotechnology areas, but such problems may well be evident at the individual level across other areas in science and technology, which have not been scrutinised as yet.

   (c) Conflicts of interest of scientific researchers (for example, financial interests) have the potential to compromise the research process. There is limited monitoring or policing of the problem, so its true extent is unknown. We found evidence of this problem in the pharmaceutical, tobacco and biotechnology sectors.

3) At the level of setting the priorities and direction of R&D, we found the following problems:

   (a) Economic criteria are increasingly used by government to decide the overarching priorities for public funding of science and technology, in close consultation with business.

   (b) Universities are being internally reorganised so that they behave more like businesses, while key attributes of the academic ethos such as openness, objectivity and independence are being seriously eroded.

   (c) Companies have expanded the number and range of partnerships with universities, focusing on business research priorities and goals. The power and influence of some corporations, and the increased pressure on researchers to bring in funding from business, means that academic departments are increasingly orientating themselves to commercial needs rather than to broader public interest or curiosity-driven goals. This is a trend especially evident in biotechnology, pharmaceutical, oil and gas, and military partnerships.

   (d) The growing business influence on universities is resulting in a greater focus on intellectual property rights (including patents) in academic work. Hence knowledge is increasingly being 'commodified' for short-term economic benefit. This can undermine its application for wider public benefit, and produces a narrow approach to scientific curiosity.

   (e) A high degree of business interest in emerging technologies, such as synthetic biology and nanotechnology, leads to decisions about these powerful technologies being taken with little public consultation. This is of particular concern because of the major uncertainties regarding these technologies, including the possibility of detrimental health and environmental impacts which they may produce.

   (f) There are particular problems within the five sectors examined in this report:

      (i) In terms of the scientific response to ill-health, the influence of the pharmaceutical industry can, for example, marginalise investigation of lifestyle changes as a method of disease prevention, or lead to a focus on disease treatments for wealthier communities able to pay for them rather than the more common global diseases.

(ii) In terms of the scientific response to food security, the influence of the biotechnology industry can lead to unjustified focus on high technology approaches to increasing crop yields rather than investigating lower-cost agricultural options or addressing wider problems of food distribution or poverty.

(iii) In terms of the scientific response to climate change, the influence of the oil and gas industry can lead to a focus on fossil fuel-based technologies or controversial biofuels rather than controlling energy demand, increasing efficiency, or a more rapid expansion of widely accepted renewable energy technologies.

(iv) In terms of the scientific response to security threats, the influence of the military/defence sector in science and engineering can drive an undue emphasis on weapons and other high technology approaches, rather than one that prioritises negotiation, arms control treaties, and other conflict resolution or prevention activities.

4) At the level of communication with policy-makers and the public, we found the following problems:

(a) If threatened by emerging scientific evidence about the health or environmental problems related to their industry, some of the larger companies are willing to fund major public relations campaigns aimed at strongly encouraging policy-makers and the public to support their interpretation of the scientific evidence (even if it is far from that endorsed by most scientists). Tactics uncovered here include funding lobby groups (sometimes covertly) to act on their behalf and presenting industry as being for 'sound science' and opponents as 'anti-science'. Evidence of these practices is especially strong in the tobacco and oil and gas sectors, with some evidence from the biotechnology sector too. Companies more willing/able to diversify from problematic product lines were found to be less likely to take this course of action.

(b) Some companies can be selective in their reporting of academic findings of efficacy or safety of a newly launched product. This 'marketing bias' was found especially in data from the pharmaceutical and biotechnology sectors.

(c) Some sections of the pharmaceutical industry 'expand' the definition of human disorders and fund patient-interest groups, which help to increase the market for their products. This can compromise both patient care and the underlying scientific basis of medicine.

Main recommendations

Our recommendations specifically focus on reforms that are relevant across the science and technology sector in the UK. They are:

1. Universities should adopt minimum ethical standards for the companies with which they have partnerships. These standards should include social and environmental criteria, as well as academic criteria and should be overseen by a special committee.
2. Universities should openly publish comprehensive data on the nature of their business partnerships.
3. A new independent organisation should be set up to disburse a significant fraction of business funding for scientific research. The aim would be to fund research which has particular public interest (and includes those areas being neglected by mainstream funding sources). The steering committee of the organisation would include representatives from a range of stakeholders.
4. Business and civil society organisations should undertake more joint work on public interest scientific projects. This could be facilitated by the Research Councils.
5. All academic journals should develop and implement rigorous processes for dealing with potential conflicts of interest, including suitable sanctions for non-compliance.
6. An open register of interests should be set up for academics, particularly those working in controversial areas of science and technology.
7. Advocacy groups on all sides of debates in science and technology (including professional institutions) should publicly disclose funding sources, to allow the public to decide potential sources of bias.
8. University ethical policies on partnerships with business should cover openness and accuracy related to any involvement in science communication activities.
9. More academic research needs to be conducted into the potentially detrimental effects of the commercialisation of science and technology, especially within universities.
10. The newly formed Department of Business, Innovation and Skills – which has responsibility for both universities and science – should be broken up. Public interest science and the universities should be given greater prominence in the government hierarchy.

11. The House of Commons Committee on Science and Technology should investigate the current emphasis on commercialisation within science policy, and whether a balance is being achieved between business and the wider public interest.
12. Public involvement in the governance of science and technology should be expanded in a number of ways, drawing on recent experience of policies and activities in this area.
13. Research Councils and other major public funders of scientific research and teaching should have more balanced representations on their boards and committees between business on the one hand and civil society on the other.
14. Steps should be taken to ensure that a balance is struck between the commercialisation of emerging technologies and wider social and environmental impacts. This could include: the setting up of a Commission on Emerging Technologies and Society; the allocation of adequate levels of funding to examine the broad impact of such emerging technologies and make recommendations on their management; and the wider implementation of ethical codes of conduct for researchers.
15. The Sustainable Development Commission should have its remit broadened specifically to cover the role of science and technology in contributing to sustainable development.
16. There needs to be a thorough review of the role of the university in society and the economy – perhaps in the form of a Royal Commission. This needs to include issues ranging from the degree of involvement of business and civil society to patenting policy.

1. Introduction

Science, engineering and technology (SET), especially in the wealthier nations, play a key role in shaping society, markedly influencing everything from the food we eat to how we are educated. At the same time, business is an integral part of the economic system that supports our industrialised world. SET and business are linked in numerous ways, not least their mutual reliance on people with high levels of expertise and skills. It is no secret that these links are increasing in number and extent, a reflection of the growing role of SET in the drive for competitiveness between the leading economies.

Both governments and business assert that this close relationship is generally positive for both SET and society. However, there is growing evidence that this relationship brings with it a variety of detrimental effects. This report sets out the results of investigations into how significant such effects are, how they manifest themselves and where their impact is felt.

Specifically, the report:

- Presents historical evidence of how commercial influence on the SET community has evolved, especially over the past 20 years;
- Examines the commercial influence on science and technology, in particular outlining and analysing the evidence of detrimental effects including:
  - narrowing the scope of the research agenda;
  - influencing the direction of, and introducing bias into the results of, specific research studies;
  - compromising the openness and transparency of research activities; and
  - misrepresenting the results of research to the scientific community and the public.
- Provides case studies of commercial influence, specifically in five sectors: pharmaceuticals; tobacco; military/defence; oil and gas; and biotechnology;
- Recommends reforms to reduce the detrimental effects: to improve the quality of SET; to build public confidence in SET; and to increase its wider benefits to society and the environment.

There is a broad context to this study. Science has for centuries been inextricably linked to engineering and technology, which, with the active involvement of science, has created the tools, methods and practical understanding with which we modify the world and create new products. The creation of new technologies is critically affected by a range of factors, including scientific uncertainty, and the political and economic power of different interest groups, as well as their social values and ethics. As such, new technologies have the potential to demonstrate both positive and negative effects (Crespi & Geuna 2006; Chapman 2007).

Increasingly, in the UK and other industrialised countries, SET takes place within a political setting which places high value on economic objectives, which include new patterns of global investment with the growth of multinational companies. As a result of these trends, business has gained a greater role in society and its links with SET have been strengthened. Many within the UK government, the business community and the science governance sector (including funding bodies and professional institutions) assert that the value and reliability of science are not influenced by this closeness to business. A recent government policy document stated, "There is no reason why the way science is conducted, governed or communicated by the private sector should be or be perceived to be any different from the public sector" (DIUS 2008). This view is also held by some SET researchers. However, a growing number of studies challenge this view. We review the evidence these studies present for the negative effects of commercial involvement in academic research, effects that favour the outcome for industry and adversely influence the objectivity, trustworthiness and openness of science.

Not only does this report throw into question the claims that commercial interests do not affect the integrity of SET, it also queries the fundamental assertion that marrying science and business brings clear economic and social benefits in the first place.

In general, governments in many countries, especially the UK and USA, view technological development, innovation and the science underpinning these as central to economic prosperity and social wellbeing – a view supported by corporate interests and lobby groups (see Langley *et al* 2008). But in fact the evidence for the positive economic effects of such investment in SET (especially when it takes the form of commercial research and development supporting narrowly-defined business objectives) is limited (see references in Crespi & Geuna 2006). Furthermore, the argument that this pattern of support for SET helps create a more socially just and environmentally sustainable society is even more questionable (see, for example, Levett 2003). This begs the question: to what extent does the emphasis on short-term profits within business actually undermine the application of science and technology to the wider public interest? These issues are also considered in this report (although, due to space constraints, we do not examine wider criticisms of the economic system).

Scientists for Global Responsibility (SGR) has long been concerned about the influence of powerful interests on SET. In recent years our focus has been on investigating the influence of the military sector – both business and government – on science and technology in the UK. This work has shown the power of the military voice, not only in terms of its role in framing the security agenda, but also in terms of the strong influence it exerts on training, teaching and research within UK universities (Langley 2005; Langley *et al* 2007; Langley *et al* 2008).

This experience has proven invaluable to our investigations of the influence of the wider commercial sector on the SET environment, as examined in this report.

The report has been written in three parts. Part I includes this chapter and chapter 2, the latter outlining key background information on SET and documenting the expansion of the commercial influence within SET in the UK over the past 15-20 years. Part II (chapters 3 to 8) provides the bulk of the evidence and analysis of the report. After a brief introduction (chapter 3), chapters 4 to 8 each examine a major industrial sector and discuss the evidence for detrimental effects on the culture and practice of SET related to commercial involvement. Part III contains the conclusions (chapter 9) and recommendations (chapter 10).

It should be emphasised that we approach the issue from a UK perspective, while drawing upon material from a wide variety of sources. In particular, chapters 2, 9 and 10 are specifically focused on the UK policy situation. However, given the transboundary nature of science and technology, we cast a wider net when examining the evidence in part II of the report, taking account of experiences in the USA – where commercial involvement in academia has a longer history and is more sustained – as well as in some other European countries.

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2. Science, engineering and technology – background on structures, policies and funding

In the more industrialised countries, science, engineering and technology (SET) is embedded within a complex social structure. SET is shaped by its practitioners (scientists, engineers etc), together with government, business and citizens. Decisions are made regarding the priorities for research, the sources of funding, the technologies that are developed, how these technologies are regulated, and so on. The extent to which each group in society can and does influence these decisions is hotly debated. For example, many citizens feel that business funding of SET can lead to bias in the research and the undermining of potential benefits to society (People Science and Policy Ltd/ TNS 2008). However, in the UK and elsewhere, governments and some people within the science and engineering community itself assert that commercial involvement in SET does not compromise its reliability (for example, DIUS 2008).

In order to examine issues such as these, we first need to describe the landscape in which SET takes place – including the organisations that fund SET and the government policies that guide it. We start with some basic definitions and broad policy background, before outlining the current situation in the UK regarding the funding and practice of SET. We then examine more closely business research and development, followed by UK government policies which have driven the commercialisation of SET over the past 15 to 20 years.

2.1 SET – some basics

A broad definition of SET is given in box 2.1. It includes both work that is publicly-funded work and also that which privately-funded. SET undertaken in universities in the UK is funded from a mix of predominantly public (national and international) sources, together with some commercial and charitable sources (Martin & Tang 2007).

While European governments have traditionally funded SET for a number of reasons including the support of economic development, they have also recognised the advancement of knowledge ('pure' research) as being of considerable intrinsic importance to their societies (Smelser & Baltes 2001). Some countries like Sweden and Germany have emphasised the advancement of knowledge as a *primary* goal of SET, and this has influenced their research and funding structures accordingly (Senker *et al* 1999). The Swedish approach, which is followed in many European countries, creates strong disincentives toward academics becoming entangled in partnerships with the commercial sector and knowledge transfer activities. The key sign of university success in Sweden is academic results and the quality of teaching and research (Huggins *et al* 2008).

Box 2.1 – Defining science, engineering and technology (SET)

Science, engineering and technology (SET) permeates society in industrialised nations. In this report, SET is considered to include a complex range of activities, namely:

- academic research (both 'pure' and 'applied' – see section 2.2);
- commercially-oriented research and development;
- the practical activities stemming from research and development;
- the testing of materials and products; and
- teaching, mentoring, and training.

Research and development (R&D) is also defined as including technology transfer – the dissemination and application of scientific and technical knowledge.

Modified from Stoneman (1999)

In a sharp contrast, in the past 20 years the UK has put a significant premium on SET as a driver of economic competitiveness (see later sections). This follows the model pursued by the USA (Washburn 2005). Here the voice of the business community is often heard by government above those of other interested parties.

Business involvement with SET has a complex history. For instance, many large businesses have played a major part in the politics of funding for research – especially in the USA – and, by the 1980s, industry was taking a very active role in funding and privatising scientific knowledge (Jasanoff *et al* 1995). But in the post-World War Two era, business philanthropy was an important element in supporting not only research but also the infrastructure of SET. An example is the Novartis Foundation, set up as an 'operationally independent' entity by the then Ciba Company of Switzerland in the 1940s. The Foundation not only provided accommodation in London for visiting scientists and medical researchers in its own premises but provided the venue for its own meetings on a range of topics in SET and medicine. Organisations from across the SET community also met to discuss issues of import to their discipline at the Foundation's premises. The resultant symposia and similar publications, featuring leading researchers' discussions and their research papers were edited by Foundation staff without company input. This was an important independent resource for the SET community. Such philanthropy still exists. The Wellcome Trust and the Leverhulme Trust both play key roles in SET today, even though this role is now played out within a highly commercialised funding environment.

2.2 Pure and applied science

SET research (see Box 2.1) can be understood as either 'pure' or 'applied'. For the purposes of understanding the role and influence of commercial interests on the research agenda a brief discussion of the differences is useful. Space does not permit a detailed discussion, but there are good accounts of how they differ in a number of texts (Sarewitz 1996; Ziman 2002; Calvert 2006).

'Pure' science (there is not strictly speaking 'pure' technology or engineering) usually appears in the R&D statistics of government (or other funders of research) as a category which reflects the open-ended pursuit of knowledge. Pure research tends to be considered as part of curiosity-driven work which is undertaken by scientists in both public and private laboratories – its aim being to provide an 'understanding' of a phenomenon. In contrast, 'applied' research aims at producing an intervention – such as a drug or new material – to address problems or develop a new approach. 'Pure', 'fundamental' or 'basic' research is defined officially as:

"….experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view" (OECD 2002).

Universities have been seen historically as institutions in which such predominantly 'pure' research was undertaken to discover knowledge for a broadly defined 'public good'. Such knowledge would be a source of objective information for the public, and could inform policy-makers in areas such as public health or environmental protection.

However these goals can be marginalised by the involvement of commercial interests wedded to short-term economic return (Ravetz 1996; Washburn 2005). A series of profound changes in the UK have altered how people perceive the role and activities of universities in society. These changes have affected what research is undertaken; for whom and why; and the proportion of research that can be described as 'pure'. In this climate many, especially in government, have begun to regard 'pure' research as a luxury.

'Applied' research is usually defined as research that has a clear set of narrowly-defined objectives, which guide its programme of activities. There is generally little opportunity to seek data outside this defined set of end-points. 'Applied' research frequently has economic gain and profit as its predominant focus – but can also be related to a specific social or environmental goal such as curing a disease, reducing greenhouse gas emissions or increasing crop yields. Superficially then one of the key differences between 'pure' and 'applied' research is how the goals of the research are defined and who is likely to benefit from the products of that research. The methods and scientific activities in 'pure' and 'applied' research are essentially the same.

The research activity tabled below comprises both 'applied' and 'basic' SET activities undertaken by the main sectors in the UK. Traditionally the Research Councils predominantly supported the more 'pure' form of research – much of which had a broadly defined set of end-points. In addition the Research Councils were expected to provide funding not coloured by the political perspectives of the government of the day – the Haldane principle[1]. While in the early days of the Research Councils some of the funding they distributed was for technological innovation and hence definable as 'applied', the proportion of their funding activities that is directed at economically defined objectives has increased in the last 20 years (see Moriarty 2008).

SET has significant potential to provide tools that can be used, through technological development for instance, to contribute to social justice or to help to address issues such as resource depletion, cleaner energy, pollution and environmental degradation (Ravetz 1996). However, there is a large body of research literature which shows that the ability of SET to fulfil that potential – its ultimate role in society – depends upon the social structure and power relationships existing within that society. Profit-driven activities and mechanisms such as intellectual property rights[2], patents and funding can often act against the public interest and bring benefit to a very few without increasing the public benefit.

SET has a number of mechanisms in place – with associated reliable methods and data – designed to help reduce the influence of special interests with the potential to introduce bias, for example those of the funder. Strict adherence to these mechanisms – which include peer review, free exchange of data and transparency – has traditionally been a prerequisite for practising SET. However, such processes must be observed by all involved in publishing and experimental protocols, for example, so as to permit data to be assessed for its reliability.

2.3 Overview of funding of science, engineering and technology in the UK

In 2007 the UK's gross domestic expenditure on R&D was £25.4 billion (Office of National Statistics 2009) – with the breakdown by each sector undertaking the R&D given in Table 2.1. This represented an increase, in cash terms, of around 9 per cent from the 2006 level. In real terms the 2006 expenditure on R&D in the UK was 1.79 per cent of gross domestic product (GDP), an increase over the previous year (Office of National Statistics 2009). In 2007 (the latest period for which we have data), government (including the Higher Education Funding Councils and the Research Councils) funded 30 per cent of all R&D performed in the UK. Business undertook around 47 per cent of all UK–based R&D.

The UK government, in common with those of other industrialised economies, spends significant sums each year either directly or indirectly upon, or in support of, a range of SET activities including R&D. Similarly, science-based business also undertakes R&D in order to expand its range of products, improve those it already manufactures, and also to reduce waste and pollution of the manufacturing process. A marked trend over the past five years is the increasing level of investment made by business in R&D. In 2006 the 850 most R&D-intensive UK companies increased their funding of R&D by 9 per cent on the previous year to £20.9 billion (BERR 2008). The pharmaceutical sector remained the largest and contributed most to total UK R&D growth in 2006. (These figures are those reported by the businesses themselves.)

In the UK, university SET research departments have five main sources of funding:

- the Research Councils;
- higher education funding councils;
- UK-based charities;
- government departments; and
- UK industry.

All have increased their funding of research in real terms in the last ten years.

Academic research is also funded by EU bodies, other sources from outside the UK (government and commercial) and a miscellaneous collection of sources, including funding derived from university investments of various kinds and from non-UK business. Academic R&D is also undertaken in locations other than the universities – these are included in Table 2.1.

Table 2.1 - Sectors in the UK economy undertaking R&D in 2007 (excluding overseas sources)

Sector undertaking R&D	Budget (£ billion)
Business enterprise	16.1
Higher Education	6.5
Government (direct spending, including within government establishments)	1.2
Research Councils	1.1
Private non-profit	0.6

Notes: The figures in this table reflect the R&D which is undertaken solely within the UK. The R&D which is undertaken in other countries, but funded by UK sources, is not shown in this table. The figures reflect various activities, many of which use SET expertise.

Source: Office of National Statistics (2009)

In the decade since 1998 government funding for the UK's seven Research Councils has almost doubled in real terms (Brumfiel 2008). Table 2.2 shows the 2007-08 budgets. Research Council funding is predominantly directed at research (and training) undertaken within universities and research council institutions, and has historically been a mix of mainly 'pure' but also some 'applied'. However, Research Councils are now expected to have a marked business focus, requiring their funding to address economic goals or to contribute to economic prosperity. Therefore they now often co-fund research with commercial partners (we discuss this further below).

Government in the UK also funds research within its own 'public sector research establishments' (PSREs), in some cases through one or more of the Research Councils. Such PSREs include museums and galleries, and departmental research entities like the Central Science Laboratory, the National Physical Laboratory and the Defence Science and Technology Laboratory – the funding being in the main for 'applied' research. Such PSREs employ many people with SET experience, often specialised and valuable.

Despite the growth in funds provided by government for SET, many within the academic research community feel that the increased funding comes with a considerable number of strings, not least of which is a heavy focus on conducting research for economic benefit as part of an ongoing shift away from 'pure' research for the broader public good. While some of the strings tie specific research to narrow commercial end-points, there is a broader and perhaps more important trend, which is that the research community is being increasingly anchored within a business setting. Such a positioning involves the commodification of knowledge and information, a culture of managerialism and secrecy, and short-term goals. This focus compromises the long-standing convivial and open environment of academics, in which the pursuit of open-ended questions is normal as is the sharing of ideas with colleagues and the public (Jacob 2003; Moriarty 2008; Brumfiel 2008). Such a situation also impacts upon the free movement of staff, especially where activities become subject to 'commercial sensitivities'.

Table 2.2 - Research Councils annual funding allocation for 2007-08

Research Council	**Budget (£ millions)**
Arts & Humanities Research Council (AHRC)	97
Biotechnology & Biological Sciences Research Council (BBSRC)	387
Economic & Social Research Council (ESRC)	150
Engineering & Physical Sciences Research Council (EPSRC)	711
Medical Research Council (MRC)	543^
Natural Environment Research Council (NERC)	372
Science & Technology Facilities Council (STFC)*	573
Sub-total	2834
Less depreciation & impairments	86
Research Council funding total	***2748***

^Figures are for 2006/07

** The STFC was formed in 2007 by the merger of the Particle Physics and Astronomy Research Council and the Council for the Central Laboratory of the Research Councils. It has, as a major goal: "increasing the UK technology capability and engagement with industry and knowledge transfer".*

Funds provided to the seven research councils from the public purse are part of the Science Budget – other recipients include the UK National Academies. There are also sums for technology transfer, Science in Society projects and capital funding.

The Research Councils not only fund research through project and programme grants and in their own institutes, but also provide support for training awards in university departments and other organisations.

The Royal Society (one of the UK National Academies) also disburses government funds through its Parliamentary Grant-in-Aid. In the year up to March 2007 this funding was £407 million and was used for research, education and training. In that period 167 project grants were supported by the Society.

Source: DIUS (2007).

The SGR report *Behind Closed Doors* (Langley *et al* 2008) described the swathe of business and government pronouncements and reports that have underscored the notion that universities should be far more 'business-facing' and consider the economic endpoints of research programmes. Many of these documents, often penned by those in the business community for government departments, seem to overlook the significant and valuable differences between universities and companies. At the same time there has been sweeping privatisation of the former government research laboratories, especially in the 'defence' area. A number of commentators have pointed to Treasury catchphrases, including 'economic competitiveness', which are to be found in research council documents and appear to erode the independence of the councils and at the same time severely curtail the amount of 'pure' research undertaken (Brumfiel 2008). Other public interest research and investment tends to become sidelined in this environment. Interestingly, this can be negative from an economic perspective as well as a social one, as public interest research can generate more economic value (Fearn 2008). Our own experience indicates that there are many within the UK research community that feel that universities have lost more than they have gained in becoming commercialised entities (Langley *et al* 2008).

2.4 Business R&D

In the 1990s, most major industrialised countries (especially those in the OECD) saw the opportunities arising from the commercial exploitation of knowledge residing in the universities. The UK government was among those keen to increase the utility of research undertaken within its academic research community (Calvert & Patel 2002). In 1993 the UK government published *Realising our potential*, which set out a strategy to enhance economic and social wellbeing by tapping into the strengths of UK SET. This White Paper and the plethora of similar exhortations for universities to become business-facing and to actively seek partnerships with business are discussed throughout this report (Calvert & Patel 2002).

In the last 20 years, science-based business in OECD countries has moved away from the tendency to support large laboratories, in which a company would undertake its entire technological agenda, and towards a more decentralised model. In this approach, corporate in-house R&D capability is supplemented by a range of specialist small companies (some of which are spun out from research groups in the research-intensive universities) and by research groups within the university sector supported on project or programme research council funding (or through commercial funds) (Coombs & Georghiou 2002; Wright *et al* 2007).

The share of business-sector R&D funding spent in universities increased across the OECD during the 1990s (Sheehan 2001). Business spending on in-company R&D grew one-third faster than combined public and business funding for university research in the period 1993 to 1998 (see section 2.3 for the current in-company R&D spending). In 2006 UK business enterprise spent about £290 million on R&D undertaken within the higher education sector (Office of National Statistics 2008).

Those with SET expertise play a major role in undertaking R&D within the OECD business community. In the UK, R&D spending in the 850 most R&D intensive companies (UK850) was £20.9 billion in 2006, an increase of 9 per cent over 2005 [3]. The spending was concentrated in five sectors:

- pharmaceuticals and biotechnology;
- software and computer services;
- aerospace and 'defence';
- fixed-line telecommunications; and
- automotives and parts.

These five sectors accounted for almost two-thirds of all UK business R&D in 2006. The biopharmaceutical and biotechnology sector was by far the largest investor (35.5 per cent of the UK850 total), the aerospace and 'defence' sector's share being 11.4 per cent (making it the second most intensive investor in R&D in the UK). Both these sectors have a very large number and variety of 'partnerships' with universities in the UK as well as in other European countries. Many of these UK partnerships are also supported by government, charity and other non-governmental monies in addition to funds from the corporate sector. As we have already pointed out, government expects universities to forge such 'partnerships' with the business community to further economic growth (see Langley 2005; Langley *et al* 2007).

Corporate interest in developing partnerships with universities has moved from a broad range of portfolios with individual academics to long-term relationships with research-intensive departments and research groups. Many of these have been discussed in previous SGR reports (see Langley 2005; Langley *et al* 2007; and also in Coombs & Georghiou 2002).

Furthermore, many companies such as QinetiQ, Novartis, GlaxoSmithKline and Rolls Royce also develop their own 'free-standing' partnerships with academia, involving a range of research activities, in addition to reciprocal staff appointments, research student recruitment and various kinds of contract research. We have been unable to obtain further detail on work practices or staffing arrangements in the university-military sector partnerships despite repeated attempts (Langley *et al* 2008). Many pharmaceutical companies also have arrangements with research groups who undertake research basic to the drug discovery process (at Manchester and Dundee, for example – see chapter 4).

In the UK Rolls Royce has around 20 University Technology Centres (UTCs), which undertake a variety of research for Rolls Royce and about which we have only scant information (see chapter 6). Many have criticised such 'embedded laboratories' arrangements because of a variety of conflicts of interest and the monopolisation of expertise for the profit-directed objectives of the companies involved (see Langley 2005 for references). However, this kind of arrangement is looked upon favourably by university managers and those researchers who receive a fairly stable source of income from such relationships. Even where these collaborations have sufficient intellectual property rights (IPR) safeguards and are transparent and accountable they should not be seen as a replacement for public funding of SET (Martin & Tang 2007).

2.5 The universities and the knowledge economy

We live in a global, information-driven world. Economic success is increasingly based upon the effective and widespread utilisation of assets such as knowledge, skills and innovative potential to provide competitive advantage. This emerging economic process has been called the 'knowledge economy'. The universities will inevitably occupy a central role in such an economy given their expertise and skills base; these are now increasingly perceived as commodities, offering economic value. The 'knowledge economy' and the place of universities within it depend upon the globalisation of markets, as effected by national and international de-regulation together with the growth of information and communication technologies, including the internet (Houghton & Sheehan 2000).

Both government and business have increasingly looked to the university sector to augment in-house R&D effort. This is in addition to government pressure exerted over the past 15 years to increase the economic utility of the publicly-funded research, carried out within university departments.

The 1993 UK government White Paper *Realising our potential* sketched out a strategy to increase 'wealth creation' and collaboration between the universities and business by harnessing SET. One of its key aims was to forge closer links between the researchers in universities and business in order to facilitate the transfer of technology (Calvert & Patel 2002). This White Paper has been followed by a swathe of other reviews, strategies, white papers and policy initiatives – see Box 2.2 for a list of the main ones – demonstrating how the primary role of universities has become one of active engagement with business in a narrowly defined 'knowledge economy'. Further detail and discussion can be found in Langley *et al* (2008).

Box 2.2 - Some major milestones in the commercialisation of UK universities

1991
- Faraday Partnerships set up by the then Department of Trade and Industry (DTI) to foster business–friendly partnerships with academia.

1993
- *Realising our potential* White Paper published. This described a variety of ways of forging closer links between universities and business.

1994
- Foresight panels set up – involving both academics and industry - to advise the DTI on research priorities.

1995
- Office of Science and Technology moved from the Cabinet Office to the DTI.

1997
- Report of the National Committee of Inquiry into Higher Education, *Higher education in the learning society*, published.

1998
- The White Paper, *Our competitive future: building the knowledge-based economy*, published by the DTI.
- The University Challenge Fund launched, providing £50 million venture capital to universities.
- Council for Science and Technology re-launched.

1999
- The first in a series of reports of the DTI 'competitiveness indicators' – which discusses knowledge transfer and R&D activity – published.
- The first 12 Science Enterprise Centres set up with government funding of £28.9 million. Their aim is to foster entrepreneurship in staff and students.
- The Baker report to the Treasury, *Creating knowledge, creating wealth*, published on the commercialisation of research in the government's public sector research establishments.
- The Cambridge University/Massachusetts Institute of Technology (MIT) Initiative launched with business and government backing.

2000
- DTI White Paper, *Excellence and opportunity* published, stressing the 'knowledge economy'.
- The Council for Science and Technology's *Technology matters* report published.
- HM Treasury's *Cross-cutting review of the knowledge economy* published.

2001
- The government sets up the Higher Education Innovation Fund to support knowledge transfer.
- The DTI White Paper, *Opportunity for all in a world of change*, announces University Innovation Centres, new Technology Institutes, plus an additional £90 million to promote the commercial exploitation of research in genomics and e-science.
- The National Audit Office publishes the report, *Delivering the commercialisation of public sector science*.

2002
- Sainsbury's *Cross-cutting review of science and research* published.
- The Roberts Review of science and engineering skills published.

2003

- The Treasury publishes the Lambert Review of business-university collaboration.
- The DTI publishes its innovation report, *Competing in the global economy*.
- A new skills strategy launched.

2004

- The *Science and innovation investment framework 2004 – 2014*, which places science centre stage as a driver of economic prosperity, published as part of the Treasury's 2004 Spending Review.
- Launch of a business-led Technology Strategy Board (TSB) to identify and support new technologies.
- The launch of a new 'Technology Strategy', inviting applications for Knowledge Transfer Networks and Collaborative R&D.
- Lambert Working Group on Intellectual Property set up.

2005

- Knowledge Transfer Networks established by the TSB to enable business to make contact and establish links with the 'knowledge economy', especially in universities.

2006

- Publication of the Warry Report to the DTI on ensuring that the 'economic impact' of the Research Councils is increased.
- The final report of the Leitch Review of skills for HM Treasury, entitled *Prosperity for all in the global economy* is launched.
- The Office for Science and Technology becomes the Office for Science and Innovation.
- Sir David Cooksey reported to the Chancellor and the Secretaries of State for Health and Trade and Industry on his review of health research and how to speed up the transition of research findings into 'health and economic benefits'. The Cooksey Report also suggested an Office for Strategic Co-ordination of Health Research and a joint MRC/NIHR Translational Medicine Funding Board.
- The Global Science and Innovation Forum (GSIF) – "a vehicle for cross-government exchanges of information and ideas to improve co-ordination of the UK effort in international science and innovation collaboration" - initiated by the newly-formed Department for Business Enterprise and Regulatory Reform (BERR). GSIF suggests that research and innovation should be used for both economic targets and development goals.
- Creation of Department for Universities, Innovation and Skills (DIUS).

2007

- The Sainsbury Review of Science and Innovation produces further support for innovation. Research Councils are required to set specific targets for the amount of R&D they conduct in partnership with the TSB. In September 2007 the TSB became a free-standing Board disconnected from the former DTI, its remit to stimulate knowledge transfer and to assist business in making wise investments in technology.
- The creation of the Science and Technology Facilities Council (STFC) from a merger of the former Council for the Central Laboratory of the Research Councils and the Particle Physics and Astronomy Research Council. The STFC saw its major role as the facilitation of technology transfer – a new departure for a research council.

2008

- The White Paper *Innovation nation* published. It sets out the government's intention to provide the best environment to "run an innovative business or public service".

2009

- Creation of a new Department for Business, Innovation and Skills under Peter Mandelson, which came about with the merger of BERR with the DIUS. The remit of the new entity is to "build Britain's capabilities to compete in the global economy" – without mention of the many other roles of universities today. Gordon Brown's office said that there would be investment in the UK's science base and "shaping skills policy and innovation" (BBC News 2009).

Current government thinking can be summed up by the view of Ruth Kelly, then Secretary of State for Education, who wrote in January 2006 to David Young, Chairman of the Higher Education Funding Council for England (HEFCE) that the provision of higher education should be "partly or wholly designed, funded and provided by employers" (HEFCE 2006). The emphasis on SET as part of the business agenda has been reinforced by the creation in June 2009 of the Department for Business, Innovation and Skills from a merger of BERR and DIUS (see Box 2.2). Both universities and science now come under the remit of this new department. Clearly the view of both government and the business community is that the primary aims of publically–supported, university-based SET are business needs and economic end-points. The current ten-year Science and Innovation Investment Framework, launched in 2004, also underscores the government view that universities as a whole should be business-facing, expertise within the universities should be commodified to drive economic growth, and education and training provided by the universities should be of direct value to the business community (HM Treasury *et al* 2004).

Universities have thus entered the commercial sector in a significant way despite grave concerns on the part of many academics (see references in Langley *et al* 2008). Similarly, the SET undertaken within UK universities is increasingly industrialised and corporate – of an 'applied' nature – constrained by its economic costs (Ravetz 1996). University-industry partnerships have proliferated in the last 20 years and have added to the concerns about conflicts of interest that can influence individuals, research establishments, the research process and the wellbeing of the SET enterprise.

Some see open and objective science as being damaged by the levels of commercialisation being foisted on those in universities (see Moriarty 2008 for example). Public surveys have also indicated that the perception of the value of SET is tarnished by its commercialisation (People Science and Policy Ltd/ TNS 2008). These themes are examined in depth in the remainder of this report.

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Notes

1. *The principle of autonomy for the UK Research Councils is enshrined in the Haldane Principle, which was formulated in 1918 by the Haldane Committee. The report that the Committee produced suggested that research needed by government departments could be separated into that required by specific departments and that which was 'open' and more general – the 'pure' research described in section 2.2. It recommended that departments should oversee specific research but the general research should be under the control of autonomous Research Councils, which would be free from political and administrative pressures that might discourage research in certain areas. The first research council to be created as a result of the Haldane Report was the Medical Research Council.*

   In the 1970s a major revision to the application of the Haldane Principle in UK research followed from the publication of the Rothschild Report (1971), and its implementation which transferred about 25 per cent of the then Research Council funds, and the decisions on the research to be funded with them, back to government departments. Significant changes have eroded the Haldane Principle in the last ten years – most noticeably the 2006 Cooksey Review of health research funding which reinterpreted the Haldane view that far more government oversight was needed with far more emphasis being given to economically-driven research supported by the Research Councils.

2. *Intellectual Property Rights (IPR) are an increasingly common means of protecting discoveries or inventions in SET. Essentially IPR protects the discovery of one individual or body against the use of that discovery by others without financial reward.*

3. *This figure is for all R&D whether in the UK or outside the country and hence differs from that quoted in Table 2.1 which lists solely UK-based R&D activity for the business sector.*

3. Introduction to the case studies

Commercial involvement with academics and their institutions in the UK and elsewhere can produce collaborations with the potential for genuinely positive outcomes. For example, academic researchers working with business create pathways by which new technologies and practices are distributed within society – with some of these technologies leading directly to health or environmental benefits. Many developments in science, engineering and medicine require innovative commercial pathways (Wright *et al* 2007). However, the key players in the corporate world are frequently very powerful and driven more by increased financial return on their funding than by 'public good' intentions; it is here that the crux of the problems with commercial involvement are to be found.

Given that universities are not commercial entities, there is a marked potential for bias and conflicts of interest to arise in collaborations between business and the academic community. Corporate partners are in a powerful position since they have access to considerable funding opportunities. Furthermore, researchers who obtain commercial funds are often perceived as bringing prestige to the university or department and can thereafter attract further support from both corporate and non-corporate sectors (Washburn 2005). Yet, as we shall see, commercial funding can also import obvious (or subtle) expectations of the outcome of the collaboration with academics.

The following chapters explore five industrial sectors in detail – pharmaceuticals, tobacco, military/defence, oil and gas, and biotechnology – to see how businesses have interacted with the SET community and how negative effects that are capable of compromising SET and the research undertaken have arisen. We focus on business-university interactions, only discussing R&D undertaken in-house within companies in a limited number of situations.

In the case studies that follow we discern both common patterns and individual differences in the ways in which each commercial sector affects SET. For instance, the tobacco industry has actively promoted those scientists who are prepared to cast doubt on the well-established relationship between smoking and illness, whilst the pharmaceutical companies are sometimes culpable in creating clear or more subtle forms of research bias. We will also highlight areas where large corporations have particularly strong influence over the R&D agenda – such as military companies in the security field or oil and gas companies in the energy field – and how this can marginalise work on alternatives.

The evidence we present comes from a range of sources: academic papers where such material exists, but also reports compiled by researchers and analysts within government, civil society organisations and business itself. We supplement this with web-based material and information from SGR contacts both inside and outside of academia. In particular, the evidence we present focuses on the degree to which business can and does:

1. Influence the nature of the research agenda, including narrowing its scope;
2. Have an impact on the direction of, and introduce bias into the results of, specific research studies (both intentional and unintentional);
3. Compromise the openness and transparency of research studies (for example, through commercial confidentiality restrictions); and
4. Influence the public interpretation of research results (for example, through lobby groups) and potentially compromise the public perception and acceptance of SET developments.

As we have discussed earlier, our intention in this report is to provide a counterbalance to the prevailing pro-business stance within most political and professional SET communities, which overlooks many of the negative effects ensuing from the commercial involvement with universities and SET more generally.

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4. The pharmaceuticals sector

The involvement of private business in academic and clinical research has become widespread since the early 1980s. The pharmaceutical industry is heavily involved in academic research worldwide (Glaser & Bero 2005). Given the health care orientation of the industry, it is often argued that such involvement has major advantages for global health care. However, numerous criticisms have been made about this close collaboration – many of which come from the academic community itself (for example, Little 2000; Anon 2001; Glaser & Bero 2005) – and, as we shall see, these criticisms give serious cause for concern. Additionally, we need to remind ourselves that human health depends upon a host of factors other than the use of pharmaceuticals – these include lifestyle, environmental, economic and social factors, as well as access to a range of other health services.

In this section, we document the main criticisms. We begin, however, with a brief overview of the role of the pharmaceutical industry within the health care system, including a description of the drug development process. We then outline the growth of the involvement of the pharmaceutical industry within the academic world, before analysing the problems that have arisen.

4.1 Background on the pharmaceutical industry

Health care in industrialised nations depends to a significant degree upon pharmaceutical and medical devices. New developments in health care owe much to 'pure' research – discovering the various processes that underpin both health and disease. The results and methodologies thus derived can lead to new therapeutic molecules, devices and therapies, which use 'applied' research for their manufacture and development. These two strands of research are undertaken within both the business and university sectors.

The pharmaceutical industry exerts considerable influence over medical R&D via its substantial economic base – see Table 4.1. Two of the top five global companies are based in the UK.

This influence is set to increase: the UK Office for Life Sciences headed by Lord Drayson has recently launched a Life Sciences Blueprint which seeks to support the pharmaceutical and biotechnology industries through a number of actions designed to speed up the availability of new treatments (SPIN 2009).

4.1.1 The drug development process

The development of new drugs or vaccines requires major R&D investments of finance and expertise within the companies themselves and increasingly in the publicly-supported universities and research institutes. In addition there is a substantial regulatory testing and standards apparatus which must be adhered to in order to produce safe and effective therapeutic molecules, especially given the problems that have arisen with the post-marketing reactions of a number of individuals to powerful drugs. All these requirements contribute

Table 4.1 - Top ten global pharmaceutical companies by sales, 2007

Rank	Company	Country	Sales (£ billions)	Market share (%)
1	Pfizer	USA	22.3	6.7
2	GlaxoSmithKline	UK	18.8	5.6
3	Novartis	Switzerland	17.2	5.1
4	Sanofi-aventis	France	16.8	5.0
5	AstraZeneca	UK	15.0	4.5
6	Johnston & Johnston	USA	14.5	4.3
7	Roche	Switzerland	13.8	4.1
8	Merck & Co	USA	13.6	4.1
9	Abbott	USA	9.6	2.9
10	Lilly	USA	8.3	2.5

Source: Association of the British Pharmaceutical Industry (2009) to the increased R&D costs of new drugs and other molecules. Clinical trials (i.e. studies involving human volunteers) of new candidate drugs and other molecules use funds from government (directly and indirectly) and from the companies themselves.

Estimates of the total cost of developing a pharmaceutical product vary widely and have been the subject of considerable controversy. However, data from various sources in the USA (which has the largest pharmaceutical market and the largest research literature) suggest that new drug development can take 10 to 20 years. This development period has grown in the last 20 years because of various regulatory requirements and the size and complexity of clinical trials. Estimated R&D costs for the drug development process (see Box 4.1) vary from $445 million (pre-tax) to around $800 million per drug (DiMasi *et al* 2003).

Box 4.1 – Drug development steps

Understanding of disease (involves university- and industry-based research)

↓ ↑

New molecular entity (NME)

↓

Series of tests and further refinement of NMEs

↓

Selection of promising NME for development

↓

Pre-clinical and non-clinical tests before administration to human population of volunteers/patients

↓

Phase I – healthy volunteers used to test the new compound

↓

Phase II – tests of NME to establish efficacy and patient safety

↓

Phase III – studies in large populations to provide safety and efficacy date for granting of a licence for the NME

↓

Licence Application in the UK – filing data with the regulatory bodies

↓

Phase IV – post-marketing studies of those receiving the NME to pick up adverse effects within the population

Whatever the exact sums involved it is clear that drug development is extremely costly and involves a lot of time and expertise. It is the spiralling costs and the sustained drive to increase profits that adds to the momentum for collaboration between universities and the pharmaceutical industry.

Considerable numbers of clinical trials at all stages of the development of novel drugs or devices are funded by the pharmaceutical industry, usually starting with the design of the study, choice of comparator drugs, and the selection of investigators. The industry increasingly makes use of outsourcing to commercial and academic Contract Research Organisations (CROs). These have been linked to bias in research undertaken and its reporting (Lenzer 2008; see also Lexchin *et al* 2003; Glaser & Bero 2005).

Of course, all companies, whether or not they are involved with the health care community, owe ultimate financial responsibility to their shareholders who demand growing returns on their investments. Many companies do in fact see the conflict between patient need and vulnerability and the drive for increasing profits (see Brennan *et al* 2006). However, evidence has been accumulating of company practices that compromise the standards of sound medical practice and patient care in the drive to increase profits (Brennan *et al* 2006). For example, there are a number of widely-reported cases where companies have, with in some cases the active involvement of universities, exerted a variety of pressures to keep researchers from disclosing information on the safety of products (see section 4.3). The overwhelming need for transparency in addressing medical research is spelt out again in a recent editorial in the *British Medical Journal* (Smith 2009).

4.2 The growing economic agenda within medical R&D

Medical R&D – both public and private – comprises a large fraction of the total R&D spending in the UK (and the industrialised world as a whole). In the UK, funding from research organisations and industry tends to be directed toward clinical, biological and genetic research rather than toward preventive measures which address the causes of the commonest diseases and how to avoid them. There is no obvious set of government priorities for public health research (Wanless 2004). In addition, there is a growing emphasis on economic end-points discernable across the medical sector.

The Wellcome Trust, for example, now sees technology transfer arising from its own research funding programmes as an essential element. The government's White Paper *Innovation Nation* of March 2008 addressed once again the drivers of economic growth and the role of SET in the innovative pathway to products and services. This White Paper announced the setting aside of £2.5 billion for the "support and promot[ion of] public service innovation over the next three years" (DIUS 2008). Included in this allocation was an extra £60 million, in partnership with the Wellcome Trust, for a Health Innovation Council to promote the discovery and adoption of innovation – most of which will involve SET expertise. Additionally, there is to be a new Office for Strategic Co-ordination of Health Research – to work with the MRC and the Department of Health with a budget of £1.7 billion per annum by 2010/11. Such initiatives are embedded within an environment which stresses the importance of partnering with commercial players and an R&D agenda directed at new treatments and therapeutic molecules – drugs, vaccines and a new generation of materials and devices – with the targets being predominantly economic end-points.

Both the Biotechnology and Biological Sciences Research Council (BBSRC) and the MRC have a number of programmes that support technology transfer from their own research funding – both Research Councils working with pharmaceutical partners in R&D. The BBSRC, joined by the Engineering and Physical Sciences Research Council (EPSRC) and pharmaceutical companies, set up the Bioprocessing Research Industry Club which funds researchers at seven UK universities, at the time of writing, to become actively involved in the drug development process (BBSRC 2009).

Other medical research charities are working with pharmaceutical companies in the development of new therapeutics for treating a variety of cancers for instance. All such collaborations make use of university-based expertise in SET and medicine in ways that mirror that found in the military and biotechnology sectors.

In 2007, the pharmaceutical and biotechnology sectors were the largest corporate investor in R&D in the UK. These sectors accounted for 37 per cent of the total budget of the UK's top 850 corporate R&D funders (known as the UK850) (BERR 2008). GlaxoSmithKline and AstraZeneca were, by far, the highest of the UK850 spenders.

Despite pharmaceutical companies spending increasing sums on R&D over the past ten years, productivity, as measured by new treatment molecules (drugs, vaccines and the so-called 'biologics') approved by the various regulatory agencies, has declined. Part of the drive to seek partners within the university community is to offset the high costs of developing and then testing new molecules for human patients. Similarly, the use of CROs to undertake R&D is an attempt to reduce the costs of the drug development process.

4.3 Problems related to commercial involvement

It is frequently argued that the expansion of R&D funded by the pharmaceutical industry is very beneficial for both the economy and the development of new therapies – and thereby for human health. However, the collaboration between the pharmaceutical industry and academia has given rise to a number of serious concerns. The concern most often expressed is bias towards the perspective of the sponsoring corporation (see Box 4.2). This can be connected to conflicts of interest of the researchers. Another concern is that the high cost of clinical studies often creates an incentive for them to be carried out in countries with less rigorous safety legislation. All these factors not only impact on the efficacy and safety of new medicines and their impact on the broader health agenda but also on the integrity and public perception of the science and medicine involved in the development and testing processes.

Box 4.2 – Bias

Bias can be of two major forms:

- *Sponsorship bias* is where the funding source for a trial of (for example) candidate molecules of potential use to patients affects the result of the trial in a systematic and significant way. Sponsorship bias includes publication bias where the publication of results is compromised by the influence of the sponsor of the research in either obvious or subtle ways.
- *Marketing bias* is where companies present their products in the best possible light, and are selective about what facts they choose to make public. This bias tends to be found in spin-off companies looking for capital, and in large companies seeking to market new and expensive products, tests or devices.

Conflicts of interest and the potential for bias of various kinds are often very subtle and not clearly seen as such. They can arise through the need to conform to industrial needs and practices without the research or publication being intentionally dishonest. Bias can also arise because of exaggerated and unsupported claims being made of new discoveries or methods, when seeking funding for commercial development. Professor Nicholas Ashford, quoted in Krimsky's book *Science and the public interest*, discussed the subtlety of bias in scientific research, and why it is absolutely vital to be open about all aspects of industrial involvement with the research process, especially the results of tests and their publication (Krimsky 2003). We read later (chapters 5 and 8) of both sponsorship and marketing bias being found in the corporate activities of the tobacco and biotechnology sectors.

Results from clinical trials (undertaken by pharmaceutical companies themselves or the CROs) are frequently seen as the property of the companies, who analyse and publish the results in carefully chosen ways (Mirowski & Van Horn 2005). There is growing evidence that some form of support from pharmaceutical companies can adversely affect perspectives and research practices (for instance Als-Nielsen *et al* 2003; Glaser & Bero 2005). Policy analysts such as Lisa Bero in the USA have documented how widely industrial funding – especially in the tobacco and pharmaceutical sectors for example – can negatively influence the outcome of studies. They have clearly shown how measures to address bias and other adverse effects, such as conflicts-of-interest policies on the part of journals, are inadequate and tend to vary across the scientific disciplines (White *et al* 2009; Giles 2005).

Krimsky has published data which showed that of the 1,396 high impact journals published in 1997, only 15.8 per cent had an explicit conflict-of-interest policy. Only 0.5 per cent of the papers published in those journals included any disclosure of conflicting interests. Such poor compliance has continued in the years since this paper was published (Krimsky & Rothenburg 2001; Ancker & Flanagin 2007; Anraku *et al* 2009). Some journals, however, have introduced more stringent publishing policies to ensure that authors declare their potential conflicts of interest (Anon 2008a).

The growing research literature on pharmaceutical funding, the clinical trials undertaken and the reporting of outcomes indicates a worryingly high level of bias. Although outright deception appears to be rare, there is burgeoning data to show that there is a pervasive tendency to distort the characteristics of various candidate drugs, their effectiveness and their negative effects (Glaser & Bero 2005; Giles 2006).

For example, evidence from systematic reviews has shown that industry funding for research is strongly associated with research findings favourable to the sponsor, independently of the statistical significance of the results (Lexchin *et al* 2003; Glaser & Bero 2005). Possible explanations for this observed outcome are the framing of the research question, study design, study conduct, and publication and related biases (see references in Glaser & Bero 2005). It has also been pointed out that this bias can be due to financial gain and personal ambition on the part of researchers (Giles 2006). A number of papers in the last decade have shown that there is a significant level of reporting bias in randomised trials (which are essential to the safety and efficacy assessment of new drugs) (Bekelman *et al* 2003; Glasser & Bero 2005; Melander *et al* 2003). Chan and Altman describe the incomplete reporting of outcomes in published articles of randomised trials, which they assert is common and hence argue that the literature describing the effects of new drugs is at best biased. They suggested that trial protocols should be made public (perhaps in the methodology section accompanying the test results in the research publication) (Chan & Altman 2005). Others have reported that the non-publication of negative findings has led to over-estimates of efficacy of antidepressants in children (Jureidini *et al* 2004) and adults (see Moncrieff *et al* 2005).

Data implicating funding bias was also discussed in a paper that looked at a large study of 370 randomised drug trials. The authors of this study showed that those trials funded by the pharmaceutical companies (today the norm) tended to be more positive about effects of the drug (51 per cent of trials funded by profit organisations) compared with similar trials not receiving commercial funding (16 per cent by non-profit) (Als-Nielson *et al* 2003).

Clinical researchers (including those in universities) involved with clinical trials are not obliged to report negative or ambiguous findings from their testing of new therapeutic molecules. Such negative results are often simply not published and, as there is no concerted effort to investigate this process, the extent is simply unknown. One such alleged example concerns the antidepressant Paxil (paroxetine) – which is of a class of drugs called ‘selective serotonin reuptake inhibitors’ (SSRI). This drug, made by GlaxoSmithKline, was used to treat adolescents in the USA. In 2006, the company alerted the public that there was an increased risk of suicidal behaviour in those who were prescribed it. However, documents released during a court case brought against the company revealed some data indicating a raised risk of this problem had been available internally since 1989. The company denied any deliberate attempt to mislead (Giles 2008).

There have also been several high profile cases reported in the press involving researchers and conflicts of interests following from financial involvement with pharmaceutical companies. For instance, three researchers at Harvard University have recently been accused of breaking conflict-of-interest rules after they failed to declare that they received substantial fees from pharmaceutical companies. The researchers, who were psychiatrists, under-reported their earnings over a period of seven years. One of them, Joseph Biederman, is a renowned child psychiatrist whose research is linked to increased use of antipsychotic medication in children. Dr Biederman was found to have earned at least $1.6 million (£810,000), much of which was not declared as required by Harvard University (Gill 2008).

‘Ghost writing’ or ‘honorary authorship’ of papers involves the academic community producing papers on research in which they have not taken an active role in writing, the paper having in fact been compiled by an employee of a pharmaceutical company. The resultant paper then carries the name(s) of academic researchers who may not even have seen the paper or reviewed its contents, although they have undertaken much of the research. Whilst such a practice does not necessarily introduce either misconduct or bias, it is clearly not open nor does it lead to responsibility being shared between all the researchers involved. Several studies have shown that this is a very common practice in the biosciences literature. Gotzsche and co-authors found ‘ghost authorship’ in 70 per cent of articles that they examined (Flanagin *et al* 1998; Gotzsche *et al* 2007).

Box 4.3: Corporate pressure on pharmaceuticals researchers

Case study A

In 2002 Aubrey Blumsohn, a bone metabolism researcher at the University of Sheffield, and Richard Eastell, Dean of Research at the University of Sheffield, signed a contract with Proctor and Gamble (P&G) to evaluate the effectiveness of the company's osteoporosis drug, Actonel. Eastell had already undertaken one strand of the evaluation, which concerned drug metabolism in the blood and urine. The latest project was intended to provide an objective overview of the research and so evaluate the clinical effectiveness of Actonel.

Eastell had already encountered problems – the company had not allowed him to undertake data analysis in work with Actonel. This meant that he could not disclose details of the experimental protocol and the results to others in the field. He suggested that in order to avoid future criticisms, analyses should be undertaken independently of the company, and he suggested to P&G that the independent investigator be Aubrey Blumsohn.

Blumsohn and colleagues undertook a large analysis of blood and urine samples of female patients, some of whom were taking Actonel and some of whom were in a control group; the researchers were 'blind' to which came from which group. Despite numerous requests after the research for the 'key' to the identity of the data in order that the work could be published, P&G refused to give permission, deciding instead to analyse the data and arrange for the material to be written up themselves, by a company-friendly ghostwriter.

In what became a long and tortuous battle, Blumsohn realised that P&G were not making available all of the patient data (around 40 per cent was missing) in the publications reporting on the effectiveness of the drug. The company continued to refuse Blumsohn sight of the patient data. When he complained on several occasions to the company about the manipulation of data, they responded by removing the misleading data from a paper with his name on it, but still only reported the positive effects of the drug in educational and other publications from the company. The University of Sheffield, in response to the approaches of Blumsohn, allegedly offered a significant sum ($300,000) for him to stop voicing his concerns and, when he spoke to the media, they suspended him from his post at the University.

This case clearly illustrates some of the serious problems that can arise when commercial factors are given too much priority in university research.

Source: Baty (2005)

Case study B

Dr Nancy Olivieri found herself in a similar battle to Blumsohn about the safety and clinical efficacy of a treatment she was studying in industry-sponsored clinical trials. In 1996 Dr Olivieri, a Canadian blood specialist, identified an unexpected risk of a drug used to treat an inherited blood disorder. She was studying the drug, an iron chelator used to treat the iron overload which results from the blood disorder, for Apotex Inc. When she tried to inform patients and colleagues about the problem, the company prematurely stopped the study, and informed Dr Olivieri that she would face legal action should she disclose the risks of the drug to any third parties.

Several months later she found a second and more dangerous risk through analysis of patient records. Again the company when it learnt of the further problems warned Dr Olivieri of possible legal action. Despite the intimidation from the company and the lack of help from either the hospital or university for whom she worked Dr Olivieri informed her patients and also spoke about the risks she uncovered to the scientific community. The dispute became public in 1998 when the findings were published by Dr Olivieri in a peer reviewed journal.

Up to 2002, when Dr Olivieri was completely vindicated through a number of independent reviews, she had been subjected to a series of outspoken public criticisms by Apotex Inc, the university and by individuals, all of which attempted to discredit her and the studies in which she participated.

Sources: Bonetta (2001); Thompson et al (2001); Olivieri (2006).

These are two cases among the many which have come to light in which individuals have been denied ways of bringing attention to negative or dangerous outcomes in drug trials. They clearly indicate the problems in trying to balance patient safety with the profit motive, as well as the lack of robust sources of support for researchers to voice their concerns, the lack of safeguards for objective science to be disseminated and the lack of sufficient support for their staff from institutions that depend upon the largesse of multinational companies (see also Smith 2009).

Given the expense of clinical trials (see section 4.1) many companies are running such trials in countries like India where the costs are considerably lower and the population is large with increasing numbers suffering from diseases to be found in the USA and Europe. Whilst there may be financial benefits to India and other economically poorer nations – the trials cost around $100 million (a 2005 figure) in India as against $180 million in the USA (Padma 2005) – the lack of tight ethical regulations have resulted in a number of high profile incidents which showed both the pharmaceutical companies and academics from the West in a poor light, as well as risking the lives of the trial participants (Padma 2005; Mudur 2009).

For example, a clinical trial of an anti-cancer drug in India attracted the scrutiny of Johns Hopkins University officials after physicians in India raised questions about the manner in which the study was conducted. The researcher was identified as serving on the biology faculty of Hopkins's Krieger School of Arts and Sciences since 1965. Conducted in 1999 and 2000, the clinical trial involved 27 cancer patients in Kerala, India, to assess a treatment to combat the growth of oral cancer. The principal investigator of the study had not obtained approval from a Hopkins institutional review board, whilst assuring administrators that the study protocol had been approved by appropriate authorities in India and that proper informed consent was obtained. It also appeared that insufficient safety data was collected (Padma 2005).

A particularly disturbing case was recently reported by journal *Science*. Young children were enrolled in clinical trials in India without adequate safeguards – and several of the infants taking part died. The trials were run with the active participation of the prestigious All India Institute of Medical Sciences (Anon 2008b).

Further examples of bias and distorted framing of research and health care stemming from pharmaceutical funding can be found in psychiatry and the prescribing patterns of psychiatrists. Here the bias does not involve the testing of NMEs, nor the funding of more basic research, but the use of psychiatric drugs. This has increased dramatically in the last decade, with antidepressant prescribing in the UK having risen by 253% in the ten years up to 2003 (NICE 2004). In the period 2000 and 2002 the UK saw a 68 per cent rise in the number of children being prescribed drugs to calm or stimulate the brain (Wong *et al* 2004). Many have shown that the prescribing patterns adopted by General Practitioners (GPs) are strongly influenced by interaction with industry representatives, attendance at drug company events, various gifts, and the impact of industry involvement with the training of GPs (Moncrieff *et al* 2005; Moncrieff 2003). In the UK and USA conflicts of interest arising from financial 'incentives' for prescribing specific drugs can negatively influence patient health and wellbeing.

There is another trend: especially in the last ten years, pharmaceutical companies have begun to actively 'expand' the definition of human disorders and thereby produce the markets for which their R&D can design and develop suitable products (Moncrieff 2003; Moncrieff 2008). 'Disease awareness' campaigns form part of the associated marketing exercises, which are created to establish or expand a niche for new drugs (Pharmaceutical Marketing 2002). One such example involves Social Anxiety Disorder (SAD). Moncrieff has described how company-sponsored research purported to show that SAD was far more prevalent than had been assumed. The US public relations company, Cohn and Wolfe, was employed by the then SmithKline, manufacturers of Seroxat (UK) or Paxil (USA). They hired academic psychiatrists and found various willing patients to speak to the media about SAD. A few months later SmithKline launched advertisements for Paxil as a treatment for SAD. By the end of the year sales for the drug hit a record high (Moncrieff 2003).

The *New Scientist* carried a special report in 2006 which looked at how certain grass-roots patient groups in the USA received substantial donations from industrial sources. The journal described how funds went to those groups which represented diseases from which pharmaceutical companies had the opportunity to profit (Marshall & Aldhous 2006). Examples included the Restless Legs Syndrome (RLS) Foundation whose 2005 revenues totalled $1.4 million (£770,000) - $450,000 of which came from GlaxoSmithKline and almost $178,000 from Boehringer Ingelheim. GlaxoSmithKline's drug Requip was approved for the RLS in 2005, and Boerhringer Ingelheim had a drug, at the time of the *New Scientist* piece, pending FDA approval. Both treatments were supposed to help with long-term control of RLS. The Depression and Bipolar Support Alliance appeared to receive around 77 per cent of its funding from 15 major donors in 2005, 12 of whom were drug or device companies (Marshall & Aldhous 2006).

Similarly, Roche, which produces anti-obesity drugs, has funded surveys of obesity in the UK and France and also genetic studies using the large human datasets from Iceland and involving the private Icelandic company deCODE Genetics (Boseley 2004). All their approaches stress the biological origin of a specific medical condition, amenable to drug treatments, rather than considering the role played by lifestyle, including our high calorie culture and sedentary lives.

Pharmaceutical companies have also influenced therapeutic drug use by direct-mail advertising to potential customers in the USA and Canada, with manufacturers in the USA spending £2.28

billion pounds on the technique in 2005. Data reported in the *British Medical Journal* in 2008 indicates that such techniques can increase the use of a drug that has been removed from the market because of safety concerns. This has important consequences, not only for prescribing patterns and patient safety, but also for public confidence in the scientific basis of drug safety testing and evidence-based medicine in general (Law *et al* 2008).

The pharmaceutical companies also look upon training and education as valuable pathways over which to exert influence. Such influence affects those already in research or clinical medicine or young people on their way to such career destinations (see Brennan *et al* 2006). Hence companies such as GlaxoSmithKline and Pfizer fund student awards (undergraduate and post-graduate), prizes and posts at universities.

In addition to funding and undertaking teaching support and R&D, many pharmaceutical and device companies also support so-called continuing medical education of health care professionals at various stages in their careers (Moynihan 2003; Godlee 2006; Moynihan 2008).

Medical education has been supported by the pharmaceutical sector to a significant extent for many years in Europe and the USA. In the latter, commercial support for continuing medical education in 2006 provided around 60 per cent of the funding for programmes that doctors must take in order to maintain their licences (Fletcher 2008). Such support can introduce pro-company modifications in prescribing patterns and tends to support an outmoded way of supplying the latest research findings to medical practitioners (Moncrieff 2003). There are some signs that things are changing. Pfizer is reducing its expenditure on direct medical education and instead funds educational programmes which are run by universities, learned societies and hospitals. Whilst this does not guarantee the removal of bias from the educational process, it does put industrial funding at arm's length from the practitioner.

Companies often invest in the infrastructure or in other tangible aspects of universities and bring to bear a variety of agreements concerning how to make use of such investments. For example GlaxoSmithKline has contributed £28 million to an imaging centre at Imperial College London and signed a ten-year research agreement with the university for using the facility (Imperial College London 2004). Whilst this kind of investment will assist research efforts in universities it also forms part of a steady process of commercialisation of the context for SET and introduces potential areas of ethical and practical difficulty.

One further area of the pharmaceutical companies' research and development effort that has attracted considerable concern is the implicit emphasis on the healthcare needs of the wealthier nations that is reflected in the investment patterns of the industry. The greater part of the investment in wealthier countries is made with the 'diseases of affluence' in mind, with a corresponding neglect of the diseases prevalent in the poorer countries. Much of the global spending on health R&D (around 97 per cent) continues to come from high-income nations. The focus tends to be on diseases such as heart disease, certain cancers and obesity-related complaints. The communicable diseases like sleeping sickness, Chagas disease and, up to a decade or so ago, AIDS simply did not attract the interest of the pharmaceutical companies and so their treatments tended to be neglected. The 1990 Commission on Health Research for Development estimated that less than 10 per cent of health research resources were used to tackle the diseases endemic in the poorer countries, where about 90 per cent of the world's health problems occurred – known as the '10/90 gap'. This major imbalance still persists (Action for Global Health, 2007). This is despite the best efforts of the World Health Organisation, and charitable trusts such as the Gates Foundation and the Wellcome Trust. Health care which is driven by the more wealthy countries not only thwarts a more socially just world but can increase the risks of conflict and disease, especially when many of the poor are facing resource and climate change problems (Burke & Matlin 2008; Chirac & Torreele 2006).

These concerns highlight a broader issue underlying much that is covered in this chapter – that the pharmaceutical industry pursues a narrow agenda in relation to healthcare as a whole. If it is allowed too much influence within R&D, it can divert resources away from other areas (for example, disease prevention) which can yield better health outcomes, but are not so economically valuable.

In summary, powerful pharmaceutical companies are able to influence academic researchers in a variety of ways and directly or inadvertently introduce bias in the reporting of trials of new drugs and other molecules. Such activities compromise the quality of SET and the research process, and undermine its value to society at large. The mechanisms in place to correct this bias and conflicts of interest are insufficient (Chan 2008). The House of Commons Health Committee Report of 2005 pointed out a number of the problems which arise from corporate influence in the R&D associated with drug development. It suggested a number of regulations that would reduce the effects, in order to protect patients and SET (House of Commons 2005). However such powerful industries are able to influence governments too – and to shape the ways in which certain areas in SET and medicine develop. This will be explored further throughout this report.

Summary of the detrimental aspects of pharmaceutical company influence on SET

- **Influence on the direction of the research agenda**

1. Concentration on R&D relevant to diseases prevalent in industrialised nations (where returns on investment can be high), with much less effort being made to address ill-health in poorer countries;
2. A predominant focus on the biological aspect of human disease which is amenable to targeting by drugs or other molecules rather than looking in a broader way at the multiplicity of disease causation factors, like the role of lifestyle and income;
3. 'Expansion' of the definition of human disorders and/or overemphasis on minor ones (for example, Restless Legs Syndrome), which can divert R&D resources away from major lethal diseases;
4. Partnerships between academic researchers and pharmaceutical companies designed to address R&D of interest to the companies involved, rather than to address issues of wider public health.

- **Influence on the direction and results of specific research studies (both intentional and unintentional)**

1. Conflicts of interest and bias introduced in trials of potential therapeutics, with a focus on the positive outcome of such tests rather than reporting all negative aspects as well;
2. Pressure can be brought to bear on researchers who draw attention to negative aspects of new pharmaceuticals to remain silent.

- **Influence on the openness of research studies**

1. Pressure exerted not to disclose information relating to tests and direction of research study;
2. Import of bias through undeclared conflicts of interest (for example, financial dependence of researchers on specific pharmaceutical companies).

- **Influence on the public interpretation of research results**

1. Bias in reporting of research results (related to above);
2. Ghost writing – where the academic researchers credited as authors of a research study do not write (or in some cases do not even see) the article written by other authors, who have close links to the funder of the study;
3. Industry funding of patient groups and creation of awareness campaigns that 'expand' the definition of illness and help increase sales of pharmaceuticals;
4. Industry funding of medical education and a culture of gifts to practitioners in order to emphasise a specific product to treat a given disease;
5. Non-disclosure of all funding sources by researchers publishing in academic journals.

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5. The tobacco products sector

Globally, the tobacco industry has had a long and especially controversial influence on the scientific research related to its products. Evidence has grown steadily of the industry's attempts over many decades to deliberately undermine the research demonstrating links between tobacco use and ill-health.

In this section, we summarise this evidence of malpractice and highlight some of the tactics used. We start, however, with some background on the tobacco industry and the health impacts of the products it sells.

5.1 The tobacco industry: some basics

Tobacco companies are powerful and influential commercial entities both in the UK and globally. Their aggressive marketing and business tactics push the sale of tobacco products worldwide. Consequently, over one billion people – one-quarter of the world's adult population – are smokers, with the vast majority living in poorer, developing nations (WHO 2008). This has led to what the World Health Organisation (WHO) has called a 'global epidemic' of tobacco-related illness. WHO statistics reveal that tobacco use is currently killing about 5.4 million people annually, more than tuberculosis, HIV/AIDS and malaria combined. If present smoking trends continue, it is estimated that by 2030 tobacco will kill 8 million people each year, with around 80 per cent of the deaths occurring in the developing nations (WHO 2008).

In the earlier part of the twentieth century it became increasingly clear that smoking entailed health risks and this led to the increased regulation of tobacco and its products and eventually to declining consumption in the industrialised nations. The tobacco companies in response expanded their markets in poorer nations and supported trade liberalisation. They undertook extensive marketing in countries demonstrating fewer smoking restrictions and limited public knowledge of the dangers of tobacco products in its various forms (McDaniel *et al* 2008; Smith 2008).

Excluding the Chinese state tobacco monopoly, the world's second and fourth largest tobacco companies by market share – British American Tobacco (BAT) and Imperial Tobacco – are based in the UK (see table 5.1). BAT earned revenues of over £12 billion in 2008 (BAT 2008).

Table 5.1 – Top five global tobacco companies by market share, 2008

Company	Country	World Market Share
China National Tobacco Co*	China	33%
Philip Morris International^	USA	24%
British American Tobacco (BAT)	UK	19%
Japan Tobacco International	Japan	17%
Imperial Tobacco	UK	9%

** China National Tobacco Co is a state-owned monopoly.*
^ Philip Morris International is part of the Altria group of companies.

Sources: He & Yano (2009) & Imperial Tobacco (2008)

At present around 10 million British adults smoke. A drop in cigarette sales followed the ban on smoking in public spaces in England in July 2007 (Lawrence 2008). Data from the Office of National Statistics reveals that 82,900 adults died from the habit of using tobacco products (18 per cent of all deaths of adults aged 35 and over) in England in 2007 (NHS 2008).

Scientific research underpins the development and manufacture of various tobacco products. Scientific work has also been used controversially, to support a range of activities in the UK, USA and elsewhere to discredit accepted research and understanding of the relationship between illness and tobacco use, as we will discuss in detail in the following sections.

Tobacco companies undertake in-house R&D, the nature of which has changed significantly as a reflection of the growing evidence of substantial links between tobacco use and ill health. BAT, for instance, currently operates research centres in Southampton and Cambridge which undertake R&D to "lessen the negative health effects of tobacco" (BAT 2009). The company employs around 300 research staff and spent around £97 million on R&D in the financial year to 2008 (Cookson 2009). BAT, like other companies, also collaborates with academic researchers to undertake R&D of interest to the business, especially in harm reduction measures, like nicotine patches.

On the other hand, academic SET expertise (outside that connected with industry) plays an important role in understanding the effects of tobacco use on the health of smokers and non-smokers and in assisting the provision of robustly-framed public health policy steps to reduce the harmful effects of tobacco. The industry has attempted to influence these areas in a variety of ways, discussed below.

5.2 Tobacco industry smokescreen: a brief history

More than any other corporate sector, the tobacco industry has a well-documented history of manipulating the funding, design, methodology and publication of research to support its own marketing goals – the sale of its lethal products (Michaels 2008; McDaniel *et al* 2008; Cummings *et al* 2007; see later discussion). Extensive documentary evidence is now available showing that the tobacco companies intentionally tried to obstruct and deny the overwhelming evidence that smoking causes lung cancer and a variety of other respiratory diseases (from early evidence which emerged in the 1920s onwards). Later, the industry used a variety of methods to weaken the growing medical consensus that second-hand smoking causes a number of illnesses in non-smokers, including infants (evidence gleaned from the US Attorneys General lawsuits and related legal cases) (see Muggli *et al* 2003 for an overview).

Box 5.1 summarises some major milestones in the scientific debate over the health effects of tobacco, emphasising some of the industry's negative activities. In the main text we provide some detail on specific cases of industrial malpractice and its impact.

Internal tobacco company documents, released as a result of legal action brought in the United States, provide a very detailed picture of the many ways in which the tobacco industry has influenced not only public policy, but also the scientific process (SourceWatch 2008a, 2008b; McDaniel *et al* 2008; Apollonio & Bero 2007). In 1998 two legal settlements led to the public release of a massive archive of previously confidential internal industry documents, and this together with earlier documentation indicates that the industry established and funded a number of research organisations and scientists who were prepared to produce research findings favourable to the industry (McDaniel *et al* 2008; Muggli *et al* 2003). The data thus produced were then used to question the scientific consensus on the effects of smoking on human health – in terms of both the correlation between smoking and illnesses suffered by smokers and the impact of second-hand smoking on non-smokers – and to frame legislation, shape public opinion and challenge litigation against the tobacco industry.

Tobacco companies in Europe and the USA have funded university-based research groups either to create credibility for the industry or to manufacture claims of the value or harmlessness of tobacco consumption over many decades.

Using the internal tobacco company records mentioned above, several researchers have shown that tobacco companies in the USA had carried out their own chemical and sensory investigations of cigarette smoke since 1929, and found carcinogenic factors in the smoke that would clearly suggest its hazards, to smoker and non-smoker alike (SourceWatch 2008b; Schick & Glantz 2007; Diethelm *et al* 2005; Fields & Chapman 2003). Studies found in the archives of the American Tobacco Company and undertaken by the industry, indicated, for instance, that second-hand smoke contained higher concentrations of carcinogenic chemicals than mainstream smoke and more nicotine, again indicating its health impact (Schick & Glantz 2007; Fields & Chapman 2003).

Research by Philip Morris and R J Reynolds in the 1950s also found a variety of chemicals in tobacco smoke which had a range of effects on health. However, the industry pursued a concerted programme of public relations activities and the funding of research in order to deny the health dangers of second-hand tobacco smoke (Schick & Glantz 2007; Ong & Glantz 2000), even though documents make it clear than the link between smoking and cancer was known and accepted by the tobacco industry by the late 1950s (Cummings *et al* 2007).

A large study of second-hand smoke and health was undertaken by the International Agency for Research on Cancer (IARC) and published in 2002 (WHO/IARC 2002). It clearly demonstrated a significantly increased risk of lung cancer in non-smokers exposed to second-hand smoke compared to those not exposed. This finding echoes that of earlier studies (for example, Ong & Glantz 2000). The IARC study, which was peer reviewed, was criticised by the media and the tobacco industry, who contended that the data did not show any increase in cancer risk for those individuals.

Philip Morris feared that the study, together with a monograph on second-hand smoke from IARC, would trigger increased restrictions on smoking in Europe. According to a paper in *The Lancet* (Ong & Glantz 2000), the company undertook an inter-industry, three-pronged strategy to downplay IARC's work. The three threads of the attack were: to undercut the IARC research by developing industry-based research that would shed doubt on the studies from IARC; to manipulate the media and public opinion to question the risks of second-hand smoking; and to prevent government action to further restrict smoking. This campaign strongly criticised the science used by IARC and suggested that the industry's view was more objective than that of independent scientists – a view supported by the media (Kennedy & Bero 1999).

The tobacco industry has also been active on the issue of second-hand smoking and child health. The link between second-hand smoking and sudden infant death syndrome (SIDS) was first clearly noted in 1992 by the US Environmental Protection Agency (EPA). The links between both prenatal and postnatal exposure to second-hand smoke and the incidence of SIDS was published in an EPA report in 1997 (republished in 1999 by the US National Cancer Institute) (NCI 1999).

Box 5.1 - Tobacco, health and corporate tactics

1929: Early tobacco industry research indicating the possibility of a link between tobacco and health problems.

1950s: In 1951 Doll and Hill began a study of 40,000 doctors born between 1900 and 1930. Their investigation followed the health of the participants, and they matched the illnesses to which they succumbed with their smoking habits. The first results published as a preliminary paper in 1950 in a peer-reviewed journal clearly indicated that the lung cancer rate amongst heavy smokers was 20 times the rate of non-smokers (Doll & Hill 1950).

1954: Tobacco Industry Research Committee (later called the Council for Tobacco Research) set up by Philip Morris to attempt to find plausible explanations of why tobacco smokers frequently developed lung cancer and other respiratory diseases. Although the Committee was supposed to support research on the links between smoking and health the majority of funds were used in public relations, legal and lobbying activities. Its activities continued until 1999.

1955: The beginning of a variety of strategies used by the tobacco company Philip Morris to strongly influence the founder of the American Health Foundation, Dr Ernst Wynder, in order to diminish any information he produced that was critical of tobacco use. A series of publications have shown that Wynder did not acknowledge industry support which he received (while routinely acknowledging those from non-industry sources such as the National Cancer Institute), in research or other publications or announcements (Fields & Chapman 2003 for instance).

1972: The US Surgeon General's Report *The Health Consequences of Smoking* was the first to draw attention to the potential health consequences of second-hand (or 'side stream') tobacco smoke.

1977: Formation of the International Committee on Smoking Issues (ICOSI), later becoming INFOTAB, by seven tobacco companies to delay or thwart tobacco control policies in light of increasing evidence of the health effects of smoking. By 1984 the organisation had 84 company members. ICOSI was part of a global network (parts of which still exist) conceived to undermine public health measures.

1988: Center for Indoor Air Research was formed as a non-profit organisation by the tobacco industry as a response to increasing concern about the health effects of second-hand tobacco smoke on non-smokers. The aim of the organisation was to: "Broaden research in the field of indoor air quality generally and expand interest beyond the misplaced emphasis solely on environmental tobacco smoke". The Center was disbanded as a result of the 1998 Master Settlement Agreement (see below) between 46 US Attorneys General and the American Tobacco industry (SourceWatch 2008a).

1990s: US Environmental Protection Agency reports on second-hand smoke (see text).

1992: INFOTAB is replaced by two smaller groups: the Tobacco Documentation Centre, which is still in operation; and Agro-Tobacco Services. Together with other company-backed organisations they produced claims of the economic importance of tobacco in developing nations.

1994-1995: Creation of a tobacco industry front group – 'Get Government Off Our Back' – in the USA to fight tobacco legislation. The major tobacco company R J Reynolds supported the group, which claimed to represent people who wished to maintain their freedom to smoke.

1998: The *Tobacco Master Settlement Agreement* was entered into in November 1998. It was originally between the four largest US tobacco companies and the Attorneys General of 46 states. In this agreement, the states settled their Medicaid lawsuits against the tobacco industry for recovery of their tobacco-related health care costs. The settlement also exonerated the companies from any private liability resulting from diseases linked to the use of tobacco products. The four companies agreed to stop certain kinds of marketing practices and to reimburse the states for some of the medical costs they had incurred due to smoking-related illnesses. The money also funded a new anti-smoking advocacy group, the American Legacy Foundation, responsible for such campaigns as The Truth. The settlement also dissolved the tobacco industry groups: the Tobacco Institute; the Center for Indoor Air Research; and the Council for Tobacco Research (NAAG 1998).

2001: Nottingham University and British American Tobacco (BAT) sign a £3.8 million deal to establish an International Centre for Corporate Social Responsibility.

2003: An article was published in the *British Medical Journal* by James Enstrom of the University of California which claimed to show that the spouses of smokers were not at increased risk of dying of lung cancer compared with the spouses of non-smokers. A number of criticisms were levelled at the study including methodological problems and the fact that Enstrom had receiving funding from the tobacco industry at several points in his career and thus was open to suggestions of sponsorship (or publication) bias. (More details are given in the text.)

The tobacco industry has however used scientific consultants to attack the evidence of the link between second-hand smoking and SIDS. In a paper published in 2005, a variety of evidence from industry sources showed that Philip Morris had paid consultants to write a number of reviews in the medical literature addressing the health effects of second-hand smoke in ways supportive of the industry (Tong *et al* 2005). This approach is similar to the use of 'ghost writers' by the pharmaceutical industry (see chapter 4). In one case cited by Tong *et al*, data shows that Philip Morris successfully encouraged one consultant to change his original conclusion that second-hand smoke is an independent risk factor for SIDS, to state that the role of second-hand smoke is "less well established", a view consistent with the company's contention that only public health officials see dangers from second-hand tobacco smoke, and not the industry (see Schlick & Glantz 2007). This is a glaring example of sponsorship bias (see section 4.3).

Although the great majority of research using the previously confidential industry material has focused on the United States, a number of researchers have pointed to the situation in Europe and especially Germany, which has had a very pro-smoking stance at the government level. For example Gruning *et al* have shown that the influence of the tobacco industry over the German scientific and medical establishment from the 1950s up to at least 2002 has been "profound and [we suggest] greater than that documented in many other countries" (Gruning *et al* 2006). The authors suggest that at least 60 senior researchers were receiving both direct and indirect (through trade associations) funding from large companies like RJ Reynolds and Philip Morris, and contend that the numbers of such industry-funded researchers may in fact be far higher. Bio-medical scientists who received funding in the 1960s and 1970s in Germany and the UK did not appear to have ethical concerns about accepting such funds, and Gruning and his co-authors suggest that this is still the case in Germany at least.

5.3 Recent academic controversies

Tobacco companies engage with the university sector in the manner described above not only to locate appropriate research expertise but also to build their credibility as responsible businesses. Large donations to universities can bring much needed funds to the host institution and also show the company as acting philanthropically (Tesler & Malone 2008; Gould 2002).

In 2001 there was considerable media coverage of a £3.8 million donation from BAT to Nottingham University to support the International Centre for Corporate Social Responsibility. Many saw this funding as a fairly blatant attempt to gain credibility at a major university while ignoring the issue that the source of the funds depended upon the promotion of a health-damaging product (Gould 2002; Chapman & Shatenstein 2001). The funding caused a number of resignations and departures from the university, including those of Dr Richard Smith, the editor of the *British Medical Journal*, who had an unpaid post as Professor of Medical Journalism at the university. Professor David Thurston, a cancer researcher at the university, moved with his research team to London University, saying "The university is seen to encourage smoking and that is ethically wrong" (Cassidy 2001). A number of articles were written at this time questioning the ethical stance of those accepting tobacco industry funding. Furthermore, the debacle at Nottingham also resulted in Cancer Research UK withdrawing plans to provide funds of £1.5 million for buildings on the campus.

The furore surrounding the Nottingham decision was instrumental in Universities UK reviewing its code of practice for funding of universities (Universities UK/ Cancer Research UK 2004). Tobacco-industry funding has met with strenuous protest at universities in Canada, the USA, Australia, Israel, UK and South Africa (Chapman & Shatenstein 2001). Recent reports however indicate that tobacco monies are still finding their way into the university sector. For instance funds from Philip Morris are going to support research at Virginia Commonwealth University in the USA with restrictive clauses attached that permit publication of research findings *only after* agreement with the company (Finder 2008).

The question of the impact of tobacco funding on research and the ethos of the university was also raised by a very well publicised paper from the University of California (Enstrom & Kabat 2003).

In 2003 the University of California was the scene of considerable discussion on this issue that, according to many within the university, revealed an absence of sufficiently robust measures to deal with the question of tobacco funds being directed at campus research groups. The problems at the University of California pivoted on the paper by Enstrom and colleagues, which purported to show that second-hand smoking did not put non-smokers at risk of lung cancer (it left aside questions about other diseases relating to second-hand smoke) (Enstrom & Kabat 2003). The data (from 1959 onwards) that Enstrom used was supplied by the American Cancer Society and the study was published in spite of having a number of methodological flaws pointed out by experts at the society (Dalton 2007). The society was not aware that Enstrom had received tobacco industry funding over a period of time for his research. Critics of tobacco funding at the University of California say that this case of less than robust research being supported by the tobacco industry shows in sharp relief the problems with universities accepting funds from the industry (Pearson 2003; Dalton 2007).

In a joint protocol issued in 2004, Universities UK and Cancer Research UK (the major charitable cancer research funder in the UK) published a number of guidelines for research undertaken within universities. It stated that those accepting tobacco funds should ask themselves if accepting such monies would be detrimental to academic freedom and the ethical guidelines normally pertaining to research. They also ask universities if accepting tobacco money would be "potentially detrimental to their reputation" (Universities UK/ Cancer Research UK 2004). Cancer Research UK also stated that it would not fund any research group that received funding from the tobacco industry.

Given the long history of distorting evidence, it is hard to envisage how research or infrastructure support (like the case with Nottingham University) from the tobacco industries could lead to open and unbiased scholarship. After all, the products of the tobacco industry will lead to health problems in many individuals, and any research which demonstrates further health concerns related to tobacco use will be challenged by companies acting to protect their market share or profits. Furthermore, the suspicion of funding or publication bias, even where it may not occur, hampers free and objective discussion of the results of research supported by the industry.

Space does not permit detailed discussion of the global campaign of denial of the various dangers of tobacco products waged by the tobacco industry using citizen, trade organisations and bogus research bodies. These campaigns have made considerable use of the views and research of a small number of (often sympathetic) scientists to cast doubt on the health dangers of tobacco products. However, a summary of some of the important landmarks in this story is given in Box 5.1. The industry made extensive use of data provided by researchers it paid. The media also played a role in obfuscating the health problems associated with tobacco use and thereby delayed both public health measures and the public understanding of the dangers of tobacco (Apollonio & Bero 2007; Michaels 2008). This followed techniques used by a number of public relations companies acting on behalf of the industry in order to marshal the popular press, in ways which are very similar to those used by oil and gas companies and discussed in chapter 7 (see also Michaels 2008; Cummings *et al* 2007; Schlick & Glantz 2007). To achieve this, the public relations sector has often resorted to messages that create the sense of considerable uncertainty or doubt about the particular science involved in examining the effects of tobacco use. Much effort has been expended in creating controversy where the weight of expert opinion sees no such controversy. The aim has been, and continues to be, to plant seeds of doubt in the minds of the public, the legal profession and regulators about the scientific basis for change (Muggli *et al* 2003).

In brief, the influence of tobacco industry funding raises many important issues of ethical and practical importance to science and medicine. Such funding also influences the public perception of science and medicine toward a negative view in ways that are far more stark than those employed by the other industrial sectors examined in this report. Some of the more obvious factors are:

* The global network of tobacco companies and manufacturers which have directly undermined public health measures (including the work of WHO);
* The sponsorship of individuals to question data clearly showing the links between smoking and ill health, often using partial or misleading methods. This is a major concern when deliberate misrepresentation of research by tobacco funded lobby groups is undertaken;
* Funding that imparts sponsorship bias in studies of second-hand smoke and ill health;
* Use of offers of funds to universities in order to build tobacco industry credibility. The guidelines for research funding from tobacco companies – from Cancer Research UK and Universities UK – partially address this problem.

Summary of detrimental effects of tobacco industry influence on SET

- **Influence on the direction of the research agenda**

1. A variety of partnerships between academic researchers and tobacco companies that skew research either to build credibility of the company/industry or to increase doubt about the risks of tobacco products;
2. Research that concentrates on reducing the harm of tobacco products in order to overcome regulatory hurdles and hence continue to widen markets for tobacco products.

- **Influence on the direction and results of specific research studies (both intentional and unintentional)**

1. Funding of researchers whose views are sympathetic to the tobacco industry, and reduction of the ease with which funded scientists can disseminate findings negative to the industry.

- **Influence on the openness of research studies**

1. Use of restrictions on publishing data arising from industry-funded research;
2. Use of in-house company publications to release data rather than the vehicle of peer-reviewed journals.

- **Influence on the public interpretation of research results**

1. Emphasis on uncertainty in any tobacco research indicating health risks, together with a general bias in research reporting;
2. Use of industry-paid consultants to write about health effects of smoking and tobacco use. Their views are sympathetic to the industry, but their links to the industry are often not declared;
3. A variety of front organisations set up by, or with funding from, the tobacco companies to argue that the scientific evidence does not necessitate further legal restrictions on smoking.

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6. The military/defence sector

The concept of 'national security' has traditionally been defined in terms of armed threats to the nation state, and thus the response to such threats has often been framed in military terms. Such thinking continues to dominate the military/defence industry today and the related research and development it supports. However, a growing number of security analysts and many within the UK government are arguing that this is far too narrow a perception and that security must be seen more broadly, with much greater consideration given to tackling the roots of conflict, including related issues such as social justice and natural resource problems (for instance Abbott *et al* 2006; Elworthy & Rifkind 2005; Cabinet Office 2008; Kearns and Gude 2008; Langley 2005).

This section examines the significant involvement of the military industry within academic research and education, and the concerns related to this involvement, not least the narrow conceptualisation of security it encourages. We begin with some background on the military industrial sector itself.

6.1 Background on the military/defence sector

Global military expenditure has increased considerably since 2001, reaching its highest level (in real terms) since World War II. In 2008, this expenditure stood at a massive $1.46 trillion (£785 billion) (SIPRI 2009a). Spending is led by the USA whose share is about 42 per cent of the total. The UK is the fourth largest military spender (in absolute terms) with the government currently devoting about £35 billion of taxpayers' money to military objectives – about 4.5 per cent of the global total (SIPRI 2009a).

The expansion in spending in the USA, UK and elsewhere has been mainly driven by the so-called 'War on Terror'. This growth has also contributed to a variety of changes in the ways in which security is framed by policymakers – many of them being very controversial. One key aspect in the UK has been the growing emphasis on high technology, weapons-based approaches to tackling security problems (Langley *et al* 2007), as is described in the UK Defence Technology Strategy, published in 2006 (MoD 2006). This obviously has a very significant effect on the science and technology communities because of the greatly increased spending on a whole range of security-related R&D and technology programmes, from weapons systems to surveillance.

Military R&D spending has also had a marked influence in many other areas, such as the biosciences, information technology and data handling. Here questions about the potential security risks engendered by the research process itself and its various outcomes are coming to the foreground (James 2006; Langley 2008; Rappert & McLeish 2007). For example, some developments in gene manipulation can increase the risks of potential bioweapons being produced (see section 8.4.4).

Corporations in the military/defence sector are often very large (see tables 6.1a and 6.1b, below) and their profits have risen considerably as a result of the 'War on Terror'. For instance Lockheed Martin increased its profits from contracts by more than 81 per cent in the period 2001 to 2006. Boeing's contracts increased by more than 52 per cent in the same period. BAE Systems – the UK's largest military corporation – saw more than a 442 per cent increase in its US contracts in the five years from 2001 (Langley *et al* 2007). There have also been a number of significant acquisition activities among the world's arms companies since 2004. These enhance the power and reach of military companies and carry their strategic influence across national borders. For instance BAE Systems acquired United Defense (USA), thus strengthening its role in the procurement process in the USA. QinetiQ, a major UK military technology company, has demonstrated an aggressive and expansionist corporate focus, acquiring four US aerospace and military companies by 2005.

Table 6.1a - Top five global arms-producing companies (excluding China), 2007

Global rank	Company	Country	Military Sales (£ billions)	Military sales as proportion of total sales	Profit (£ billion)
1	Boeing	USA	15.3	46%	2.1
2	BAE Systems	UK	15.0	95%	0.9
3	Lockheed Martin	USA	14.7	70%	1.5
4	Northrop Grumman	USA	12.3	77%	0.9
5	General Dynamics	USA	10.8	79%	1.0

Table 6.1b - Top five UK arms-producing companies, 2007

UK rank*	Company	Military Sales (£ billions)	Military sales as proportion of total sales	Profit (£ billion)
1	BAE Systems	15.0	95%	0.90
2	Rolls Royce	2.3	31%	0.60
3	QinetiQ	1.1	79%	0.05
4	Babcock International Group	1.0	58%	0.08
5	VT Group	1.0	78%	0.06

** Globally, Rolls Royce ranks 17th in the world, with QinetiQ, Babcock and VT all ranking in the top 40.*

Source: Figures from SIPRI (2009b) converted to UK pounds.

Integral to the market dominance and power of this industry is a sustained high technology R&D effort, which receives considerable funds from government sources, particularly in those countries with a marked military budget like the USA and the UK (Langley 2005). The military companies also undertake significant levels of in-house R&D activity. In the UK, the aerospace and 'defence' sector is the second most R&D intensive after the pharmaceutical and biotechnology sector (BERR 2008). Most of the R&D effort which is focused on military objectives in the UK tends to be concentrated in the big companies like BAE Systems, Rolls Royce and QinetiQ, but there are 'hot spots' of intense R&D effort in small specialised companies within the sector (Langley *et al* 2007) .

The world's largest funder of military R&D is unsurprisingly the US Department of Defense whose budget for the 2009 fiscal year is $82 billion (£44 billion) – 56% of the US government's total R&D budget (AAAS 2008). According to the available figures, the UK government – through the Ministry of Defence (MoD) – is the third highest public funder of military R&D in the world, with an annual budget of about £2.6 billion – around 30% of the total UK public R&D budget (Langley *et al* 2007; DIUS 2008).

Military corporations tend to be powerful entities with close connections to government circles, and they undertake significant lobbying activities, through trade associations like the Society of British Aerospace Companies and also through public relations companies (Langley 2005), an activity commonly found across the corporate sectors and discussed throughout this report. The focus of this lobbying emphasises the high technology approaches to security.

6.2 Military involvement in UK universities

The gradual commercialisation of UK universities discussed earlier in this report has created the scope for various kinds of partnerships to be forged with military companies (especially in aerospace and materials) – facilitated by taxpayers' money. Since the early 2000s the UK government has provided funding for a number of military-university consortia (comprising academic research groups, corporations and government departments) to pursue R&D with military objectives (Table 6.2). Many universities, such as Southampton, Oxford, Imperial College, Cambridge and Cranfield, receive sizeable research funds through their involvement in these 'partnerships' to undertake essentially military R&D. Such a situation owes much to the changes occurring in the last two decades not only in UK science policy, the universities, and within the government 'defence' and aerospace research establishments, but also within the military companies themselves where R&D activities have been largely restructured (Langley 2005; Langley *et al* 2007).

One result of these changes is that in the UK and USA, university research groups often have considerable military research portfolios. This trend has been examined by Scientists for Global Responsibility, but otherwise has attracted little comment (Cantor *et al* 1990; Langley 2005; James 2006; Langley *et al* 2007). Edgerton has pointed out that the role of the military-industrial complex in the UK's military stance has received scant attention from the academic community (Edgerton 2006). Those wishing to look in detail at the extent and nature of the military involvement (both government and corporate) with researchers in universities and with the school curriculum are encouraged to read our earlier publications (Langley 2005; Langley *et al* 2007). However, to place military corporate involvement into its broader context some details are essential here.

We have found during the course of our studies over the past five years that the funding provided by military corporations leads to a widespread culture of secrecy and unwillingness to openly discuss questions about research or teaching (Langley *et al* 2008). Section 6.3 discusses this issue in more detail.

Table 6.2 - University-military consortia in the UK

University-military partnership[1]	UK Funding source: Military corporations	Ministry of Defence (MoD)	Other government departments	Research Council
Defence Technology Centre	✔	✔	-	-
Defence Aerospace Research Partnership (DARP)	✔	✔	✔	✔
FLAVIIR[2]	✔	-	-	✔
Towers of Excellence	✔	✔	-	-
Joint Grants Scheme	-	✔	-	✔
University Technology Centre (UTC)	✔	-	-	-
Other university collaborations with the military sector[3]	✔	-	✔	-

1. All the military partnerships involve university research groups which receive funding from non-military sources too, including the Research Councils, foundations, and the government support mechanisms for research and teaching.

2. FLAVIIR is a collaborative programme between BAE Systems and EPSRC to the tune of over £6 million for unmanned airborne vehicles and involves ten UK universities including Cranfield, Cambridge and Imperial College London.

3. These forms of partnership include joint military and non-military funding of centres, research programmes or training within universities. They can be of short or long duration.

Military research and development seeks to provide new and more effective weapons systems, support platforms for weapons systems, and other forms of high technology – such as communications and surveillance – that are central to the modern concept of warfare. In the UK, the MoD has a key role in securing such equipment and ensuring corresponding military 'superiority'. The MoD has a complex and largely clandestine relationship with the military corporations to whom they turn for the provision of military technology. The large corporations have a number of clients in addition to the MoD, and the R&D effort which they undertake serves their whole client base not just that of the UK.

With research being fundamental to the design and development of new high-technology military systems, the universities tend to be involved in the early stages of the military production cycle (Langley 2005; Street & Beale 2007). The military corporations participate not only in the MoD-led partnerships (consortia) but also have their own in-house R&D laboratories with highly skilled researchers, plus a variety of 'stand-alone' collaborative programmes with academic research groups. These partnerships and programmes are summarised in Table 6.2 and are discussed in more detail below.

The MoD and other government departments which engage in funding R&D with a military focus (as well as other R&D which may not primarily be military but is dual use – military and civilian) enable corporations to actively seek expertise within academic research groups. Many in the universities see corporate funds for research and teaching as a key to gaining prestige and attracting further funds from both corporate and government sources (Langley *et al* 2008; see also Washburn 2005).

In the Fiscal Year 2005/6, the MoD provided around £22 million through its Science and Technology Programme to UK universities (Langley *et al* 2007). Additional support for university R&D for military objectives (generally in the form of project co-financing) has come from the former Department of Trade and Industry (DTI – now subsumed into the Department for Business, Innovation and Skills).

Other, non-commercial sources of funding for military R&D find their way into UK universities. For example, the US government provides military funding for UK research through the Departments of Defense and Energy and the Office of Naval Research. The European Union is also set to provide funding for EU-wide 'security research' which will draw European universities into R&D with a military focus (Hayes 2006).

We will briefly discuss the government and joint government-corporate military initiatives with UK universities first and then examine in some detail the corporate schemes which engage with academic research, training and teaching.

Currently there are four main ways in which corporate funding can, with the assistance of government and Research Council co-funding, reach universities for broadly 'defence' R&D activities (Langley 2005). These are:

1. *Defence Technology Centres*. At present there are four, with the MoD earmarking £90 million for them over five years. Corporate partners include BAE Systems, General Dynamics, Thales and Roke Manor Research. We describe their structure and corporate involvement below.
2. *Interdisciplinary Research Centres (IRCs)*. Two are in nanotechnology and one in advanced computation. These centres, in the main, are supported by the Ministry of Defence and the Research Councils, but the level of corporate involvement in these centres is not clear (Langley *et al* 2007). The IRC at the University of Birmingham had Rolls Royce as a corporate 'partner' in the period 2001-06 (Street & Beale 2007).
3. *Defence and Aerospace Research Partnerships (DARPs)*. These are part-funded by the MoD, the Engineering and Physical Sciences Research Council (EPSRC) and formerly the DTI, as well as by industry. At the time of writing there are four DARPs involving two universities.
4. *Towers of Excellence*. These are joint partnerships with industry, the research community and government. Unfortunately, detailed, up-to-date, information is lacking although they are discussed in the 2006 Defence Technology Strategy, when Thales, BAE Systems, Defence Science and Technology Laboratory, and Alena Marconi were known to be active in these partnerships (Langley 2005; Langley *et al* 2007; Street & Beale 2007).

The MoD also sub-contracts through its own Defence Science and Technology Laboratory. Other government schemes are discussed in our earlier publications.

The Defence Technology Strategy reiterated the intention of the military sector to draw further upon the expertise within the academic research community, and also launched new initiatives to provide innovative ideas for high-technology approaches to security from both business and the academic community (MoD 2006). This approach is intended to complement the wider government policies which emphasis the commercialisation of SET, as discussed in chapter 2.

The three largest UK military/ defence corporations – BAE Systems, Rolls Royce and QinetiQ (see Table 6.1b) – each run major R&D programmes with academia in addition to the consortia described above.

BAE Systems operates a variety of relationships with around 60 universities globally for its own R&D effort. Four of these relationships are for 'strategic' purposes. Additionally, BAE Systems has a suite of training and degree programmes with universities in the UK. Loughborough University, for example, with core funding from the East Midlands Development Agency, collaborates with BAE Systems in the Systems Engineering Innovation Centre. This centre has supplied systems engineers to BAE (one thousand between July 2004 and the end of 2005). Given the competition within industry for skilled engineers, those recruited to the military sector tend to stay there rather than move to the civilian industries (Langley 2008) (see section 6.3 for more on the competition for resources between the military and civilian sectors).

BAE also has a collaborative programme with the EPSRC (called FLAVIIR), funded to the tune of over £6 million for research into unmanned airborne vehicles that involves ten UK universities including Cranfield, Cambridge and Imperial College London. Such autonomous or robotic vehicles are playing an increasing role in surveillance and attack functions in conflict situations, as seen currently in Afghanistan and Pakistan. Use of these by the US military has attracted criticism, not least for the civilian casualties arising from these operations (for example, Sharkey 2007; OpenDemocracy 2009).

BAE Systems declined to respond to our repeated questions seeking basic information about its collaboration with the university research community (Langley *et al*, 2008).

Rolls Royce, with its own funding together with monies from the UK government, has set up University Technology Centres (UTCs) to support research mainly in turbine engineering and materials (Langley *et al* 2008). At present there are a total of around 20 such centres in the UK and Scandinavia. The intention of such centres is to tap into the local university knowledge base to address specific questions of value to the company. In some situations the UTC's work complements that of other military corporations' research programmes. For example, the University of York UTC in systems and software engineering complements that of BAE Systems funded Dependable Computing Systems

Centre and the DARP in high-integrity real-time systems, all of which are located in the University of York. Such intensification of military influence within university departments can be found throughout the UK – examples include the universities of Cranfield, Sheffield, Imperial College London and Southampton (see Langley 2005; Street & Beale 2007; Langley *et al* 2008).

QinetiQ, a major corporate player within these military consortia, with business in the UK and USA, intends to strengthen and widen its reach into the university SET community (Langley *et al* 2008). It already has interactions with universities which include Bath, Cardiff, Oxford, Imperial College London, Southampton, Surrey, Lancaster and York. QinetiQ staff are on industrial advisory boards and the committees of the EPSRC and play a role in the Industrial Awards in Science and Engineering PhDs (part funded by QinetiQ and the EPSRC). During the research for our report *Behind Closed Doors*, we were unable to obtain any detail of the nature of these varied collaborative ventures even though we tried repeatedly (Langley *et al* 2008).

Boeing, a very powerful military company globally, also funds science-based R&D activities in the UK, such as in the Advanced Manufacturing Centre, a £45 million collaboration with the University of Sheffield in manufacturing and composites. The company also has a partnership with the universities of Cranfield, Cambridge and Sheffield in information technology, aeronautics and manufacturing.

These various collaborations and consortia involving publicly supported academic researchers and the military sector – private and government – tend to pursue high-technology means of addressing security. The primary focuses of the UK military consortia are at present: sensors; autonomous vehicles (robotic land and air vehicles); communication and computational technology; guided missiles; and complex weaponry (see Langley *et al* 2007; Street & Beale 2007). There are also significant links with similar programmes in the USA.

6.3 Problems related to military corporate involvement

A major criticism of military R&D in general is that the current level of funding is so high compared with that for some key civilian sectors. For example, in 2006, governments in the richer, industrialised nations of the OECD spent a total of \$96 billion (£48 billion) on military R&D, but only \$56 billion on R&D related to health and environmental protection (OECD 2007). Renewable energy R&D only attracted \$1.1 billion (IEA 2007) despite the global problems associated with carbon emissions and climate change (see chapter 7). A similar imbalance exists in the public funding of R&D in the UK, with military objectives attracting more than twice that for health objectives, and more than 15 times that which supports environmental protection (DIUS 2008). This imbalance has serious opportunity costs. With so much funding (and, indeed, expertise) tied up in large military R&D budgets, it is unavailable for other urgent needs to which SET can make a contribution such as treatment of 'neglected diseases', cleaner energy sources, or technology transfer to poorer countries.

Furthermore, much publicly-funded military R&D is actually undertaken by the commercial sector. For example, in 2005 (the latest figures available), the UK government spent £939 million on military R&D undertaken by UK industry, while the UK military industry itself only provided £375 million (DIUS 2008). This represents a considerable subsidy to the sector.

There are further subsidies for military involvement in the university sector. Street and Beale (2007) detailed the military involvement at 26 UK universities and found that the civilian research council, the EPSRC, was involved in the part-funding of almost one-third of the military projects in the case study universities. There has been no open discussion about this level of hidden support for the military industry or the opportunity costs of undertaking such R&D within the universities.

The predominant way in which security is framed in the UK is through the use of high technology weaponry and their support platforms, together with a sophisticated network of communications derived from such R&D. Some of the UK's battlefield technology needs to be interoperable with that of the USA's armed forces. This follows from the closeness of UK and US foreign and military policies – as part of the 'special relationship'. This results in the UK's security strategy having a high reliance on military approaches – and thus being very expensive. Associated security programmes operated by the Home Office and the Foreign and Commonwealth Office also have a technological theme (Langley 2005; Langley *et al* 2007). The military focus of the UK's security stance continues despite enormous shortcomings becoming apparent during the 'War on Terror', showing quite clearly that this approach has serious failings. Despite speaking about the need to take a far wider view of the ways in which security can be developed, the National Security Strategy launched in March 2008 (Cabinet Office 2008) still saw a central place for force projection – as was in vogue during the Cold War.

The complex nexus which supports the militarised security strategy of the UK depends in many ways upon corporate R&D, which is increasingly outsourced to university research groups and highly specialised spin-out companies, some of which involve academic researchers. This is a trend which goes hand-in-hand with the growth of commercialised universities in the UK. Our previous reports discuss this situation in detail (Langley 2005; Langley *et al* 2007; Langley *et al* 2008).

The budgets which are made available to other, non-offensive, forms of security are far smaller than that given over to the military. In 2007/08 for instance, compared to an MoD budget of £33 billion, only £5.3 billion was allocated to overseas development by the UK government (DFID 2009). Many areas of development funding are key to building peace in poorer countries – and indeed to helping reduce the security risks faced by the UK, as the government acknowledged in the National Security Strategy. To aid peace building, the Conflict Prevention Pools have been set up, and are run jointly by the MoD, Foreign and Commonwealth Office and the Department for International Development. However, the total budget for the pools in 2007/08 was only £74 million (CPP 2007) – a very small fraction of the MoD budget.

As it is a finite resource, any university expertise that is used to augment that from the commercial sector in the research, design and building of military equipment and its various platforms will inevitably reduce that which is available to other ways of securing and building peace, including the understanding of the conditions necessary for non-violent conflict resolution. We have discussed the range of alternatives to this situation in more detail in our previous reports (Langley 2005; Langley *et al* 2007), but in a nutshell:

1. The approaches to security problems favoured by successive UK governments and the military industries are too focused on the use of military force (with a strong reliance on cutting-edge technology) rather than giving due priority to the use of diplomacy, international arms control treaties, 'bridge building', and technology transfer with those nations at risk of conflict, especially those with unstable governments and failing economies (see also Abbott *et al* 2006);
2. As a number of commentators have pointed out, the lack of spending by successive UK governments in other areas – such as poverty alleviation and environmental protection – will, if not dealt with, contribute to major breakdowns in security (see also Abbott *et al* 2006; Stavrianakis 2006).

It is important to recall that military R&D in both government laboratories and those of industry is supported by an infrastructure of non-military research and staff in the university sector. Additionally it is often difficult to disentangle the actual contributions, in terms of both finance and expertise, made to joint partnerships by the government and commercial military sectors.

The university-military partnerships tend to be tightly knit and not open to scrutiny. This can result in the formation of a specific kind of security stance which, as we have discussed, concentrates on high technology and emphasises 'force projection', hindering a shift to a more broadly defined approach to security (Langley 2005). The overall effect is exacerbated by the closure and amalgamation of university physical science departments. Importantly this nexus also helps stimulate technological arms races, which are further enhanced by the EU security research programme (Hayes 2006).

What impact does this pervasive involvement of the military corporations have on SET and the universities? As we mentioned earlier there is little academic research data on the issues of funding bias and the framing of the R&D agenda brought about by military-university collaboration in the UK. Similarly the influence on career choice and perception of SET brought about by the widespread influence of the military in schools and colleges (described briefly in our earlier reports – see Langley 2005; Langley *et al* 2007) has attracted limited investigation.

Consequently, SGR carried out a further research project (Langley *et al* 2008) to obtain some basic information on these issues to augment that in our previous reports. The overall intention was to provide some data to better understand the impact of military sector involvement with the academic community in the UK, and to trigger discussion and more in-depth studies of the commercialised university. We used the Freedom of Information Act and individual interviews together with questionnaires, publicly available sources of information and approaches to the military corporations themselves to build up a picture of any effects. We investigated a sample of 16 UK universities, some of which were selected for their high levels of military involvement (such as Cambridge, Imperial College, London and Oxford), others because we lacked detailed information about their levels of military support (these included Bournemouth, Newcastle and Exeter). This work complemented another project carried out during a similar period (Street & Beale, 2007). The main conclusions of the SGR report – entitled *Behind Closed Doors* – are given below. Also included are some selected conclusions from Street & Beale.

1. Military involvement (both commercial and government) in and funding of research, teaching and training at UK universities is far more pervasive than generally acknowledged:

- Financial data collected in the study indicates that official figures for research with military objectives carried out at universities underestimate the extent of military involvement considerably, possibly by as much as *five* times. In the sample of universities examined in *Behind Closed Doors*, the average size of military funding received per university was £2 million per annum – a figure similar to that found by Street & Beale. This amount was five times that recorded in government statistics (Langley *et al* 2008). But, of course, funding is only part of the influence exerted by the military within academia and in shaping the career choices of graduates.
- Data assembled from our own studies (Langley 2005; Langley *et al* 2007; Langley *et al* 2008) and that assembled by Street & Beale indicate that a very high proportion of the universities in the UK (which number more than 100) receive military funding. For example, 42 out of 43 UK universities investigated in these four studies have been found to receive funding to pursue military objectives (data on the remaining university being inconclusive). Street & Beale report that in the period 2001 to 2006 more than 1,900 military R&D

projects were undertaken in the 26 sample universities worth an estimated £725 million.

- High prestige universities and departments of engineering and physical sciences receive significant sums for undertaking military R&D. The less research-intensive departments and universities (including those with an avowed 'business-facing' stance) tend to attract funds for specific training and teaching of value to the military sector rather than for R&D. These funding effects may well limit the availability of skilled staff for work in alternative civilian areas, because it is likely that lucrative contracts from the highly profitable military sector will have appeal to departments and research groups with tight budgets. Close involvement with military industry can also build a high technology view of how to pursue security, which marginalises other ways of framing security.

2. Universities present themselves as open, accountable institutions yet, when challenged through Freedom of Information Act approaches were seriously deficient in several respects including:

- Detailed, comprehensive data on military involvement in universities was very difficult to obtain due to a combination of incomplete record keeping, commercial restrictions, pressures on researchers and, most disturbingly, evasiveness on the part of officials.
- Senior university staff, corporations and researchers were reluctant to discuss details of their activities related to military-universities partnerships, despite these institutions receiving significant public funding or co-funding.
- It has become clear during the course of our studies over the past five years that there is considerable disquiet among non-military funded staff in UK universities about growing military involvement. One main concern is about the power of vested interests – especially large corporations – in influencing the research agenda and making it more 'conformist', and compromising the autonomy of researchers. These concerns have been echoed throughout this report. Some of those to whom we have spoken have pointed out how high technology, weapons-based approaches to dealing with issues including security threats or other global problems are given undue priority over, for example, political, diplomatic or other non-technological approaches. Funding and other pressures mean that these staff members often do not feel able to express their concerns openly.

3. There was some limited evidence that the quality of research publications – as indicated by the number of peer-reviewed papers – arising from military funding may not be as high as that originating from non-military funded researchers.

Summary of the detrimental effects of military/defence commercial influence on SET

- **Influence on the direction of the research agenda**

1. Strong support is created for a high technology, weapons-based approach to security, which marginalises consideration of alternative approaches;
2. Public funding of military R&D is large compared with several important civilian sectors, such as health and environment. Much of the military R&D is used to fund work within industry, which is forging increasing links with universities. This reduces the scientific and technological resources available for tackling urgent non-military problems in areas such as poverty alleviation and environment protection;
3. Corporate involvement imports a business ethos to the research environment which can hamper alternative, non-commercial ways of understanding security issues;
4. The presence of military corporations either as funders or consumers of expertise (in training or teaching) on campus is associated with a sense of prestige in the mind of researchers and policy-makers. This encourages pursuit of further funding of this nature.

- **Influence on the direction and results of specific research studies (both intentional and unintentional)**

1. Consortia involving military corporate and/or government partners reduce the non-military work individual researchers can undertake (see above);
2. Some limited evidence that less peer-reviewed publications result from military support.

- **Influence on the openness of research studies**

1. The R&D funded by the military sector – government and corporate – in the universities tends to be undertaken in a less transparent way than non-military funded work. Secrecy and evasiveness can prevent a more open discussion of the research.

- **Influence on the public interpretation of research results**

1. In public fora, military corporations strongly promote a high technology, weapons-based approach to dealing with security problems, including the R&D to support that approach;
2. The military corporations use their own lobbyists, as well as those which represent military and aerospace industry as a whole, to shape both the security agenda and the related priorities for R&D (both public and private).

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7. The oil and gas sector

The fact that the oil and gas industry provides over half of the world's energy supply gives an indication of its power and reach throughout modern society. Indeed, the world's largest privately owned company – ExxonMobil – is an oil and gas corporation (Financial Times 2009).

Unsurprisingly, the industry has a great deal of influence on scientific research and technological development, including direct funding of R&D – both in-house and within universities – and involvement in education and lobbying activities.

In this section, we focus specifically on the industry's heavy involvement with public relations campaigns that have sought to undermine public acceptance of the scientific evidence that humans are causing climate change. This includes adopting a perspective known as 'climate scepticism'. We then look at their considerable influence in the field of energy R&D and involvement in UK universities. We start with some background to the industry and a summary of the current scientific evidence for climate change.

7.1 Background to the oil and gas industry

Crude oil is human society's largest energy source, providing 34% of the world's 'primary' energy supply (IEA 2008a). It is also the raw material for many commodities that are central to our modern lifestyle. Corporations that extract oil are generally also heavily involved in the extraction of natural gas, because reserves of oil and gas are often co-located. With natural gas making up a further 21% of the world's energy supply (IEA 2008a), it is no surprise that oil corporations have become very powerful and influential. Given that global energy demand could, based on current policies, grow by 45% by 2030 (IEA 2008b), there is a lot of scope for these companies to remain powerful for many years to come.

In 2008 the global oil and gas industry posted record revenues – with the top five privately-owned companies alone receiving a staggering £975 billion ($1,800 billion) – see Table 7.1. Net profits for these five companies amounted to over £70 billion – this is equivalent to £8 million every hour. As with the pharmaceutical industry (see chapter 4), the oil and gas sector has also been marked by mergers and acquisitions, which means that a small number of corporations have acquired considerable economic power. ExxonMobil, the largest non-state owned oil and gas corporation – and which owns Esso in the UK – generates considerably more profit than its competitors (see Table 7.1).

The economic strength of the industry means that it can easily access government officials and research expertise. Hence, as this chapter will show, it has much influence in relevant policy areas, including science and innovation policy.

Oil and gas companies invest large sums in R&D, mainly focused on exploration for, and the extraction and production of, fossil fuels. However, in recent years they have begun to invest in other energy technologies as well, including renewable energy sources (especially liquid biofuels, wind and solar). We will discuss this further in section 7.4.

Two issues are currently critical in the policy debates related to science and technology in this sector: climate change and 'peak oil'. As we discuss in more depth in the next section, climate change is a key issue for the sector because oil and gas combustion – for example, in cars, power stations, factories, aircraft and homes – is one of the main activities causing this global environmental problem.

Table 7.1 – The world's top five privately-owned oil and gas companies by revenues, 2008

Rank	Company	Country	Revenues (£ billions)	Profit (net) (£ billion)
1	ExxonMobil	USA	247	24
2	Royal Dutch Shell	UK/Netherlands	246	14
3	BP	UK	197	12
4	Chevron	USA	143	13
5	Total	France	142	11

Sources: Figures from ExxonMobil (2009), Royal Dutch Shell (2009a), BP (2009), Chevron (2009), Total (2009) – all converted to UK pounds.

'Peak oil' is defined as the point at which global extraction of oil reaches a maximum and then begins to fall. The major concern is that the peak may be reached soon and that this will lead to a rapid rise in oil prices leading to serious global economic problems. There is much disagreement over when the peak might be reached. Some – such as the Association for the Study of Peak Oil (ASPO) and the UK Industry Taskforce on Peak Oil and Energy Security – argue that it will be in the next few years (ASPO 2008; ITPOES 2008). Meanwhile some senior figures in the oil industry argue that it is several decades off. The International Energy Agency (IEA) – which advises governments and industry on energy policy – recently stated that it expects 'conventional' oil production to level off before 2030, with further growth coming from 'unconventional' resources which are much more costly and energy intensive to exploit (IEA 2008b). It calls for major global investment in new energy infrastructure and technologies over the next two decades to prevent serious economic problems due to this 'plateau' in conventional oil production. However, if the more pessimistic predictions of ASPO and others are right, serious economic problems will occur much sooner.

7.2 Climate change: the accumulation of evidence

Climate change is one of the greatest threats to human society and natural ecosystems over the coming decades and beyond. In November 2007, in a *New York Times* article on the issue, the UN Secretary General stated that "we are on the verge of a catastrophe if we do not act" (Moon 2007).

Human activities are releasing billions of tonnes of 'greenhouse gases' into the atmosphere. The main greenhouse gas emitted by humans is carbon dioxide and the dominant source of carbon dioxide emissions is the combustion of fossil fuels, including oil and gas. Once in the atmosphere, these gases act to trap extra heat from the sun and so cause a global temperature rise, known as 'global warming'. Climate scientists warn that this is leading to changes in the global climate system, which are very likely to have major negative impacts on human society and natural ecosystems. Projected impacts include increasingly extreme weather events (including droughts, storms and floods) which will jeopardise the availability (both locally and globally) of fresh water, food and other resources essential to human society. If global emissions of greenhouse gases continue to rise unchecked, hundreds of millions of people will be adversely affected over the next few decades, with the numbers increasing thereafter (IPCC 2007a).

Evidence that the global climate is changing and that humans are a key driver of this change has been rapidly accumulating over the past two decades. The climate change problem first gained widespread public attention in the late 1980s when senior NASA scientist James Hansen warned of the threat in testimony to US congressional hearings. Subsequent policy discussions led to the formation of the Intergovernmental Panel on Climate Change (IPCC – see box 7.1) in 1988 whose aims are to summarise the latest scientific evidence on the scale of the problem and to present options for dealing with it.

The IPCC has published numerous reports on various aspects of the problem in the years since, including extensive 'assessment' reports every five or six years, the latest of which came out in 2007 (see box 7.1). The process for compiling these reports is lengthy and involves a wide range of expertise to ensure their findings are supported by extensive data and hence robust. For example, the 2007 IPCC assessment report took three years to research and prepare. It was written by over 1250 scientists with another 2500 experts taking part in a two-stage review process (IPCC 2007b). Four 'summaries for policy-makers' were prepared, each one having to be approved line-by-line by the scientific representatives of the over 100 member nations of the IPCC.

Some climate scientists have argued that such a painstaking process results in reports that are too cautious (Leggett 2000; Pearce 2007). They point in particular to the problem of seeking

Box 7.1 - Intergovernmental Panel on Climate Change (IPCC)

The IPCC was established in 1988 by the United Nations Environmental Programme and the World Meteorological Organisation. It is the leading international advisory body on climate change, its aim being to "provide decision-makers and others… with an objective source of information… relevant to the risk of human-induced climate change, its observed and projected impacts, and options for adaptation and mitigation" (IPCC 2009). The IPCC itself does not conduct research nor does it monitor climate change data, its role being to summarise existing data from reliable sources such as peer-reviewed academic journals and elsewhere.

The IPCC's work is dealt with by four main groups. These groups are: Working Group I, which examines the physical basis of climate change; Working Group II on climate change impacts, adaptation and vulnerability; Working Group III on climate change mitigation; and a Task Force to assist in compiling national greenhouse gas inventories.

The assessment reports, produced by the IPCC every five years or so, all include a volume by each of the three Working Groups – to report on the state of the scientific evidence on climate change. Four such reports have so far been published: in 1990; 1995; 2001; and 2007.

approval from representatives of nations which are politically opposed to significant action to reduce greenhouse gas emissions (some with close links to the oil industry, as we will discuss below) – even though such representatives are ostensibly only allowed to make changes based on scientific grounds.

Nevertheless, the findings presented in the IPCC assessments reports have, over the years, become increasingly pronounced regarding the issue of whether human activities are directly causing climate change and the scale of the impacts that this climate change will have on human society. The first assessment report, published in 1990, stated that it is "certain" that greenhouse gas emissions will result in "warming of the Earth's surface" and highlighted a range of potential global impacts over the coming century should action not be taken to reduce them (IPCC, 1990). Five years later, the second assessment report went further, stating that the observations now suggested that there was already "a discernible human influence on global climate" (IPCC 1995). The 2001 report spoke of "new and stronger evidence" of this human influence (IPCC 2001), while the fourth assessment report in 2007 ended any lingering doubts by stating, "Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic [human-induced] greenhouse gas concentrations" (IPCC 2007a). The assessment reports have also pointed to increasing certainty about the global scale of the impacts and the urgency of action needed to avoid them.

The IPCC findings have also received backing from science academies across the world, including the UK's Royal Society (see for example: Royal Society *et al* 2005). The level of agreement among climate scientists, both that climate change is happening and that humans are the main cause, is extremely high. Donald Kennedy, editor of the authoritative journal *Science*, wrote after the publication of the 2001 IPCC assessment report, and after news of President Bush's decision to go back on his commitment to regulate the carbon dioxide emissions from power plants in the USA, "Consensus as strong as the one that has developed around [global warming] is rare in science" (Kennedy 2001). Kennedy added that on climate change there was little room for any "doubt about the seriousness of the problem" (Kennedy 2001).

The latest IPCC assessment report has also given the clearest indication yet of the scale of action needed to reduce greenhouse gas emissions. It highlighted that to keep global temperature change to about 2˚C above pre-industrial levels – a limit recently endorsed by the world's major economies (BBC news 2009) – global emissions need to peak in the next few years and fall by 50 to 80% by 2050 (IPCC 2007a). To achieve this, considerable reductions in the use of fossil fuels are needed – something not yet accepted by the oil and gas sector. Indeed, climate scientists have pointed out that a large fraction of the existing reserves of fossil fuels will probably need to stay in the ground if this target is to be met (Allen *et al* 2009). Given the difficulties of rapidly expanding the use of alternative energy sources, curbing energy demand will also be necessary to achieve the scale of reductions needed (see, for example, Bows *et al* 2006).

At this point, it is worth highlighting the contribution that individual oil and gas companies themselves make to climate change. The US-based Union of Concerned Scientists (UCS) has calculated the contribution made by ExxonMobil, the largest. If one adds the greenhouse gas emissions from the company operations to the emissions resulting from the end use combustion of all the fossil fuel products it sells, then its total emissions would exceed one billion tonnes of carbon dioxide. If ExxonMobil were a country, it would rank as the sixth highest carbon-emitter in the world (UCS 2007).

We discuss two areas where the oil and gas industry has influenced science and technology to hold back more widespread consideration of climate change: public perception and the research agenda. The major oil corporations – in concert with other interests such as the coal and automobile industries – have been at the forefront of promoting 'climate scepticism', arguing mainly that climate change is either not caused by human activities or will not be a major problem. The industry also has significant influence on academic research and teaching in the energy field, which can lead to R&D for areas such as energy demand reduction and renewable energy not receiving the necessary level of funding. These two issues are tackled in the next two sub-sections.

7.3 The fossil fuel industry: promoting 'climate scepticism'

As we have shown, there has been robust evidence for two decades that climate change is a key global problem and human activities are a key cause. Throughout this period, industrial lobbies – including parts of the oil and gas industry – have used their enormous power and influence to promote climate sceptic views. The aim has been, and continues to be, to plant seeds of doubt in the minds of the public and policy-makers about the scientific basis for efforts to restrict greenhouse gas emissions.

Many of the activities pursued by businesses in this area have similarities to those described earlier for other industrial sectors. Indeed, there is clear evidence that the oil and gas industry used some tactics first employed by the tobacco industry (Monbiot 2006; UCS 2007). For instance, as we document below, there has been wide use of public relations companies and lobby groups (who often do not reveal details of their funding). These organisations employ sympathetic scientists, including those without a background in climate science, to promote the idea that the scientific evidence for climate change is not robust. There have also been notable attempts to influence processes within climate research itself, especially when such research may be directly used by policy-makers (such as IPCC reports) (Leggett 2000; UCS 2007).

One key tactic used by climate sceptics is to dwell upon any area of uncertainty in the science underpinning the understanding and description of global climate change. But uncertainty is inherent throughout science; the climate sceptics fail (or choose not) to acknowledge the context of the climate science uncertainties and thereby distort their significance.

Given the accumulating wealth of evidence for human-influenced climate change and the extensive attempts to include scientists from across the relevant research areas through the IPCC processes (see previous section), it is hard to find an area of policy-relevant science which follows a more robust model (UCS 2007). Furthermore, climate scientists, in general, are publicly funded via research councils and scientific foundations and so are less likely to be influenced by powerful external interests such as business. This is in direct contrast to many climate sceptics – despite their repeated claims to be acting in the interests of 'sound science'.

In some cases the information presented by climate sceptics is simply inaccurate. This was demonstrated starkly by the British TV programme, *The Great Global Warming Swindle* broadcast on Channel 4 in 2007. The programme featured some of the industry-funded scientists mentioned later in this chapter, and made inaccurate statements about a wide range of issues, including the influence on climate of solar activity and volcanoes. It was widely criticised by climate scientists for its inaccuracies (see, for example: RealClimate 2007; MediaLens 2007).

The early activities of corporate-funded climate scepticism were led by an organisation called the Global Climate Coalition (GCC), a group comprising fossil fuel businesses, automobile companies and their allies, all opposed to action to curb greenhouse gas emissions (Beder 1999; Leggett 2000; UCS 2007). Membership of the coalition included all of the large, privately-owned oil and gas companies, including Exxon, BP and Shell. The GCC was set up in 1989 with one of its main activities being to question the reports issued by the IPCC. It was active in trying to water down the text of the 1990 assessment report, and it was at the centre of allegations that the IPCC had distorted the scientific evidence presented in its 1995 report (Leggett 2000). However, following broad acceptance that the IPCC procedures had been robust, the spotlight moved to the fossil fuel lobby groups and the GCC started to lose support. BP withdrew in 1997 with Shell following in 1998. Both companies began to take action to control their operational emissions of greenhouse gases and invest in renewable energy. The Coalition was finally 'deactivated' in 2002.

However, Exxon – now ExxonMobil following a merger – chose to continue to support climate sceptic activities in other ways. Most critically, it made significant contributions to George W Bush's campaigns for presidency and one outcome of this – once Bush was in office – was the withdrawal of the US from the Kyoto Protocol (the treaty agreed in 1997 to curb international greenhouse gas emissions). Another disturbing facet of the Bush administration was its willingness to interfere in the scientific process, including having political appointees (some of whom had links to the oil industry) edit scientific reports on climate change and a range of other issues to make them more favourable to the administration's position (US House of Representatives 2003; UCS 2007; EDF 2008). Such a situation helped the climate sceptic lobby considerably.

ExxonMobil has also funded numerous other lobby groups, 'think tanks' and individuals who misrepresent the scientific basis of climate change. UCS published a wide-ranging report documenting the company's main climate sceptic activities over the period from 1998 to 2005 (UCS 2007; Hamilton 2007). This presents an extensive outline of ExxonMobil's "disinformation" tactics, which entailed the company funnelling almost $16 million (£8 million) into a network of 43 advocacy groups. Some are influential and well known, such as the American Enterprise Institute, the Cato Institute, the Heartland Foundation (which also receives money from the tobacco industry), the Heritage Foundation, and the George C Marshall Institute. These organisations take a strongly sceptical view of climate science, and share political worldviews which are neoliberal and free-market based. They underplay the amount of agreement within expert climate science circles and maintain, with little evidence, that scientists do not agree on the role of carbon emissions and the nature of climate change (UCS 2007; EDF 2008).

The report also shows the reach of individual ExxonMobil-funded voices who move from one advocacy group to another carrying their bogus message. Many, such as Patrick J Michaels, Frederick Seitz and S Fred Singer, are widely reported in the media, often without any mainstream climate scientist being provided to balance their contrarian views (Monbiot 2006). Greenpeace USA argues that the influence of ExxonMobil extends even further than this (Greenpeace USA 2009). Using data from the company, they have identified a total of more than 140 organisations that have extolled climate sceptic views and that have had links with the corporation. Many of these groups have been widely quoted in the media in the UK and USA.

There are also cases when the oil and gas industry has funded climate research that has emphasised uncertainties (see, for example, Goodess 2003).

Because some policy-makers and sections of the media have continued to take seriously the accusations of the climate sceptic lobby, detailed academic investigation has been carried out to examine whether the level of scientific consensus on the human causes of climate change claimed by the IPCC and others really was solid. Naomi Oreskes, a distinguished historian of science at Stanford University in the USA, analysed 928 abstracts of papers published in refereed scientific journals between 1993 and 2003, using the keywords 'global climate change' (Oreskes 2004, 2005). The analysis found that 75% of the examined abstracts either explicitly or implicitly backed the consensus view, while none directly dissented from it. In 2007, Oreskes expanded her analysis, resulting in a book. Her findings included that around 20% of abstracts explicitly endorsed the consensus on climate change, that is: "Earth's climate is being affected by human activities". In addition, 55% of abstracts "implicitly" endorsed the consensus by engaging in research to characterise the ongoing and/or future impact of climate change or to mitigate against predicted changes. The remaining 25% focused on either paleoclimate or developing measurement techniques. This is a far cry from the picture of scientific uncertainty that the sceptics point to when promoting the corporate-based view (Oreskes 2007).

In the last couple of years, ExxonMobil has softened its stance on climate change, notably withdrawing funding from the climate sceptic Competitive Enterprise Institute (Greenpeace USA 2009). This may have partly been in response to a 2006 letter from the Royal Society in which the oil company's support of such lobby groups was subjected to strong censure (Royal Society 2006). However, it is clear that ExxonMobil has continued to support sceptic organisations, one such being the American Enterprise Institute (AEI). Following the publication of the 2007 IPCC assessment report, the AEI offered scientists and economists $10,000 each to "undermine" the report's findings (Sample 2007). The funds from the AEI were to persuade those approached to attack the IPCC panel as being "resistant to reasonable criticism and dissent and prone to summary conclusions that are poorly supported by the analytical work". The AEI has received over $1.6 million (£0.8 million) from ExxonMobil. Lee Raymond, a former head of ExxonMobil was, at the time of writing, on the Institute's Board of Trustees.

While most corporate-funded climate sceptic organisations have been US-based, there has been significant activity in the UK. Indeed, in the letter to ExxonMobil mentioned above, the Royal Society also sought to obtain information from the company on the extent of their funding of climate sceptic groups in the UK. The response, from Kenneth Cohen, Vice President of Public Affairs in the USA, provided a great deal of information on one of the university-based funding programmes undertaken (at Stanford University in the USA) and the attempts of the business to reduce its carbon footprint but said nothing of its UK climate sceptic funding (Royal Society 2006).

Nevertheless, some information is available on prominent climate sceptic organisations in the UK and their corporate connections. For instance, the Scientific Alliance was set up by Robert Durward, Director of the British Aggregates Association and Mark Adams of the PR company Foresight Communications (Lobbywatch 2008). The Scientific Alliance is linked to US climate sceptic groups, and also embraces a range of anti-environmental views. However, it does not disclose its current funders. It led the recent legal action against the showing of Al Gore's film *An inconvenient truth* in schools (Scientific Alliance 2007).

The International Policy Network (IPN), also based in the UK, styles itself as a think tank and like the Scientific Alliance is very coy about who its funders are. Nevertheless, independent sources show that the IPN has received grants from ExxonMobil, and other oil companies (UCS 2007; EDF 2008). It is linked to the Institute of Economic Affairs (IPN's Executive Director had previously been employed there), Britain's leading free-market think-tank (Institute of Economic Affairs, 2009). The IPN also has links with the US Competitive Enterprise Institute, which had until recently been funded by ExxonMobil (see above). Other IPN staff members have formerly been at rightwing think tanks (SpinProfiles 2009). In 2004 IPN released a report claiming that climate change was "a myth". All the climate sceptic think tanks strongly deny that their research findings are influenced by their corporate donors, claiming to be non-partisan and only interested in scientific 'truth' (SpinProfiles 2009).

7.4 Energy R&D, the oil and gas industry and UK universities

Curbing energy demand and expanding 'low carbon' energy technologies are essential elements in tackling the problems of climate change and peak oil. Timely R&D is critical, both in helping to speed technological development in this area and in contributing to the design of policy measures to control energy use. The power and influence of the oil and gas industry mean that their policies and activities have a major influence on the direction of energy-related R&D and the degree to which society is successful in tackling these problems.

Energy R&D has had a chequered history in the UK. In the late 1970s and early 1980s, government funding for energy R&D was high, reaching a peak in 1981 of over £700 million (2007 values) (IEA 2007). Over the next 20 years it fell 95% following the privatisation of the energy industry and their associated research laboratories. While the intention of the government of the day seemed to be that industry would expand its R&D to compensate, the available data suggest this did not happen (RCEP 2000). And, despite the urgent threat of climate change, the government has been very slow to reverse this decline. The available figures suggest its funding for energy R&D only began to rise in 2004 and still remains at a small fraction of that of the early 1980s. Across the industrialised world, the situation has been more positive, but government funding for energy R&D is still significantly lower than in the early 1980s. For example, spending by the member nations of the International Energy Agency was £6 billion in 2007 – only 60% of its peak value (IEA 2007).

So what of the role of the oil and gas industry? Reliable sector level data on business-funded R&D is difficult to obtain in virtually all industrial sectors, and the oil and gas sector is no exception. However there are a number of observations that can be made, especially concerning the behaviour of individual companies.

According to their annual reports, oil and gas companies in general focus their investment, including R&D, on supporting their core businesses of fossil fuel exploration, extraction and processing. However, those that dropped their climate sceptic position in the late 1990s, such as BP and Shell, have been willing to invest significant amounts in renewable energy (such as wind, solar and biofuels) and improving the efficiency of their activities, whereas others, such as ExxonMobil, have shown much less interest until the last few years.

Nevertheless, even Shell and BP's worldwide spending on renewable energy and other alternatives technologies continues to be only a small proportion of their annual capital expenditure, as shown starkly in Table 7.2. Despite a series of public relations campaigns promoting their 'green' credentials, their investment in alternatives is only a few percent of their total budgets. (Neither company publishes figures in its annual report for the percentage of R&D funding allocated to renewable energy.) Sadly, even the figures in Table 7.2 paint a rosy picture. Shell has since announced it is to disinvest from all renewable energy except liquid biofuels (which is the most controversial) (Webb 2009). Meanwhile, BP is set to reduce its budget for alternative energy by about half in 2009 (Macalister 2009). The companies defend this small proportion of funding by arguing that (for example) the renewable energy industry is still developing and hence their investment makes a key difference, but given the urgency of the threat of climate change and the record profits that the industry has experienced in recent years, there is a strong case for the major companies to dedicate far more of their in-house activities to these areas.

How do these factors influence research at UK universities? Again there has been little systematic examination but the available evidence does give cause for concern. A 2003 report co-published by the New Economics Foundation found that there were around 1,000 R&D projects being undertaken in UK universities concerned with petroleum objectives, estimated at a total value of £67 million per year (Muttitt 2003). Most of the projects were concerned with exploration and the engineering infrastructure for extraction, with only 2% of the funding being directed towards studying environmental impacts. The report documented a range of connections between the oil and gas industry and academic departments, including: industry-funded research centres; joint research projects; staff positions funded partly or wholly by industry; industry-sponsored courses, studentships and other education grants; and careers and recruitment activities. The industry focuses its activities on relevant academic disciplines including geology, engineering (especially chemical), and those dealing with safety. This makes it difficult to find university departments in these areas which do not have connections with the industry. Yet, despite this heavy involvement, over 50% of the projects identified by the report were paid for by public funds, with a further 23% being part-funded by the taxpayer.

Table 7.2 – Comparison of spending on alternative energy sources and R&D for the three major privately-owned oil and gas companies, 2008

Company	Capital expenditure (£ billion)	Spending on 'alternatives' * (£ billion)	Spending on alternatives as proportion of capital expenditure	Total spending on R&D (£ billion)
Royal Dutch Shell	19	0.2^	1%	0.7
BP	17	0.8	5%	0.3
ExxonMobil	14	?	<1%?	0.4

** For Shell, 'alternatives' includes renewables and carbon capture and storage (CCS). For BP, 'alternatives' includes wind, solar, biofuels, CCS, hydrogen and efficient gas power. ExxonMobil funds a small number of projects in areas such as biofuels and batteries for electric cars, but published no figures on total amounts spent in its annual report. However, comparing the scale of their reported activities with other companies indicates their total activity in these areas is lower.*

^ Annual average for last five years.

Sources: Figures from Royal Dutch Shell (2009a, 2009b), ExxonMobil (2009), BP (2009) – converted to UK pounds.

A number of universities – for example, Aberdeen, Cambridge, Heriot-Watt and Imperial College London – have received considerable funding from the fossil fuel industry to concentrate their expertise into dedicated research centres (Muttitt 2003). A large majority of these concentrate upon oil and gas technologies, exploration geology and petroleum production. Companies also make use of such focal points of expertise to provide training for business needs (as at Imperial College London).

With the recent increase of funding for renewable energy R&D, a number of UK universities have expanded their research and education activities in this area. However, there are no clear figures available that provide a comparison of the level of funding for oil and gas R&D with that for renewable energy R&D. Indeed, as we have discussed elsewhere, direct financial involvement is only part of the influence that industry can have within academia. Given the power and influence of the major fossil fuel companies and the relatively small size of the renewable energy sector, it is reasonable to continue to question whether the research and teaching in relevant university departments will give sufficient weight to efforts to move away from fossil fuels.

Data on the level of R&D supporting efforts to curb energy demand is even more difficult to find. There are research programmes on improving energy efficiency – some carried out by the oil and gas sector itself – but these often take place within an overall view that energy demand will continue to expand. Given that the sales of fossil fuels by the oil and gas industry continue to increase, it seems there will be little support from that particular interest group.

One further issue is also worth noting: that of the oil and gas industry's broader involvement with science education. For instance, the industry (like many other sectors including the military) actively works with schools and contributes to activities set within the science curriculum. Examples include the 'Shell Education Service' which operates in the UK and in continental Europe (Royal Dutch Shell 2009c). Similarly, the London Business School provides the opportunity for all graduates to attend the ExxonMobil Graduate Development Programme, run by the London Business School. The modular programme is designed to cover three main areas – interpersonal skills, business awareness and people management (LBS 2009) – and provides opportunities for graduates to join ExxonMobil. The company also has a scheme run jointly with the Royal Academy of Engineering for young academics to hold ExxonMobil Engineering Teaching Fellowships (RAE 2009). A similar array of industry-funded partnerships with the university sector is to be found in the USA. All increase the influence of the oil and gas industry, and its worldview, among young people.

In conclusion, the oil and gas industry is the most influential in the world. It has a major influence on science and technology, but some of its influence has been highly detrimental – notably, ExxonMobil's support of 'climate sceptic' organisations in the face of the overwhelming evidence of human-induced climate change. While some oil companies have been more progressive in supporting R&D on renewable energy, their efforts have been much smaller than is justified by the environmental problems we face, and their unwillingness to support controls on energy demand is also highly counterproductive.

Summary of the detrimental effects of oil and gas industry influence on SET

- **Influence on the direction of the research agenda**

1. A large majority of the R&D funding from the oil and gas sector has been for the technology related to exploration, extraction and processing of fossil fuels;
2. In the last decade, some oil and gas companies have put significant funds into R&D for alternatives technologies, including renewables. However, some companies – notably ExxonMobil – have been much less willing to fund work in these areas while, overall, the level of the funding for alternatives has been much lower than the industry could afford;
3. The oil and gas industry does not encourage a viewpoint that supports curbs on global energy demand, which is a key option for tackling climate change, peak oil etc;
4. The major oil and gas companies have numerous links with UK university departments, especially in engineering and geology. This allows them a great deal of influence within academic circles, and especially with young engineers and scientists.

- **Influence on the direction and results of specific research studies (both intentional and unintentional)**

1. Oil and gas interests have funded research which emphasises uncertainty in climate change research;
2. Corporate science funded by the oil and gas industries does not sufficiently emphasise the urgency of developing technology and policy options for tackling climate change.

- **Influence on the public interpretation of research results**

1. The oil and gas industry – especially ExxonMobil – has been heavily involved in funding climate sceptics to publicly undermine the scientific evidence that climate change is caused by human activities;
2. Corporate influence on government from the oil industry, especially in the USA, has undermined the robust application of scientific knowledge in policy;
3. Oil and gas companies fund a variety of initiatives in science education in UK schools, which encourage students to be sympathetic to the perspective of the industry.

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8. The biotechnology sector

Biotechnology is perhaps the most obvious example of a scientific field that is increasingly shaped by 'industry-led needs' with a research agenda tied to deriving the greatest return on investment. Many of the ethical and practical issues we raise below stem directly from the 'commodification' of naturally occurring entities – like genes, their products and processes – closely tied to economic end-points that are usually short-term.

This section starts with a brief introduction to biotechnology and the issue of gene patenting. It then highlights the wide range of ethical controversies that abound in this sector. The growth of commercial involvement is then discussed, followed by details of the problems that have arisen due to this growth. Biotechnology is an immense and constantly evolving field, so our description must necessarily be an overview.

8.1 Biotechnology and gene patenting

Biotechnology covers a bewildering array of methods, topics and research specialities; essentially it integrates the experimental techniques and models from biology with a range of methods from the physical sciences and engineering. The predominant focus of biotechnology is on the gene, its products, various interactions and their manipulation.

The gene – a discrete section of DNA - has become a primary commodity. It is treated as private property (especially as a patentable entity), which represents the means to increase profits and the range of products that companies can market (Gilbert *et al* 2005; Kesselheim & Avorn 2005; Bainham *et al* 2002; Tokar 2001). Genes and their manipulation have thus given corporations and spin-out companies both power and influence. The ability to produce genetically modified (GM) plants and animals has not only meant that such entities can be bought and sold – for example as 'disease models', crops and seeds – but that cells and tissues with GM genes must be licensed for use (for example, in medical tests), which brings profit to the owner of the GM patent whilst correspondingly increasing the costs of some medical procedures. Patent protection also has a major impact upon innovation in the USA and UK (Kesselheim & Avorn 2005).

One example here is that of Myriad Genetics Inc., which has nine US patents on the breast/ovarian genes BRCA1 and BRCA2. In addition the company has patents on the associated BRCA antibodies. Any use of the BRCA1 and 2 gene sequences in principle requires payment to Myriad Genetics (which passed to the University of Utah in November 2004). In the UK Myriad licensed the BRCA tests to Rosgen – a commercial offshoot of the Roslin Institute in Edinburgh - in February 2000. Rosgen has pointed out that it intends to waive fees for use of the Myriad patents for NHS patients (Eaton 2000).

Myriad faced growing opposition to its breast cancer gene patents from patients, genetics societies and researchers. A lawsuit brought by cancer patients, clinicians, activists and researchers is at the time of writing being pursued which challenges the validity of patenting the BRCA1 and BRCA2 genes (Anon 2009). The complaint against the patents on the BRCA genes cites examples of the company impeding research, restricting clinical practice and denying people access to medical information (Marshall 2009). Although there are complex conditions attendant on the patented tests for breast cancer susceptibility, such uses of patents will involve added costs to healthcare systems or the patient. These costs would not follow if there were no patents in place on these or other clinically important genes (Cook-Deegan *et al* 2009, which also discusses the broader issue of patents and diagnostic costs). We discuss other examples later.

There are aspects of gene patenting which make it especially controversial when compared with other forms of patenting. Critics argue that genes are not 'inventions', but naturally occurring entities. Hence they should not be amenable to private ownership through patenting. Two main arguments, however, are used by advocates to justify gene patenting. The first is that the discovery and isolation of genes that appear to code for specific desired traits require research expertise, investment and skills. These research skills also involve the detailed searching of large areas of DNA in order to locate genes of interest. The second justification sees the isolated gene as a novel product – an 'invention' - derived from human agency, and hence patentable. The gene patent argument revolves around the sequence of DNA (the gene of interest) being a modified version (a so-called copy-DNA or c-DNA) of the natural sequence with various features having been changed by the extraction process (Krimsky 2003).

In 2002 the Nuffield Council on Bioethics (an expert, independent body set up by the Nuffield Foundation) published *The ethics of patenting DNA* (Nuffield Council on Bioethics 2002). The report, whilst not ruling out the patenting of genes, does argue that the tests which are applied to secure a patent on a particular gene should be far more robust than they are at present, and the report's authors question whether allowing patents on genes really is in the public interest.

The biotechnology sector is characterised by diversity; biotechnology research is undertaken in a wide variety of industries (Smith *et al* 2008). The field also increasingly involves the transfer of technology from universities to the business sector through spin-out companies and the use of intellectual property rights (IPR). This phenomenon, also found in other university-corporate interactions, is seen as an essential business tool, which we discuss elsewhere in this report. Commonly, alliances are formed between new and more established companies on the basis of the trading of IPR, such as gene patents. Gary Pisano at the Harvard Business School has pointed out that there has been a mismatch between the objectives and requirements of academic scientific research and those of the biotechnology business (Pisano 2006). We will focus now on major ethical controversies and the role of the gene.

8.2 Major ethical controversies in biotechnology

This section examines a number of specific examples where the techniques and tools of biotechnology are used within a heavily business-focused R&D effort, and briefly describes some of the problems which occur as a result.

There are five major areas of biotechnology R&D which, in the last 20 years, have been especially controversial:

- Agricultural biotechnology (including genetically-modified crops)
- Animal models of human disease
- Commercialisation of the human genome
- Xenotransplantation
- Synthetic biology

All these areas involve powerful techniques and have considerable corporate involvement, which has helped to shape the research and development undertaken and created a number of ethical and practical problems. This section introduces the five areas; some of the key ethical problems are outlined later in section 8.4.

The first area is agricultural biotechnology. In this area scientists have altered genes in both plants and animals, mainly to improve disease resistance and increase levels of nutrients (see Tokar 2004). While these aims may be desirable, this form of genetic modification (GM) has raised a great deal of public opposition due to concerns about possible negative effects on human health and the environment (see section 8.4), as well as about the increasingly widespread and monopolised corporate control of agriculture. These issues also raise significant concerns regarding food security, the food chain and the livelihood of poor farmers. A three-year, intergovernmental-supported expert study of agriculture, which included an analysis of GM technology, pointed out that current problems regarding food security have more to do with shortcomings in distribution than in production, and hence argue for a change in the focus of R&D efforts to move away from a predominantly biotechnological one (IAASTD 2008).

The second area of concern is the creation of animal models of human disease by the use of GM technology. Here surrogates of human disease are created in other species in order to test possible treatments on them and to identify regions of the human gene sequence involved in the diseases (BUAV 2003). GM animals are used as models of human disease despite a number of concerns including species differences, the poor predictability of such models in many cases, and a variety of ethical objections about the use of animals in research of this nature. In addition, this approach can shift the focus from tackling the many causes of illness, including lifestyle, economic factors and nutrition. Similar criticism can also be made of the use of human gene screening without paying sufficient attention to other factors – not least the reliability of the test. (We return to this latter issue in section 8.4.2, where the UK Biobank is discussed.)

The commercialisation of the human genome is the third area of concern. This has raised worries not only about commercial access to confidential aspects of people's medical records, but also about the legitimacy of companies 'owning' an individual's DNA and how this might impact on privacy and insurance liability.

GM has also been used in a very contentious experimental approach to understanding and possibly treating various medical conditions: xenotransplantation, the fourth area of concern. Xenotransplantation is designed to overcome the shortage of human organs available for transplantation, and entails attempts to 'humanise' organs from non-human animals in order to provide replacement cells and tissues for transplant into a human recipient. Work in xenotransplantation was initially held back due to fears of pig viruses being inadvertently imported into the transplant host (Langley & D'Silva 1998). The field has seen a revival, however, following the genetic manipulation of pigs to overcome such risks of infection. The early corporate players included Imutran, owned by the pharmaceutical company Novartis. Now companies in the USA like Revivicor are producing GM pigs to supply tissues and perhaps whole organs for transplant into humans (Coghlan 2008). Even if GM pig organs are accepted in human patients, donors face not only the suppression of their immune systems for life but also, potentially, the need to take other drugs to stop unwanted blood clotting and other symptoms of rejection.

The momentum behind the creation of animal models and xenotransplant organ 'donors' owe a great deal to corporate pressure, since undertaking and commercialising such research is of great potential interest to them if they hold the gene patents. In fact, the technique relies on simplified views of gene function in health and disease (BUAV 2003). Focusing on this type of high-tech approach pushes funding for research that supports preventative health care to the margins. A further consideration is whether the problems that xenotransplantation seeks to address would be better tackled through changes to the donor system for human organs (discussed in Anderson 2006).

Synthetic biology is the fifth area of research in biotechnology which throws up a number of profound issues. It can be defined as the design and construction of novel artificial biological systems, devices or pathways, or the redesign of already existing natural biological systems. As such, it has been labelled the science of 'creating new life-forms'. Synthetic biology has emerged from the coming together of knowledge and methods from other disciplines like physiology, physics, nanotechnologies, genetic engineering and computer modelling (RSC 2008; NEST 2005). The blurred boundaries with other technologies and the power of the synthetic approach create a number of ethical, practical and legal questions. Although synthetic biology is still a relatively new discipline it is highly likely to involve an increasing level of corporate interest in the UK, as is already the case in the USA. Companies like BP, Shell, Chevron and DuPont are currently heavily investing in synthetic biology in the USA. Although presently the UK situation is less well developed than in the US, several UK Research Councils have begun a number of collaborative programmes to enhance the UK synthetic biology research base. We return to this issue in section 8.4.

8.3 Growing corporate influence on biotechnology

In this and the following section, we focus on recent growth areas in biotechnology which attract corporate interest and pose particular problems, examining in more detail four issues of pressing concern.

Regardless of their point of view most commentators agree that we now live in an 'Age of Biotechnology'. The American magazine *Business Week* first coined the phrase "The Biotech Century" in 1997 (Casey 1997) and all the evidence supports this contention in the 21st Century. The power and reach of transnational corporations in the life sciences sector impacts not only on academic researchers, the universities and the biotechnology research process, but also on the lives of everyone. Biotechnology and its various methods are developing at considerable speed, with corporate funders able to influence developments towards their own economic interests. The global biotechnology market is considerable, the leading countries including the USA and UK with contributions from Japan, China and Australia growing apace. As mentioned earlier (see chapter 4), the pharmaceuticals and biotechnology sectors were the largest corporate investor in R&D both in the UK and globally in 2007 (based on data on the top companies - BERR 2008) and this trend looked set to continue until the current global economic downturn. Healthcare and related services account for the target markets of over 75 per cent of all UK biotechnology companies, and these businesses undertook almost 90 per cent of biotechnology R&D and received all of the external investment in the UK biotechnology sector in 2006 (Critical I Limited 2006).

At the strategic level, UK governments have been keen to ensure that institutions like public service research establishments (PSREs) and universities are given the kind of financial support which helps them forge business R&D collaboration to secure economic advantage, especially in new technology growth areas, such as biotechnology.

A variety of changes, occurring between the 1970s and 1990s and linked to economic globalisation, offer a key to understanding how biotechnology corporations function, and help to explain their market dominance and their role in shaping the regulation of biotechnology (Kuszler 2006).

During this period, major companies integrated with those in other sectors – such as the chemical and pharmaceutical – and thus secured control of specific areas within biotechnology, such as seeds, processing and marketing (Kuszler 2006; Newell 2003). Recently there have been a frenzy of mergers between the large pharmaceutical companies and the smaller, specialist biotechnology firms – the Swiss giant Roche made a surprise $44 billion bid for the 44 per cent of Genentech, the world's largest biotechnology outfit by stock market value, that it does not already own. AstraZeneca bought MedImmune for $15.6 billion and Takeda of Japan paid $8.8 billion for Millennium (Anon 2008). This activity has an impact on both the power and influence of the resulting companies, but just as importantly on the innovation process and the production of valuable – but less economic – molecules and techniques.

Such acquisitions together with monopoly patents and market dominance have given a small group of companies unprecedented control over commercial food, farming and health areas and their associated R&D. This powerful position that companies hold has implications not only for food security, the economies of poorer nations and human healthcare, but also the broad practice of sustainable agriculture (Shand 2001).

The acquisition programmes began with the 'life science' businesses buying up large seed companies, an example being Monsanto's buy-up of Cargill's seeds in 1998. Biotechnology innovation requires that companies design suitable processing and seed markets (pathways) to take full advantage of the R&D in which they have invested. The pathway is part of the sector's business model and shapes the form of biotechnology that develops and the investments undertaken.

Dominant transnational companies like Monsanto, Dow and DuPont are characterised not only by their technological integration within a given market but also, as we discuss later, by their simultaneous dominance of multiple markets within agriculture. For instance Cargill, the largest grain exporter in the USA (and probably – according to available data – the world), is also dominant in soybeans and cotton (see, for example, Corporate Watch 2001).

As we pointed out above the biotechnology sector is both diverse and complex. It comprises large multinational companies with interests in agribusiness, chemicals, pharmaceuticals and other areas that involve R&D activities not solely related to gene technologies (here use is sometimes made of subsidiary companies). In addition, there are smaller companies, which are described as biotechnology businesses and which focus mainly on using gene technologies and related approaches. The larger companies include some of the major pharmaceutical corporations discussed in chapter 4, together with BASF, Dow Chemicals, Monsanto and Syngenta. These companies are economically very powerful – for example, BASF reported sales of €62 billion (£49 billion) in 2008 (BASF 2009). The smaller companies operating in this sector include (at the time of writing) Amgen, Genentech, and MedImmune. However, even these companies are fairly sizeable – Amgen's sales in 2008 were nearly $15 billion (£7 billion) (Amgen 2009). These companies are often acquired by the more powerful ones to diversify R&D portfolios and hence products.

8.4 Problems related to commercial involvement in biotechnology

The range of issues raised by both biotechnology itself and the corporate involvement we have briefly described is huge and necessarily we can only provide a limited analysis in this report. We wish to concentrate in this section on particular examples of where corporate interest influences the nature of the research process and how funding introduces a variety of problems, not least bias, conflicts of interest and the potential for misuse. All of these, of course, have important consequences for the practice and health of science and its application.

In addition, corporate-backed lobby groups not only try to influence the public acceptance of GM techniques and products, but also help shape government attitudes and the research agenda. For instance the Agricultural Biotechnology Council (set up by BASF, Monsanto, Dow Agrisciences and Syngenta) has access to the ear of government; the first chair of the Council was Stephen Smith, the former head of Syngenta Seeds. The Council has organised, through the public relations outfit Lexington Communications, a pro-GM publicity campaign targeting public perception of the technology. CropGen is another biotechnology industry-funded lobby group with a determinedly pro-GM stance (Lobby Watch 2007); it calls itself an "education and information initiative for consumers and the media".

In February 2009 the UK group Sense About Science (which was set up in 2002 in order to "promote evidence and scientific reasoning in public discussion") published a new guide to GM crops and food entitled Making sense of GM (SAS 2009). The publication was written by a group of scientists and focused solely upon the claimed benefits of GM for increasing crop reliability and yield. The guide did not discuss any of the broader scientific, ethical, social or economic aspects of GM technology and practice. Far more worryingly, whilst there were brief biographies of the authors in the guide, there was no mention that many were linked to UK institutions and groups closely connected to the GM industry (GMWatch 2009).

Other aspects of Science About Science (SAS) are also noteworthy in this context. Recent accounts show that SAS receives approximately half of its income from business, with large donors including the biotechnology company AstraZeneca (SAS, 2008). The founder and current Chair is Dick Taverne, whose background is in law, politics and business rather than science. He has been very critical of the attention given to a number of environmental concerns, and has, for example, derided opponents of GM crops, criticised the conclusions of the IPCC (the UN's advisory body on climate change – see chapter 7), and accused environmental groups of 'eco-fundamentalism' (for example, Taverne 2003). Furthermore many of the Board of Trustees of SAS do not have a background in science, and a number are involved with the 'LM network' which lobbies for GM food, human cloning, denial of global warming, and against restraints on corporate activity (Monbiot 2003; LobbyWatch 2007).

Such groups help to create a pro-industry backdrop both to the public understanding of the issues surrounding GM technology and to funding decisions made regarding agricultural research priorities. Public relations companies play a central role in the 'information war' which projects positive claims about GM technology and marginalises informed criticism (they play similar roles in other industrial sectors areas too, as discussed in chapters 5 and 7, for example). Both Lexington and the Bivings Group have been active in attempting to subdue GM-critical voices. For instance, Bivings was involved in a campaign to have *Nature* retract a paper it published, which alleged that native Mexican corn had been contaminated by GM pollen (Monbiot 2002a, 2002b). Recent research has confirmed that Mexican corn has been contaminated by genetically modified plants (Piñeyro-Nelson *et al* 2009).

In the pages which follow we look at four aspects of biotechnology for which there is sufficient data to allow further discussion of corporate effects and how they go towards shaping biotechnology:

- seed research, development and supply;
- conflicts of interest;
- synthetic biology; and
- broad concerns about biosecurity.

8.4.1. Seed research, development and supply

Over the past forty years plant breeding and seed sales have been increasingly privatised in the USA and Europe (including the UK). For biotechnology corporations across the world, the patented seed is the specific vehicle through which their proprietary technologies – genes and their means of manipulation – are delivered. There has also been a marked growth in agricultural research by the private sector at the same time as that carried out in government laboratories falls (Shand 2001).

Corporate involvement in biotechnology has steered R&D (and seed supply) to focus largely on GM crops and away from more traditional plant breeding – including virtually ignoring agro-ecological methods, such as organic farming and other forms of 'pro-poor' approaches to farming. The dominance of GM approaches, especially in the hands of large powerful companies like Monsanto, marginalises other forms of agriculture and food provision. Such technologies are primarily for large-scale commercial farmers of the rich world (Scoones 2009). The use of patents and intellectual property rights reinforces this approach, and ignores the needs and choices of the public and farmers alike (see contributions in Tokar 2001 and Glover 2009).

Corporate control and ownership of seeds has profound effects upon food security, the research agenda across the biosciences, and the economic standing of farmers, especially in the poorer countries (FAO 2003). In July 2005, Phillips McDougall a UK-based agricultural business analyst, quoted the value of the global commercial seed market at $19 trillion and estimated that the top ten companies control around 51 per cent of the whole market. Despite continued controversy and the lack of public acceptance of GM plants in many parts of the world, GM seeds are gaining market share. In 2005 Phillips McDougall estimated that GM seeds represented about 25 per cent of the total value of the global commercial seed market (ETC 2005) yet only a few per cent when measured by acreage (FOE 2009).

Let us spend some time now looking at the activities of Monsanto, which is the world's leading producer of GM seeds. Monsanto is a major seed and herbicide business and dominates the global market for GM crops with specific traits (Glover 2009). Monsanto has joined other major agribusiness companies in supporting third-party organisations such as the Biotechnology Industry Organisation, the International Food Information Council, the Agricultural Biotechnology Council and others who have vigorously promoted GM crops as a safe and appropriate technology (see discussions in Glover 2009).

Monsanto's influence is projected through the R&D it funds and undertakes, the seeds it produces, and the arguments it uses to persuade government and those in science that gene technologies should be the predominant means of providing food, a corporate view neatly packaged by lobby groups, third-parties like those mentioned above and public relations companies like Lexington (Monbiot 2002a; 2002b; Glover 2009).

This high level of market dominance and financial power wielded by large companies like Monsanto has shaped the global agricultural research agenda. Work on more sustainable ways of growing food has become marginal in the face of such high technology approaches.

A study for the US Department of Agriculture examined the biotechnology research that was promoted through the domination of a small group of companies in the seed industry.

Box 8.1 – The corporate reach of Monsanto

At the time of writing the following are major seed companies affiliated to or owned by Monsanto. The data that we have used is the most complete available and more extensive than that obtainable from industry sources:

* DeKalb Seed Company – has 11 per cent of the US corn seed market
* Holden Foundation Seeds – 35 per cent of US corn acres are grown with Holden seeds. Companies like Du Pont and Plant Genetic Systems purchase the parent seed from Holden and subsequently develop the crop
* Asgrow Seed Company – Monsanto's soybean seeds are produced by Asgrow, which remains part of Mexico's Savia
* First Line Seeds – Canadian soybean company
* Plant Breeding International (Cambridge, UK) – a former research institute of Cambridge University founded in 1912, which was transferred to Unilever under the government's privatisation drive in 1987, and subsequently sold. It now has an established breeding programme for various crops including oilseed rape, potatoes, winter wheat and barley

Monsanto also owns the following research companies:

* Calgene – a former small biotechnology laboratory which developed Flavr Savr Tomato, the first GM crop marketed in the USA
* Agracetus – a research company currently developing pharmaceutical crops – plants that produce drugs and other therapeutic molecules as a result of genetic engineering
* Cereon Genomics – plant gene sequencing subsidiary

Sources: Greenpeace (2008); ETC (2005)

The study used the number of field-trial applications for GM crops from private firms and divided this number by the sales from private industry of seed for each major crop. This calculation provides a measure of 'research intensity' which can be compared across the different crops. Using this methodology for corn, soybeans and cotton indicates that, as the seed industry became more concentrated in the 1990s, private research intensity declined. The authors thus concluded that reduced competition led to less R&D, reducing innovation even in gene-based agricultural research rather than increasing it (Fernandez-Cornejo & Schimmelpfennig 2004; ETC 2005). This is despite claims from the biotechnology corporations to the contrary.

In the UK the Research Councils, in particular the Biotechnology and Biological Sciences Research Council (BBSRC), work with the biotechnology sector to provide support for a high technology, pro-GM approach. Although it is difficult to locate reliable information on the extent of GM research funding in the UK, there are some illustrative examples among the activities of the BBSRC: a £10 million partnership with the food industry in the Diet and Health Research Industry Club; the Biotechnology Young Entrepreneurs School; CASE awards; and the Business Plan Competition. However, the BBSRC has joined forces with the UK Department for International Development to provide £7 million for sustainable agricultural research within the government's programme of support for international development. According to its website this programme appears to fund the use of selective breeding and gene identification, there being no mention of GM technology, but details are not unequivocal on this score (DFID & BBSRC 2008). Whilst such apparent diversification of research is to be welcomed, it is a small sum in comparison with the overall budget of the BBSRC, projected to be £471 million in 2010-2011, and the £34 million which the BBSRC currently has available simply for supporting business competitiveness (DIUS 2007).

A great deal of the antipathy towards GM crops shown by the public in the UK and in other European countries concerns the potential health and environmental impacts of such crops. With powerful industrial lobbies strongly influencing both governments and scientific research, there is much distrust of the safety assurances given in this area (Tokar 2004). The four principle areas in which safety assessments are undertaken are: (a) direct health effects – toxicity; (b) the ability to provoke an allergic reaction; (c) the stability of the gene which is inserted into the crop (or animal); (d) any unintended effects that are triggered by the inserted gene.

Many of the tests that have been undertaken to assess these effects depend upon animal models of dubious relevance to humans. Long-term assessment of humans consuming GM food is either not being undertaken or is so over-simplified as to risk missing complex effects. A robust large scale study in places where people are already consuming GM products (such as the USA) could give data about the long-term consequences of GM crops in the diet over time and in different populations. However, trying to unpick the many complicating factors within human populations with respect to diet and its influence is notoriously difficult. Nevertheless this does not remove the need for there to be firm data on human health consequences of consuming GM food.

The transfer of GM genes from commonly allergenic sources is actively discouraged unless it can be shown that the product of the transferred gene does not provoke an allergic response. The Food and Agriculture Organisation and WHO have evaluated tests for picking up allergenicity from GM sources and whilst they appear to be satisfactory in the laboratory, it is unclear if they can identify risks across human populations over long periods of time. Genes carrying antibiotic resistance would have important consequences for human health – but again there is a lack of solid, well-controlled data to assess this area (WHO 2009).

The movement of GM genes into conventional crops or related species in the wild (outcrossing) as well as the mixing of non-GM with GM crops may have an unintended effect on food safety and security. Evidence that this risk is real comes from the case of a GM maize harvest that was only approved for animal feed use being mixed with maize for human use in the USA (WHO 2009). In order to be sure of the human and environmental safety and impact of GM crops, it is essential to have in place robust post-marketing monitoring of GM food products. There are also difficult issues concerning who carries the liability for environmental harm should the monitoring pick up problems. Simple assurances from GM lobbies and governments should not stand in place of reliable data and a more precautionary approach.

8.4.2. Biotechnology research and conflicts of interest

As described earlier, there is a marked tendency for bias and conflicts of interest to follow from corporate sources of research funding. In chapter 4 we examined the twin issues of conflicts of interest and bias in the case of research into new therapies and the testing of potentially new pharmaceuticals that had been funded by pharmaceutical companies.

Biases such as these not only compromise the validity of research results, but also adversely impact on the quality of, and public confidence in, science and technology. As we discussed earlier it is essential that any possible or actual conflicts of interest and the potential for bias should be disclosed in order to enable peer reviewers of journal papers, editors and readers to be able to judge for themselves the nature of the findings and the reliability of data and conclusions.

In new and emerging areas like those found in biotechnology, bias is also likely to arise in the form of exaggerated claims made about the new approaches or products. Such bias is difficult to control or account for in the early stages of development of new technologies. The claims made of synthetic biology (see section 8.4.3) clearly show that a great deal is expected of the discipline. A recent BBSRC report looked at the social and ethical challenges presented by synthetic biology (Balmer & Martin 2008). The authors, independent researchers with knowledge of the impact of new technologies, warned that one area of biotechnology in particular – synthetic biology – "must not be over-hyped by its supporters and critics should not exaggerate the risks it poses".

The issue of the failure to declare potential conflicts of interest is illustrated by a study of 79 papers in molecular biology (including areas in biotechnology) submitted to the journal *Nature* in a six-month period in 2005 (Mayer 2006). This study shows that, in two-thirds of the papers in which authors had patent applications or company affiliations which might be considered to present competing financial interests, the authors did not disclose them. Only four papers in the study actually declared that some of the authors had competing financial interests. This is despite the International Committee of Medical Journal Editors stating that interests must be declared "whether or not the individual believes that the relationship affects his or her scientific judgment" (ICMJE 2008). The impact of such conflicts of interest, including financial ones, is highly likely to introduce 'publication bias' (a form of sponsorship bias that we discussed in section 4.3) into data presentation and so pose questions about the reliability of journal reports (Ioannidis 2005).

Nature is one of the most prestigious science journals and the integrity of the research it publishes is essential to its reputation. The objectivity and integrity of science – and the public's confidence in it – depend upon such journals upholding the highest standards of openness and avoiding publication bias. As the author of the study pointed out, the study extended and confirmed other reports of possible publication bias in areas other than pharmaceutical sciences (Mayer 2006) and adds further concern about the corporate funding of cutting-edge science (Bekelman *et al* 2003). Clearly in areas where funders are powerful and the stakes are high, journal editors must enforce the disclosure of financial interests far more rigorously than is presently the case.

Conflicts of interest, aside from publication bias, which involve corporate collaboration in the biosciences, have been discussed in the professional press. The University of California (Berkeley) began a five year partnership in 2003 with Syngenta (the Swiss biotechnology firm formerly part of Novartis) which provided $25 million to the university's plant research effort. Although the deal brought research income to the university it also raised a number of ethical worries, not least about the propriety of the arrangement and the question of intellectual property rights (Dalton 1999; Dalton 2004; Bero 2008). In 2004 an independent analysis of the collaboration, undertaken by Lawrence Busch, was begun because of widespread unease in the University's Department of Plant and Microbial Sciences which received the Syngenta funds. The view of the resultant Busch report in 2004 was that the partnership arrangement with Syngenta "compromised the mission of the university" and created serious conflicts of interest. Out of the 20 patents which arose as a consequence of the collaboration, Syngenta followed only six and no licence agreements had been negotiated with the University of California (Dalton 2004). This example demonstrates how patents can be taken out (thus restricting academic research) even when there is little potential for commercial benefit.

The publication of the draft human genome in 2001, the first vertebrate genome to be published, was the result of a race between public and commercial research groups (IHGSC 2001). The prize for publishing first went to the public consortium. But the project rested on a complex foundation of commercial and public funding and research endeavour – too detailed to be described here (Baltimore 2001). The project has led to a significant increase in the understanding of the identity of genes, related in various ways to human disease. However, it has also quickened the pace of the commercialisation of the human genome and individual genes or groups of genes.

A notable example of how a publicly-funded gene research project, building on the research data released from the Human Genome Project, can be influenced by the views of a small number of corporate figures (with the active involvement of government) is the UK Biobank. This £61m project is funded by the Medical Research Council (MRC), the Wellcome Trust, the Department of Health, the Scottish Executive and the North West Regional Development Agency. The research intends to link a national DNA database with patient records from the NHS and thereby trace the role of certain patient's genes in the diseases to which they succumb. The intention is to predict and prevent common illnesses such as cancer and heart disease. The idea was first floated by George Poste, then at SmithKline Beecham, and was later supported by senior figures involved with the commercial sector such as Richard Sykes, then Chair of GlaxoSmithKline, David Cooksey, founder of Advent Venture Partners and Mark Walport, Head of the Wellcome Trust. A detailed account of the route by which this small group of industry-linked senior figures pushed a project based on the commercialisation of the human genome, linked closely to a significant expansion of the pharmaceutical market, is given in GeneWatch (2009).

Despite expert criticisms of the underlying science of treating 'pre-symptomatic' individuals and of gene-screening a huge population (see Barbour 2003), the UK Biobank is going ahead. The project throws up several of the criticisms that are fundamental to our critique of corporate involvement with science and research activities in the university sector, in particular:

* The commercialisation and subsequent patenting of genes together with the creation of a knowledge economy-based approach to healthcare;
* The Biobank project addresses the 'needs of business' rather than looking disinterestedly at a means of using gene techniques to understand disease.

Many have criticised the value of predictive gene tests but these criticisms have not been incorporated into the project;

* The decision-making process involves non-accountable industry figures working with government without fully independent oversight and transparency;
* A whole raft of problems arising from commercial access to electronic patient records and issues of privacy;
* The issue of public expertise residing in universities being used to benefit business;
* The central role of the goals of economic benefit and innovation as a stimulus for research – with public good and broader social benefits coming second;
* The failure to address public concerns about commercialisation and patenting of genes in the decision-making process;
* The fact that no independent cost-benefit analysis of the prediction and prevention hypothesis, central to the Biobank project, has been undertaken.

8.4.3. Synthetic biology

The declared aim of synthetic biologists is to design and construct novel life forms using engineering and computational techniques (RSC 2008). Synthetic biology represents a major step change from the manipulation of genetic material to the construction of biological parts, involving assembly instructions in ways that can clearly invent 'new life forms' and hence raise important ethical, scientific and practical issues. Space does not allow us to provide a detailed account of synthetic biology and the new developments being reported. Excellent accounts of synthetic biology and its potential, positive and negative, may be found in a number of reports (ETC 2007; RSC 2008) and on relevant websites[1].

Our purpose in this section is to briefly indicate what synthetic biology seeks to achieve, its approaches and the possible risks which are posed or exacerbated by corporate involvement with the area. Because synthetic biology has developed from a merging of many different fields within science and engineering the potential uses of the approach are enormous. A discussion meeting held under the auspices of the Royal Society in June 2008 suggested the following examples of possible applications using the tools presently available:

* Development of cheap anti-malaria drugs and other treatments for tropical diseases
* Initial steps towards the high-yield production of cheap and sustainable forms of energy to replace fossil fuels
* Programmable cells for gene therapy
* Environmental de-contamination using novel 'constructed' organisms
* Molecular computers

The expert members of the discussion group did however voice the need for the topic to be open and to have oversight, especially given the pace of developments (RS 2008).

Others have suggested the design of new food sources, autonomous vehicles and novel therapeutic agents which could be developed by synthetic biologists. The combination of peak oil, climate change and the increasing costs of energy and fuel production have provided an added impetus to research in and funding of synthetic biology. University-business partnerships have already become part of the synthetic biology research culture; an example is the partnership between BP and the University of California at Berkeley. Other corporations like DuPont, Proctor and Gamble, Shell and Chevron have entered into a variety of university-industry partnerships in the USA. In the UK the Research Councils have begun a funding programme involving collaboration between several universities including Cambridge and Bristol to build up the UK research base in synthetic biology.

However, several professional bodies in the UK and USA including the Royal Society and US National Science Advisory Board for Biosecurity have warned of some potential negative effects of developments in synthetic biology (RS 2008; and discussion in Samuel *et al* 2009). Some of their concerns echo our own. For instance, the costs and technical barriers impeding gene manipulation and the building of artificial life forms are being rapidly removed. The ETC Group estimates that the price of synthetic DNA has fallen to a tenth of 2000 prices (ETC 2007). Such cost reductions are likely to continue. Laboratory costs for undertaking synthetic biology are also low and falling. Similarly the skills needed to undertake such research are to be commonly found at the undergraduate level (ETC 2007). The implications for biosecurity (possible weaponisation and similar threats – see section 8.4.4 below) and biosafety (accidental release) are of considerable concern and could directly follow from manipulations of the genes of various organisms to make them into bioweapons (RS 2008; Kelle 2007; Samuel *et al* 2009). For instance the synthesis of a virus or bacteria is highly feasible in the very near future using existing synthetic biology methods, steps having already been made by US-based research groups.

There are at present more than 70 commercial firms which offer gene-synthesising and building short genome (ETC 2007) segments (DNA libraries). Such developments have the potential to pose serious environmental and security problems, and are discussed later.

A number of US government agencies, including the Departments of Defense and Energy, the National Institutes of Health, and the National Science Foundation (NSF), have invested of millions of dollars in synthetic biology centres and research projects. Venture capital companies have also been providing funds for synthetic biology projects. The published NSF research priorities for 2009 indicate synthetic biology funding may increase (Caruso 2008). Foundations with a science portfolio such as the Bill and Melinda Gates Foundation are investing in synthetic biology projects. Establishments like the Whitehead Laboratory and the University of California at Berkeley have been recipients of such funding. This will very likely drive science to address predominantly economic objectives rather than those of a broader importance and scope. The situation is more difficult to assess in the UK, but a study by the Royal Academy of Engineering and the Academy of Medical Sciences (its main brief being systems biology[2] as well as synthetic) suggested in 2007 that the establishment of new specialist centres be made a priority. They also added that further investment in the area is urgently required, together with the fostering of interdisciplinary skills and supportive research environments for systems and synthetic biology.

The BBSRC in the UK has already set up seven systems biology centres and, together with the EPSRC and other research councils, plans to devote monies to develop the infrastructure for synthetic biology to thrive (BBSRC 2008a). At present Imperial College London, and the Universities of Cambridge, Edinburgh, Glasgow and Manchester have large research groups in synthetic biology. The drive to develop synthetic biology is thus well underway and, given the economic focus that all the Research Councils are supposed to champion in the universities (see chapter 2), there will be significant commercial programmes with corporate partners participating in all these developments. As has been seen elsewhere in this report there is little evidence of plans for public or non-partisan oversight. This is despite the advice of an independent BBSRC Report (Balmer & Martin 2008) and the joint Royal Society/Royal Academy of Engineering Report on Nanotechnology, which stressed the need for both public engagement and oversight in such new technologies (RS/RAE 2004).

The BBSRC allocates around £19 million a year to research activities in synthetic biology (BBSRC 2008b) whilst the Economic and Social Research Council (ESRC) is funding a Genomics Network to the tune of a modest £12 million, designed to better facilitate both expert and lay discussions of the social, economic, ethical and practical issues which are raised by advances in gene technologies including those to be found in synthetic biology[3]. What is missing, however, is some substantial objective input to the decision-making process in order to balance the power of the economic agenda (apparent within both corporate and public funding) that is present within synthetic biology – both in the UK and the USA. An independent and influential overview that gathered views from the public as well as expert opinion would help to monitor the pace of development in this powerful field.

8.4.4. Biosecurity and biotechnology

The Royal Society convened an international workshop in 2006 which brought together 84 leading researchers and policy experts to discuss the Biological and Toxins Weapons Convention (BTWC) and various developments in science and technology, including in synthetic biology. The workshop warned that there were significant security problems associated with synthetic biology advances – not least the cheapness of DNA technology which could lead to 'garage biology', with the consequent risk of bioweapons development, which we discussed in the previous section (RS 2006). The workshop participants stressed the need for well-constructed regulatory mechanisms, which did not hinder legitimate research. However, they did not comment on the fact that the corporate sector is a powerful and largely unaccountable driver of the growth of this area of research. It is clear that commercial influences were an important aspect in the failure of negotiations on the BTWC verification protocol in 2001: these collapsed under industry pressure that commercial confidentiality arrangements should not be compromised (see the discussions in Rappert & McLeish 2007).

Powerful new technologies that may use infective organisms in their research have the potential for 'dual use', i.e. although not intentionally related to military use, the research has the potential to create bioweapons. A number of areas in biotechnology possess the risk, albeit at present quite remote, of abrogating the BTWC (Rappert & McLeish 2007). These include:

* Increasing the virulence of existing pathogens or novel agents by changes to the gene(s);
* Changing existing non-pathogenic (harmless) organisms to enable them to cause infections and attack humans and other animals by means of genetic modification;
* Modification of infective agents to avoid human immune mechanisms and thus increase their ability to kill or cause harm;
* Genomic targeting – the use of techniques from gene therapy to target bioweapons to distinct ethnic groups.

Whilst some of these techniques are still in their infancy, the rate of development in biotechnology presents a possible future risk of biosecurity lapses. This is made more likely given the negative aspects – such as secrecy and lack of transparency – that stem from corporate funding and involvement in biotechnology research and governance. A number of commentators have discussed how biotechnology might be regulated in balanced ways which take account of the concerns of researchers, business and the public using a modified 'code of conduct' for researchers. Such codes would build upon the expertise of all involved in the area – funders, researchers, regulators and commercial players. The adoption of codes would draw attention to potential bioweapons areas and the presence of national and international conventions and regulations. Such codes could identify dual-use issues clearly, where developments in, for instance, medical aspects of biotechnology have the potential for bioweapons purposes. Several authors discuss a number of examples of possible codes of conduct (Rappert & McLeish 2007; James 2006; Caruso 2008).

In summary, commercial influence on biotechnology R&D is considerable, contributing to a strong focus on genetic technologies and a lack of adequate consideration of alternative approaches in fields such as agriculture and medicine. This is in an area that abounds with complex, ethical issues, and is characterised by a great deal of scientific uncertainty. The evidence we have presented demonstrates how commercial pressures can marginalise the proper consideration of wider concerns, with industry-supported lobby groups exerting strong influence over the debate, especially in the policy realm.

Summary of the detrimental effects of biotechnology commercial influence on SET

- **Influence on the direction of the research agenda**

1. There is an overwhelming concentration on the gene and associated technologies. The gene has become a commodity of financial interest to those holding the patent on specific sequences;
2. In agricultural R&D, GM crop technologies have become dominant, marginalising alternatives without demonstrating superiority in social or environmental terms. A small number of large corporations, such as Monsanto, have been responsible for bringing about this dominance;
3. In the medical R&D sector, there has been a growing focus on exploring the genetic routes of disease (for example, in the UK Biobank), again marginalising exploration of alternatives;
4. Biotechnology company representatives occupy important positions within the governance of science and technology without appropriate counter-balance from those with other interests;
5. Partnerships of various sorts between academic researchers and biotechnology companies are focussed on addressing R&D of interest to the companies involved.

- **Influence on the direction and results of specific research studies (both intentional and unintentional)**

1. Significant conflicts of interest and bias are introduced into research studies, mainly through industry funding;
2. The biotechnology corporations tend to financially support university research – often with UK Research Council support – that addresses only one aspect of the area of interest (for example, crop science).

- **Influence on the openness of research studies**

1. Clearance of commercially sensitive data is necessary before it can be published;
2. Increasing commercialisation of R&D in universities creates a business ethos which stresses confidentiality and secrecy and downplays exchange of ideas and data;
3. The biosafety and biosecurity aspects of (especially) synthetic biology necessitate a great deal of care in R&D, particularly regarding access to materials and information. Commercial pressures can interfere with attempts to control or monitor such activities in the public interest.

- **Influence on the public interpretation of research results**

1. Bias in the collection of research results (see above) leads to biases in the reporting of that research;
2. Pro-GM lobbies and public relations organisations (funded by biotechnology industry) stress the potential value of gene technologies (such as GM crops and synthetic biology), and act to marginalise criticism. Science lobby groups which are supportive of GM claim to be unbiased, but many remain secretive about their sources of funding and in fact maintain close links to the industry, making it difficult to judge the reliability of their claims;
3. Voices within the biosciences that are critical of GM technology are not given sufficient opportunity to be heard. The public relations companies play an important role in ensuring that any environment for serious debate has a pro-GM backdrop. Whilst there is media interest in anti-GM voices, there is much less critical input in policy circles.

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Notes

1. *Relatively independent digests of synthetic biology can be found at: http://syntheticbiology.org/ This site is maintained by US-based synthetic biology researchers. For news on EU-based research go to: http://cordis.europa.eu/nest/findproj.htm This site provides access to NEST (New and Emerging Science and Technology).*

2. *Systems biology seeks an integrated view of the various interactions between biological systems. The approach uses engineering and computational tools to understand how genes and protein systems work together. Systems biology uses many of the models and approaches of synthetic biology but does not aim to construct new life forms (see http://www.systemsbiology.org/ for more detail).*

3. *Three centres have been set up by the ESRC in the following areas: Centre for Social and Economic Research on Innovation in Genomics (Innogen) at Edinburgh University; Centre for Genomics in Society (Egenis) at Exeter University; and the Centre for Economic and Social Aspects of Genomics (CESAGen) at the Universities of Lancaster and Cardiff. In addition the ESRC funds a Genomics forum and a large programme of responsive research across the UK.*

9. Conclusions

Science, engineering and technology have long relied on funding from a range of sources, including private benefactors, business and the State. Maintaining the right balance between the sources is fundamental to ensuring that society reaps the benefits of these endeavours. The evidence we have gathered in this report reveals that the relationship has become distinctly unbalanced, and that this is not good either for science and engineering or, in the long run, for commerce itself.

Over the last 20 years, governments in the UK and other industrialised nations have come increasingly to view science, engineering and technology principally as part of the engine of economic growth. Thus, activities in these fields have taken on a narrow and markedly commercial identity in many areas. Governments argue that this situation is broadly beneficial, with commercialisation being a main route through which benefits of research funding are passed on to society. However, in this report, we have outlined two serious and interlinked concerns:

- That the quality, reliability and public perception of scientific activities are being compromised by close involvement with the commercial sector; and
- That the emphasis on economic goals is undermining the ability of science and technology to deliver a diverse range of social and environmental benefits.

In a recent science policy document, the UK government stated, “There is no reason why the way science is conducted, governed or communicated by the private sector should be or be perceived to be any different from the public sector” (DIUS, 2008). This is a view also shared by some working in science and technology. The rationale is broadly that scientists are professionals who will do their job competently regardless of who is funding or employing them. But the reality is far more complex and more disturbing, as demonstrated by the evidence that we have presented in this report across five major sectors – pharmaceuticals, tobacco, military/defence, oil and gas, and biotechnology.

A central problem is that, not only is business orientated towards private financial gain, it has also become very powerful – both economically and politically. Some individual corporations, as we have seen, are as economically powerful as large countries. Given the way in which innovation can support economic growth, this means business has gained considerable influence over the agenda for scientific research and (especially) technological development. We showed in chapter 2 how UK government policy decisions on science and technology have increasingly been orientated towards the interests of business for at least two decades (and indeed this trend is accelerating). Within this framework, particular business sectors (and companies) have significant input at senior levels of public funding bodies, such as Research Councils, as well as into universities. The latter is manifested through strategic funding of research centres, professorial chairs, fellowships, and individual research projects and courses. In a number of disciplines, especially engineering and some applied sciences, it becomes difficult to find university departments without connections to one or more powerful industrial interests. This can create an environment where the questioning of the merits and ethics of particular lines of research becomes significantly more difficult.

Consequently it does not require scientific misconduct (in the conventional understanding of the term) for there to be a significant bias created by the involvement of industry with the academic community. Indeed businesses can and do choose to support researchers who have a particular research interest and point of view that coincide with industrial priorities. In the chapter on the pharmaceutical sector, we presented strong evidence from peer-reviewed sources of how studies funded directly by a company are much more likely to yield results favourable to that company. In the chapter on the oil and gas sector, we showed how scientists who doubt that humans cause climate change can be funded by the industry to widely publicise their point of view. The chapter on the military/defence sector revealed how difficult it is to find a UK university which does not receive funding from this industry.

The situation, however, can be even murkier. Some scientists do not always declare a conflict of interest when, for example, receiving industry funding when they publish data on the safety or efficacy of a given pharmaceutical product. Some companies use commercial confidentiality rules to avoid publication of research results unfavourable to them. Others in sectors such as biotechnology and military/defence strongly influence the research agenda leading to a dearth of funding for alternatives to their products. And yet others covertly fund lobby groups to argue that ‘sound science’ is being ignored. Perhaps of most concern is the fact that different industries are learning subversive tactics from each other in order to further their narrow business interests. For example, one pattern which emerges from our evidence is that public relations tactics first used by the tobacco industry, during the debate over the links between smoking and ill-health, have subsequently been applied by the oil and gas sector in the climate science debate, and also by the organisations in the biotechnology industry to promote their perspective on research they fund.

Defenders of the status quo argue that cases of misconduct are few and far between, while systemic problems are not significant

(Anon 2002; and discussion in Bird & Spier 2005). There is good reason to believe that occurrences of the more severe forms of misconduct – falsification, fabrication and plagiarism of data – are rare (Greenberg 2007). However, systematic investigation of bias and related problems has only been carried out in any depth in parts of the pharmaceutical and tobacco sectors and, as we have shown, here there is rigorous and extensive evidence of significant problems. In other sectors, such as oil and gas, biotechnology, and military/defence, it is also straightforward to find high profile cases of problems, as we have documented. Furthermore, Scientists for Global Responsibility – through our membership and other academic contacts – have been repeatedly alerted to particular concerns about the creeping commercialisation of the research agenda and its detrimental effect on research, teaching and training within universities. However, in-depth academic research looking at the effects of commercial influence in many areas has simply not been carried out.

Some further information is noteworthy at this point. One example is a recent UK opinion survey which indicated that members of the public have significantly less trust in corporate funded/influenced science (People Science and Policy Ltd/ TNS 2008). It seems that the public, like us, does not accept government assurances that science which is supported by the commercial sector is as robust or reliable as the publicly-funded kind. A further piece of evidence is also revealing. A recent study for the 'Russell Group' of research-intensive universities in the UK indicates that, even in simple economic terms, 'pure' or blue skies research can have a far greater social and economic impact than research undertaken with specific commercial end-points in mind (Fearn 2008). Other evidence from the USA indicates that academic technology transfer offices often do not generate significant incomes for their host universities (Greenberg 2007). Technology transfer pathways within the university sector in the UK and Europe are complex and variable. This complexity calls into the question the prevailing and overly simple government/ business view that the 'corporatisation' of universities, and science and technology more broadly, is necessary and of benefit, even from a narrow economic perspective (Smith *et al* 2008).

What of the interest groups outside of the commercial sector that influence science and technology? It has been claimed, for example, that environmental groups and some other civil society organisations (CSOs) have too much influence over the science and technology agenda – and unduly exaggerate potential problems (for example, Taverne 2003). It is true that in some public debates on scientific issues environmental groups can be influential. However, given the wealth of scientific evidence for major environmental problems (UNEP 2007) and the considerable evidence that society has been slow to act in the past (EEA 2001), one has to question whether the political influence of environmental groups is the significant problem here. Where problems can arise is when the CSO in question is not open about its funding sources or some of its political/ethical viewpoints, and it turns out to be close to, for example, a hidden special interest. This, as we have shown in this report, is a clear problem with interest groups close to commercial interests.

In practice, the influence of CSOs remains much more limited than that of business, largely because their access to finance is considerably less. Indeed, in the one sector where CSOs are major funders of scientific research – the health sector – their involvement is widely seen as positive. This raises the question of whether there should actually be more government/public funding available to CSOs to encourage their greater involvement in scientific research. This is an issue we take up in our recommendations in the next chapter.

In summary, then, the main concerns about commercial influence on science and technology presented in this report are as follows:

1) There is clear evidence that large-scale, commercial involvement in university-based science, engineering and technology has impacts that can be very detrimental, such as the introduction of significant bias and the marginalisation of work with clear social and environmental benefits. These impacts occur at different levels, including during individual research studies, the agenda-setting process for R&D, and communication of findings to fellow professionals, policy-makers and the public. While academic examination of these impacts has so far been limited, there is nevertheless credible evidence of serious problems across all the five sectors examined in this study.

2) At the level of the individual research study, we found the following problems:

    (a) Direct commercial funding of a research study increases the likelihood that the results will be favourable to the funders. Evidence of this mainly came from academic research in the pharmaceutical and biotechnology sectors. One way in which this bias – known as sponsorship bias – happened in the cases under examination was that funders tended to choose scientists who were already sympathetic to their viewpoint. Intentional distortion or suppression of data was much less common, although it did occur, especially in pharmaceutical and the tobacco funded areas, and it may well be more prevalent.

    (b) Openness in research can be compromised through the use of commercial confidentiality agreements (including patents) and other intellectual property rights considerations. We found evidence for this in the pharmaceutical and biotechnology areas, but such problems may well be evident at the individual level across other areas in science and technology, which have not been scrutinised as yet.

(c) Conflicts of interest of scientific researchers (for example, financial interests) have the potential to compromise the research process. There is limited monitoring or policing of the problem, so its true extent is unknown. We found evidence of this problem in the pharmaceutical, tobacco and biotechnology sectors.

3) At the level of setting the priorities and direction of R&D, we found the following problems:

(a) Economic criteria are increasingly used by government to decide the overarching priorities for public funding of science and technology, in close consultation with business.

(b) Universities are being internally reorganised so that they behave more like businesses, while key attributes of the academic ethos such as openness, objectivity and independence are being seriously eroded.

(c) Companies have expanded the number and range of partnerships with universities, focusing on business research priorities and goals. The power and influence of some corporations, and the increased pressure on researchers to bring in funding from business, means that academic departments are increasingly orientating themselves to commercial needs rather than to broader public interest or curiosity-driven goals. This is a trend especially evident in biotechnology, pharmaceutical, oil and gas, and military partnerships.

(d) The growing business influence on universities is resulting in a greater focus on intellectual property rights (including patents) in academic work. Hence knowledge is increasingly being 'commodified' for short-term economic benefit. This can undermine its application for wider public benefit, and produces a narrow approach to scientific curiosity.

(e) A high degree of business interest in emerging technologies, such as synthetic biology and nanotechnology, leads to decisions about these powerful technologies being taken with little public consultation. This is of particular concern because of the major uncertainties regarding these technologies, including the possibility of detrimental health and environmental impacts which they may produce.

(f) There are particular problems within the five sectors examined in this report:

(i) In terms of the scientific response to ill-health, the influence of the pharmaceutical industry can, for example, marginalise investigation of lifestyle changes as a method of disease prevention, or lead to a focus on disease treatments for wealthier communities able to pay for them rather than the more common global diseases.

(ii) In terms of the scientific response to food security, the influence of the biotechnology industry can lead to unjustified focus on high technology approaches to increasing crop yields rather than investigating lower-cost agricultural options or addressing wider problems of food distribution or poverty.

(iii) In terms of the scientific response to climate change, the influence of the oil and gas industry can lead to a focus on fossil fuel-based technologies or controversial biofuels rather than controlling energy demand, increasing efficiency, or a more rapid expansion of widely accepted renewable energy technologies.

(iv) In terms of the scientific response to security threats, the influence of the military/defence sector in science and engineering can drive an undue emphasis on weapons and other high technology approaches, rather than one that prioritises negotiation, arms control treaties, and other conflict resolution or prevention activities.

4) At the level of communication with policy-makers and the public, we found the following problems:

(a) If threatened by emerging scientific evidence about the health or environmental problems related to their industry, some of the larger companies are willing to fund major public relations campaigns aimed at strongly encouraging policy-makers and the public to support their interpretation of the scientific evidence (even if it is far from that endorsed by most scientists). Tactics uncovered here include funding lobby groups (sometimes covertly) to act on their behalf and presenting industry as being for 'sound science' and opponents as 'anti-science'. Evidence of these practices is especially strong in the tobacco and oil and gas sectors, with some evidence from the biotechnology sector too. Companies more willing/able to diversify from problematic product lines were found to be less likely to take this course of action.

(b) Some companies can be selective in their reporting of academic findings of efficacy or safety of a newly launched product. This 'marketing bias' was found especially in data from the pharmaceutical and biotechnology sectors.

Table 9.1 – Summary of evidence of detrimental effects due to commercial influence on science and technology in five industrial sectors

	Sector				
Area of detrimental effect	**Pharmaceuticals**	**Tobacco**	**Military**	**Oil and gas**	**Biotechnology**
On direction of research agenda	XXX	XX	XXXX	XXX	XXX
On specific research studies	XXX	XXX	X	XX	XX
On openness of research studies	XXX	XX	XX	X	XX
On public interpretation	XXX	XXXX	XXX	XXXX	XXX

Scale:

x – least evidence of detrimental effects/ least detrimental effects

xxxx – most evidence of detrimental effects/ most detrimental effects

(c) Some sections of the pharmaceutical industry 'expand' the definition of human disorders and fund patient-interest groups, which help to increase the market for their products. This can compromise both patient care and the underlying scientific basis of medicine.

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10. Recommendations

Although business involvement with science and technology has a variety of potentially positive effects — for example, the generation of employment or the creation of innovative and useful technologies —there are numerous problems arising from insufficiently accountable corporate activity, as this report documents. The problems identified touch on issues related to the funding for science and technology, the conflicts of interest that can arise from the source of some forms of funding, and the overall policies governing work in this area. In this final section, we examine some of the options available for tackling these problems, and make recommendations for reform. We focus on recommendations which are broadly relevant across the science and technology sectors. (Some sector-specific reforms have been recommended elsewhere, for example House of Commons 2005 and Langley 2005). It is also worth noting that our recommendations could have significant benefits for business – especially more recognition for ethical behaviour, for example – as well as for universities and science and technology more generally.

The evidence presented in this report relating to commercial involvement in science and technology flagged up one important issue repeatedly, which is the ethical record of the companies concerned. Concerns about ethics raises the question of whether universities should decline to become involved in partnerships with companies whose ethical records are especially poor.

The activities of the tobacco corporations, in particular, have led to numerous academics and universities refusing to accept funding from them (Michaels 2008). Indeed, Cancer Research UK – a major charitable funder of health research – refuses to fund university research groups which have any connections with the tobacco industry. It is also significant that Universities UK has issued a joint protocol with Cancer Research UK on tobacco industry funding. While Universities UK does not specifically exclude such funding, it does state that the "expertise, facilities and resources of universities should not knowingly be made available for purposes that would be damaging to the public interest or common good, e.g. to public health" (Universities UK/Cancer Research UK 2004). It would seem reasonable to interpret this statement as also applying to the receipt of funding from other industrial sectors whose ethics come into question.

Some academics and students are actively lobbying for their universities to take a stronger ethical position regarding their involvement with business. One notable case concerns the Open University where – following its involvement in a major partnership with military industry – a working group of academic staff and trade unionists has called on the institution to adopt a set of minimum ethical standards that prospective industrial partners should meet (UCU-OU 2008). The group argues that partnerships with companies with poor ethical records – including some of those involved in the case above – will reflect badly on the university's public standing, as well as involving it in projects of a questionable nature. They have recommended an approach that draws in particular on the experiences of The Co-operative Bank, which uses a set of minimum ethical standards to decide the companies to which it should grant financial loans.

Universities may have concerns that ethical policies such as these could reduce the range of funding available to them. There are two responses to these concerns. The first is that such policies may encourage more funding from sources (including businesses) that value high ethical standards – indeed, this is the experience of The Co-operative Bank (The Co-operative Bank 2009). The second is that there are other ways in which they may benefit from the business funding that has been more creatively utilised as a result of such policies, as we will discuss below.

Recommendation 1:
Universities should adopt minimum ethical standards for the companies with which they have or form partnerships. These standards should include social and environmental criteria, as well as academic standards. The practical application of such standards should be overseen by a committee within each university, co-ordinated on a national basis. The committees would comprise a range of interests and expertise.

A related problem, which was encountered across all the sectors examined in this report, was a lack of openness on relationships between universities and business. Even use of the Freedom of Information Act yielded only partial data (for example, see chapter 6). To ensure proper oversight of university partnerships, there needs to be a major improvement in transparency. In one of our earlier studies (Langley et al 2008), we noted that the University of Cambridge had a much more transparent system for reporting business-university involvement than many of its compatriots.

Recommendation 2:
Universities should openly publish, as a matter of course, comprehensive data on the nature of their business partnerships. This will allow more reliable oversight to take place.

Our report has also highlighted the problem of sponsorship bias – where funding for scientific work from a particular source (such as a company) – can influence the way that the research is undertaken and reported. As we have pointed out, such an effect need not be due to scientific malpractice, but it is problematic nevertheless, especially when funders are powerful corporations. Hence, it would be very useful if there were new mechanisms through which funding from business could be provided for scientific work that neutralise the undue influence that that funding can impart.

Two interesting options should be considered for dealing with this problem. The first is to set up an independent funding body which receives money from business, but disburses it according to the needs of curiosity-driven or public interest research. It could have a steering committee to include a balance of representatives from academia, government bodies, business and civil society organisations. A useful example here from another sector is the Community Foundations Network (CFN 2009), which funds UK community groups through donations from business, government and individuals. The Wellcome Trust has also worked with and funded a variety of groups (public and academic) to engage with both public and commercial audiences (Wellcome Trust 2009).

The second option is that funding from business (for a research project, for example) is given in the form of joint funding with another organisation. This is already common for many academic research projects, where the partner can be a Research Council or government body. However the aim in the vast majority of these cases is simply to help a particular company engage in more research to assist it in meeting its commercial objectives. Far less common is joint funding between funders with differing, and sometimes even competing, interests. This can be useful, for example, in research examining social and environmental issues related to technological development, where a study funded simply by business would not be accepted as sufficiently independent.

One groundbreaking study in this regard was a project investigating public views on GM crops carried out by the Policy, Ethics and Life Sciences (PEALS) research institute at Newcastle University (Wakeford *et al* 2003). It was jointly funded by Unilever, Greenpeace, the Consumers' Association and the Co-operative Group; organisations with a range of — often competing — views on the issue. The project also had an 'oversight panel' composed of experts on different aspects of the issue, which included academics as well as a balance of representatives from industry and civil society. It demonstrated that funders with diverse interests could work together to carry out robust research on a controversial issue. Indeed, to encourage more projects such as this, public money could be made available, especially given that environmental groups and other civil society organisations tend to have much smaller budgets for scientific research compared with those of industry.

Of course, these two options may not immediately appeal to some businesses, but government could assist by providing economic incentives (for example, tax relief or grants) to facilitate donation to particular trusts. Another option would be to insist that large companies funding academic R&D should allocate a certain percentage to be spent either through an independent trust or on joint research with a civil society organisation.

Recommendation 3:
A new independent organisation should be set up to disburse a significant fraction of business funding for scientific research. The aim would be to fund research which has particular public interest (and perhaps is being neglected by mainstream funding sources). The steering committee of the organisation would include a balance of representatives from academia, government bodies, business and civil society organisations to ensure the research is indeed carried out in the public interest.

Recommendation 4:
Business and civil society organisations should undertake more joint work on public interest scientific projects. Research Councils should facilitate such collaborative working, and incentives could be given to encourage participation in this form of partnership. Each project should have an oversight group which ensures that both academic standards and ethical concerns are given due weight.

Related to the issue of sponsorship bias is the general concern about conflicts of interest in scientific and medical work. The evidence we have presented indicates that, while this is considered a very important issue, there is a lack of firm action to deal with it. There needs to be far more rigorous means of identifying and clarifying conflicts of interest when papers are submitted to journals, for instance. Some academic journals do insist that authors of papers published in those journals declare any financial interests they have related to the paper (for example, the *British Medical Journal* and *The Lancet*), but *all* journals should do this more vigorously and consistently. Furthermore, there should be sanctions for authors who are found not to have complied accurately with such declarations. Possible sanctions include barring the author from publishing with a given journal for a certain period of time. More broadly, academia could follow the practice common to some other professions of keeping 'registers of interests'. This is a requirement in politics, for example. Such mechanisms would have the added benefit of increasing public trust in academic work, especially if the research area were controversial.

Recommendation 5:
All academic journals should develop and implement rigorous processes for dealing with all potential conflicts of interest. Such processes should cover journal editors as well as authors. There should be sanctions for non-compliance.

Recommendation 6:

An open register of interests should be set up for academics, starting with those who work in controversial areas of science and technology. This should cover financial and other interests.

One particular area where businesses involved in science and technology have been found to be acting in a deliberately misleading way is the area of science communication – in particular, through covert funding of public relations and lobbying groups. Ideally advocacy groups on all sides of debates within the science and technology realm should be open about their funders. This would allow policy-makers, journalists and the public to make up their own minds about whether a particular viewpoint has been unduly influenced by a funding source. However, it would be difficult in practice to enforce such disclosure, so there should be sanctions against companies that are found not to be open about their public relations activities. For example, a requirement on openness could be incorporated into the university ethical standards discussed in Recommendation 1.

Recommendation 7:

Advocacy groups on all sides of debates in science and technology (including professional institutions) should publicly disclose funders, to allow the public to decide whether this may be a source of bias.

Recommendation 8:

One of the criteria within a university ethical policy on partnerships with business should be to require openness and accuracy in relation to any involvement in science communication activities.

A recurring theme in our investigation has been that, despite the extensive evidence of detrimental effects that we have gathered, there are still important areas which have attracted little attention from (especially) academic researchers. For example, there has been a lot less examination of the role that conflicts of interest play in UK-based research activities than in the USA. Similarly, there is little data on the publication practices of research staff involved with university-industrial partnerships in the UK.

Recommendation 9:

More academic research needs to be conducted into the potentially detrimental effects of the commercialisation of science and technology, especially within UK universities.

Arguably the most substantive and contentious issue in the debate about commercial involvement in science and technology is the influence of government policies related to this involvement. This report has highlighted that the explicit agenda for commercialisation has been a powerful and expanding aspect of science and technology policy in the UK (and elsewhere) over the past 20 years. This is due to the position that science and technology hold as key driving factors within the economy. But, given the problems outlined in his report, there is a strong case for policy changes that would lead to a better balance between economic concerns and the wider public interest.

First and foremost, there needs to be more recognition that considerable economic benefits can still be gained through the funding of 'pure' or blue skies research – with significant evidence demonstrating that these benefits can even outweigh those produced by R&D focussed specifically on commercial endpoints (Martin & Tang 2007; Fearn 2008). There also needs to be more recognition that measures which focus specifically on increasing the commercialisation of research often fail to yield the intended economic benefits (for example, see Greenberg 2007). This further strengthens the argument in favour of a science policy agenda that takes a much more balanced approach to the issue of commercialisation. As we have noted, the recent policies implemented in the UK tend to echo those in the USA, rather than a more measured approach seen in other parts of Europe.

There are two key high-level policy changes which could help to redress the balance.

Recommendation 10:

The newly formed Department of Business, Innovation and Skills – which has responsibility for both universities and science – should be broken up. Public interest science and the universities should be given greater prominence in the government hierarchy, especially at Cabinet level.

Recommendation 11:

The House of Commons Committee on Science and Technology – which was formed again as this report went to press – should investigate the current emphasis on commercialisation within science policy, and whether a balance is being achieved between powerful interests – such as big business and the military – and the wider public interest.

A strong case can also be made for greater public involvement in setting the overall priorities for science and technology – and to prevent business having undue influence. For example, the policy think-tank Demos has recommended more 'upstream engagement' (Wilsdon & Wills 2004; Wilsdon *et al* 2005), where the public is actively included in discussions about the wider aims of research and development at an early stage (i.e. upstream) in the process. Some science organisations – including some government bodies and the Research Councils – have begun carrying out activities in these areas. Two examples in the field of nanotechnology are the 'NanoDialogues' and the

Nanotechnology Engagement Group (Wilsdon *et al* 2005). However, such schemes are still very small in comparison with the initiatives being pursued with commercial aims. There needs to be far more effort directed towards counterbalancing the pervasive influence of business, and making science and technology policy more transparent.

Recommendation 12:

Public involvement in the governance of science and technology should be expanded. More resources should be directed towards expanding upstream engagement with the public, including the use of citizens' juries.

A related problem in the science policy realm is the growth in the number of business representatives on the boards and committees of the Research Councils and elsewhere in the governance of science and technology. There needs to be more of a balance, with an increase in the number of representatives from civil society organisations.

Recommendation 13:

Research Councils and other major public funders of scientific research and teaching should have more balanced representations on their boards and committees between business on the one hand and civil society on the other.

In research related to high technology, this report has highlighted particular concerns about the balance between the commercialisation of the technologies and the investigation and management of wider social and environmental impacts of those technologies. Emerging technologies, such as nanotechnology and biotechnology based on synthetic biology, can be especially problematic due to the high level of uncertainty related to their effects on humans and the environment. In particular, this report has highlighted biosafety and biosecurity concerns.

To address issues such as these, Demos has recommended that a Commission on Emerging Technologies and Society be set up, with its remit being to ensure thorough consideration at the policy level (Wilsdon *et al* 2005). Another option is to allocate a proportion (for example, 20 per cent) of the public funding earmarked for emerging technologies to be spent on examining and managing the potential social, health and environmental impacts of those technologies. One precedent in this area is the longstanding practice in the USA – now starting to be applied in Europe – where the 'ELSI' (Ethical, Legal, Social Issues) money is a fixed percentage on top of Federal grants. There are some moves in this direction in the UK, but more needs to be done especially in areas such as synthetic biology. One further option is the greater use of ethical codes of conduct in specific areas of research in emerging technologies.

Recommendation 14:

Steps should be taken to ensure that a balance is struck between the commercialisation of emerging technologies and the wider social and environmental impacts. This could include the setting up of a Commission on Emerging Technologies and Society, the allocation of adequate levels of funding to examine the wider impacts and make recommendations on their management, and the wider use of ethical codes of conduct for researchers.

Recommendation 15:

The Sustainable Development Commission, a leading government advisory body, should have its remit broadened to specifically cover the role of science and technology in contributing to sustainable development. This could include investigating the role of powerful interests in shaping the broader science agenda.

In general there needs to be a thorough review – perhaps in the form of a Royal Commission – into the roles that universities can and should play in our society. Only such a high-level review, with the full range of stakeholders participating, is likely to be able to adequately address the issues raised in this report.

Recommendation 16:

There needs to be a thorough review of the role of the university in society and the economy – perhaps in the form of a Royal Commission. This needs to include issues ranging from the degree of involvement of business and civil society to patenting policy.

Finally, although this report has not examined the wider issues related to corporate behaviour and the economic system, these should not be forgotten. The global financial crisis of late 2008/early 2009 has demonstrated in spectacular fashion the major problems that can be caused by a key economic sector being under-regulated. Meanwhile, serious questions exist about whether the current economic system will push society beyond environmental limits (see, for example, New Scientist 2008). Independent academic research, such as in the discipline of 'ecological economics', can provide vital analysis here. Such work needs to be expanded and taken more seriously by policy-makers.

Science and technology have long been supported and funded from a range of sources, including business. However, over the last two decades, economic goals have become dominant, both through direct support from business and as a condition of state funding. This has led to a range of detrimental effects that are not being adequately addressed (or, in some cases, even acknowledged) by senior policy-makers. This urgently needs to change.

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Acronyms and abbreviations

AAAS	American Association for the Advancement of Science
AEI	American Enterprise Institute
AHRC	Arts & Humanities Research Council
ASPO	Association for the Study of Peak Oil
BAT	British American Tobacco
BBSRC	Biotechnology & Biological Sciences Research Council
BERR	Department for Business, Enterprise and Regulatory Reform
BTWC	Biological and Toxins Weapons Convention
CCS	carbon capture and storage
CRO	contract research organisation
CSO	civil society organisation
DARP	Defence Aerospace Research Partnership
DIUS	Department of Innovation, Universities and Skills
DTI	Department of Trade and Industry
EPA	Environmental Protection Agency (USA)
EPSRC	Engineering & Physical Sciences Research Council
ESRC	Economic & Social Research Council
GCC	Global Climate Coalition
GDP	gross domestic product
GM	genetically modified/ genetic modification
GP	General Practitioner
GSIF	Global Science and Innovation Forum
HEFCE	Higher Education Funding Council for England
IARC	International Agency for Research on Cancer
ICOSI	International Committee on Smoking Issues
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPN	International Policy Network
IPR	intellectual property rights
IRC	Interdisciplinary Research Centre
MoD	Ministry of Defence
MRC	Medical Research Council
NERC	Natural Environment Research Council
NME	new molecular entity
NSF	National Science Foundation (USA)
OECD	Organisation of Economic Co-operation and Development
PSRE	public sector research establishment
R&D	research and development
RLS	restless legs syndrome
SAD	social anxiety disorder
SAS	Sense About Science
SET	science, engineering and technology
SGR	Scientists for Global Responsibility
SIDS	sudden infant death syndrome
SSRI	selective serotonin reuptake inhibitors
STFC	Science & Technology Facilities Council
UTC	University Technology Centre
WHO	World Health Organisation

Scientists for Global Responsibility

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About this report

It is no secret that links between the commercial sectors and science and technology are increasing. Many policy-makers, business leaders and members of the science community argue that this is positive for both science and society. But there is growing evidence that the science commercialisation agenda brings with it a wide range of detrimental effects, including bias, conflicts of interest, a narrowing of the research agenda, and misrepresentation of research results. This report takes an in-depth look at the evidence for these effects across five sectors: pharmaceuticals; tobacco; military/defence; oil and gas; and biotechnology. Its findings make disturbing reading for all concerned about the positive role of science and technology in our society.

About Scientists for Global Responsibility (SGR)

SGR promotes ethical science, design and technology, based on the principles of openness, accountability, peace, social justice, and environmental sustainability. Our work involves research, education, advocacy and providing a support network for ethically concerned science, design and technology professionals. Founded in 1992, we are an independent UK-based non-profit organisation with over 1000 members. SGR is affiliated to the International Network of Engineers and Scientists for Global Responsibility (INES).

Please help support SGR's work by becoming a member.

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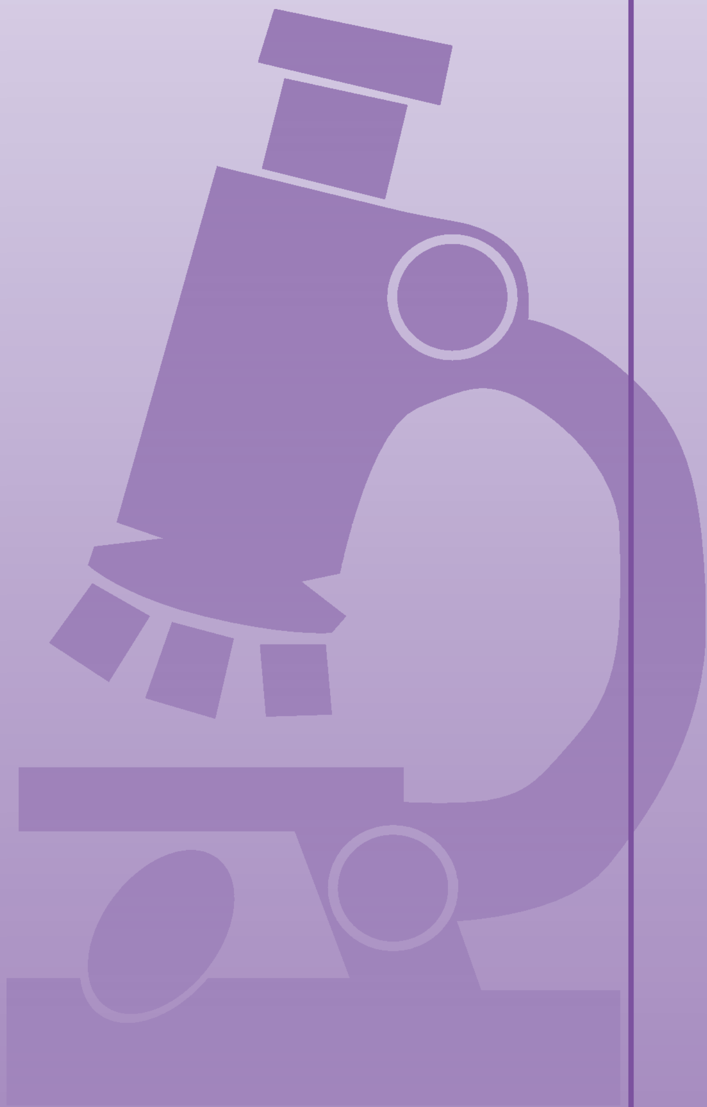

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