UK COMMISSION FOR EMPLOYMENT AND SKILLS

Strategic Skills Needs in the Bio-medical Sector

A report for the National Strategic Skills Audit for England 2010

Evidence Report 14
March 2010

Analysis › Understanding › Insight › Expert advice

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Terence Hogarth, Derek Bosworth, Colin Davis and Stacey Price
Institute for Employment Research, University of Warwick

Dr Richard Garrett
Research Manager
UK Commission for Employment and Skills

Foreword

Launched on 1st April 2008, the UK Commission for Employment and Skills is a key recommendation in Lord Leitch's 2006 review of skills Prosperity for All in the Global Economy: World Class Skills. The UK Commission aims to raise UK prosperity and opportunity by improving employment and skills. Its ambition is to benefit individuals, employers, government and society by providing independent advice to the highest levels of the UK Government and Devolved Administrations on how improved employment and skills systems can help the UK become a world class leader in productivity, in employment and in having a fair and inclusive society.

Research and policy analysis plays a fundamental role in the work of the UK Commission and is central to its advisory function. In fulfilling this role, the Research and Policy Directorate of the UK Commission is charged with delivering a number of the core activities of the UK Commission and has a crucial role to play in:

- Assessing progress towards making the UK a world-class leader in employment and skills by 2020;
- Advising Ministers on the strategies and policies needed to increase employment, skills and productivity;
- Examining how employment and skills services can be improved to increase employment retention and progression, skills and productivities;
- Promoting employer investment in people and the better use of skills.

We will produce research of the highest quality to provide an authoritative evidence base; we will review best practice and offer policy innovations to the system; we will undertake international benchmarking and analysis and we will draw on panels of experts, in the UK and internationally, to inform our analysis.

Sharing the findings of our research and policy analysis and engaging with our audience is very important to the UK Commission. Our Evidence Reports are our chief means of reporting our detailed analytical work. Our other products include Summaries of these reports; Briefing Papers; Thinkpieces, seminars and an annual Research and Policy Convention. All our outputs are accessible in the Research and Policy pages at www.ukces.org.uk.

This report was commissioned by the UK Commission to contribute to the evidence base for Skills for Jobs: Today and Tomorrow, the National Strategic Skills Audit for England 2010. A further two reports were commissioned to identify the strategic skills needs in the Financial Services and Low Carbon Energy Generation sectors and a fourth, Horizon Scanning and Scenario Building: Scenarios for Skills 2020, investigated the potential implications for skills of future national and global scenarios. We hope you find the report useful and informative in building the evidence we need to achieve a more prosperous and inclusive society.

PROFESSOR MIKE CAMPBELL
DIRECTOR OF RESEARCH AND POLICY

LESLEY GILES
DEPUTY DIRECTOR AND HEAD OF RESEARCH

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Acknowledgements

Many people have contributed to the production of this report. The authors would like to thank Dr. Richard Garrett, Project Manager at the UK Commission for Employment and Skills for his encouragement and support throughout the study. Vicki Belt and Mark Spilsbury also gave advice at various stages.

The research team benefited considerably from the expertise of Brian Murphy at Cogent and Helen Lindsay at SEMTA, for which much thanks are due.

A large vote of thanks is due to the many stakeholders who provided their views on the future skill needs of the bio-medical sector and gave the authors some critical insights into the operation of the sector.

At IER, Faye Padfield and Rachel Gowlett provided administrative and secretarial support, and Luke Bosworth and Peter Millar provided computing support.

The content of the report is solely the responsibility of the authors.

Executive Summary

The Bio-Medical Sector

The aim of the study is to assess the strategic skill needs of the bio-medical sector. This sector has been defined as the combination of the pharmaceutical, medical biotechnology, and medical technologies sectors; in other words, those industries which produce the drugs, therapies, and equipment for the health care system in the UK and abroad.

Because of major scientific breakthroughs over recent years which have the scope to radically improve the well being of the population - especially those currently suffering or at risk of chronic illness – the industry is very much seen as one with colossal future potential. From an employment and skills perspective there are many uncertainties relating to the situation in England but, on balance, the outlook is an optimistic one.

England currently has an enviable position in the global market given the level of research and development activity which is concentrated in the country, especially around Cambridge and the corridor from the west of London and along the Thames Valley towards Oxford. It also has a substantial manufacturing capacity to be found across the country but notably in the North West and South East.

Looking to the future, the key findings from the study reveal the following.

The Importance of the Bio-Medical Sector

- It an important sector for the national economy with respect to output and employment. It is also a principal constituent of the knowledge economy, with the pharmaceutical sector not only being the largest investor in R&D in the country, but also at the forefront of global developments to bring about a major transformation in the treatment of illness in the 21st Century.

- The investment in R&D reflects the pharmaceutical industry’s strong demand for highly qualified scientists, engineers, and technologists, often qualified at postgraduate level with skills at the cutting edge of the latest scientific developments. The industry has been able to articulate precisely the scientific skills it requires over the medium-term even though it is difficult to quantify the level of skills demand.

- Arguably, the level of technological change is such that skill demand will always outpace skills supply. Of vital importance is the extent to which the supply-side can catch up with demand relative to that in other countries. Collaboration between higher education (HE), the health service, and industry through clustering and networking appears to be the principal mechanism though skills supply has largely been developed to support scientific and technological advancement.

- England is a dominant player in the global pharmaceutical market, though this is not the case in the medical technologies sub-sector. Much of the industry’s success has been dependent upon the rich supply of research scientists extant in the UK, and the relative strength of the UK higher education sector in subjects allied to the industry. The relationship would appear to be mutually reinforcing with the capacity to attract highly skilled and qualified people from around the world.

Drivers of Change in the Bio-Medical Sector

- Forecasts of future employment and skill demand suggest that overall employment levels will remain more or less static. But as mentioned above there a number of uncertainties – threats and opportunities - which the industry faces over the medium-term, including, amongst others:
    - the capacity of scientific breakthroughs to result in new products and therapies which willre place those which are currently nearing the end of their patents;
    - the demand for health care which results from demographic change (e.g. people living longer with chronic conditions and the pressure this places on the health service);
    - environmental considerations (e.g. the need to reduce waste);
    - constraints of health care expenditure (e.g. the need to constrain in some way the almost infinite demands being made on national health care systems to provide the latest treatments, and the need to develop treatments which might reduce health care costs – such as telemedicine);
    - consumer demand and expectations (e.g. the willingness of patients to pay for new treatments);
    - globalisation and corporate strategic choice (e.g. the corporate decisions which are made about where products are developed and manufactured to serve the global market).
- Technological change provides a number of opportunities for the industry, such as the development of the next generation of drugs which use biological rather than chemical processes. These are generally considered positive for the industry's development because they will generate a stream of new products and therapies. Given England's concentration of R&D activity, and the critical mass of research scientists in the country, it is well placed to retain its position as a pre-eminent centre of innovation and product development. But this cannot be taken for granted. It is important that investment continues in R&D both within the sector and in the external R&D sector (i.e. HE) to maintain this position.

Employment Levels

- The sector in England is estimated to employ around 95,000 people - and many of these people are occupied in skilled trades and machine processing jobs – with, in addition, a substantial number of people employed in the supply chain. Compared to the sector's position as a centre for innovation and product development, medium term prospects for employment in the manufacturing part are less clear.

- One version of the future sees mass production increasingly being transferred to lower cost countries as the leading companies look to cut their costs because of the increasing levels of investment required to successfully bring new products to market, and due to patents lapsing.

- More positively, as some drug treatments become more bespoke, requiring manufacture to exacting standards but in relatively small batches, this raises the prospect of niche production becoming important. Hence employment growth amongst the niche producers may replace any loss from mass production being transferred elsewhere.

- Though overall employment numbers are unlikely to show much growth over the medium-term with the numbers employed in each occupation, other than managers and professionals, showing a decline, the workforce is relatively aged which suggests that there will be substantial replacement demands across the occupational structure of the sector. The challenge here is to attract people, especially young people, into an industry which signals that the overall number of people it employs is in decline.

Skill Demand and Supply

- As the foregoing has said, the future of the high-tech, knowledge intensive part of the industry is dependent upon the future supply of highly qualified scientists engineers and technologists. What is less clear is the extent to which the existence of a prestigious R&D sector is sufficient to safeguard manufacturing employment. This would appear to be subject to both the strategic choices the principal companies in the sector make about where they want to locate production and the extent to which developments in the sector push manufacturing increasingly towards niche manufacture.

- Without doubt the manufacture of bio-medical products is dependent upon intermediate level skills – skilled trade workers and technicians. Without a supply of these skills manufacturers are likely to face skill shortages which will impose constraints on production. Manufacturing is also dependent upon management being well versed in the skills required to operate in the sector of the market into which they may find themselves migrating. For example, in the case of the production of goods which are becoming increasingly commoditised, then skill sets may need to migrate to focus more than ever on keeping costs down (e.g. lean manufacture, etc.).

The Future

- Whilst there are considerable uncertainties attached to the future direction of the sector there are grounds for substantial optimism for this country because of the range of new treatments which are likely to come on stream over the medium-term.

- Often the debate is very much focused on the pharmaceutical sector, and with good cause too given the colossal scale of its R&D investments and its capacity to bring on line those drugs and therapies which will safeguard the well being of the population. The medical technologies sub-sector receives much less focus because it is relatively small with respect to output, R&D and employment, and is not so recognisably a world leader compared to either the USA or Germany.

- It is readily apparent that developments in health care will be dependent upon medical technologies and that there is, through the use of communication technologies, the potential for the convergence of drug therapies with medical technologies. Future demand for medical technologies could be a major source of employment growth and skill demand which might provide a boost for the country's engineering sector. The demand here, in the first instance, is to equip engineering firms with the strategic skills which will allow them to diversify into the medical market and negotiate access to health care markets both here and abroad. In the second instance, skill demand relates to manual engineering skills at Levels 2 and 3 which will be required to meet future demand. Engineering is a sector which has encountered relatively high skill shortages over the recent past and the types of skilled people they require are subject to considerable replacement demands over the medium term.

- Overall, the assessment provided in this report suggests that there is significant employment potential in the sector which will be dependent upon skills supply being adequate at a number of levels. In pharmaceuticals the country is in an enviable position as a world leader and with respect to medical technologies there is considerable scope for the country's engineering sector to take advantage of an expanding market.

1 Introduction: Aims and objectives of the study

1.1 Introduction

Maintenance of advanced economy status is dependent upon being at the forefront of the latest technological advances. The ancient Greek and Roman economies were built upon the development and application of technologies considered to be advanced for the time, similarly the strength of many west European economies is rooted in their ability to have harnessed the potential of the technologies which gave rise to the Industrial Revolution. At various junctures in history there have been technological breakthroughs which have changed the face of industry: water-power, steam, electricity, internal combustion engines, micro-processors, etc. Bio-medical technologies may well be the new paradigm for the 21st century. This very much classifies bio-medical technologies as a state-of-the-art, cutting edge industry dependent upon the skills at the very highest levels of scientific and engineering know-how. But there is a need to temper this view a little. While this description of the industry is accurate for at least part of it, there are other important sub-sectors which produce the everyday goods and services required by the population, such as the standard medicines and equipment upon which the health service is dependent for the treatment of large numbers of patients, which are important sources of output and employment. Producing these goods is often a profitable one for the organisations concerned but their skill needs will be different from those at the cutting edge of bio-medical technologies. From an employment and skills perspective both are important: one provides many jobs now, the other the potential to create many jobs in the future.

New Industry, New Jobs (BIS, 2009) proposal for targeted intervention by Government to foster growth in key industries mentions the life sciences and pharmaceuticals sector as one which has significant potential for growth. As this report will highlight, Government through its funding of research and development in the higher education sector is already substantially involved in the bio-medical sector. More directly, the Office for Life Sciences within the Department for Business Innovation and Skills was established in January 2009 to provide targeted intervention to help the sector realise its potential. So the “new activism” that New Industry, New Jobs calls for is already extant, to some degree, through industry-higher education-health service collaborative relationships and a dedicated policy focus. Of course, this is all relative and in a competitive global market the key question is whether these relationships are as effective as those found in other countries.

This report is concerned with skills. Skills supply can be a constraint on output and employment growth where it is quantitatively or qualitatively mismatched with demand. There is evidence, though now somewhat dated, that a failure to invest in skills development over the economic cycle can result in future skills shortages which, in turn, can exacerbate future economic downturns (Hogarth and Wilson, 2002). Analysis by Cogent and SEMTA, which this study draws upon, has highlighted the characteristics of skill demand for the sector and the extent to which skill demand has been, and is likely to be, satisfied (Cogent, 2006, 2009; SEMTA, 2006). In a sector which is subject to relatively quick technological change, skills supply is always likely to lag behind skills demand hence the need to have as clear a view as possible of the emerging characteristics of skill demand. This report looks at the drivers of skill demand across the sector as a whole – from the ultra high-tech activities to more everyday ones - and the issues this raises for the supply side. As will become evident, the sector’s critical skill needs are multifaceted and range from doctoral level research scientists to intermediate level technicians.

1.2 Aims of the Study

The broad aims of the study are to:

i. develop an overview of the economic, social and technical drivers of change in the bio-medical sector with a demonstration of why the sector is so important to the economy;

ii. develop an in-depth analysis of global and national trends in skills and employment within the bio-medical sector; including skills insight and foresight and labour market impact. This will give consideration to the priority skills within the sector;

iii. consider future strategic challenges and trends for the sector, outlining possible alternative sector scenarios and implications and consider how they impact on the labour market and skills.

The specific questions the study addresses are listed below.

- How is the sector/sub-sector of interest defined?
- Why is the sector of particular economic importance?
- What are the current technological developments in the sector and how might these change in the future?
- What are the likely growth trends (of both output and employment) in the sector?
- What are the opportunities and risks associated with a particular growth sector?
- What are the current and future employment and skills implications of growth for the sector?
- Will change be quantitative (more/less of the same) or qualitative (i.e. see the emergence of new skills, the combination of skills sets, a new application of old skill sets, etc.?
- What is the spatial dimension to growth and skill needs: regional, national, European, global?
- What would be an appropriate response to the skills challenge in the chosen sector?

The study has been conducted through an analysis of various statistical sources, including the production of occupational employment projections derived from the Working Futures database, a literature review, and interviews with key stakeholders in the industry.

There are three elements to the study:

i. a review of the literature;

ii. a review of available statistics and economic forecasts for key elements of the bio-medical sector;

iii. a series of interviews with key stakeholders (see Appendix 1).

1.3 Defining the Sector

Defining the sector according to the Standard Industrial Classification (SIC) is not straightforward because the SIC is based on historically developed classifications and, at best, gives a partial coverage. The categories of the SIC which appear to be most relevant are:

24.4 Manufacture of pharmaceuticals, medicinal chemicals and botanical products

24.41 Manufacture of basic pharmaceutical products

24.42 Manufacture of pharmaceutical preparations

24.42/1 Manufacture of medicaments

24.42/2 Manufacture of non-medicaments

33 Manufacture of Medical, Precision and Optical Instruments, Watches and Clocks

33.1 Manufacture of medical and surgical equipment and orthopaedic appliances

33.10 Manufacture of medical and surgical equipment and orthopaedic appliances

For convenience the sector is referred to as the bio-medical sector. It refers to those employers and employees who are engaged in the production of goods and services which are inputs to the health system. The health system itself of course is also involved in the production of these goods and services but it is exceedingly difficult to measure this activity. Research also shows that many companies in the bio-medical sector involved in the production of medical technologies tend to be involved in various other manufacturing activities as well. Medical technologies or technologies, though a significant part of their output, are not their principal output and so they are not categorised as medical technology producers. Again this affects the measurement of the sector.

More conceptually the bio-medical sector can be defined as a combination of:

- Pharmaceuticals;
- Medical technologies; and
- Medical biotechnology.

Biotechnology refers to the use of biological systems, living organisms, to make or modify products and processes. Its application is not limited to the bio-medical sector given that it has uses throughout industry and consequently it is not readily identifiable in industrial classifications. From a conceptual perspective the sector is defined as pharmaceuticals plus medical technologies, and that part of the biotechnology sector concerned with medical applications. As the next chapter will reveal, while mutually exclusive statistical information is available for the pharmaceuticals and medical technologies sub-sectors this is not so for biotechnology. Data relating to medical biotechnology, where available, overlaps with pharmaceuticals and, to a lesser extent, with medical technologies such that there is a danger of double-counting.

As well as defining the sector according to the SIC, the sector can also be defined with reference to the technologies it uses. The areas of technology are set out in the International Patent Classification (IPC)[1], which broadly speaking fall under A61 (medical or veterinary science; hygiene).[2]

1.4 Overarching Approach to the Study

At a generic level, future skill needs are usually seen to be driven by:

- innovation and technological change;
- demographic change;
- environmental change;
- legislation / regulation;
- changing patterns of consumer demand;
- globalisation.

[1] http://www.wipo.int/classifications/ipc/ipc8/?lang=en.

[2] This includes a wide range of sub-classes from high technology areas (e.g. various parts of A61B, diagnosis; surgery; identification) to areas of relatively low technology (e.g. various parts of A61K, preparations for medical, dental, or toilet purposes)

In many respects the principal driver is innovation and technological change. The industry is primarily concerned with problem solving – essentially how to stop people becoming ill or incapacitated and, if they are unfortunate enough to be so, to make them well again. The levels of R&D expenditure in the sector are large by comparison with many other industries and the degree of technological and scientific progress over the past half century or so has been rapid. Whilst demographic change, environmental change, and so forth are challenges which the industry needs to address, it is through the development of new products and processes that these challenges will turn into opportunities. Hence a considerable part of this report is given over to assessing the level of technological progress and how that might be optimised over the medium term.

Skill requirements, both strategic and tactical, stem from both the need to innovate and from the consequences of those innovations being introduced into the health system. The study is not solely concerned with the latest, large-scale scientific and technological advances, such as stem cell research or new genetic therapies, but also a range of more commonplace developments which have the capacity to both aid well being and increase economic output and employment. In the medical technologies sub-sector, for instance, there are many incremental technological advances which have considerable potential albeit in a less headline grabbing fashion.

1.5 Structure of the Report

The structure of the report is as follows. Chapter 2 provides an indication of the sector's scale in England and its importance to the economy. Chapter 3 summarises the drivers of change.

Technological change is the principal driver of change in the sector and the emerging technological trends reflected in patenting activity, and their potential to affect skill levels, are outlined in Chapters 4.

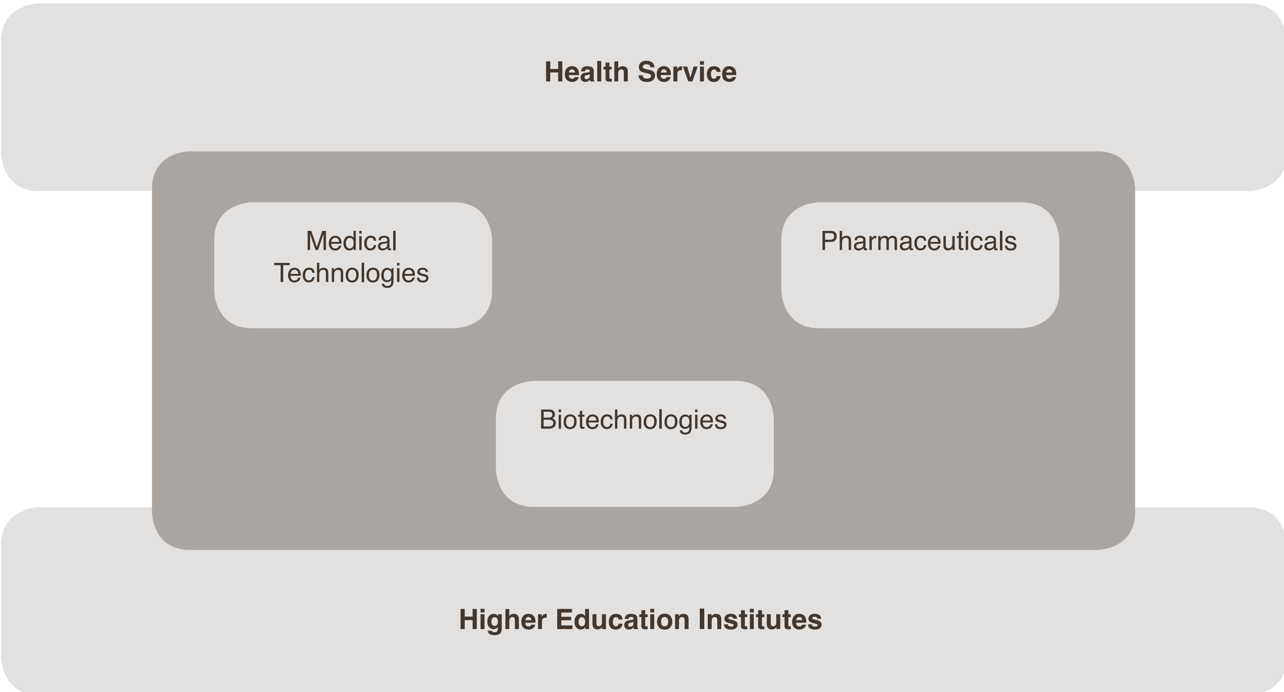
Chapter 5 provides an assessment of future skill demand generally based on Working Futures data but also other assessments which provide a more detailed breakdown of skill needs. Chapter 6 considers the skills supply side and the factors which might be giving rise to reports of shortages for key skills. In Chapter 7, the importance of clustering and networking is considered. Finally Chapter 8 provides a conclusion and highlights some of the issues germane to the skills policy debate.

2 The Importance of the Sector: Output and Employment

2.1 The Structure of the Sector

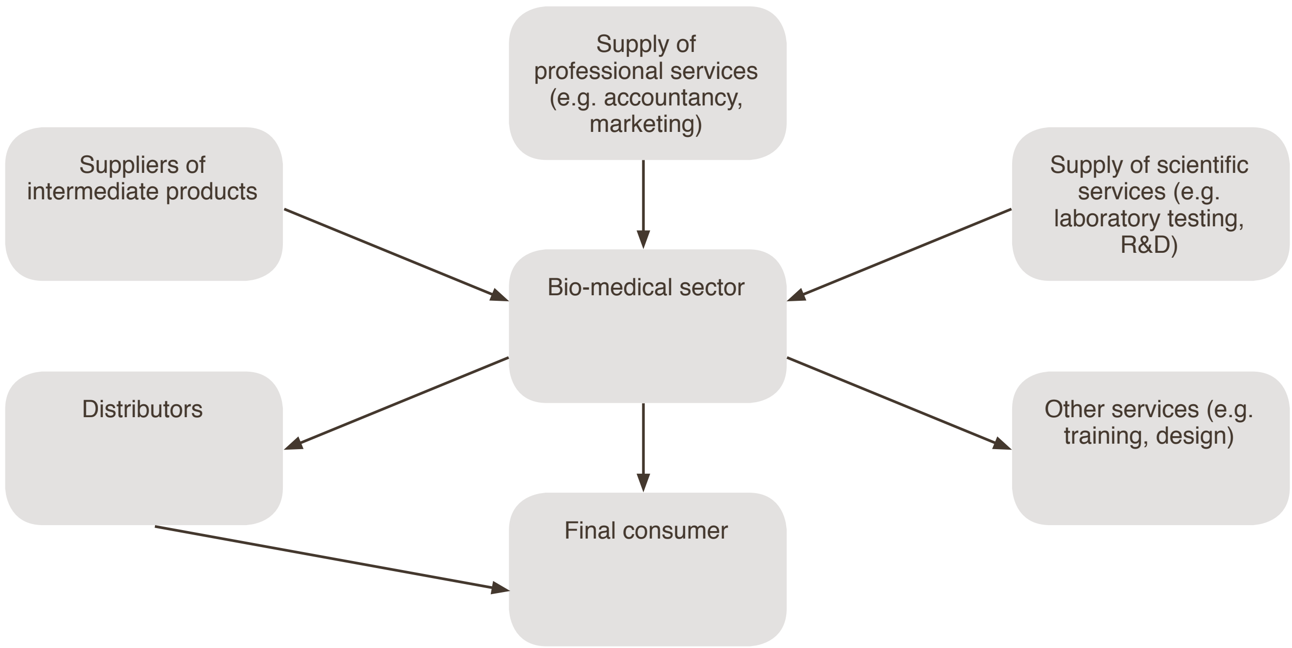
Chapter 1 provided a brief description of the sector based on SIC and patent classifications. In practice, the structure of the sector is much more complex than these classifications indicate. In general, the sector as a whole overlaps with the health service (mainly the NHS) and higher education institutions (see Figure 2.1). The NHS in many respects is the main consumer of the outputs of the bio-medical sector, but it is also engaged in the development of new products and processes. Higher education institutions (HEIs) are also an important part of the sector in that they are engaged in the development of many new products and processes, sometimes in partnership but also on a sole basis. The health service and HEIs are also competitors for skills in the sector.

Figure 2.1 Schematic Structure of the Bio-medical Sector



The study is concerned very much with the sector as defined at the core of Figure 2.1. It needs, however, to be recognised that there are important forward and backward linkages to be considered. These can be important in employment terms; for example, the supply of intermediate goods for inclusion in the production of pharmaceuticals and medical technologies. The forward and backward linkages are set out in Figure 2.2 simply to clarify the importance of the sector to other areas of activity in the economy.

Figure 2.2 Forward and Backward Linkages to the Bio-medical Sector

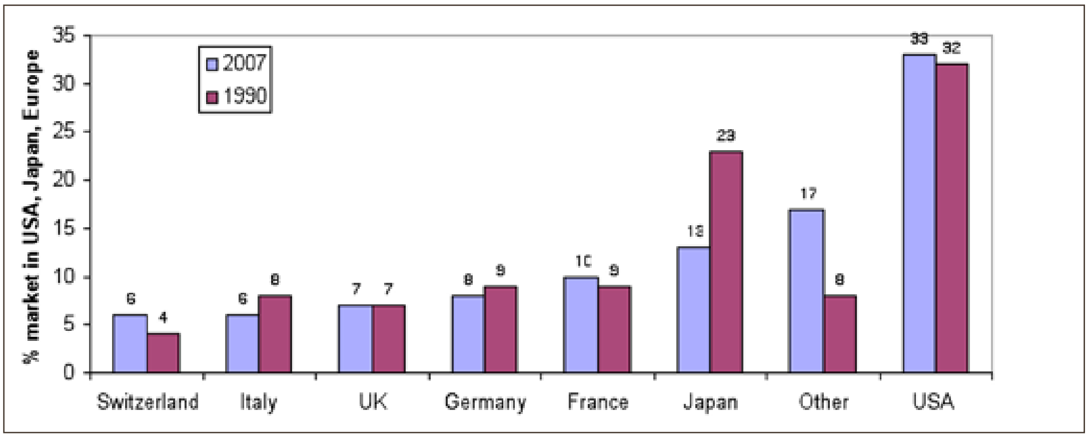


2.2 The World Market

Statistical evidence is unable to fully capture the scale of activity of the sector as outlined in either Figure 2.1 or 2.2 above. Instead there is a need to make-do with estimates produced for the pharmaceutical and medical technology sectors respectively. Based on this evidence the market for bio-medical products is large.

Vfa estimates that in 2007 the output of pharmaceutical producers in the USA, Japan, and Europe amounted to Euro 352 billion (Vfa, 2009). US producers accounted for a third of output (33 per cent) and the UK (7 per cent). Over time there is relatively little change in the share of the market held by the major producers except for the decline in the share accounted for by Japan (see Figure 2.3). Vfa notes that over time medium-sized European countries such as Ireland, Austria, Belgium and Switzerland have been able to expand the volume of their pharmaceutical production (Vfa, 2009). The implication of Figure 2.3 is that the UK has been able to maintain its share of the pharmaceutical market.

Figure 2.3 Share of Production in USA, Japan, and Europe, 1990 and 2007



Source: OECD, EFPIA, Pharmaceutical associations of the European countries, vfa; http://www.vfa.de/en/statistics/economy/

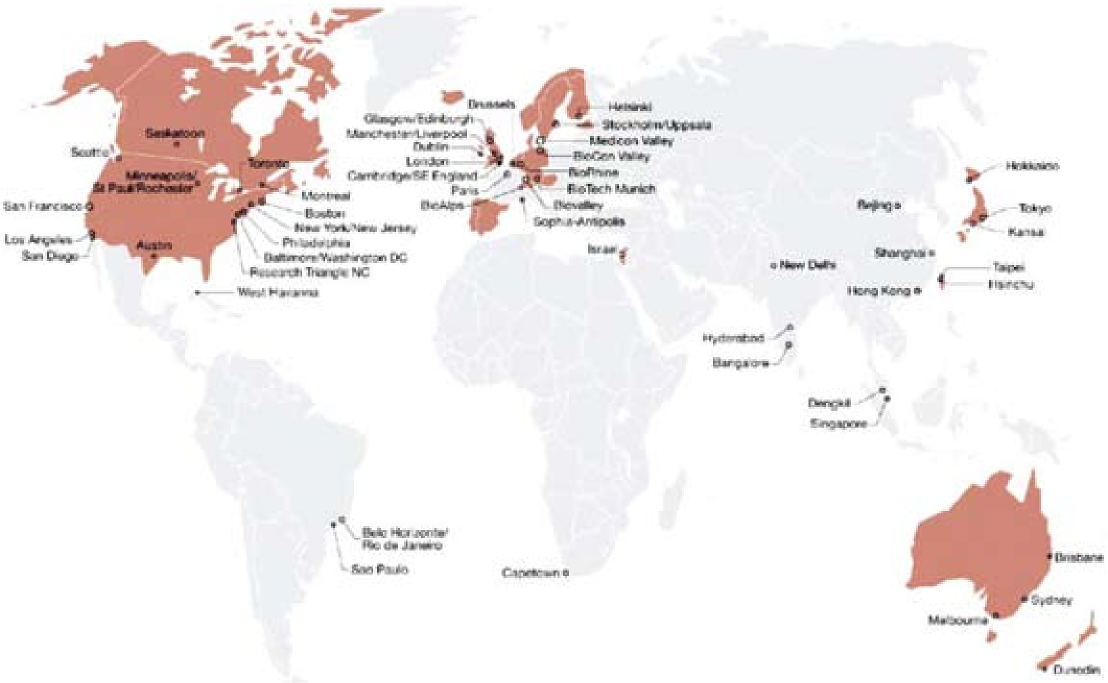
Estimates of the size of the medical technologies market are more difficult to obtain. In 2004, the world market was estimated to be worth $169 billion (approximately £260 billion) with USA producers accounting for 43 per cent of the market, the EU 21 per cent, and Japan 15 per cent (AdvaMed, 2004). More recent data suggests that the medical technologies market is estimated to be worth £150-170bn worldwide with growth rates forecast at 10 per cent a year over the next five to six years, such that the market size will be worth a projected £300bn by 2015 (BIS/UKTI/DoH, 2009). The US market is the largest at an estimated £70bn.

Growth in global demand for medical technologies is expected to be buoyant over the medium term as a consequence of demographic change and the emergence of increased demand from developing economies in, for example, Brazil, India, and China. This is discussed in more detail below. What is less clear at this point is the extent to which existing producers in the West will need to develop production facilities in markets they are serving, rather than relying upon exports, the nature of the production agreements they might develop with indigenous producers, and the extent to which they will be pressed into lowering prices (Hodson et al., 2008; Deloittes, 2009). These developments seem inevitable; it is scale of these developments which is of interest, not whether they take place.

The latest Government report on the medical biotechnology sector indicates that the global medical biotechnology market is worth around £45-48bn, and experienced growth rates of more than 20 per cent a year between 2002 and 2007 which, the report notes, is more than double the rate for the pharmaceutical market. The USA is estimated to account for around two thirds of the market (65 per cent of all sales) (BIS/UKTI/DoH, 2009).

Because at least part of the sector has been identified as being capable of generating relatively high levels of output and employment growth over the medium-term, it has created intense competition from countries around the world which are all keen to steal a lead in developing a critical mass of activity. Map 2.1, below, reveals where the critical mass of activity is currently in the biotechnology sub sector. As can be identified from the map, there are few major industrial countries which have not developed a cluster of biotechnology activity, typically based around company – HEI collaboration and partnership. It is also apparent that the UK, especially England, is well represented.

Map 2.1 Clusters of Activity in Biotechnology



Source: Rinaldi (2006) p. 135

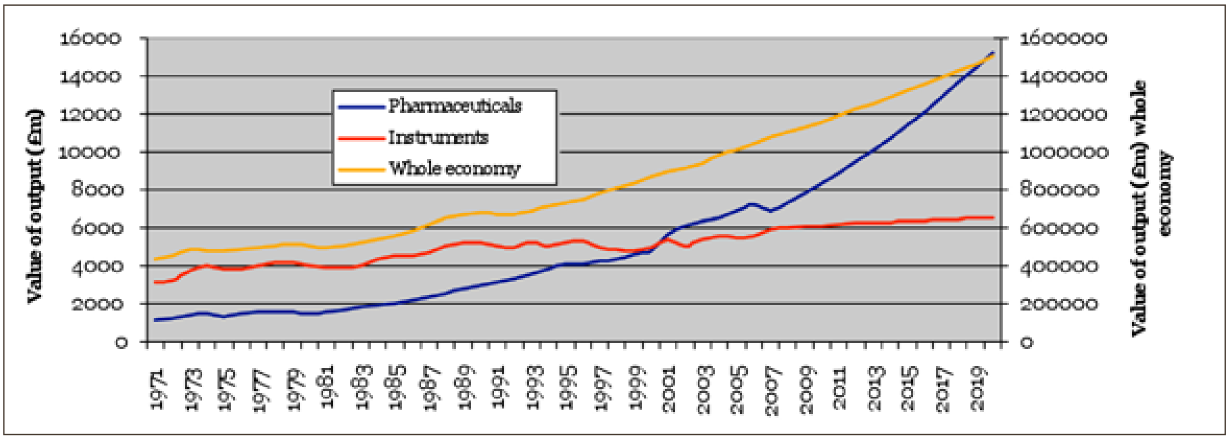
Note: Countries coloured in brown rank highly in the Growth Competitiveness Index 2004–2005, World Economic Forum. Black circles represent selected biotechnology and life-sciences clusters

2.3 Output in the UK

The evidence suggests that the UK is one of the leading producers of bio-medical goods and services in the world. This is especially so in pharmaceuticals and biotechnology. In the latter (biotechnology) – though not all of this is medical related – the UK would appear to have the largest number of employees in Europe, and the second largest number of companies behind Germany (Critical I, 2006a).

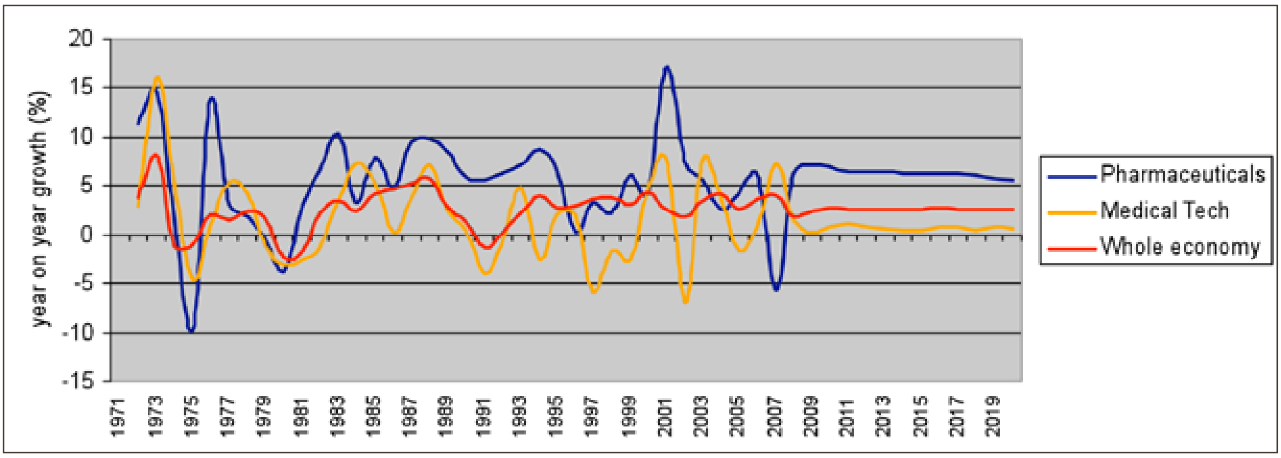
The value of output in the bio-medical sector is difficult to measure for a number of reasons relating to how the sector is defined. Based on measures of output for the pharmaceuticals sector, and an estimate of the output from the instrument engineering sector attributable to medical technologies, an approximate estimate of the value of output is £15,235 millions (2005 constant prices) – approximately 1 per cent of total output (Cambridge Econometrics, 2009). The trend in output is provided in Figures 2.4a and 4.2b and reveals a relatively strong output growth, especially in pharmaceuticals, although output trends in this part of the industry are subject to a degree of fluctuation.

Figure 2.4a Output Trends in the Bio-Medical Sector in the UK, 1971-2020



Source: Cambridge Econometrics Database; own calculations

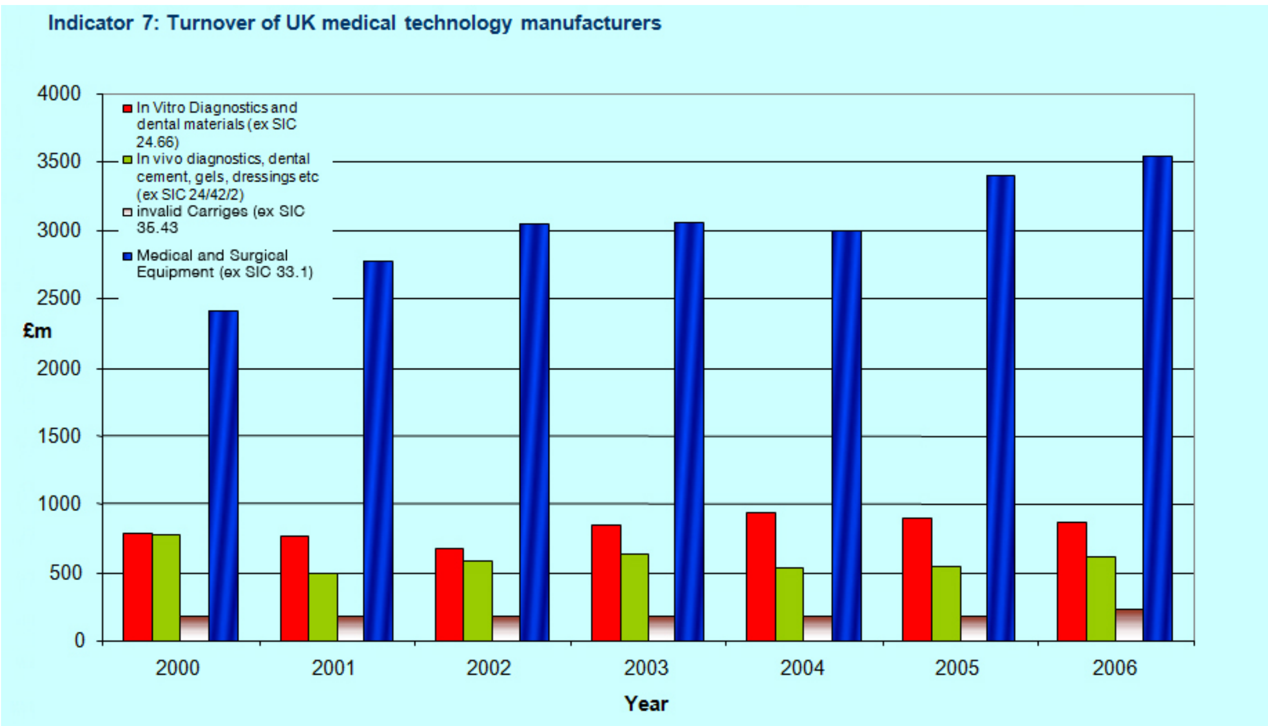
Figure 2.4b Output Trends in the Bio-Medical Sector in the UK, 1971-2020 (annual percentage growth)



Source: Cambridge Econometrics Database; own calculations

The Medical Technologies Metrics series published by BERR (now part of BIS) provides a precise estimate of the value of output from the medical technologies sector (BERR, 2008a). This suggests the sales turnover of UK manufacturers was around £5,000m in 2006 (see Figure 2.5). The total market in the UK has an estimated value of £8,000m. The data for 2006, also suggests that the value of exports (£4,528m) exceeded those of imports (£4,395m), but these data also highlight relatively high levels of trade between the UK and abroad.

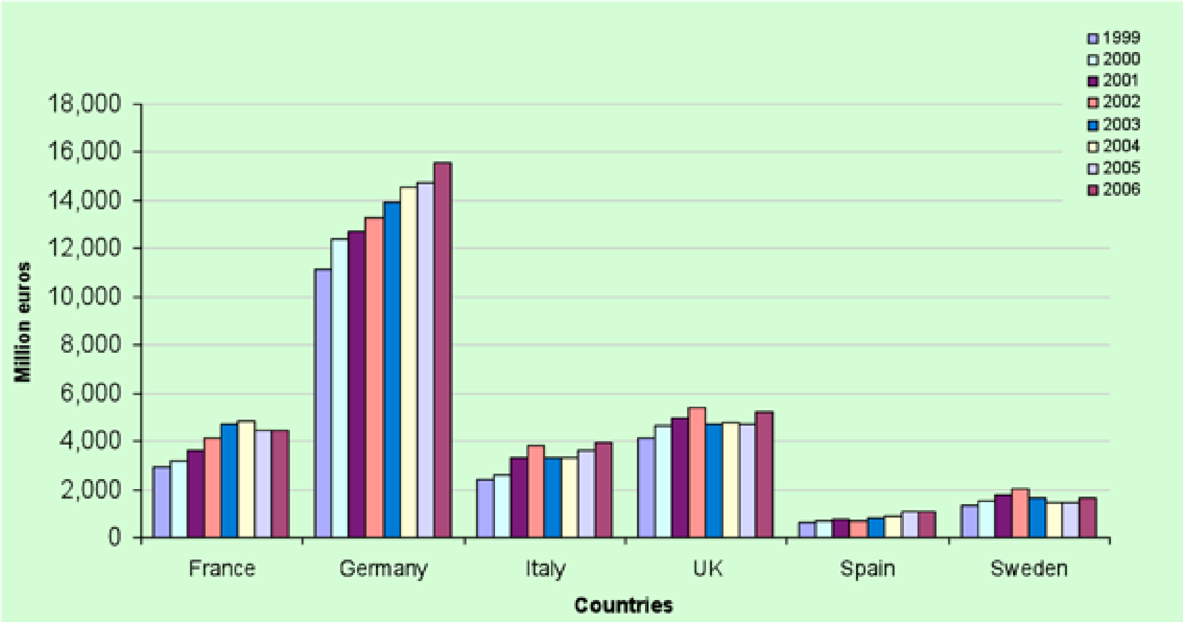
Figure 2.5 Sales Turnover of UK Medical Technology Manufacturers



Source: BERR Medical Technology Metrics Table 7, BERR, 2008a

The data provided by the BERR database also indicates that UK production of medical technologies is relatively small compared to that in Germany (see Figure 2.6).

Figure 2.6 Production of Medical technologies in the EU,1999-2006



Source: BERR, 2008a, Indicator 17 derived from Europrom data

2.4 R&D Expenditure

The R&D Scorecard produced by BIS demonstrates that the pharmaceutical and biotechnology sector is the largest investor in R&D in the UK. A number of stylised facts reveal how significant the sector's contribution is to innovation in the UK (BERR, 2008b, p.26):

- the pharmaceuticals and biotechnology sector was the largest contributor to R&D in both the top 850 and the top 1400 UK companies in 2007;

- pharmaceuticals and biotechnology companies accounted for 37 per cent of the R&D spend of the top 850 companies;

- eight of the top 25 R&D investors globally are pharmaceuticals companies: they include two firms with major UK based facilities, GlaxoSmithKline and Astra Zeneca;

- GlaxoSmithKline and AstraZeneca dominate R&D spend in the UK pharmaceuticals sector. They spent 89 per cent of the sector total, and 37 per cent of the UK850 spend;

- R&D in the pharmaceuticals and biotechnology industry continues to grow more quickly than sales amongst the largest investors.

To some extent the figures above relate to the scale of the companies in the pharmaceuticals sector, but the R&D Scorecard also reveals that on measures of R&D activity, such as the ratio of R&D expenditure to sales, pharmaceutical and biotechnology companies stand out. Eleven out of the top fifteen companies ranked by the ratio of sales to R&D expenditure are involved in the production of pharmaceuticals or health care equipment (see Table 2.1).

Table 2.1 Companies with the highest ratio of R&D expenditure to sales (2007)

Company	R&D as a proportion of sales (%)	R&D (£m)	Growth in R&D over last year (%)	Sector
Solexa (now Illumina Cambridge)*	1,768	14.8	60.8	Health care equipment & services
Ark Therapeutics	1,301	14.6	12.4	Pharmaceuticals & biotechnology
CeNeS Pharmaceuticals (now part of Paion, Germany)	1,081	5.9	-19.6	Pharmaceuticals & biotechnology
Paradigm Therapeutics (not Takeda Cambridge) (now part of Takeda Pharmaceutical, Japan)*	697	7.1	24.9	Pharmaceuticals & biotechnology
Lombard Medical Technologies	632	6.4	33.1	Health care equipment & services
MediGene*	591	4.3	-17.9	Pharmaceuticals & biotechnology
ClearSpeed Technology	524	6.4	5.7	Technology hardware & equipment
Celtic Pharma Development*	503	10.1	131.3	Pharmaceuticals & biotechnology
Sosei R&D*	460	13.2	27.9	Pharmaceuticals & biotechnology
Oxford Biomedica	307	22.1	13.4	Pharmaceuticals & biotechnology
TIBCO Software*	303	2.9	209.2	Software & computer services
Osmetech	295	2.8	-50.9	Pharmaceuticals & biotechnology
Antonov	293	2.3	90.0	Automobiles & parts
Summit	277	8.4	186.2	Pharmaceuticals & biotechnology
Acambis	266	25.3	-31.6	Pharmaceuticals & biotechnology

Note: * - foreign owned firm
Source: BERR 2008b, Table 8, p.31

UKTI estimates that UK companies account for 40 per cent of all products in the pipeline by European public companies, and goes on to say: “ The country’s success in life sciences – with UK companies accounting for 45 per cent of new biotechnology drugs in late-stage clinical trials in Europe – is driven by its rich pool of talent and skills. Its world-class scientific institutions, impressive research base and track record in product development continue to attract and retain healthcare innovators.”[3]

Strategically, the evidence base suggests that the UK is well placed to capture future gains in the medical biosciences field, because:

- there is relatively little regulation governing genetic research compared to other countries (e.g. stem cell research);
- a strong R&D base in both companies and higher education; and
- a centralised healthcare system (the NHS).

In contrast to the pharmaceutical and biotechnology sector, R&D expenditure in the medical equipment sector is estimated to be around £150m (2007) (BERR, 2008a).

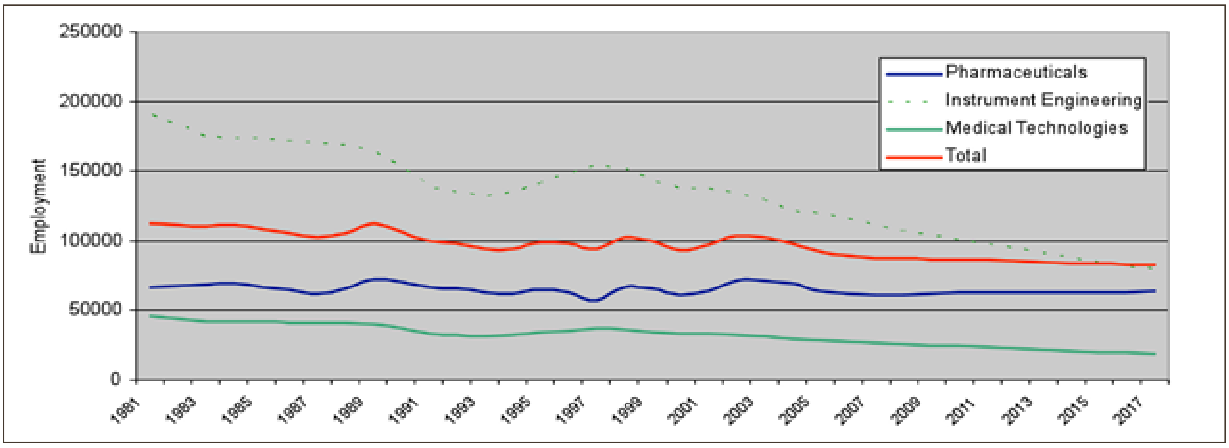
2.5 Overall Employment Levels

In the UK, the pharmaceutical industry employs around 73,000 people many in high level occupations.[4] BIS/UKTI/DoH (2009) estimates that around 24,000 people are employed in the medical biotechnology sub-sector in the UK, but it is likely that many of these people are already accounted for in the pharmaceutical sector’s employment total. The medical technologies sector is also an important source of employment. The ABI estimates that around 40,000 people are employed in the sector in the UK, but the Labour Force Survey estimates that around 60,000 are employed reflecting the fact that companies engaged in manufacturing medical technologies sometimes do so as a secondary or tertiary activity. Hence people may be working full-time on medical applications but the principal activity of their employer is classified as something else. In its latest report, the Government estimates that 52,000 people are employed in the sector in the UK (BIS/UKTI/DoH, 2009). The overall trend in UK employment, based on a time-series derived from the Working Futures database, is presented in Figure 2.7. The latest estimate for the UK would suggest that around 130,000 people are employed in the UK.

The Working Futures database suggests that around 92,000 people are employed in the bio-medical sector in the UK. This may slightly under-estimate the number of people employed because of the difficulties associated with measuring employment in medical technologies (see above). An upper-estimate, based on the data cited by BIS (see above), suggests around 130,000 people employed in the sector in the UK. If one were to take a mid-point between the two estimates this would indicate employment of around 110,000.

[3] http://www.ukinvest.gov.uk/UKTI-publications/4046341/en-GB.html (accessed October 2009)
[4] http://www.berr.gov.uk/whatwedo/sectors/biotech/pharmaceutical/page10219.html

Figure 2.7 Employment Trends in the Bio-medical sector in the UK, 1971-2020



Source: Cambridge Econometrics Database; own calculations

Employment in the sector is divided between a limited number of large multinational corporations and a large number of small organisations. In general, the larger employers have sought to manage risk and cost containment by outsourcing key activities often to smaller organisations. In certain segments of the market, small employers are numerous because they represent spin-off companies seeking to develop new products. This can also mean that the population of employers can be volatile with a large number of new entrants and exits each year (Critical I, 2006a and 2006b). In addition, until relatively recently when the economic downturn commenced, there was a high level of merger and acquisition activity, with key large players taking over small ones when they were near to bringing a product to market.

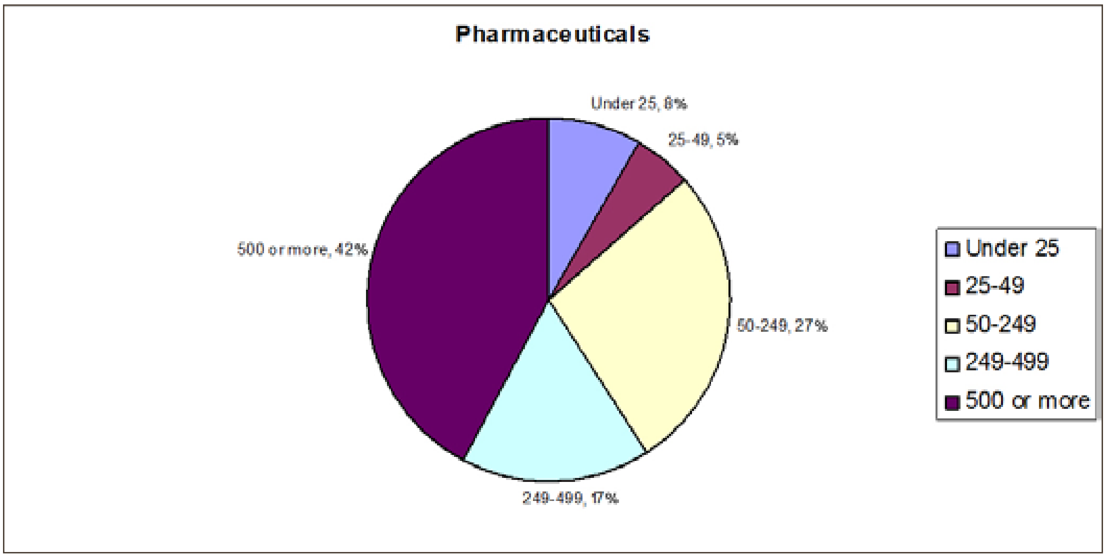
In sub-sectors such as medical technologies the structure of the market appears skewed towards medium sized companies (34 per cent of all employment in medical technologies was in companies with 50-249 employees), and 31 per cent with more than 250 employees (BERR, 2008). Other data suggests that 47 per cent of companies in medical technologies have between 0 and 4 employees and 6 per cent more than 100 (BIS/UKTI/DoH, 2009). As previously mentioned, estimates of the size of medical technologies sector need to be treated with some caution because many companies significantly engaged in the sector are not necessarily classified as medical technology companies where their principal product relates to another good or service. The LFS, because it asks people about the main activity of their employer which people will tend to answer with respect to the activities they are involved in, surmounts this problem to a degree. Based on LFS data for England it is possible to look at the extent to which employment is accounted for by organizations of different sizes, and the regional distribution of employment.

The size structure of the market varies by sub-sector and size (see Figure 2.8) with smaller workplaces accounting for a larger percentage of employment in the medical technologies sub-sector. The size structure of the sector is important. As will be highlighted later, commentators have mentioned that smaller firms often lack access to venture capital, and the practical know-how needed to bring a product to market, or navigate the procurement regulations which govern the health service. Moreover, from a training and skills development perspective, smaller employers often face a unique set of problems (Edwards, 2009; Hogarth et al., 2009; Bosworth, 2009).

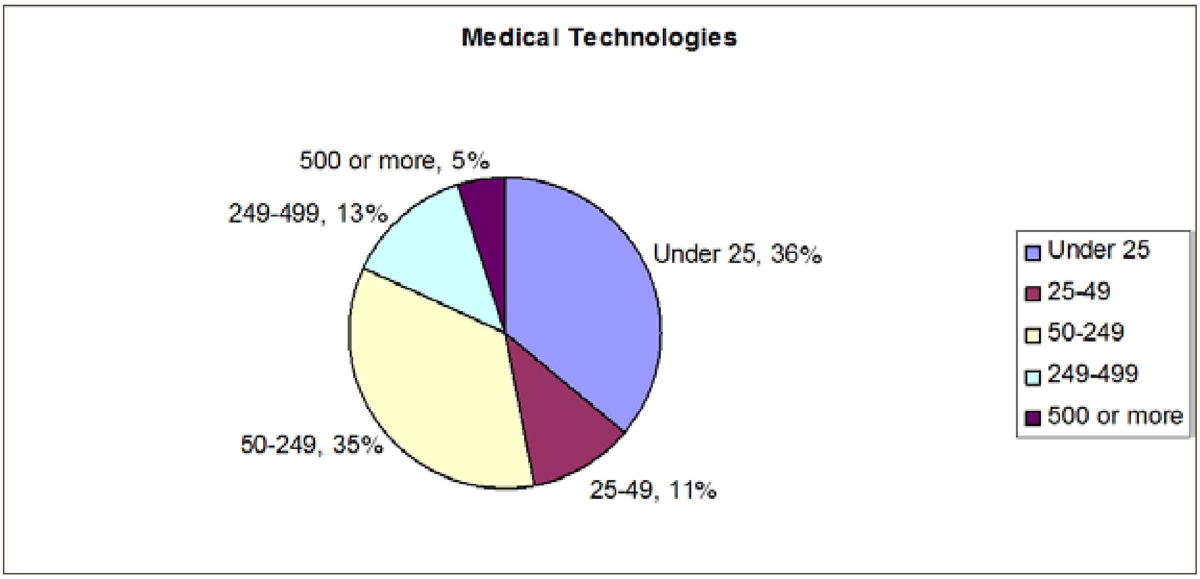
In contrast to the medical technologies sector, in the pharmaceutical industry employment is concentrated in large companies. The UK is the home of some of the largest pharmaceutical companies in the world such as Astra Zeneca and GlaxoSmithKline. Though many of the large pharmaceutical companies are also involved in medical biotechnology, where firms are wholly engaged in this activity they tend to be small. The medical biotechnology sub-sector is comprised mainly of SMEs with 99 per cent of companies having less than 249 employees (BIS / UKTI / DoH, 2009). Indeed, the evidence suggests that 42 per cent of companies have been 0 and 4 employees in this sub-sector, and only 4 per cent had more than 100 employees. As noted above, the medical biotechnology sector is characterised by a large number of small enterprises, which have been in existence for only a few years which have the aim of capitalising upon an idea or innovation.

Figure 2.8 Percentage of Employment by Size of Workplace in England, 2009

(a) Pharmaceuticals



(b) Medical technologies

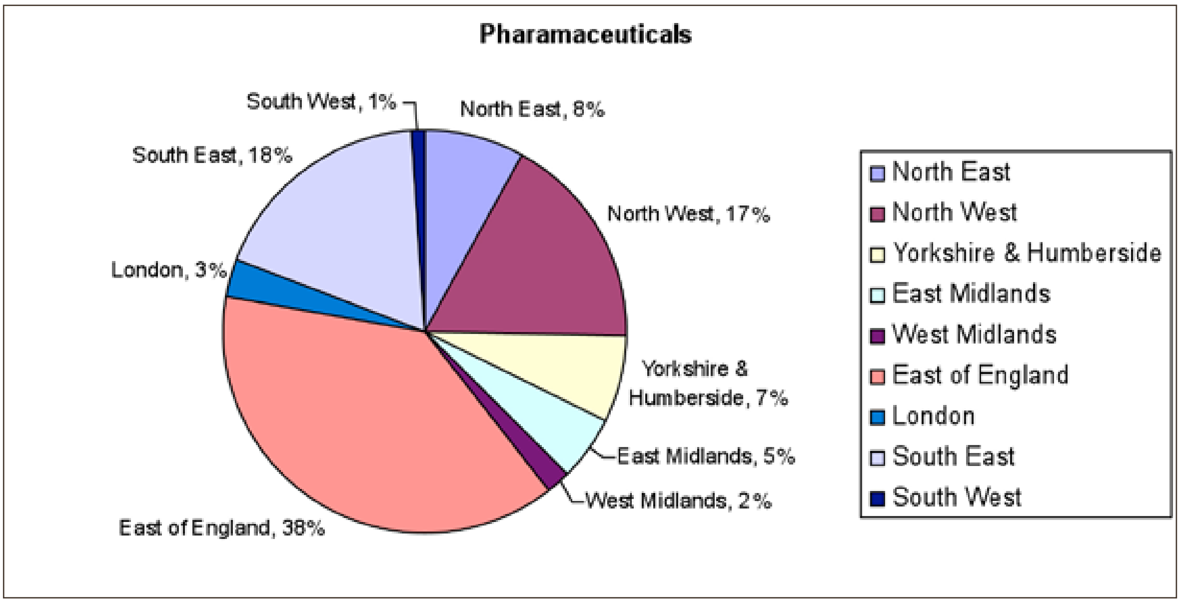


Source: Labour Force Survey; own calculations

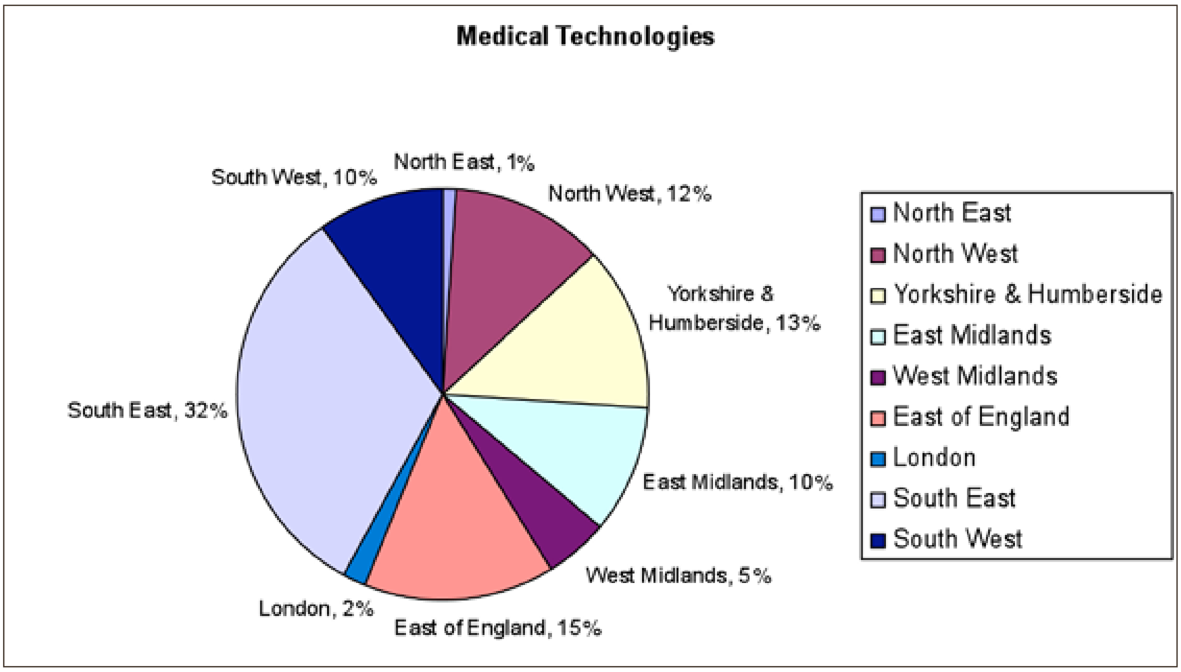
There is a significant concentration of employment in the East of England in relation to pharmaceuticals (38 per cent of all employment in England), followed by the South East (18 per cent) and North West (17 per cent) – see Figure 2.9. In relation to medical biotechnology, the South East and East of England are the main areas for employment (BIS/UKTI/DoH, 2009). In medical technologies, the South East region accounts for around a third of all employment in England (32 per cent). There does appear to be significant agglomerations of activity not just in England (especially so around Cambridge, the Thames Valley west of London, and the North West), but also across the US and Europe. The evidence suggests that companies' location decisions may be determined by the existing presence of similar types of company (Deloittes, 2009; Rinaldi, 2007).

Figure 2.9 Percentage of Employment by Region, 2009

(a) Pharmaceuticals



(b) Medical technologies



Source: Labour Force Survey; own calculations

2.6 Conclusion

The brief summary provided above indicates that the Bio-medical sector is important to the UK economy with respect to levels of output, employment, and R&D. In the UK it is estimated to employ between 92,000 and 130,000 people directly. A mid-point estimate suggests employment of around 110,000. Its strategic importance, perhaps, lies in the likely development of new products and processes over the medium term – reflected in the relatively high levels of R&D expenditure – which have the capacity to generate a large volume of employment. As the next chapter will indicate, there is a degree of uncertainty over where those jobs will be created, especially those related to manufacturing.

3 Factors Driving Change

3.1 Drivers of Change

The bio-medical market is undergoing a period of major change including:

- the shift from chemical to biological based pharmaceuticals;
- the greater use of biomaterials;
- a decrease in the ratio of new products coming to market relative to investments in R&D;
- a slowdown in product development due to the economic slowdown;
- pressures to reduce costs and lower prices especially for pharmaceuticals;
- increased use of outsourcing and networked solutions in production in an effort to increase efficiency;
- a shift in emphasis towards the invention of preventive therapies and treatments to aid well being;
- the potential to integrate technologies and drug treatments to reduce in-hospital care.

The general view is that the pharmaceutical and medical technologies sectors have suffered less than some other sectors during the current economic downturn, but have not been wholly immune to its effects on output and employment. Indeed, the pharmaceuticals sector across the world appears to have been barely affected by previous recessions (Vfa, 2009). But as the following discussion will demonstrate there are significant drivers of change in the sector which will have consequences for levels of employment and skills demand.

The principal drivers of employment change in the sector are:

- technology;
- innovation and R&D;
- health expenditure / public sector spending constraints;
- demographic change;
- regulation;

- sustainability;
- corporate strategic choice and globalisation.

How these are affecting the industry is explored in the remainder of this chapter.

3.2 Technology and Innovation

The study has identified a number of technological changes both in products and processes. From a product perspective these can be largely categorised into those summarised in Table 3.1.

Specific and current examples of these changes and innovations have been mentioned by respondents in interviews or picked up in the literature and information searches. Some of these that relate to change in the sector as a whole are commented on below and those with a specific link into the West Midlands are commented on in the case study section.

There is a long way to go, but there is increasing recognition of the benefits and advantages of using the human's own systems (as in stem cell processes) or other "natural" substances and processes in a bacteriological or other biologically based system to produce compounds and structures rather than a chemically based manufacturing process. In many instances there is a better chance of bio compatibility with the human body and reduced risk of adverse reaction or rejection - apart from the economics involved.

A much improved understanding of genetics is leading to a raft of new processes including the possibility of genetic modification to avoid predispositions to disease as well as the possibility of customised solutions to particular conditions. There are major ethical considerations in this whole area of research and therapy development and these may well slow or change progress considerably but potentially such approaches could lead to a major shift in the way that we address diseases and their transmissions. The convergence of biological, chemical, genetic, computational, medical and related healthcare sciences is leading to the growth of multi disciplinary groups including "life science" faculties in the HE sector including England. This carries a number of implications at the strategic skills level in R&D in the public and private sectors and will flow over into senior management and personnel in the sector's leading corporations and collaborating companies. At a process level, there will be a range of regulatory and training issues but largely a requirement for adaptation.

Table 3.1 Technology Drivers

Technology	Pharmaceutical (P) or Medical Device (MD)	Description
Bio-pharmaceuticals	P	The use of biological rather than chemical agents in drug treatments
Personalised medicine (i.e. medicines which are designed to take into account the individual’s genetic code)	P	Personalised medicine focused on using individuals’ genomic information and other personal traits to inform decisions about their health care
Regenerative / predictive / preventative medicines	P	Testing which can identify ailments which are likely to emerge, treatments to offset those ailments (e.g. via personalised medicines), or to regenerate decaying tissues
Bioinformatics	P	The combination of information technology with biotechnologies, the capacity to store information in digital format, model or simulate biological processes
Biological devices	P / MD	The medical technologies which are at the interface with the development of biological & pharmaceutical therapies
Implantable devices / biomaterials	MD	Implants which are designed to remain in the body after a procedure (e.g. pacemakers, cochlear implants, etc.)
External devices	MD	Including surgical equipment, orthopaedic supports & therapy related devices
Diagnostic devices	MD	The diagnosis of disease through a range of sensors to detect physical and functional abnormalities
Informatics	MD	Increasing the use of wireless technology to provide data & its analysis, remotely, for clinicians
Nanotechnology	MD	The miniaturisation of components and devices, especially for implants, invasive procedures & “lab on a chip” technologies
Imaging	MD	Composite imaging from MRI, CT, ultrasound and other techniques to show soft & hard tissues as well as brain responses to stimulation

In looking at the drivers, there are both long and short-term demands made upon the sector. Short-term demands include the capacity to react quickly to issues such as swine flu which has been a huge learning opportunity for the whole healthcare sector from statistical prediction of pandemic evolution and spread in a highly mobile modern society to the time scales available to develop and produce politically acceptable and equitable supplies of pharmaceuticals, to the possibilities and effectiveness of infection controls – not to mention the health economics involved. Each of these areas carry implications for the availability and volume of skills required and while the swine flu situation cannot be regarded as over yet, there is enough data to recognise how difficult it is, and will be, for any stable economic structure to ever cope with that degree of fluctuation in demands, expectations or delivery of skills.

There are also longer term demands such as the need to be more effective with a range of relatively common diseases, including treating long-standing problems related to increasingly difficult infections such as MRSA, C-Difficile, etc. Treatment of long-standing problems or infections is giving rise to a number of practical innovations, such as using UV light to kill airborne pathogens such as these, push plate door surface materials, and door handles being coated to limit or prevent infection transfer and cross infection. These solutions prompt the potential of a much better understanding of biological / material interfaces to assist with the limitation and prevention of spreading disease.

There are new imaging techniques including proton and heavy ion devices which will improve the ability to image nerves and soft tissues. Such techniques are expensive at present but are expected to come down in cost as laser and other acceleration techniques improve. Whilst the development of the machines themselves has tended to focus on big companies in the USA and Germany, there is significant research activity in England on image analysis techniques and processing software. New ultrasonic developments are also providing better imaging techniques for nerves and the surrounding tissues.

Better imaging and understanding of soft tissues and neural pathways is also going hand in hand with new approaches to regenerative techniques and physio therapies. For the first time it is becoming more practical to provide feedback of results from nerve regeneration concepts. Apart from traumatic conditions, it is equally becoming easier to map the physical manifestation of mental stress and depressive disorders which affect significant proportions of the population.

It is making increasing sense for psychoanalysts and psychiatrists to work much more closely with medical engineers in such fields but there is an expectation that there will be a large gap opening up between the demand for such skills and their availability. This links closely with English University & NHS project groups working with these imaging techniques and also with NHS PCT based pathfinder programmes to increase the number of competent mental health staff to work alongside an increase in access to Computer Based Cognitive Therapies.

Regenerative medicine and healthcare techniques are on the brink of major change, closely linked to stem cell and genetic research. There is every expectation that within the next few years it will be possible for women to re-grow their own breast after surgical removal of cancerous tissue.

Whilst such regenerative technologies and genetic techniques are opening up new horizons for healthcare, they are also opening up minefields of ethical considerations which may well slow their adoption. Insurance companies, for example, would dearly like to know the genetic disposition and susceptibility of their clients to differentiate insurance risks and to limit access to insurance by poor prospect clients.

Telemedicine and healthcare support in a domestic or care home environment is becoming increasingly prominent with more and more sensor and monitoring devices coming on to the market. The explosion of such devices also links closely to the use of less invasive technologies as well as the use of technologies and techniques that are more robust in untrained hands – promoting private consumer purchase as much as purchase by professional practices. Devices include stand alone ECG, blood pressure and monitors of other vital signs but they also include the development of intelligent clothing items for longer term wear. In less than 18 months in the UK, for example, there has been the spread and availability of “DIY” defibrillators into many public buildings and other strategic locations.

The concept for many of these sensory devices is that they will link into the Primary Care structure in England with the General Practitioner as a key focal point for monitoring what is happening as far as the patient and their healthcare are concerned. This presents major skills issues for PCT structures which are not geared up to provide Continuing Professional Development in relation to such technologies and there is already a shortfall of technicians to provide support.

The trend to miniaturisation continues, both from the point of view of less invasive procedures and from the point of view of smaller, lighter and more portable devices.

By the end of this year there is an expectation that cancer will have replaced cardiovascular disease as the main disease related cause of death throughout the world. During 2010 it is estimated that 12 million new instances of neoplastic disease will occur throughout the world and that 7 million people will die from a malignant tumour according to the World Health Organisation Institute for Cancer Research.

The technological breakthroughs which are being made – as evidenced in the next chapter on patent activity – are taking place to differing degrees. For example, while blue-skies research is making advances in stem-cell research this is yet to materialise in major products being brought to market, while in the medical technologies sector more incremental changes are materialising which has resulted in new applications and products being developed. To some extent, the technological challenge facing the pharmaceutical sector is a formidable one. Many existing, high earning medications are nearing the end of the patents which will allow in generic manufacturers; at the same time, though pharmaceutical R&D expenditure is increasing, proportionately fewer new products are coming to market (ABPI, 2008). In other words, new products require higher expenditure on R&D.

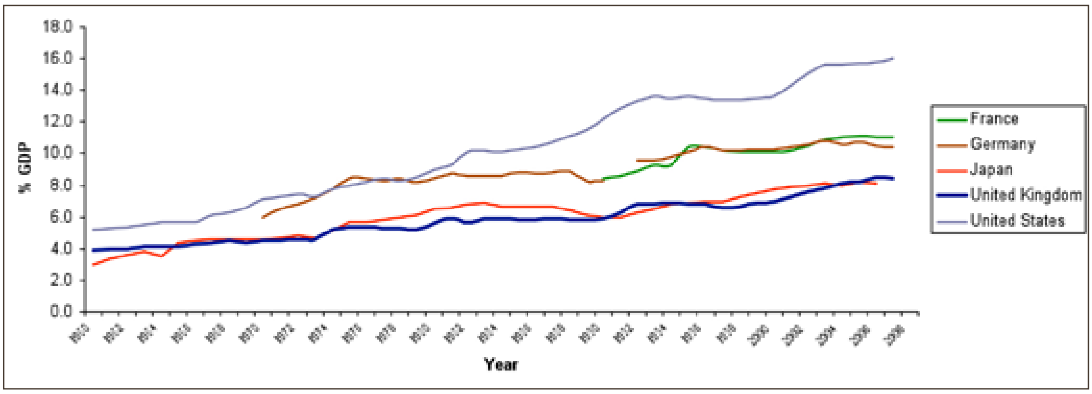
It is not just physical health which can be assisted through the use of medical technologies. Treating psychological distress can also be assisted through the development of suitable suites of software to deliver self-help programmes which may have the potential to avoid people requiring drug treatments.

Serious Games techniques are particularly appropriate in the case of Cognitive Behaviour Therapies (CBT) and are likely to play a much more important role in a range of depression and other mental health problems in the future. Hence there is a direct linkage to the software services sector.

3.2 Health Expenditure Public Sector Spending Constraints

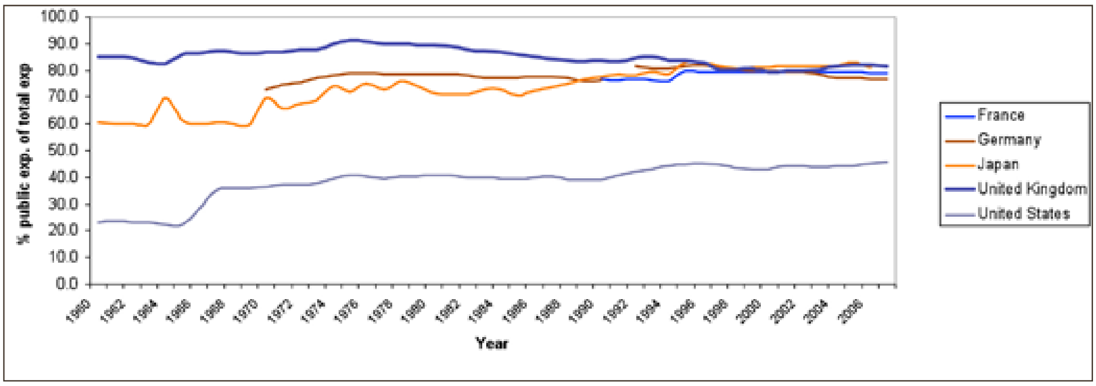
Technological advances are taking place against a background of a need to reduce health care costs in many countries – either because of the insurance premiums required to cover health care costs, or because of pressures in general on public expenditure in many countries in the West and a need to curb the infinite demands which are being placed on health care systems due to demographic change and increased consumer awareness of the availability of treatments. While it is apparent that the UK spends relatively less of its GDP on health care, like many other countries it is dependent upon public expenditure to meet much of its health care costs (see Figures 3.1 and 3.2). Hence, a further driver of demand is public expenditure on health care.

Figure 3.1 Share of GDP on Health Care



Source: OECD

Figure 3.2 Share of Total Health Care Accounted for by Public Expenditure



Source: OECD

One potential outcome of the rising pressures on current healthcare systems and the increasing impossibility of their economics could be an increased recognition of the importance of sensing and diagnosis of illness at a much earlier stage and of focusing funding systems and healthcare structures on a much higher proportion of preventive measures and cures.

Despite better knowledge and an increasing array of therapies it is still expected that 50 per cent of people contracting cancer will die of the disease. New medications being used in oncology can be up to 300 per cent more expensive than traditional approaches yet are only 20 per cent effective – posing a major problem for health economists. There are already numerous heartrending cases reported in the press where the health service cannot afford to make treatments freely available to everybody and where selective criteria have to be applied.

The problems of health economics are also manifesting themselves in other ways for the pharmaceutical industry. Pharmaceutical companies are structured financially to recover the enormous and increasing research and development costs of new drug discovery on the back of drug sales. If the drug is a therapy which is likely to be applied multiple times by a patient in the course of their lifetime and if a high percentage of the population is likely to be or become a patient then the drug rapidly becomes a low cost Over-The-Counter (OTC) product. If the drug is a cure only ever used once by a small percentage of the population then it is an extremely, and increasingly, difficult equation to balance - whether the drug is publicly or privately funded.

3.3 Demographic Change and Consumer Demand

Part of the challenge facing the industry is the development of medicines and devices which will help manage a number of health care challenges. There is an on-going demand to develop therapies which will alleviate, manage, or cure a number of life limiting or fatal “dread” diseases (e.g. cancer) and chronic conditions (e.g. diabetes) all of which come with a high cost of healthcare. This demand has been exacerbated by an increase in life expectancy whereby the number of years the health service needs to treat a person with a chronic disease has increased, and a consequence of increased longevity is that the probability of someone developing a dread illness and / or chronic condition has also increased.

The increase in longevity also means that implants, not least orthopaedic ones, are now expected to be in place for a longer period than the life of the device or its fixation, leading to the need for a second, and in some cases a third, operation and replacement device.

Moreover, people are more aware of the therapies available – hence people are challenging the decisions where their health care systems are unwilling to fund treatments – and while they may not be able to influence their clinicians in the public health care system, there is the option to purchase these therapies privately. While this has placed enormous pressures on health care systems around the world it has, at the same time, created a potentially lucrative market for medicines and medical technologies which will relieve pressures on the health care system.

In England and elsewhere, an increasing range of healthcare therapies and devices being sold over the counter of pharmacists and drug stores or through specialist technology outlets has been observed. Increased consumer awareness of their own health, coupled with much higher levels of discretionary spend available to many people, is leading to a growth in the OTC sale of personal health monitoring devices which used to be the prerogative of the clinician including stethoscopes, blood pressure instruments and heart rate monitoring devices.

Similarly, in relation to medical technologies, there is increasing attention being focused on developing devices which are either stand alone delivering direct benefits to the patient/user or allow for remote monitoring, diagnosis, and treatment through independent or private services using the improved mobile phone, WiFi or various information technology and communication networks.

As far as being a market opportunity is concerned, this has been succinctly expressed:

> "In the United States which accounts for approximately 43 per cent of total industry sales, medical device companies view the hips and hearts of the 78 million-strong, baby boomer population with an accountants green eyeshade. Globally the trends are equally compelling. In the developed nations, the population of older than 60 years will climb to 33 per cent in 2050 from 19 per cent in 1999" (Hodson et al., 2008. p.1).

3.4 Regulation

It is not just in relation to permitting research to take place that regulation has an effect, there is also the process by which medicines, therapies, and devices are approved for use. There are stringent rules across the Western world in this regard. In many respects, given the global nature of the system, it is not just about obtaining approval for a product in the UK and then gaining access to the NHS, but also achieving the same in other health care markets. This can be a particular problem for SMEs.

Depending upon the relative regulatory burden in the UK compared to other countries, this can speed up bringing products to market. This is not just related to the speed with which product licences are granted but also the ease of access to the health service procurement system. As will be discussed later, one of the principal skill needs of medical technology producers is the capability to develop effective relationships with the NHS. Regulation, however, ought to be viewed in a European and international context too since companies are often looking to market their products globally.

3.5 Sustainability

With reference to the sustainability agenda, the health service is one of the largest guilty parties when it comes to once only use rather than re-use of devices and instrumentation etc. let alone synthetic drapes, textiles, paper and many other materials. Sterilisation technologies and methodologies are coming under the focus again to become a more sustainable sector. This relates very much to understanding the bio burden and how you can avoid creating waste in the first instance and, if unavoidable, how you make it safe (e.g. sterile) in the most energy and waste limiting way possible.

There are also examples of companies in England which are currently operating a supply chain that is extended across the world to pick up low labour cost components and who are now looking at the economics more carefully. The low labour costs are coming under pressure in many cases, volume commitment to contracts mitigates against flexibility of design change and customisation demands makes that even worse. The ability to innovate and at the same time maintain quality and reliability standards is also more difficult at a distance and in different cultures. Just as there is now recognition of climate change and carbon costs to be accounted for in regard to food miles, so there is also an increasing awareness of the likelihood of component and material miles. In some cases, companies are taking a strategic decision to bring manufacture, or elements of it, nearer to the product assembly plant, largely for sustainability reasons.

3.6 Corporate Strategic Choice and Globalisation

How bio-medical companies will respond to changes in the market is a moot point. It is evident that the market for health care goods is an international one in two respects: (i) many of the leading companies are multi-nationals; and (ii) there are significant trade flows in bio-medical goods both in intermediate and final products. Hence, companies have a degree of strategic choice in where they locate their activities. To date there is evidence of the sector outsourcing many of its activities across the world. Although the sector is not wholly geographically mobile given the costs of establishing, for instance, pharmaceutical plants, companies nevertheless have some choice as to where they undertake their R&D, product development, and manufacturing. Companies clearly have the option of transferring their mass production activities to counties with lower labour costs (Cogent, 2009). At the same time, the introduction of bio-pharmaceuticals, personalised medicine, new medical technologies will stimulate growth in niche producers many of which are SMEs.

As already noted, the sector as a whole is comprised of a few large multi-nationals and a multitude of SMEs. In the UK, there is the potential for more employment to become concentrated in the SME segment of the market which raises demand for skill sets appropriate to this group of companies. SMEs capability to fully develop their innovations can be limited with evidence pointing to difficulties in raising venture capital to successfully bring products to market (Deloittes, 2008). Moreover, SMEs also lack the know-how to navigate their way around the procurement systems in national health care systems. At the same time, part of the strategic choice the industry’s leading players have adopted is to allow smaller companies to develop products and processes and then acquire the companies when their innovations have proven market potential.

There are some advantages for SMEs in the healthcare sector however, including the relatively low volumes needed for many of the devices and innovations. Generally this means that if there is a defined healthcare need, albeit in low numbers, that the cost – price relationship is not as critical as it may be in other sectors and the lower volumes are also less likely to attract big company, big market competitors. It is factors such as this that have encouraged the growth that has taken place in areas such as the West Midlands where much of the activity has come about through diversification from other sectors under severe cost – price pressures (Hogarth et al., 2005).

Spin-off companies are an important means of generating agglomerations or clusters of, typically, high value goods and services. Some stakeholders recognise that spin-off companies often lack the investment and management capability to successfully bring their products to market. This is especially so in relation to dealing with the various regulatory bodies which grant product licences and also accessing the health service procurement system. The larger companies, in contrast, possess the wherewithal to engage with national procurement systems in abundance.

The above points to the importance of networks between companies. Whilst these can be developed on a national or international basis there is a tendency for companies to cluster together in selected locations. Hence in countries such as the USA, Germany and the UK it is apparent that agglomerations of activity have developed. In the USA, there are clusters of activity in Boston, Illinois, New Jersey, and northern California; in Germany around Baden Württemberg and Bavaria, and in the UK around Cambridge, a corridor between Oxford and West London taking in the Thames Valley, the North West, and around Edinburgh. Part of the agglomeration process, certainly in relation to the development of new products and processes, appears to be driven by the linkages with the R&D sector especially in the higher education sector.

For the time being, especially so in pharmaceuticals, the UK as a whole is well placed to capture the R&D / product innovation segment of the market given its existing strengths. The establishment of industry links with the HE / R&D sector – which is driving both innovation and regional specialisation – has played an important role here, as has the regulatory environment in which research has taken place. The UK, in contrast to the USA, has had a more supportive attitude to public funding of stem cell research whereas under the administration of President Bush Jnr., there was an eighty-year ban on federally funded research (FT, 2009).

3.7 Conclusion

As Map 2.1 above revealed there are many centres around the world which have created a critical mass of activity in the life sciences. To date, the pharmaceutical industry in the UK, rather more than the medical technologies sector, has been successful in maintaining a critical mass of activity. There is evidence that countries such as Germany (Baden Württemberg and Bavaria) and the USA have been more successful in capturing the market for big-ticket items, such as imaging equipment, in the medical technologies market. Part of the UK's relative strength relates to its existing strong base, especially in pharmaceuticals, and the strength of the higher education system. Meeting the challenge of globalisation relates to:

- supporting spin-off ventures by ensuring they have the capital and skills to bring innovations to market;
- establishing incentives for industry – HEI collaboration (c.f. the Lambert Review[5]);
- maintaining a strong skills base, especially so amongst highly qualified scientists and engineers.

[5] The Lambert Review of Business Industry Collaboration (Lambert, 2003) drew attention to the importance of HE- industry collaboration for both regional and national economic growth and competitiveness. It also drew attention to the competing demands made upon HEIs.

It was noted that many of the major companies operating in the sector are large multinationals which have a degree of strategic choice as to where they locate their R&D and manufacturing activities. Hence the importance of establishing a strong intellectual base for the development of the sector since this is likely to retain activities in a given place. Research reveals that while many top scientists regard themselves as highly geographically mobile, few have any desire to move (Feldman, 2001). Hence the UK's existing strong intellectual base provides it with a key strategic advantage.

Despite the relatively strong position from which the UK starts there are a number of challenges which need to be met if the sector is to continue to be a major source of value-added and employment. These are summarised in Table 3.2 below alongside the implications for employment. Technological change and innovation in the bio-medical sector – and especially in medical biotechnologies – suggests that its economic prospects are good. Perhaps of all the manufacturing sectors it is the only where a substantial decline in employment is not projected in the period to 2020. Employment prospects are, however, a little uncertain. While there is no evidence that sector will experience any major fall in employment in the period to 2020 it is apparent that over the longer-term that the growth in world markets will see production and, perhaps, R&D activity increasingly located in emerging markets. So long as output levels continue to grow at their current rate this may have a relatively modest impact on employment levels in the UK. Moreover, the relative strength of the UK's bio-medical R&D sector is such that its pre-eminence will be maintained. Strong output growth is, it must be said, dependent to some extent upon major scientific breakthroughs being translated into products, and those products being cost-effective. While there is every reason to believe that this will increasingly occur, it cannot be taken for granted.

Related to the globalisation issue, though it is outside the scope of this report, is the capacity of the country to capture the supply chain for the provision of intermediate products and services used in the production of bio-medical goods. This is likely to be a relatively large market though much of it will lie outside of the bio-medical industry as classified in this report.

Table 3.2 Drivers of Demand in the Bio-medical Sector and their

Driver of Change	Description	Employment Implications
Technological Change, Innovation and R&D	On-going research activity	Strong demand for high skilled labour in the R&D sector, especially professional scientists and engineers
	Major breakthroughs in new therapeutics	Employment increases in relation to production of new products. If niche production required this may be retained in England
Health Expenditure	The Exchequer in many EU countries is meeting majority of health care expenditure	The need for countries in the West to constrain real levels of public expenditure will boost the demand for cost-saving therapies (see above), but may inhibit the diffusion of more costly treatments
Demographic Change	Large market increase resulting from increased levels of life expectancy	A demand for products which reduce the costs imposed on national health care system resulting from people living longer – especially those who have chronic medical conditions. This has the potential to boost employment levels.
Regulation	Permissive attitude towards conducting stem cell research has benefited UK R&D	Increases employment in R&D – and draws in scientists from around the world. Has the potential to increase production jobs if new products materialise.
	Regulation of products	Can inhibit employment growth where firms (SMEs) struggle with the process of meeting national safety requirements and selling to national health care systems.
Sustainability	Need to reduce waste levels/improved waste disposal	Design of products which limit waste
	Energy conservation	Use of new materials/bio materials
Strategic Choice	Outsourcing of critical mass of activity to other countries	Threat of mass production being moved to countries with lower cost production. Potentially leaves England with R&D and product development, perhaps linked to production of small scale output. But large scale employment decline is not realistically on the horizon to 2020.
	Outsourcing product development to SMEs	There has been growth of the SME sector, especially in biotechnology. But as small firms they face a number of potential barriers relating to obtaining capital, negotiating the health system which may affect employment levels. Employment levels depend upon the extent to which UK manufacturers can capture this market.
	Opening of new markets in developing countries	Whilst there is the potential for export activities, globalisation is likely to result in production taking place in new emerging markets, coupled to prices being driven down. R&D employment is still likely to be in the UK, but some may increasingly be located in the markets being served.

Source: IER

4 Technological Progress in the Bio-medical Sector

4.1 Aims and Scope

The present section explores emerging technological trends relevant to the bio-medical sector. The future prospects and skill requirements of any given sector depend crucially on the underlying rate and nature of technological change (e.g. relating to the invention of new products and processes), as well as the speed of diffusion (use in production) of these new technologies across the relevant parts of the economy.[6] Information about emerging technological changes can rarely be directly translated into precise implications for current and future skills needs, but knowledge of the changing technological landscape can be an important weapon in the strategic planner's armoury.

Systematic work on monitoring the rate and direction of technological change and investigating its effects on growth and performance began to emerge in earnest as long ago as the late 1940s and early 1950s (e.g. Solow, 1956, 1957, and Jorgensen and Griliches, 1967), with more recent work associated with the emergence of the "new growth theories" (e.g. Romer, 1986, 1990, and Lucas, 1988, as well as a review by Solow (1991). This section draws upon several aspects of the empirical strand of this area of research, including R&D statistics (e.g. Bosworth, et al. 1993) and, more particularly, patent data (e.g. the series of articles about the uses of US patent statistics by Schmookler, leading up to Schmookler, 1966); for a review of the early literature see Bosworth, 1987).

Enormous strides have been made in the empirical investigation of technological change with the emergence of large scale electronic R&D, patent and scientific publication data bases, and there is the scope for significant further research, beyond that undertaken as part of the present study, that would aid policy design in this area (see Appendix 2 for a brief discussion of the use and limitations of patent statistics for the present purposes). The present work focuses primarily on the patent information, where much more detail is available about the areas of technology in which advances are accelerating or declining.

This section continues with a discussion of many of the conceptual issues associated with understanding the central role of technological change in influencing future skill needs (Section 4.2). While the question of high level skills is discussed, including those associated with the invention and innovation processes, consideration is also given to broader issues of skill demands at the sectoral and national levels, caused by the nature of technological change, and the rates of innovation and diffusion of new technologies. Section 4.3 provides a brief discussion of the trends in health related R&D in the UK and, for comparative purposes in the USA. Section 4.4 goes on to consider patenting activity by area of health technology, attempting to identify areas of rapid technological advance, particularly those in which Europe remains an important player, and areas where technological opportunities appear to be diminishing and/or the USA and Japan appear to be developing a major technological advantage. Finally, Section 4.5 provides the main conclusions of the present section. In doing so, it sets out some of the main findings about areas of continuing technological opportunity, but also about the degree of competition in the production of new technologies globally. In addition, the conclusions outline some of the ongoing research designed to bring the study more in line with sectoral interests, such as the investigation of technological activity

[6] This should not be taken as an indication either that technology is the only driver or that change in the sector is simply driven by technological opportunities. The speed and direction of technological change is itself a function of many of the other opportunities and challenges facing the sector; some of these influences are set out in EFILWC (2007).

according to six alternative “technology platforms”, which would be recognised by players in the sector, as well as by four different areas of application within the health sector (see Appendix 3).

4.2 Conceptual framework

4.2.1 Conceptual issues

Projecting future skill needs is not possible without an understanding of technical and technological changes:

- *technical changes* occur where the technology set is given (e.g. the product and process technologies), but nevertheless there is a substitution of one input for another (e.g. from less to more highly qualified labour as the latter become relatively more efficient in production); and,

- *technological changes* are associated with changes in the technology sets themselves (e.g. new products are produced or new processes emerge).

Technical changes are often driven by movements in relative factor prices. For example, as skilled labour become more expensive relative to less skilled labour, there is an incentive to economise on the more skilled workers and utilise a higher proportion of the less skilled workers.

Technological change can be:

- skill-neutral, for example, where a given mix of more and less highly qualified labour become increasingly productive – proportionately less of both are needed – because of improvements in technology;

- skill-biased, for example where improvements in technology save more of one type of labour (e.g. relatively more unskilled labour is saved per unit of output than skilled labour, causing a relative shift towards the demand for skilled labour at current relative factor prices).

The effects of technological change on skill levels are not fixed over the life of the technology (as the discussion of technical changes suggests). The initial stages of technological change are often relatively skill intensive, but, as the technology matures and competition in the area of techology increases, there are greater incentives to seek ways of economising on the more expensive, skilled labour and utilise less skilled individuals. These sources of competitive improvements often lead to the movement of technologies away from the initial innovating country to parts of the globe where, at some point in the changing skill needs of the technology as it matures, broadly the same skill levels can be obtained at lower factor prices.

Technological change may have both quantity and quality dimensions; technological change may increase:

- the number of units of output that can be produced with any given volume of inputs (e.g. person hours of skilled and unskilled labour);
- the quality of the existing units of output that are produced with any given volume of inputs.

Of course, the quality of inputs may also change, for example, as highly qualified labour assimilates new knowledge which improves the productivity of this type of labour in the production process (see Bosworth, 2005, pp. 69-102).

The present section focuses on technological changes, which will, in principle, if adopted, drive future skills needs as they impact on products and processes used in the supply of health care. This is carried out at a broad level of technological activities (see Section 4.4 for further details), as it is at this level that can probably best inform government policy about skills trends at the leading edge. However, future work needs to also consider the resulting future technological changes that might accompany such trends.

4.2.2 Technological Forecasting

Technological foresight

Technology foresight is widely recognised as a source of strategic information for policy making. It can be defined as:

> "... the systematic attempt to look into the longer-term future of science, technology, the economy and society, with the aim of identifying the areas of strategic research and the emerging of generic technologies likely to yield the greatest economic and social benefits" (Martin, 1995, 140).

Foresight has been associated with "picking winners", but, in more recent years, it has been recognised as having a more nuanced set of roles, for example,

- "Foresight is no longer undertaken with the claim to forecast or predict a certain future situation but recognises the possibility of alternative futures and also tries to shape or create certain paths of development;
- the foresight process with its stimulation of communication and future orientation among the actors of the innovation system is regarded at least as important as the outcomes in terms of identified areas of strategic research and emerging generic technologies;

- accordingly, the function of mobilising and 'wiring up' national innovation systems adds to the function of informing science and technology policy-making, e. g. for purposes of priority setting". (Aichholzer, 2001, p. 3)

According to Eerola and Jørgensen (2002, p. I and p. 12), Nordic technology foresight (TF) is defined as:

> "… systematic, future-oriented interaction processes contributing to shared visions concerning long-term technological developments. In the TF exercises, technological developments are examined in their real-world, economic and societal context, with attention to a wide pool of knowledge and the viewpoints of various interest groups. The processes can be broad-scope or more focused. The purpose is to facilitate communication between the interest groups and to increase decision-makers' and key actors' knowledge base, so that desirable technological developments can be supported with relevant Nordic strategies, decisions and actions. Both analyses and interaction are important in this respect". [*itals* added]

Demand-pull

As will be discussed further below, however, a demand-pull focus is also needed to balance out the tendency for technology foresight exercises to be inherently technology-push in nature when examining these issues (*ibid*. p. 6). The problem arises from the tendency to rely too heavily on experts from the "supply-side". The Austrian Delphi study recognises this area of potential bias, acknowledging that it "… ought to give an at least equal weight to demand", however, "[m]ethods to forecast long-term demand for high-tech goods … are still lacking" (Aichholzer, 2001,. p. 9).[7] Examples of attempts to consider the demand-side for key French technologies can be found in Durand (2003).

One key area where, in some sense, demand is relatively easy to establish is that of health needs. It is possible, for example, to identify illnesses and diseases for which new technologies will ameliorate human suffering and extend human life. The problem here is that pricing is a major ethical issue in the control of "demand" and the health sector is forced to operate systems which translate "demand" (or "want") into "need", by means of medical judgement (an across the board form of triage). Here judgements may be informed by growing statistical evidence of quality adjusted life years (QALY).

In the UK, the largest source of demand for medical technologies is the NHS, which intermediates between the health demands of individuals and "health supply". In the context of the present study, the Department of Health has recognised the failure to fully realise the potential benefits of new medical technologies (House of Commons Health Committee, 2005). Several reasons have been put forward, for example, that:

[7] The Austrian study breaks down the demand side into relevant fields, which distinguish between technological focus (e.g. medical technology and support for elderly people) and societal/cultural focus (e.g. ageing and life cycle). It also notes the role of "political factors" where society's (voters') views (e.g. about changes to the health insurance system) may intervene in selecting areas for future development..

> "The NHS comprises a federation of 700 Trusts; inconsistent policies and practices in relation to the development of new technology, its application and purchasing policies create difficulties for suppliers and result in variations in the availability of technologies to patients. The use of different and incompatible makes of equipment leads to many problems, including the need for training in the use of each piece of equipment. The result is a drain on resources and the potential for mistakes. The inability to move money between Trusts' budgets can also result in a lack of integration." (HCHC, 2005, p. 3)

There is a tendency to think of these problems occurring within medical institutions (e.g. the surgery or hospital), but they are a wider issue:

> "There are limitations to the use of new technologies. They can be expensive, especially if not implemented correctly. Installing new technologies outside the clinical environment, for example in patients' homes[8], can create problems: patients can find it difficult to use the technology and the reduced human contact with practitioners might also be reflected in reduced contact with carers and kin; alternatively, it might increase the burden of responsibility on carers. However, handled properly these limitations should not be a bar to the wider use of the technologies." (ibid. p. 3)

4.2.3 Which Technologies? Radical technologies, incremental innovations and the broader aspects of technological and technical change

Research, health supply and outputs for use in the healthcare sector

When discussing medical technology, biotechnology and life sciences, there is a tendency to focus on radical developments – new technology platforms that will change the face of medicine (often referred to in economics as "general pupose technologies", GPTs). Undoubtedly such technologies are important, especially from a health perspective, and one would expect them to be adopted within the health service in the UK. However, this is a different issue to the following:

- there may be other more incremental technological improvements that, while generating modest improvements to individual patients, neverthless can be of enormous benefit when considered across the health sector as a whole;
- the adoption new technologies by the health service is a quite distinct issue from the question of what new products, based on new and existing technologies, should be produced within the national economy.[9]

[8] This might also apply to residential and care homes, etc.

[9] In a way, this is an issue that was wrestled with in the development of the theory of "comparative advantage". The fact is that different factor endowments (and different degrees of technological capability in different areas) mean that there are economic gains from different countries concentrating their efforts in areas or production where they have a relative (comparative) advantage.

Thus, there appear to be a number of issues here, although, in part, they are likely to be inter-related:

- what new technologies should the country be developing through research, medical testing and assessment, etc.;
- what new medical, biotechnology and life science technologies should the country be adopting for use in its health services;
- what new products and services to be used in the delivery of health services (not necessarily just for use domestically) should the country be *producing*?

The skills implications of each of these three questions are, to some extent, distinct:

- the *development* of new technologies might be carried out primarily through the science base, maintaining and developing high levels skills within universities, university hospitals, private R&D laboratories, etc.;
- the *adoption* of new medical, biotechnology and life science technologies is primarily the remit of the health sector, with implications for skills to ensure successful introduction of the technologies, but also implications for the skills (and skills mix) of staff who will operate the technologies to deliver new health improvements;
- the *domestic production* of products and services to be used (primarily) by the health sector (domestically and internationally) has implications for the skills of the relevant manufacturing and service sectors (largely outside of the health supply sector), which are the remit of the relevant SSCs (e.g. Cogent[10], Semta[11], etc.), although the input-output matrix linking business supply and demand will pull in a potentially much wider range of sectors.

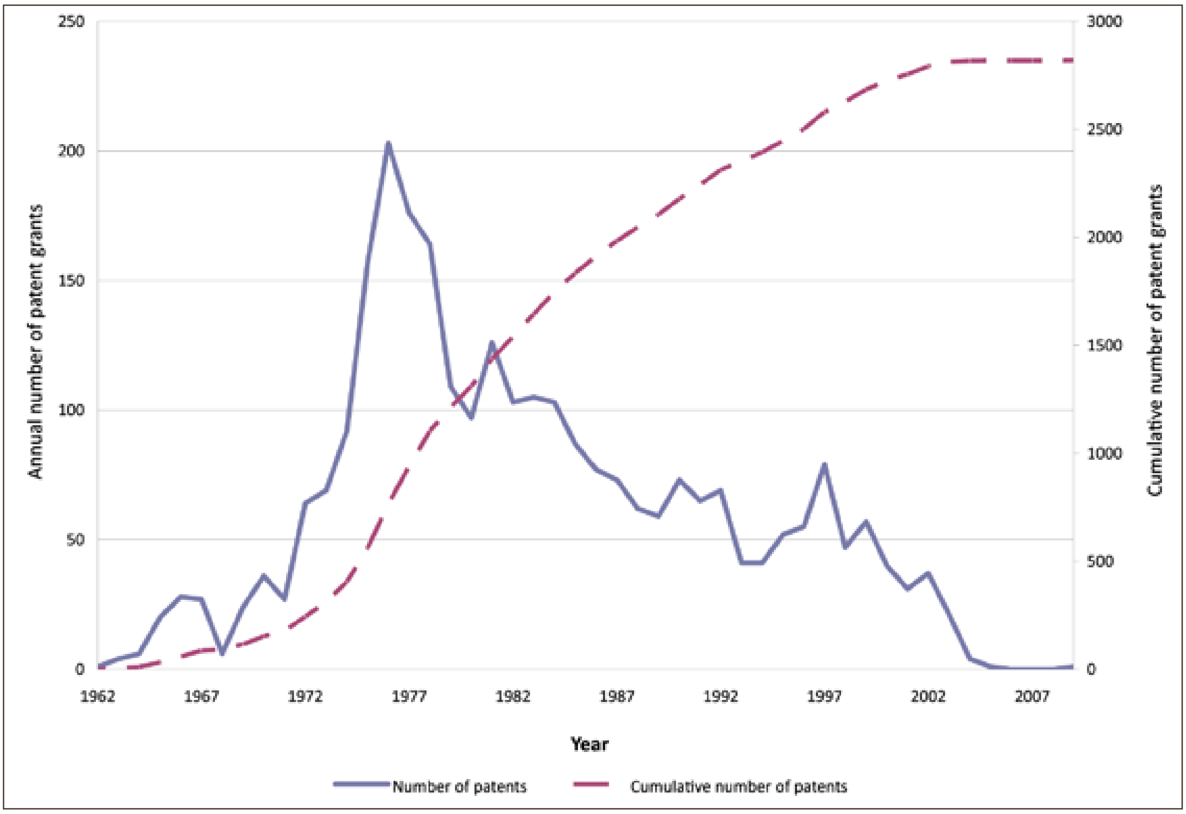
Technological opportunity, mining and exhaustion

Bearing in mind their limitations, patent statistics can be used to identify areas of technological activity and the trends in such activity over time. There is a rich literature setting out the uses, limitations and results of patent mapping activities (see particularly publications in Research Policy, e.g. Meyer, 2000, Meyer, et al. 2004, and Engelsman and van Raan, 1994). Patent statistics have been used to examine technological activity and the impact of such activity at most levels of disaggregation from the firm-, to the sector- and to national levels (e.g. Griliches, 1995, through to, e.g. DIST, 1996 and DTI, 2001 – many of which have been annual publications of activity and performance).

[10] Chemical and Pharmaceutical, Oil, Gas, Nuclear, Petroleum and Polymers (www.sscalliance.org/SSCs/LinkstoSSCs.aspx).
[11] Science, Engineering and Manufacturing Technologies (www.sscalliance.org/SSCs/LinkstoSSCs.aspx).

Figure 4.1 provides an example at a very detailed level, reporting the results of patenting activity through the USPTO, in the area of cephalosporins. The annual year on year activity rises to a peak in the mid-1970s, after which it falls as the area of technology becomes "exhausted" or some other more productive area of technology takes over. The cumulative patent activity curve shows the broadly "sigmoidal" shape which tends to typify particular areas of technology. Thus, again with some caution, the relative levels and shapes of such curves (both annual and cumulative) can be used in qualitatively assessing both the historical trends in activity and the future potential of particular areas of technology.

Figure 4.1: Growth and decline of USPTO patenting activity in cephalosporins



Source: own data, constructed from interrogation of the USPTO patent database.

Taking an area of technology (e.g. luminosity), rather than a specific technology itself (e.g. mercury lamps) (see Wills, et al. 1972, pp. 106-109), there is often a cumulation of successive "sigmodial" curves that supersede each other. Thus, the growth behaviour of a field of technology is often the sum-total of many technological strands of advancement, each which generally follows its own "logistics-type life story" (Shvartz, et al. 1981). One approach to modelling the field of technology rather than individual technology strands is to fit a logistic envelope curve (e.g. tangential to the individual technology curves) (ibid.). While evidence for such envelopes is not as prolific as for individual strands of technology, it seems very likely that these too are generally sigmoidal in shape.[12]

[12] In this case, the upper limit of the envelope function is often determined by some physical law (such as the speed of light).

Technological change, diffusion and the "optimal mix of skills"

There is a tendency for political commentators to believe that producers should be using the most advanced technologies and, if they do not, then there is some "technology gap" that should be made up. The technological diffusion literature indicates that this is clearly not the case. Diffusion takes time and a variety of economic (and other) factors influence the pattern of diffusion, making it more profitable for some enterprises to be early adopters and some enterprises to be later adopters (Karshenas and Stoneman, 1993). Of course, this does not mean to say that the influences on the rate of adoption are given and immutable, they themselves might be the subject of policy changes aimed at increasing social welfare (e.g. in the equality of provision across patients – see below).

Diffusion of any new technology is invariably "sigmoidal" in shape over time[13]. A variety of functional forms have been used to represent the cumulative adoption of technologies over time, such as the logistic curve, which has long been recognised as characteristic of a great number of phenomena, including technological development (Ayers, 1969; Linstone and Sahal, 1976; Martino 1973). As a new technology gradually takes over from an older technology (or a group of older technologies), new and old technologies coexist and do so, sometimes, for very extensive, periods of time. Insofar as these new and old technologies require different skills to operate or produce them, this allows a sector to work with a mix of skill and qualification levels.

This may be essential from a labour market policy perspective, as a concentration of demand amongst the highly skilled and qualified would leave those supplying lower level skills without employment. It might also result in an excess demand for those with high level skills, with associated higher wage rates for these groups, which reduce the profitability of the newest technologies and, thereby, their rate of diffusion.

On the other hand, in the health service it may create ethical, social and political problems, insofar as new technologies are being introduced in some parts of the service (with associated health benefits), but not in others (where individuals with the same health needs are being treated with the old technology). This leads to political pressures, such as those associated with the so-called, "postcode lottery".

Whatever the resulting problems, it is almost certainly the case that rates of diffusion are endogenously determined by factors such as skills availability (this has been apparent for many years, see, for example, Solo, 1966; Amsden, 1989), it also points to the fact that diffusion processes can be influenced by government and regional policy makers:[14]

- this might be through incentives to produce new technologies or adopt new technologies, which would utilise higher educated and skilled individuals;

- equally, it may be through changing the supply of skills and qualifications of different types, of different levels and in different localities.

[13] In some cases, such as technological failures, only part of the "s-shaped" diffusion curve may be observed.
[14] In a sense, it is the entire national innovation system that is relevant, in other words, the entire network of institutions in the public and private sectors that interact to "… initiate, import, modify and diffuse new technologies" (Edquist, 1997).

Radical and incremental technologies, and technology life-cycles – implications for a more holistic skills approach

Radical new technology platforms may be the major engines of future growth and development. However, their are at least three major considerations in governing their adoption and use:

- it does not always pay to be the (first[15]) innovator, later adoption is sometimes the more economic and socially optimal route (see the discussion of optimal diffusion and skills below) – likewise, it does not always pay to introduce the most radical advances, which may not be best suited to the economic, social or cultural needs of the population;[16]

- incremental advances (see above) may be the only improvements available in some areas (in others they may complement more radical advances), but their impact across the health sector (and its customers and suppliers) as a whole may be significant, and the more so when their cumulative impact over time is taken into account;

- the contribution of technologies (new and old) should be viewed in the context of their life cycle and, what many commentators omit, in the context of the need to manage their life cycle (Bosworth, 2005, pp. 352-359).

While there can be intense "consumer pressure" for the adoption of the most advanced health technologies in relatively wealthy nations, such as the UK, it is not clear that this is always the socially optimal route. For example, the benefits of the most advanced technologies (which are often very expense in their early stages) may only be afforded at the cost of a reduction in the widespread use of existing technologies, within a health service in which funding and resources are ultimately limited.

Nevertheless, being leaders in the development of new technology platforms is important, for example, it offers:

- the option of early adoption and broader explotation of the underlying technologies;

- knowledge and skills for the more effective and efficient diffusion of related technologies (even where they are invented elsewhere);

- the option of staying out of the invention of the currently emerging technology, with the ability to jump in at a later stage, when a new or modified form of the technology becomes feasible.

[15] While innovation generally refers to the "first use", it is often qualified as being the "first successful use", which, in some respect, allows the first use to be unsuccessful. In addition, a distinction is often made between "global" and "local innovation", where global refers to the first (successful) use anywhere in the world and local to the first (successful) use in a particular country (or even more locally, within a particular region, sector or enterprise).

[16] The example of developing countries, which can often neither afford nor provide the skills for the early adoption of radical technologies, is an extreme case.

However, being at the scientific[17] forefront in the past has not always resulted in the expected down-the-line benefits for the suppliers of products and services to the health sector. For example, while the basic research on MRI scanners is largely attributed to UK and US scientists (e.g. Peter Mansfield of Nottingham University and Paul Lauterbur, at that time a Professor of Chemistry at the State University of New York, who were jointly awarded the Nobel Prize), a current list of major producers of MRI scanners and closely related technologies[18], suggests relatively few links between the original scientific work and the later distribution of production and employment.

Part of the problem with the more radical technologies is that their market exploitation (e.g. in the form of new products and services) often require knowledge and skills (e.g. Solo, 1966; Amsden, 1989; for a recent review see Hanel, 2007) and that these might be more readily available in other countries (e.g. the US, Germany and Japan).

Solo (1966) was amongst the first to argue that the existence of formally educated scientific and technical elites is a necessary but not sufficient condition for the diffusion of new technologies and economic development. Solo (1966) argued that sustained development can only take place when the skills of the middle mass of “mechanics and technicians” reaches a sufficient threshold. Amsden (1989, p. 9) takes up this argument in the context of the “take-off” of Korean economy, pointing out that, while “[S]alaried engineers are a key figure in late industrialization because they are the gate keepers of foreign technology transfers”, nevertheless “... Korea was a successful learner [of foreign technology] partly because it invested heavily in education ...” (ibid. p. 23).

Incremental technological advances, which are often the successor to earlier more radical technologies[19], are themselves a source of growth and employment. In the case of incremental technologies, the knowledge and skills implications may be more modest than in the case of radical technologies. Insofar as such technologies are more readily adopted and diffused amongst existing companies, their potential for generating employment, alongside a more modest rate of increase in skills may nevertheless produce significant benefits for the economy.

The third point, which relates to the role played by existing technologies, is that the nature of technology life cycles often means that more mature technologies often provide more employment opportunities than new technologies. The slow (if increasing) initial uptake of radical technologies means that they tend to create relatively little employment in the early phases and, what employment there is, tends to be relatively specialised and highly skilled (although, by implication, relatively well remunerated). Existing, mature technologies may still employ more individuals than even radical new technologies, until the final phases before their demise.

[17] Even being at the technological forefront does not guarantee success in the example of the eventual “victory” of VHS over Betamax video storage.

[18] http://www.ebyte.it/library/NmrMriCompanies.html#mrioemscanners.

[19] See Schumpeter’s wave of, on balance, increasingly more minor inventive and innovative activity, that follows in the wake of the introduction of some radical new platform, but which stimulates an upturn in the economy that only slows when the potential of the new area of technology becomes “mined out” (Schumpeter, 1949, p. 230).

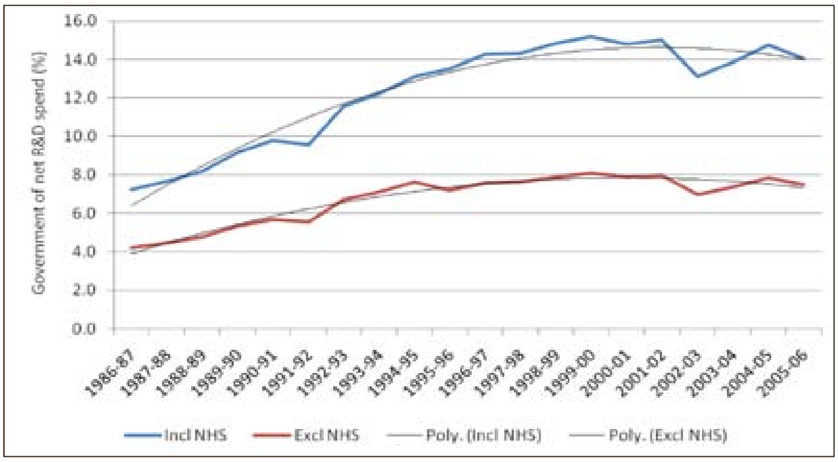
What is extremely important is that the changing mix of technologies and the employment opportunities they give rise to needs to be monitored and, to some degree, controlled to ensure that the jobs on offer at each point in time broadly require the skills supplied to fill them, bearing in mind the capacity to train and up-skill. The aim would be to produce a changing mix of technologies and jobs over time that allow the economy to be on a rising skills (productivity and income) profile. The implication of these arguments about existing technologies and incremental improvements is not that radically new technology platforms should be ignored – they are potentially of enormous future importance, but their introduction and diffusion needs to be managed in the light of the contributions of incremental technological advances and the gains from managing the decline and, eventual, demise of existing technology platforms (Bosworth, 2005, pp. 352-359).

4.3 R&D health spend

4.3.1 Domestic R&D

The evolution of R&D spend in the area of health is set out in an Excel workbook by BERR.[20] The results of this are reported in Figure 4.2. Two principal results are shown, which are both derived from a single series, which has a discontinuity in 1995-96, caused by the shift in scope of health R&D in order to include research activities of the NHS in more recent years. Thus, the higher of the two series (which is probably the more useful) approximates the path of R&D including the work of the NHS and the lower of the two gives the corresponding result excluding the NHS.[21]

Figure 4.2: R&D health spend as a proportion of all R&D



Source: www.berr.gov.uk/files/file22056.xls. Note: estimated series (based upon data that include NHS expenditure from 1995-96 onwards and excludes it prior to this date).

[20] SET Statistics. UR0000000048-08-1-I/on. www.berr.gov.uk/files/file22056.xls.

[21] This margining of the two series was carried out by projecting forwards and backwards the individual series without and with the NHS R&D respectively, to provide an overlapping observation, which was used in the adjustment of both series. The estimated trend in the series which includes the NHS prior to 1995-96 implicitly assumes that the NHS spend remains proportional to that of the non-NHS R&D spend; the estimated trend in the series which excludes the NHS spend after 1995-96 implicitly assumes that the non-NHS spend remains proportional to that of the NHS.

A significant rise in the proportion of all R&D devoted to health over the first half of the period is clearly apparent. The results suggest that the increase in this proportion slows and falls to zero just after the end of the 20th century and, if anything, the series itself begins to fall slightly after that point. As a first approximation, it appears likely that, for the foreseeable future health R&D, including NHS activity, will form a substantial part of all R&D. probably at around 14-15 per cent of the total. This conclusion is, in part, a qualitative assessment, based upon: the current growth in technological opportunities in health (supply push) and the aging population (demand pull); set against, other priorities which will also put demands upon the R&D budget, such as the need to develop “green technologies”.

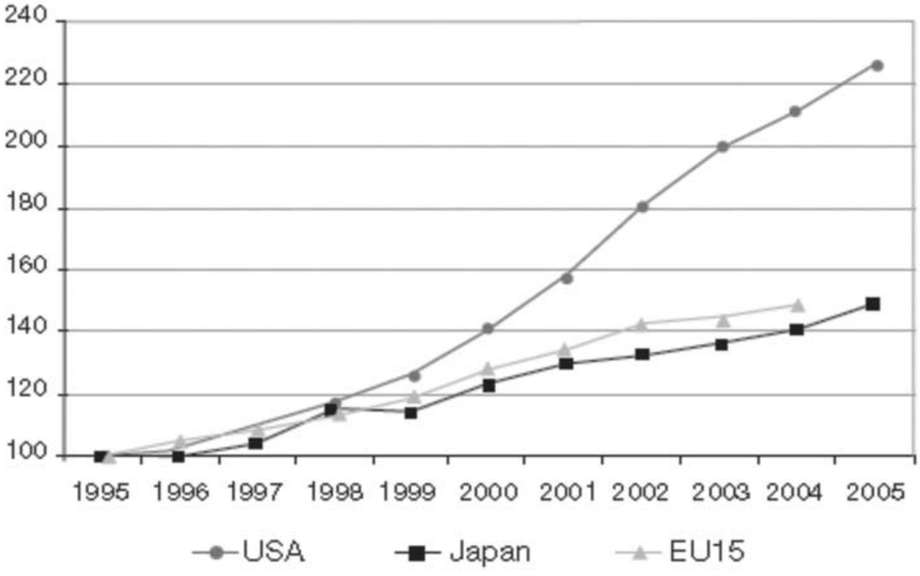
4.3.2 US R&D

While health appears to be a priority area in the UK R&D budget, it is clear that the US spends much more on medical research – more than Europe does (and much more than the UK does). Billing, et al. note that:

> “Yet no matter how the available data are analysed and compared, Bio-medical research funding in the USA is much larger than in Europe. Relative to GDP the USA non-market sector spent between 0.25 and 0.43 per cent in 2004 on Bio-medical R&D (depending on the way university research is included and on the data source used), compared with 0.17 per cent for the EU 15 countries [in] the same year. The most credible estimate for the USA lies between 0.37 and 0.40 per cent more than twice the European spending relative to GDP and almost three times the European spending when measure relative to the size of the population. (Billig, 2007)

Figure 4.3 compares the research spending in the US, Japan and the EU 15 countries relative to 1995 spending. The relative amount of spending in the US is increasing more rapidly than in Europe and Japan and the US was spending more on R&D to begin with.

Figure 4.3: Trends in nominal medical research expenditures in national currencies



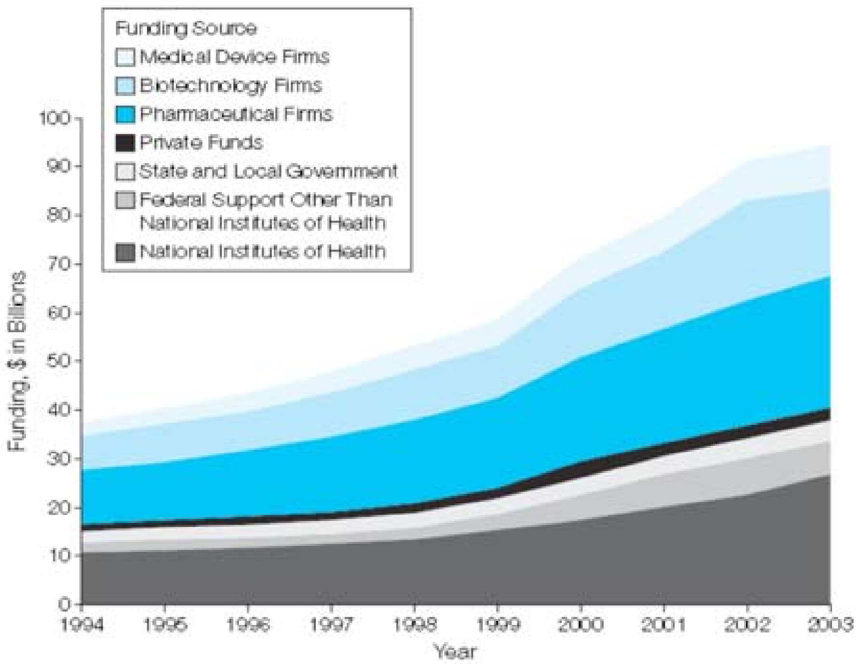
Source: Billig, H., et al. (2007, p. 19). Note: R&D performed in the non-market sectors, relative to 1995 levels (=100).

The amount of US spending on Bio-medical research between 1994 and 2003 is shown in Figure 4.4 below. According to Moses, et al. (2005),

> "Bio-medical research funding increased from $37.1 billion in 1994 to $94.3 billion in 2003 and doubled when adjusted for inflation" (Moses, et al. 2005, p. 1333).

The majority of this spending (between 56 to 61 per cent) comes from industry and the rest from the US government (ibid. p. 1335).

Figure 4.4: Funding for bio-medical research by source, USA, 1994-2003



Source: Moses, et al. (2005, p. 1336).

4.4 Patenting Activity: broad technological trends

4.4.1 Interpreting patent statistics in the context of the changing economic climate

Figure 4.5: NASDAQ Composite Index 1983-2002

While there is a large amount of potentially informative patent statistics about the evolution of different areas of technology, the most recent technological trends are made more difficult to decipher by the recent economic downturn and, in the case of the technologies of interest here, the "dot-com bubble" (see Figure 4.5).

The problem is that, while the recent economic downturn has, broadly speaking, had a broad ranging effect on all activity, including R&D and patenting activity, the "dot-com bubble" was much more "technology specific" involving the more speculative areas of both research and commercial activity. Thus, the speculative bubble of (roughly speaking) 1998-2001[22] had a differential effect on IT, biotechnology, genetic engineering and a number of other areas of technology central to future health provision. The speculative bubble peaked in March 2000 and the market was still in decline through the early part of the 21st Century. It was further overtaken by the growth in real oil prices and the worldwide crisis and recession caused by the failure of financial markets. At the time of writing, the recovery from the failure of financial markets is still on-going, but the period covered will be at least 2007 to 2009/10, with some commentators predicting recurring problems beyond that period.

[22] http://www.stock-market-crash.net/nasdaq.htm.

As a consequence, while the many of the patent areas of considerable interest to health are still viewed as having enormous technological potential and commentators still believe that they will radicalise the provision of health services in the future, they are severely affected by these recent economic events.

The current discussion of longer term trends in patenting activity initially includes discussion of broad areas of technology of relevance to health. Appendix 2 provides further information on the use patent data. The data are taken from the OECD statistics portal[23], and include series for biotechnology, micro-organisms, information communication technologies (ICTs), medical preparations and nano-technology. ICTs are included for completeness, as they are a general purpose technology (GPT) with fundamental implications for the development of technology in the other areas of health. Finally, there is a brief discussion of the trends in nano-technology, which is an area that also appears to have significant implications for health, particularly in the medium to long term.

4.4.2 Life Sciences/Biotechnology

In this Section, the term “life sciences” is used to refer to the manipulation of cellular, sub-cellular, or molecular components in living things. The IPCs that fall under this definition coincide with those listed under the “biotechnology” area in the OECD’s patent data. Thus the terms life sciences and biotechnology are used interchangeably in this section. In order to see what technologies the OECD definition of biotechnology includes see van Beuzekom and Arundel, 2009).

Figure 4.6a sets out the changing level of patent applications to the European Patent Office (EPO) in the area of biotechnology, based upon the OECD compiled statistics (again, see van Beuzekom and Arundel, 2009). The strong upward trends through to about 2000 are followed by a levelling-off and, then, a fall in activity. The minor upturn in 2006 seems likely to eventually be replaced by a further downturn as the financial crisis and the consequent world recession bite. US activity appears to have been particularly adversely hit by the dot-com bubble, while the Japanese activity, which is a relatively small proportion of the total, is less significantly affected.

Figure 4.6b provides the cumulative totals of the data that appear in Figure 4.6a. All of the series except for Japan suggest the exponential period of advance in this area of technology may have been coming to an end by the late 1990s, even before the dot-com bubble burst. Given the size of patenting activity in this area and the size of technical know-how that has been accumulated over the years, this will, nevertheless, remain an important area of technology and technological advance for some time to come. In addition, care needs to be taken that the perceived rate of diminution of the advance in biotechnology at the margin is a real one, and not an artifact of any special economic or political influences on that sector.

[23] http://stats.oecd.org/index.aspx.

Figure 4.6: Number of patent applications filed at the EPO in biotechnology between 1985 and 2006, by geographical location of the inventors

Figure 4.6a: Biotechnology (number)

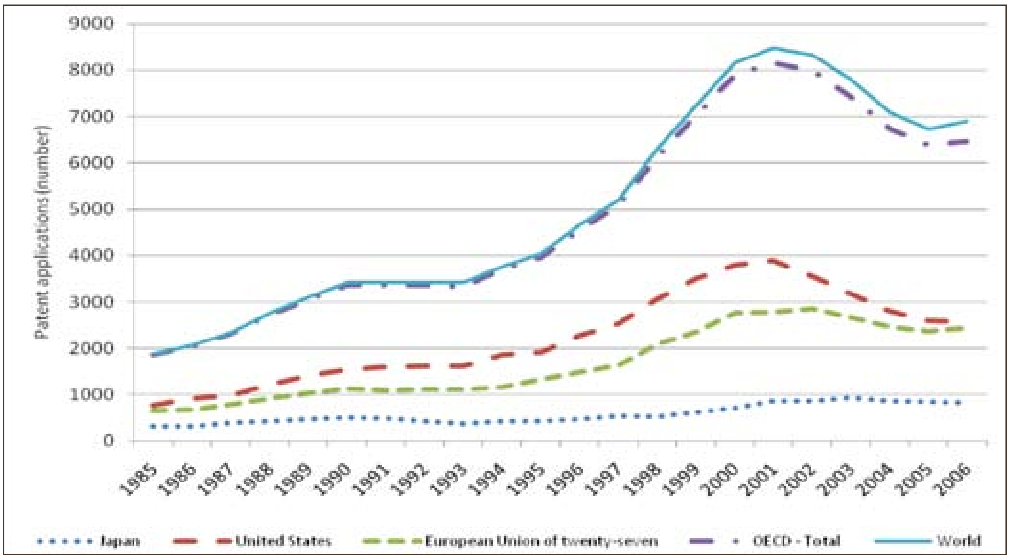


Figure 4.6b: Biotechnology (cumulative number of all patent applications)

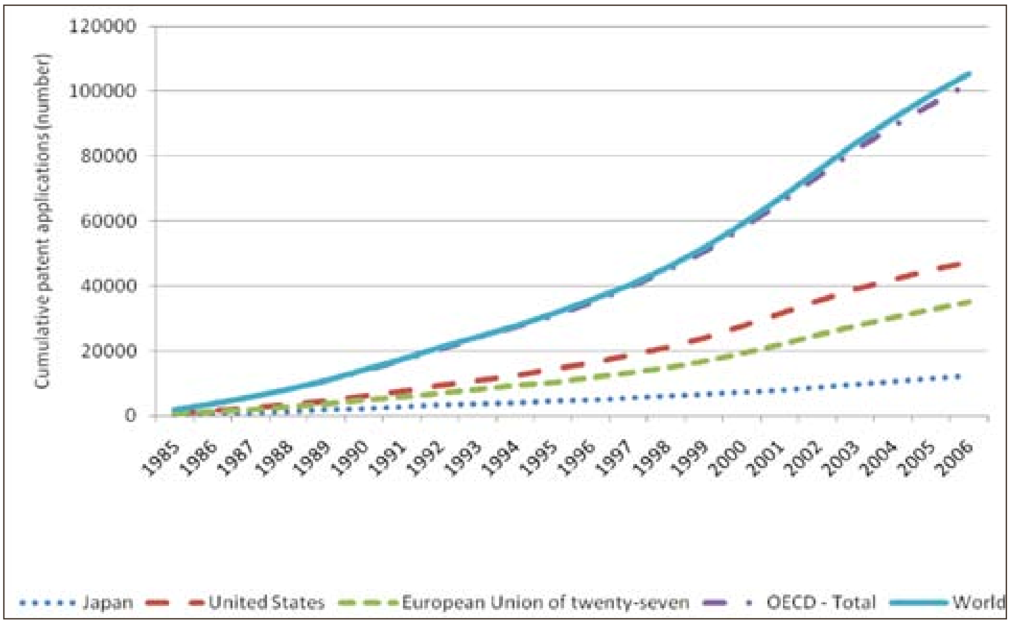
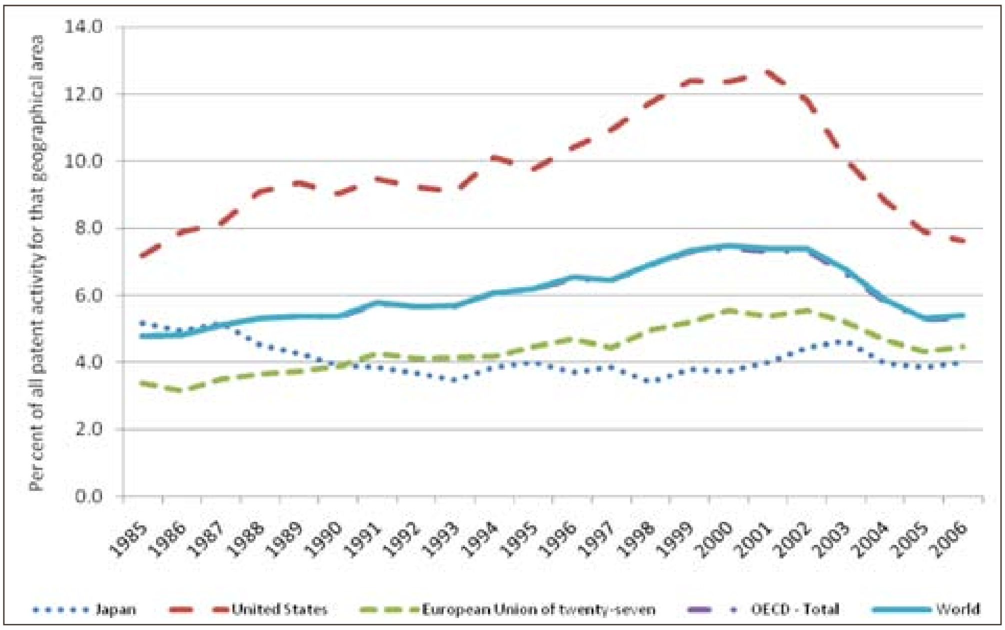


Figure 4.6c: Biotechnology (per cent of all patent applications)



Finally, Figure 4.6c reports the corresponding percentages of biotechnology activity (as a proportion of total patent applications for each of the geographical areas). The fall in activity at the end of the dot-com boom is, again, perhaps not surprising, although the size of the impact on the biotechnology area is; by the end of the period, the proportion for the US was not far off its 1985 level (at under 8 per cent of all US EPO patent applications). There appears to have been a significant reassessment of the relative importance of biotechnology as an area of technological effort and technological change, particularly in the USA, but also in the EU. While Japan does not appear to show the same degree of change, particularly with regard to the dot-com bubble (Japan had its own financial crisis in the latter part of the 20th Century), biotechnology applications formed a smaller proportion of its EPO patenting in 2006 than in 1985.

The class C12N, "micro-organisms"[24], is a particulary important area of biotechnology. As this class includes patents relating to stem cells, tissues and genetic engineering, it was decided to examine this class in slightly more detail. Figures 4.7a – 4.7d show the patenting trends in micro-organisms. The overall patterns in application activity (Figure 4.7a) appear to be similar to those for biotechnology in Figure 4.6, with perhaps two important exceptions. First, if anything the growth to the peak and the subsequent decline after the dot-com bubble are even steeper than in biotechnology as a whole. Second, the peak in micro-organisms activity appears to be more closely associated with the dot-com bubble. Nevertheless, there is no real sign of recovery through to 2006 (after which the effects of the financial crisis may produce a further negative effect). At this stage, it appears that there has been a downward re-evaluation of the future prospects of technological advances in the micro-organisms area.

Figure 4.7b shows the cumulative amount of patenting activity, which confirms the discussion in the previous paragraph. There appears to be exponential growth in patent applications in micro-organisms up to and including 2001, but the upward trend after that suggests a sgnificantly slower rate of accumulation of technology in this area. There is some evidence that the more adverse situation can also be found in Japan, but perhaps starting in 2003 rather than 2002.

[24] The term "micro-organisms" is a catch-all – see below.

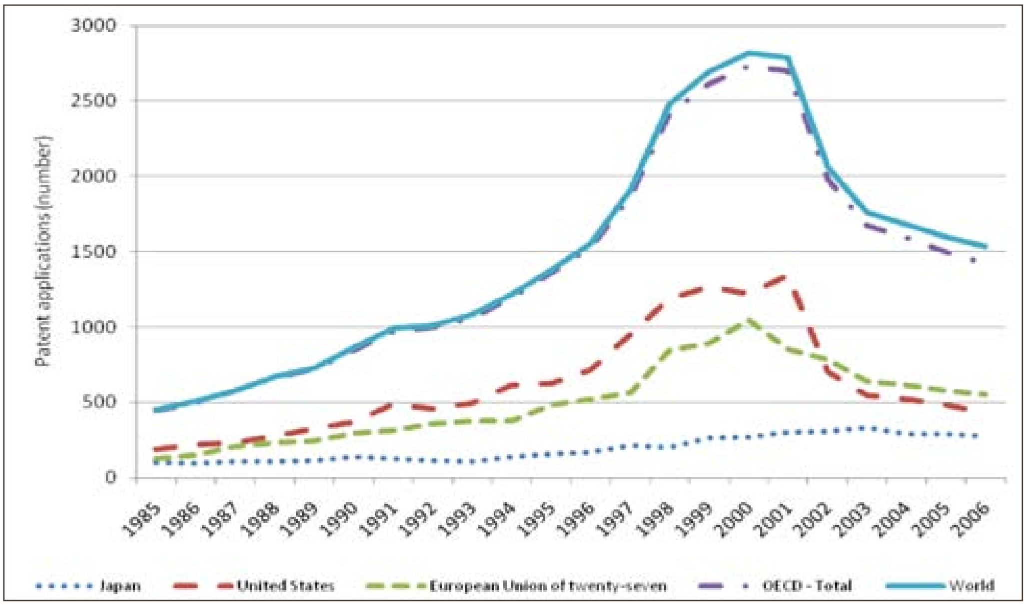
It is clear from Figure 4.7c that this pattern is not just the effects of the economic situation on patent activity as a whole, as the proportion of micro-organism patent applications within the total of all patent applications also shows the same pattern. As in the case of biotechnology, Japan appears to be largely immune from the impact of the dot-com bubble, while, if anything the USA is more severely affected in the case of micro-organisms than in the case of biotechnology (by the end of the period, the US has a smaller number of EPO applications in this area than the EU – see Figure 4.7a). Again, the relative down-turn in activity appears to take place in Japan beginning in 2003 rather than 2002.

As C12N includes such a diverse range of technologies[25], its subclasses were examined to see if all aspects of the class follow the same patterns as micro-organisms and biotechnology as a whole. This more detailed data concerns patent applications filed to the U.S. patent office which published in 2003 and 2008.[26]

As Figure 4.7d shows, the number of published patent applications in micro-organisms declined between 2003 and 2008. The decline was particulary dramatic in the three largest subclasses: C12N1 (micro-organisms), C12N9 (enzymes) and C12N15 (genetic engineering) There was a small increase between 2003 and 2008 in the C12N5 subclass which relates to cells and tissues and includes stem cell technology.

Figure 4.7a - c: Number of patent applications filed at the EPO between 1985 and 2006 in micro-organisms, by geographical location of the inventors

Figure 4.7a: Micro-organisms (number)



[25] The subclasses within C12N and their subject matter are: C12N1 micro-organisms, culture media therefor; C12N3 spore-forming or isolating processes; C12N5 undifferentiated human, animal or plant cells, tissues, cultivation or maintenance thereof, culture media therefor; C12N7 viruses; C12N9 enzymes; C12N11 carrier-bound or immobilised enzymes and carrier-bound or immobilised microbial cells, preparation thereof; C12N13 treatment of micro-organisms or enzymes with electrical or wave energy; C12N15 mutation or genetic engineering; DNA or RNA concerning genetic engineering, vectors.

[26] Future work will explore the consistency of the results between the EPO and USPTO patent routes.

Figure 4.7b: Micro-organisms (cumulative number)

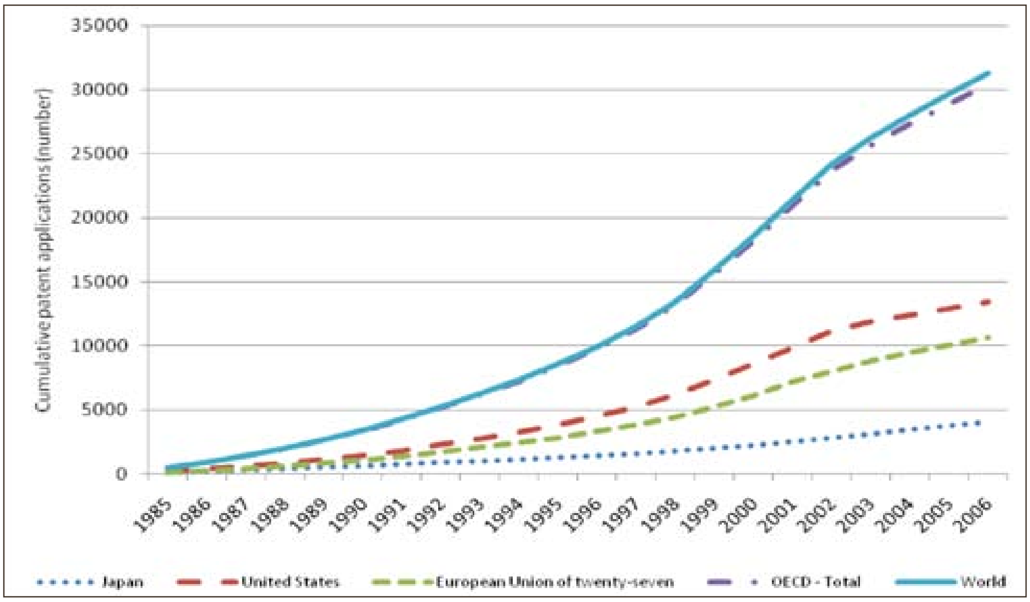


Figure 4.7c: Micro-organisms (per cent all patent applications)

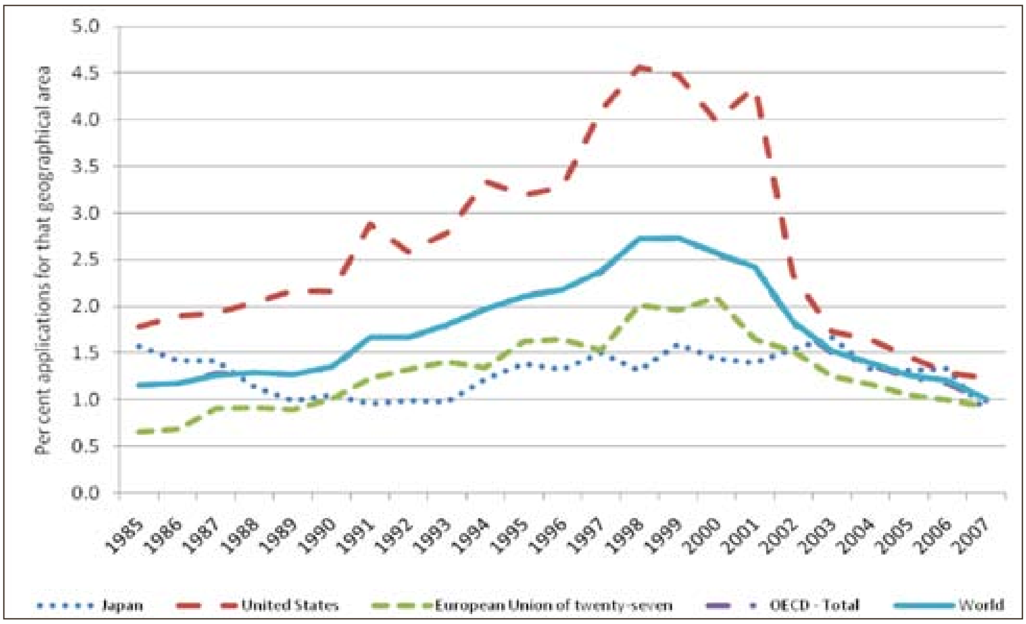
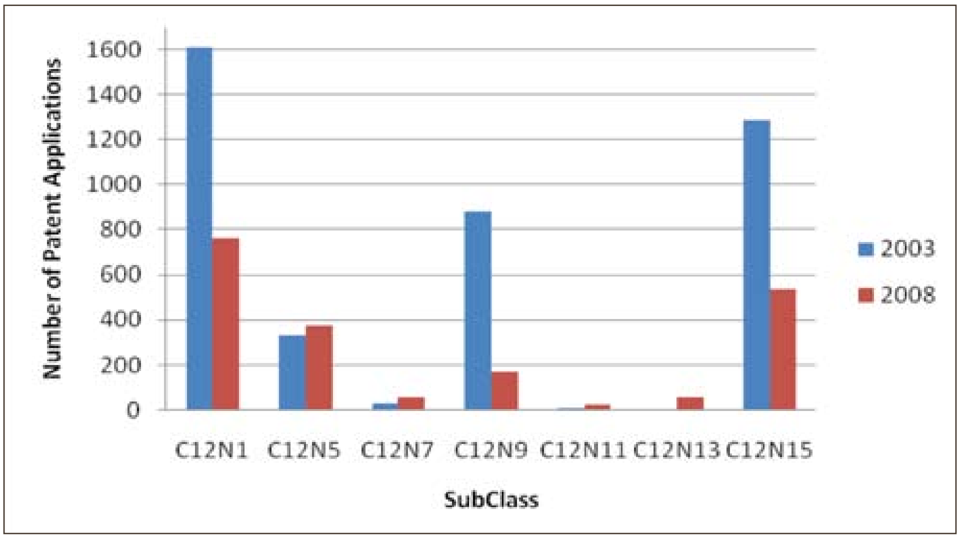


Figure 4.7d: Number of published U.S. patent applications in 2003 and 2008 within micro-organisms by subclass



4.4.4 Medical Preparations and Pharmaceuticals

The pharmaceutical patent technologies analysed here include medicinal preparations (class A61K) and the therapeutic activity of chemical compounds (A61P).[27]

This is a very active area both in terms of the number of patent applications (Figure 4.8a) and in terms of the percentage of total patenting activity that it comprises (Figure 4.8b). It is clearly an area of considerable importance to the UK, given the role played by pharmaceutical companies within the domestic economy. However, it is also an area which appears, at least based upon trends over the last couple of decades, to be experiencing dminishing returns to R&D, perhaps because of the falling magnitude of technological opportunity in this area (e.g. the early evidence of Ballance, et al. 1992, p. 94-95). Nevertheless, despite the effects of the dot-com bubble, the overall trends in numbers of patents have been upwards for the different geographical blocs (see Figure 4.8a). While Figure 4.8b, which shows the cumulative total of EPO patent applications for medical preparations, shows a distinct "kink" in the curves around 2002 for all of the geographical areas (although less so for Japan than the others), this change in trend caused by the dot-com bubble bursting is somewhat less severe in nature than in the case of biotechnology and micro-organisms.

[27] There is some overlap between the patents classified as pharmaceuticals and as part of biotechnology because the A61K technology group as a whole contains some areas that could be classified as part of the biotechnology caterogy (e.g. genetic medicines). However, these subclasses make up only a small part of A61K so we analyzed the class in its entiriety here.

Figure 4.8: Number of patent applications filed with the EPO in medical preparations between 1985 and 2006, by geographical location of the inventors

Figure 4.8a: Pharmaceuticals (number)

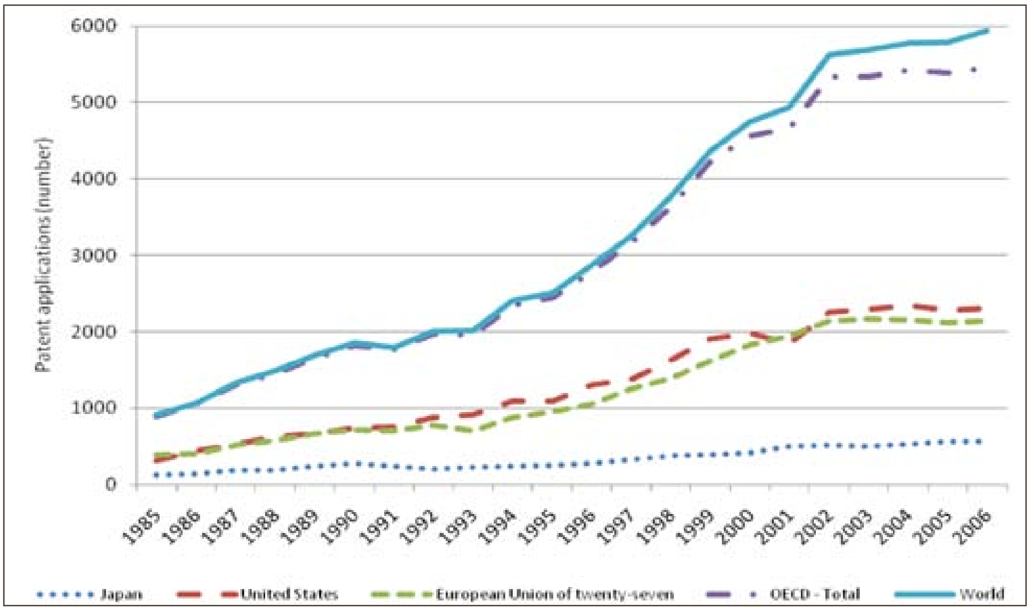


Figure 4.8b: Pharmaceuticals (cumulative number)

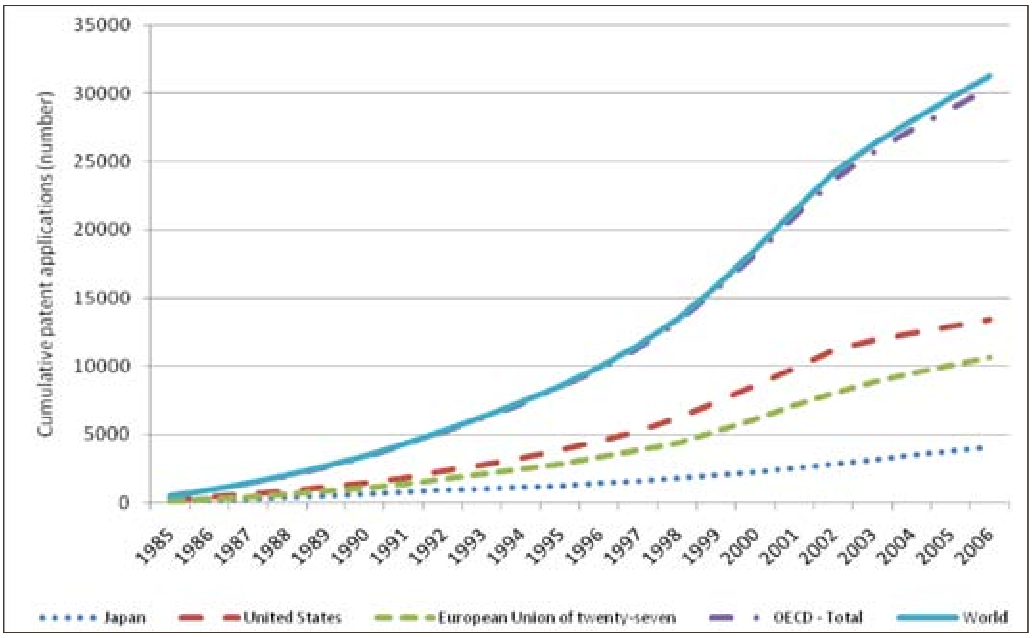
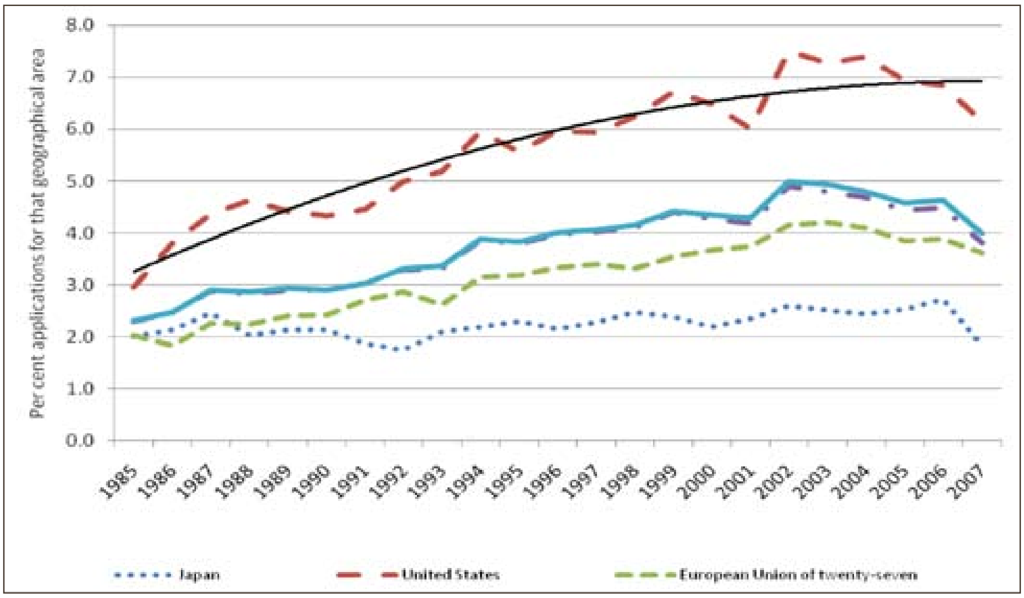


Figure 4.8c: Pharmaceuticals (per cent all patent applications)



The proportion of total patenting activty formed by pharmaceuticals, although growing through much of the period, did so at a diminishing rate (Figure 4.8c), and finally showed some signs of falling overall following the dot-com crisis (though not in any way like biotechnology as a whole or micro-organisms). This is confirmed by fitting polynomial functions to the various areas which reflect the medium to long term trends. The results suggest that the proportion of patent applications attributable to this area has been growing roughtly linearly in Japan, but growing at a diminishing rate in all the other geographical blocs (a cubic trend line has been incorporated in Figure 4.8c for the US to illustrate this point).

4.4.5 Medical technologies

In this section, medical technologies are defined by the international patent classes:

- A61B (diagnosis, surgery, identification);
- A61C (dentistry);
- A61F (prostheses, medical technologies, bandages, dressings);
- A61G (transport, personal conveyances or accommodation specially adapted for patients or disable persons and operating tables and chairs);
- A61H (physical therapy apparatus);

- A61J (containers specially adapted for medical or pharmaceutical purposes, devices or methods for administering medicines);

- A61L (methods or apparatus for sterilising materials, bandage, dressings, absorbent pads, surgical articles);

- A61M (devices for introducing media into or onto the body and devices for taking media from the body such as covers suction, pumping or atomising devices for medical use);

- A61N (therapy, ultrasound therapy).

It can be seen from Figure 4.9 that this is a major area of technological activity, which has increased significantly in importance over the period since 1985. What is not immediately apparent from just looking at the figure is that the most rapid increase over the period was associated with Japanese applications (the 2006 value was just under 9 times larger than the 1985 value), although Japan started from a very low base. The rate of growth of US applications outstripped that of European applications, but, while the US was more active by the end of the period than Europe, the two geographical blocs exhibited broadly similar magnitudes of activity by that stage.

Figure 4.9: Number of patent applications filed at the EPO in medical technologies, by geographical location of the inventors

Figure 4.9a: Medical technology applications (number)

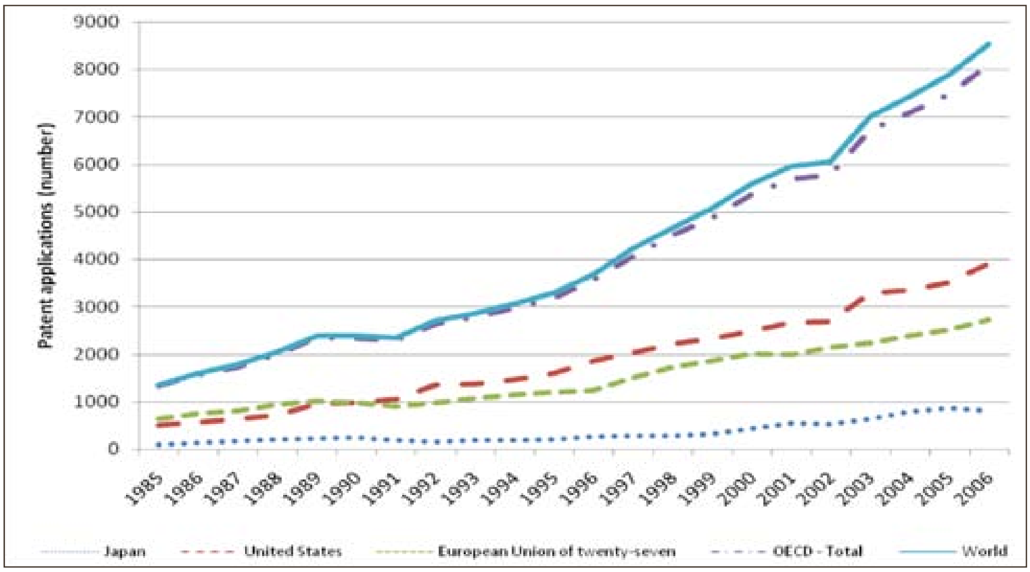


Figure 4.9b: Cumulative medical technology applications (number)

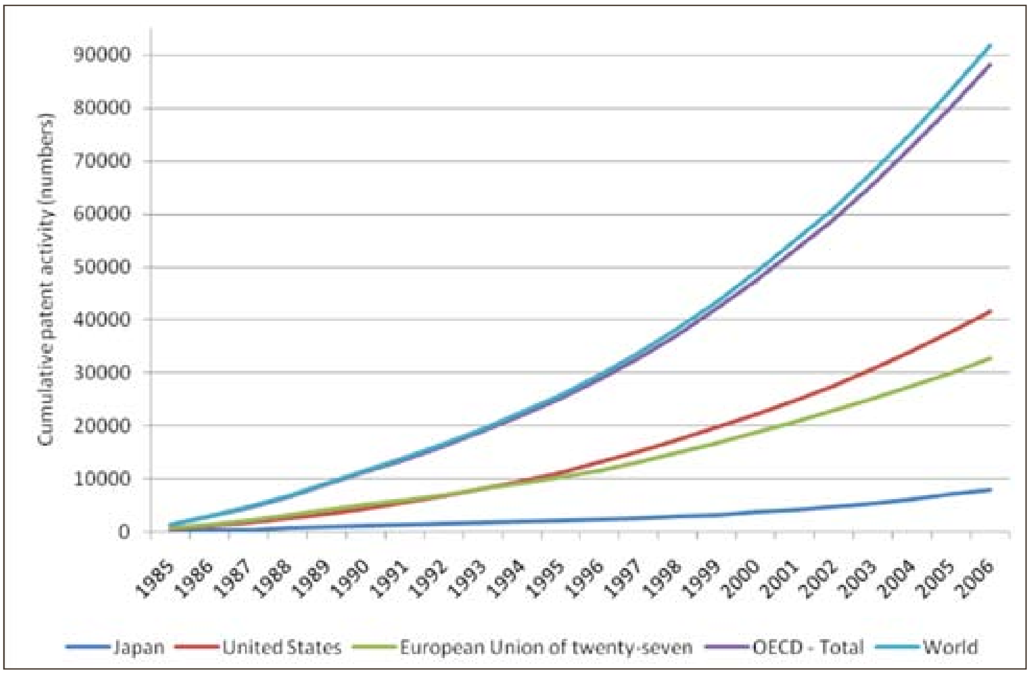
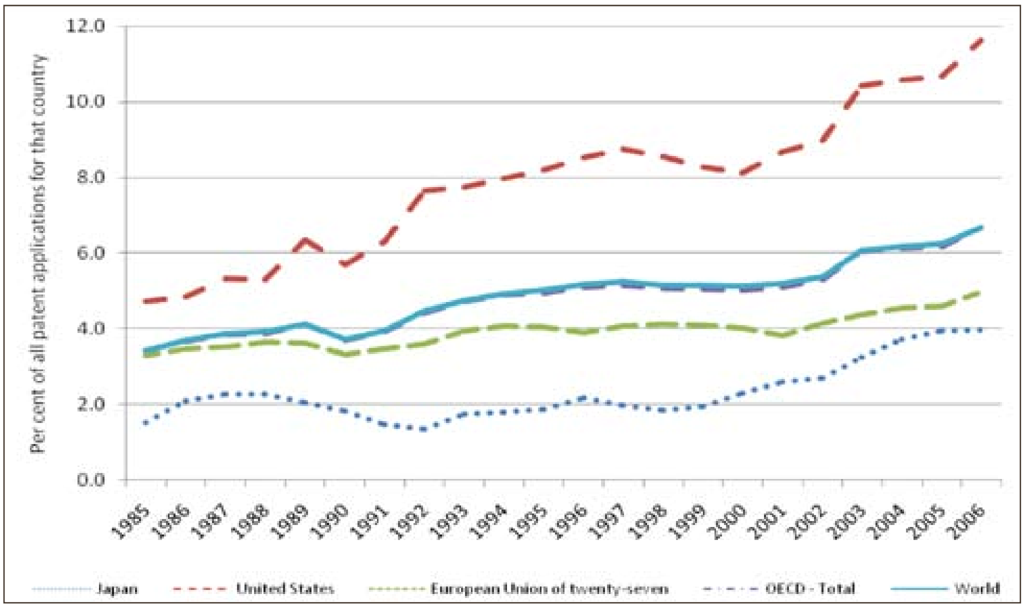


Figure 4.9c: Medical technologies (per cent of all patent applications)



The data for all of the geographical areas in Figure 4.9a suggest that this is an area of technology where patenting activity is increasing strongly year on year. This is confirmed by Figure 4.9b, which shows the cumulative number of patent applications for the same group of countries. The shape of the curves suggests that medical technologies are still in the "expansionary phase" of the sigmoidal curve normally associated with the development and exploitation of any given area of technology.

Further evidence of the growing importance of the medical technologies sector can be found in Figure 4.9c, which shows the proportion of each geographical area's patent applications to the EPO that fall in the medical technologies area, as defined above. In the case of the USA, for example, medical technology applications formed nearly 12 per cent of all US applications to the EPO in 2006 (provisional estimates for 2007 suggest that this rises to 12.6 per cent in 2007). While the EU leads Japan in terms of the overall percentage of EPO patent applications associated with medical technologies, the rate of increase was faster for Japan.

Given the overall importance and relatively positive features of technological advance in this area, Figures 4.10a - 4.10d explore some of the areas of medical technology in more detail. These four areas are: diagnosis surgery identification (class A61B); filter, prostheses, bandages, dressings and first aid kits (A61F), devices for introducing media into, or onto, the body ; devices for transducing body media or for taking media from the body (A61M) and ultrasound therapy and other similar types (A61N) While some of these areas appear to be associated with "lower", if new, technology (e.g. bandages and dressings), in some sense, this requires further investigation and, even if this proves to be the case, it does not mean to say that there is not a profitable market for new products based upon these technologies (and associated employment opportunities). In addition, it should be noted that this group includes a number of recognised high technology areas, such as various kinds of scanners used in the diagnosis of illnesses and diseases.

One other feature of Figures 4.10a - 4.10d is the growth in activity in these areas by the USA relative to the other countries (with the exception, perhaps, of A61M). The other notable feature is that, while Japan tends to show patterns similar to other areas of technology outlined above in three of the areas of medical technology, it shows quite a distinctive pattern in, A61B, the area of "diagnosis, surgery, identification, etc.". This area of technology becomes more important in Japan (vis a vis other areas of technology) than in the EU by the end of the period.

Figure 4.10: Patent applications filed at the EPO in medical technologies, by geographical location of the inventors (per cent)

Figure 4.10a: Diagnosis, surgery, identification (A61B)

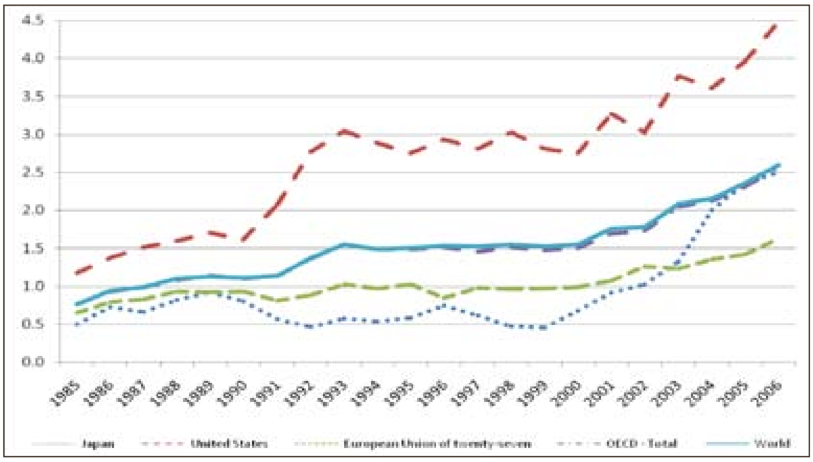


Figure 4.10b: Prostheses, medical technologies, bandages, dressings, ... (A61F)

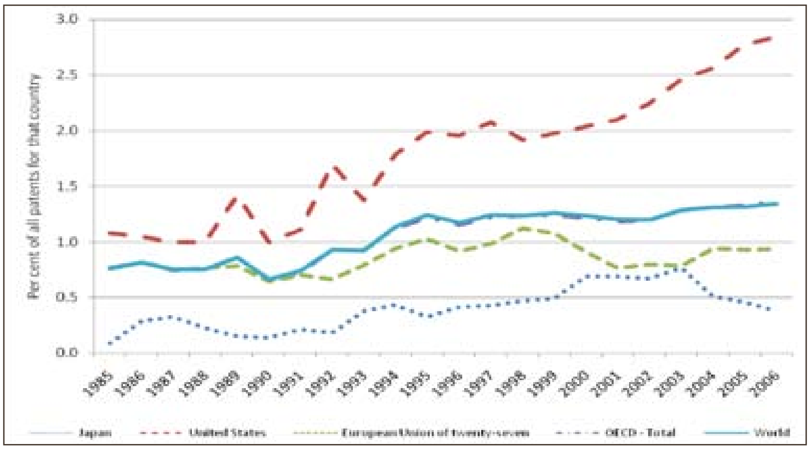


Figure 4.10c: Devices introducing media into/taking media from the body (A61M)

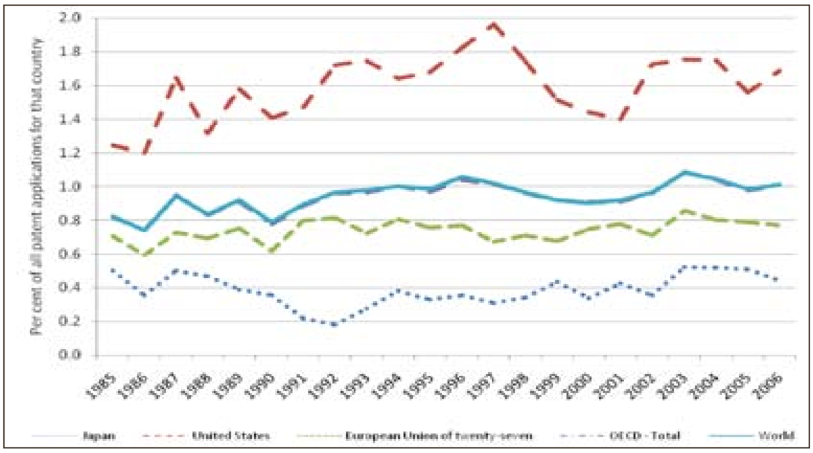
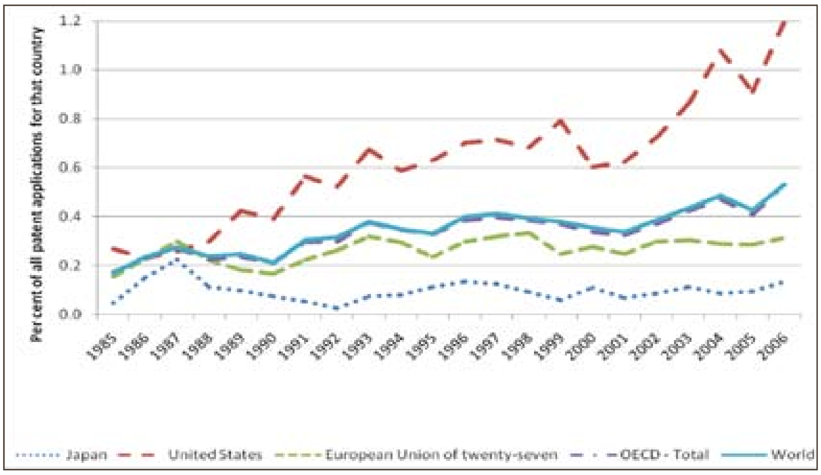


Figure 4.10d: Devices for therapy, ultrasound therapy, … (A61N)



4.4.6 Information Communication Technologies (ICTs)

While ICTs do not fall within the biotechnology, pharmaceuticals and medical technology, nevertheless, it is clear that many developments in health technologies are related to advances in ICTs. Obvious examples of this type include the scanning technologies that have emerged to radicalise the diagnosis of various health conditions, and the incorporation of wireless communications in medical technologies. Figures 4.11a to 4.11c show the corresponding numbers and percentages for ICTs that were discussed for health technologies.

While ICTs were at the heart of the dot-com bubble, Figure 4.11a suggests that technological advances in this area have not been affected to the same extent as most areas of health technology, such as the areas of biotechnology and micro-organisms. There appear to be at least three reasons for this: first, although it is not immediately apparent why, the extent and nature of Japanese technological advance does not appear to have been so adversely affected as that of other geographical blocs by the dot-com bubble, especially the USA; second, ICTs are both heavily influenced by Japan and also form a high proportion of Japanese technological activity; third, ICTs form a GPT (general purpose technology) which remains both crucially important and potentially profitable in the medium and long term future, mitigating against any short-term adverse effects, such as the dot-com crisis.

Figure 4.11b demonstrates that the cumulative trends in ICT applications show an exponential pattern, with no obvious indication of any "turning-point" that would indicate a diminution of technological advance in this area over time. Interestingly, all three geographical blocs have cumulative series which are very similar, with the EU surprisingly overtaking the USA (which is almost certainly a feature of using EPO patent applications rather than US or PCT patent data).

Figure 4.11c shows the importance of ICTs relative to all patenting activity for each of the three geographical blocs and for the World and OECD countries as a whole. What stands out is the Japanese focus on ICT technologies; ICTs patent applications form between 40 and 50 per cent of all Japanese patent applications at the EPO. The proportion of ICTs within the total is also higher for the US than for the EU. While the Japanese focus on ICT technologies is a major strength during the period that ICT advance remains in its "expansionary phase", it may also be a major source of problems if Japan has to switch its focus to other areas of technology as the area of ICT advance matures.

The corresponding trends in nano-technology are shown in Figures 4.12a to 4.12c. The field of nano-technology is in its relative infancy, so its application to advances in health technology are one step further removed. Nevertheless, nano-technology appears to have the potential to create radical new opportunities for advances in health technology in the medium to long term.

While the minor jumps in the series, both down and up, at the end of the period will have had some effect, the overall picture from looking at cumulative patent applications is one of expontential growth (see Figure 4.12b). The rapid increasing in patenting activity in nano-technology in the second half of the 1990s has the effect of driving the cumulative series upwards even more steeply. While growth in annual activity has slowed since then, the overall picture in the cumulative series is strongly upwards. This, therefore, appears to be a technology in the early, exponential stages of its technological advance.

All of the geographical regions show some sign of a slowing or even a slight downturn around 2001, however, this is, again, clearest in the case of the US. Nevertheless, based upon polynomial functions of up to power 3 (see Figure 4.12c)[28], the medium to long term projections would still be for increasing rates of activity in this area, with nano-technology becoming a relatively more important area within the total of all technologies.

[28] Higher powers than 3 begin to pick up the downturn at the end of the series.

Figures 4.11 and 4.12: EPO patent applications in complementary technologies

Figure 4.11a: ICTs (number)

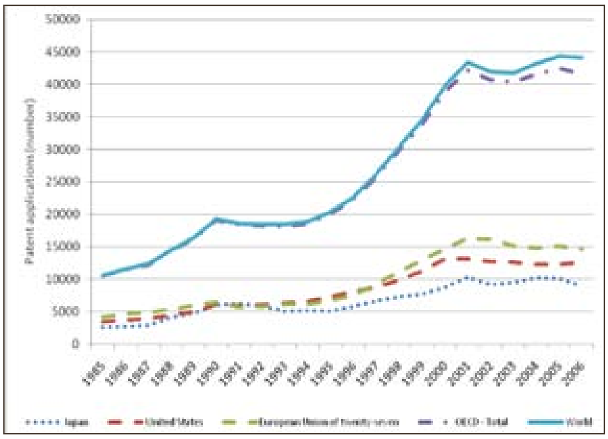


Figure 4.12a: Nanotechnology (number)

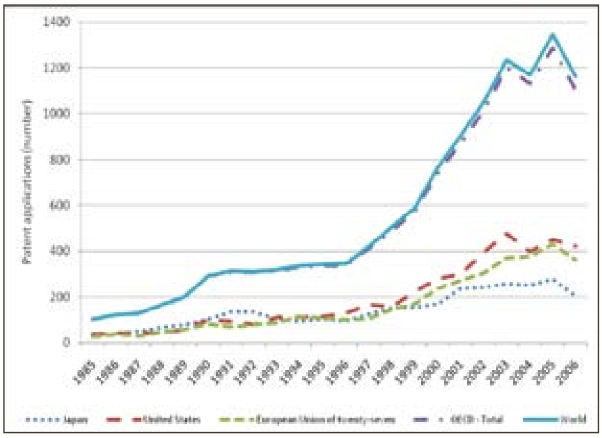


Figure 4.11b: ICTs (cumulative number)

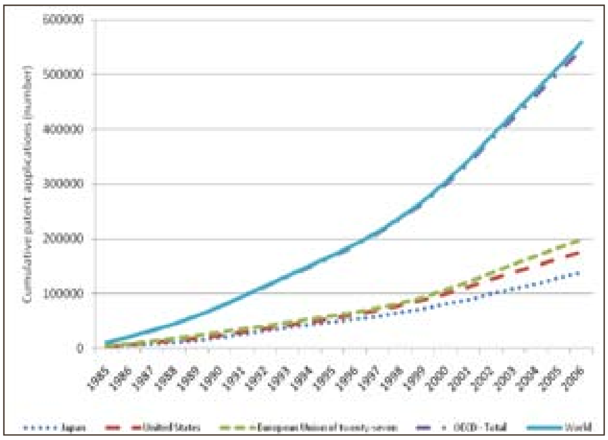


Figure 4.12b: Nanotechnology (cumulative number)

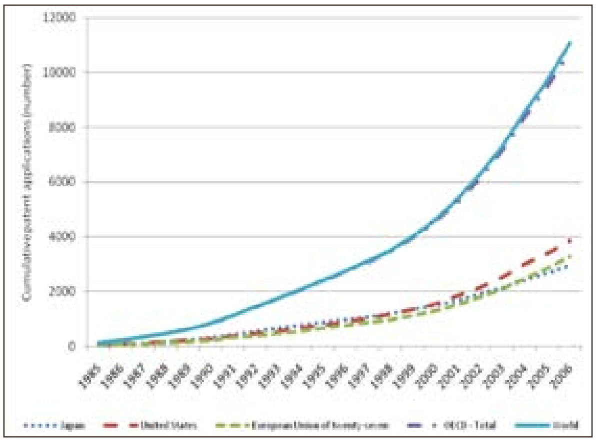


Figure 4.11c: ICTs (per cent all patent applications)

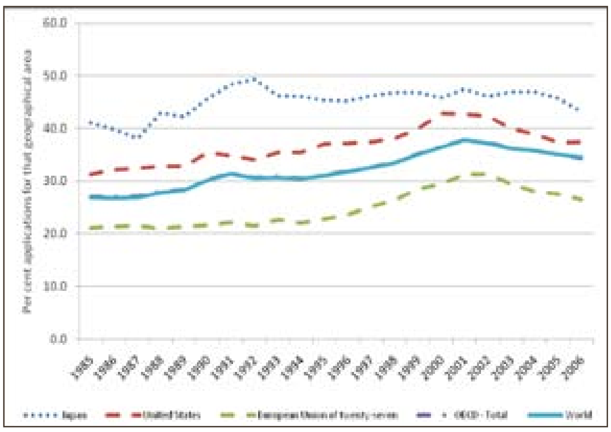
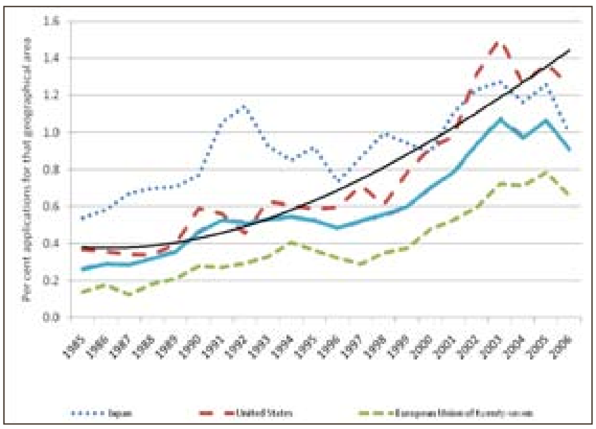


Figure 4.12c: Nanotechnology (per cent pat applications)



4.5 Conclusions

This chapter has provided a preliminary investigation of the patterns of technological change in the area of bio-medicine. Ideally, it would have said more about the diffusion of existing and likely future technologies, along with the resulting skills implications. Given the present state of the empirical literature and data sources, the present chapter is largely restricted to looking at recent trends in technology to examine:

- which appear to be the broad areas of technological opportunity for the future;

- to what degree are different geographical zones well placed to be at the forefront of such areas; and, in combination with later parts of the present report;

- what is the likely match between these technology areas and, at a broad level, the existing skills and knowledge base of UK industry, bearing in mind the absorptive capacity of the workforce for upskilling in new areas of technology.

Before turning to some sector-specific issues, there are some general conclusions that can be drawn from the present analysis:

- "bio-medical" technologies, as defined above, are a major area of R&D and technological activity, driven partly by the growing demands for (and on) health care services (e.g. as populations round the world become richer, as individuals live longer, etc.) and (in certain newer areas of technology), by technological opportunity and by (often currently ill-defined) future commercial applications;

- the size of the global effort in the advancement of bio-medical technologies is extremely large and, hence, international competition to be at the forefront of many of the associated areas of technology is intense:

  - in many of the areas, the USA is not only the country which dominates in terms of R&D and patenting activity, but also shows the strongest upward trends, reflecting its effort to be the technology leader;

  - there are exceptions to this "rule", such as ICTs, where Japan still appears to be concentrating a considerable part of its efforts – but, ICTs have such a pervasive range of applications, that Japan seems likely to benefit from the growth of other areas (such as medical scanner technologies) without the need to be leader in other aspects of the technology;[29]

  - the EU is often a secondary player to the USA, although often showing some advantage over Japan. As the UK is a small (though important) player within the EU as a whole, the implication appears to be that the UK not only needs to find technological niches where it will have a comparative advantage, but also a strategy with regard to the optimal adoption of technologies produced elsewhere, including outside of the EU;

[29] Although the application of ICTs to other areas (such as scanners) might also give Japan a door by which it might enter into these technologies at other levels.

- certain areas of technology have been particularly impacted by the effects of the "dot.com bubble" (e.g. micro-organisms) and have yet (if they ever do) recover to the earlier levels of activity[30]. Interestingly, the patterns of change for ICTs seem little affected by the bursting of the "bubble", as does the overall activity of Japan, which tends to specialize in ICTs.

At a "sectoral level", the results of the present work boil down to addressing a small number of dynamic structural issues, in particular, two that will be highlighted here:

- despite the significant forces for change faced by the pharmaceuticals sector, it remains a major employer within the UK, both in terms of its high-level technological activities (e.g. R&D), but also in terms of the number often less-skilled production jobs that it currently gives rise to – jobs that are particularly at risk of going abroad as part of the general pattern of globalisation;

- the automobile sector as a whole (both assembly and the associated supply chain) is experiencing a shift in production away from the UK, again as part of the general globalisation process. While this is part of a longer term trend, it has been accentuated by the recent financial crisis and resulting recession, hitting certain areas (e.g. the West Midlands) particularly hard, and resulting in the loss of skilled jobs, whose previous incumbents are often either unemployed or moving into lower skilled employment;

- while the evidence suggests that there has been, over recent decades, a massive increase in patenting activity in biotechnology, the data also suggest that this trend is sensitive to the investment climate. Following the bursting of the dot com bubble in the early 2000s patenting activity fell away though it has picked up again recently. Given the pace of scientific endeavour in this field and the level of R&D investment to translate scientific breakthroughs into products this would appear to be most promising area of activity. From an employment perspective, it is not clear whether this will feed into large-scale or niche manufacture;

- the medical technologies sector is one where there have been relatively strong levels of patenting activity over recent years. Many of the activities here are engineering related which has potential to create employment in the engineering sector in the UK.

The question arises as to whether the technology trends outlined in this section throw any light on these two "structural problems". Whilst not wanting to overstate the case, based upon an initial investigation of the R&D and patenting evidence, it does seem possible to draw some useful conclusions about these two issues:

- despite the problems reported by the pharmaceuticals sector (including the apparent, long-standing trend in diminishing returns to R&D), patenting activity has continued to increase for much of the period since 1985.[31] It is only in the period since 2001 that the rate of increase appears to have

[30] The effects of the financial crisis and the associated global recession lie at the very end of the period of study and nothing of substance can be said about their effects on technological activity at the present time.

[31] Again, corroborative evidence needs to be sought outside of the EPO data, for the USA PTO and other sources..

slowed, which may be simply a reflection of the dot.com bubble or it may be something more long-term. There is, however, probably considerable life left in the pharmaceuticals sector yet and the loss of the leading technological role that this sector plays in the UK would have serious consequences for the UK science base. In addition, the loss of this leading role would almost certainly accelerate the demise of the more commonplace production activities of the sector, with accelerated job losses to China, India and other developing countries;

- perhaps the most surprising result, at least to the research team, was the level and growth of technological activity in the medical technologies area. This is an area where, broadly speaking, whilst some way behind the USA, the EU may be within "striking distance". While there are clearly a number of very high technology areas, where countries such as the US and Germany have an important lead, many of the technologies are less clearly at the cutting edge of science, and may be associated with new products and processes that could be produced in the UK, where there may be a readily available supply of suitable skills if enterprises could be encouraged sufficiently to move into this area. The potential, for example, of firms in the automotive supply chain in the UK to capture this market is particularly considerable (Hogarth et al., 2005).

5 Current and Future Skill Demand

5.1 Introduction

This chapter is concerned with current and future skill demand in the bio-medical sector. It draws on evidence from the Working Futures database – a specially constructed time-series of data relating to the bio-medical sector - and a variety of surveys which have been conducted in various sub-sectors. It should be stated at the outset that some of the surveys conducted provided relatively little evidence about the population of employers they have surveyed or the extent to which the survey is representative of that population. Nevertheless, by comparing a number of sources it is possible to identify some common trends across the sector with respect to current and future skill demand.

5.2 Working Futures Projections of Employment Demand

In order to provide a consistent set of estimates of current and future skill demand in the bio-medical sector, a time series of employment was created from the Working Futures time series. Working Futures provides a historical time series dating back to the early 1980s, and projects the future employment demand to 2017. Though the projections were prepared just as the scale of the current economic downturn was becoming apparent, they still provide a robust view of trends over the medium-term.

An employment time series was produced for the following sub-sectors:

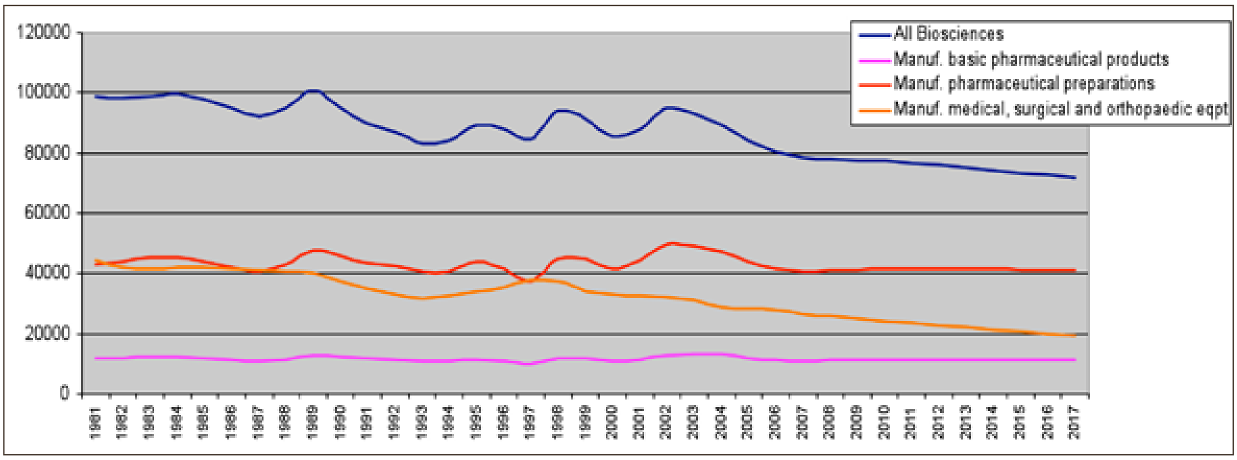
- Manufacture of basic pharmaceutical products;
- Manufacture of pharmaceutical preparations; and
- Manufacture of medical, surgical and orthopaedic equipment.

This provides a partial coverage of the sector as described in Section 1.3 but nonetheless is likely to contain the majority of people who work in the bio-medical sector.

Figure 5.1 shows the overall employment trend between 1981 and 2017 based on a series derived from the Working Futures database. In 2007, it is estimated that 79,000 people were employed in the sector overall in England. Of this, 27,000 were employed in medical technologies and 52,000 in pharmaceuticals. Based on data reported by BIS (see Chapter 2), an upper estimate of total employment in England would be around 110,000. If one were to take a mid-point estimate, this would suggest around 95,000 people employed in the bio-medical sector in England.

The general trend - derived from the Working Futures database - is for employment to decline gradually, especially so in medical technologies, but much less so in pharmaceuticals. Table 5.1 summarises employment change across the sector and reveals that employment in the pharmaceuticals sector has been, and is expected to continue to, fairly stable over the forecast period, with most of the employment loss attributed to medical technologies. It should be noted that these data ignore replacement demands which, as Working Futures demonstrates, tend on balance to be positive over the medium-term.

Figure 5.1 Employment Trends in Pharmaceuticals and Medical Technologies



Source: Working Futures Database

Table 5.1 Total Employment Change in Pharmaceuticals and Medical Technologies in England, 1997-2017

	1997	2002	2007	2012	2017
All Bio-medical	85	95	79	76	72
Manuf. basic pharmaceutical products	10	13	11	11	12
Manuf. pharmaceutical preparations	37	50	41	42	41
Manuf. medical, surgical and orthopaedic eqpt	38	32	27	23	19

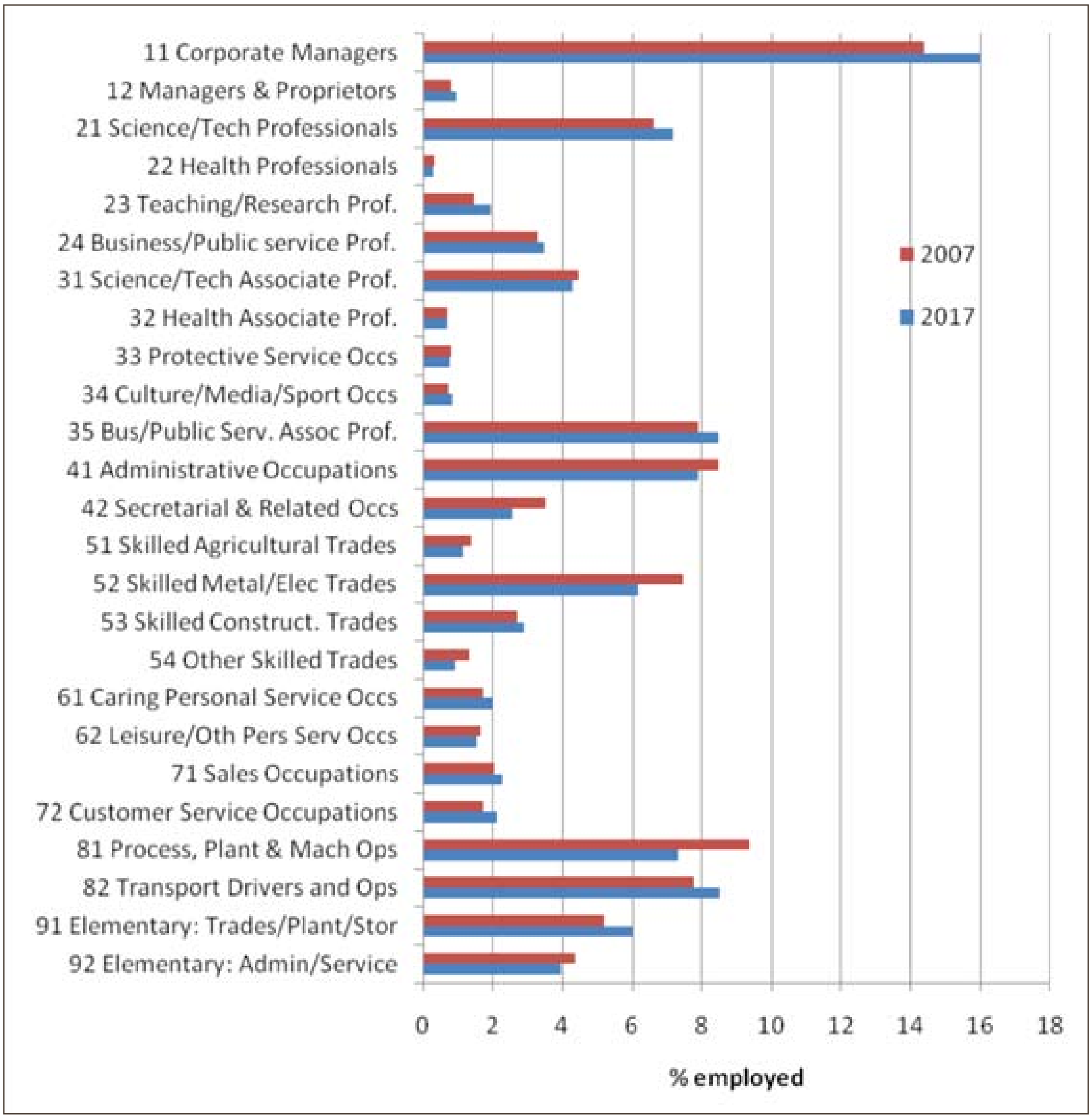
	Growth Rates		
	1997-2007	**2007-2012**	**2012-2017**
Per cent pa			
All Bio-medical	-0.6	-0.8	-1.1
Manuf. basic pharmaceutical products	1.3	0.8	0.1
Manuf. pharmaceutical preparations	0.9	0.5	-0.3
Manuf. medical, surgical and orthopaedic eqpt	-3.4	-3.0	-3.3

	Change (000s)		
	1997-2007	**2007-2012**	**2012-2017**
Change *=(000s)			
All Bio-medical	-5	-3	-4
Manuf. basic pharmaceutical products	1	0	0
Manuf. pharmaceutical preparations	3	1	-1
Manuf. medical, surgical and orthopaedic eqpt	-11	-4	-4

Source: Working Futures Database

Figure 5.2 shows the occupational structure in the bio-medical sector both currently and how it is expected to change over the medium-term. It is immediately apparent that while much of the debate is about the demand for highly qualified managers and scientists on which the future development of the sector depends, much employment is also concentrated in relatively less skilled occupations related to skilled trades and machine operatives. Skilled trade occupations, especially those allied to engineering, are often ones in which recruitment problems are fairly common. So there is a need in considering the skill needs of the sector to bear in mind that there is a requirement for a large number of intermediate and lower skilled people.

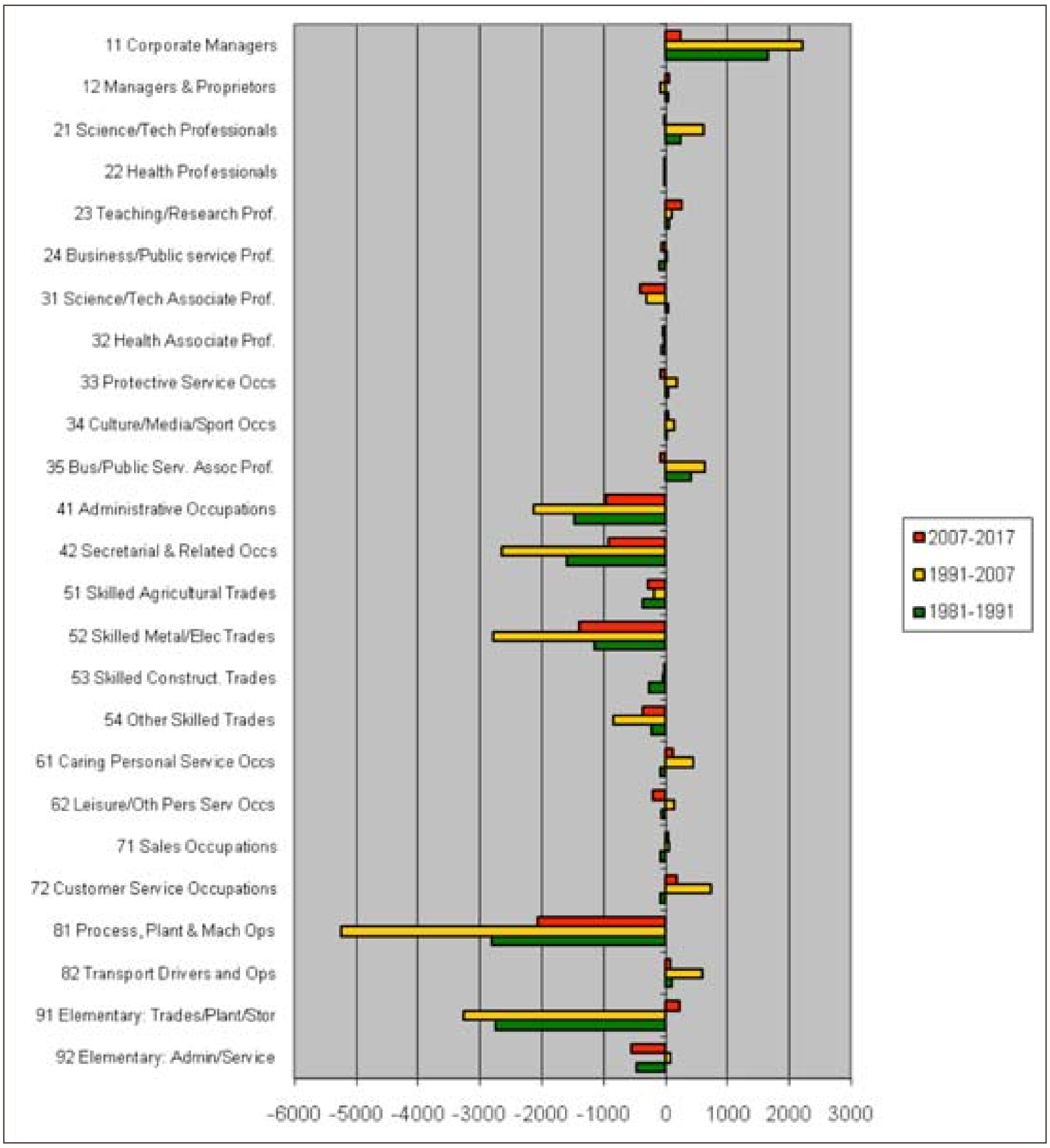
Figure 5.2 Structure of Employment in the Bio-Medical Sector



Source: Working Futures Database

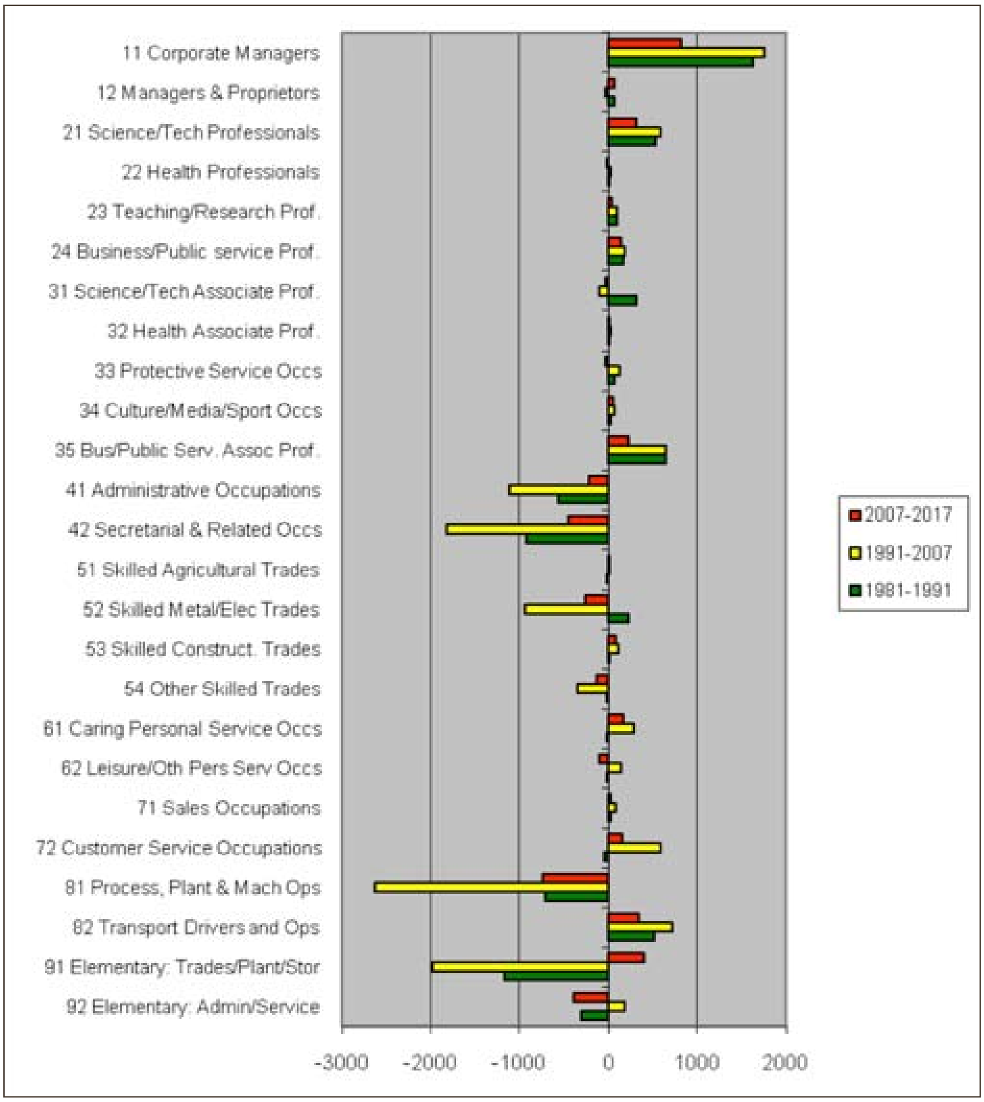
The overall pattern of occupational change is provided in Figures 5.3 to 5.5 which show that it is amongst the higher level occupations, notably managers and science professionals, in which employment is expected to grow over the medium-term. In medical technologies the overall pattern of change is for total employment across all occupations to be in decline over the medium-term.

Figure 5.3 Occupational Change in the Pharmaceuticals and Medical Technologies Sector, 1981-2017



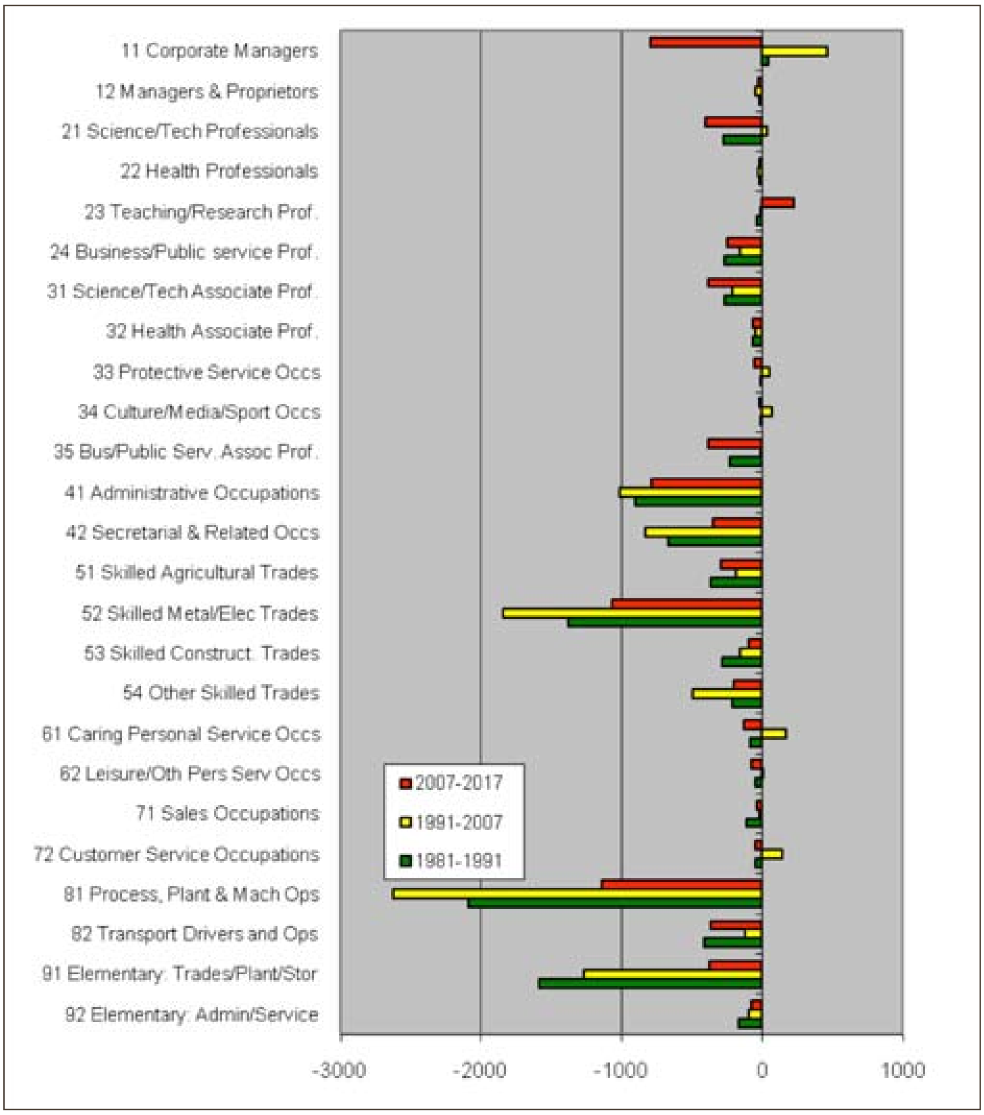
Source: Working Futures Database

Figure 5.4 Occupational Change in the Pharmaceuticals, 1981-2017



Source: Working Futures Database

Figure 5.5 Occupational Change in Medical Technologies, 1981-2017

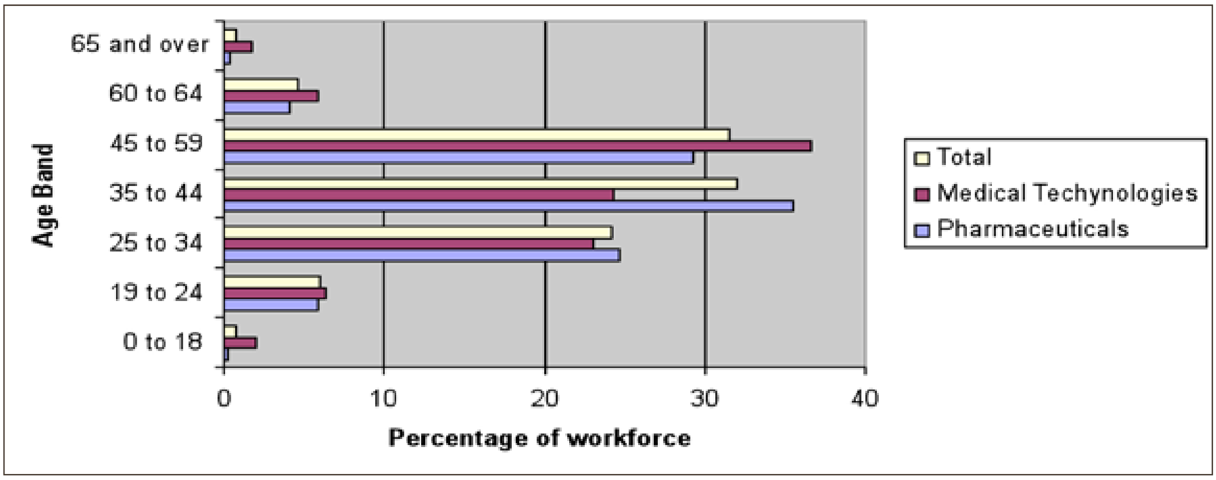


Source: Working Futures Database

Projections of future employment suggest that there will be an increased demand for people qualified at graduate and postgraduate levels across the economy (Wilson, 2008). In particular a substantial increase in the number of people qualified to graduate and postgraduate levels in engineering and biological sciences will be required. At a postgraduate level, an additional 112,000 people with a postgraduate qualification in Biological Sciences will be required (representing a 70 per cent increase between 2007 and 2017) and an additional 220,000 postgraduates in engineering. This suggests, other things being equal, that employers in the bio-medical sector will face increasing competition for the highly qualified staff they need. The available evidence reveals that it is common for the bio-medical sector to report a demand for substantial numbers of postgraduates. In Medicon Valley in Denmark at the beginning of this century projections were being made of a huge additional requirement for people qualified to PhD level in subjects allied to the bio-medical sector (Thomsen, 2004).

In general, replacement demands are likely to be considerable across occupations in the bio-medical sector. Figure 5.6 shows the age structure of the workforce and reveals that around a third may be expected to retire over the next ten to fifteen years. Cogent in relation to the pharmaceutical sector expects the total level of replacement demand over the next decade to be around 27,000 (by 2020 with around 60 per cent of this being concentrated in higher level occupations, 25 per cent in technical occupations, and 10 per cent in process occupations (Cogent, 2009).

Figure 5.6 Age Structure of the Bio-medical Workforce



Source: LFS, 2008 Q1-Q3

5.3 Specific Skill Needs in Pharmaceuticals

Working Futures uses generic occupations to show how skill structures are developing, but there is also a need to look further into the specific skills which are emerging in relation to the sector interest. Based on a review of the literature a number of high level skills have been identified as being critical to the future success of the sector (see Table 5.2). Where information was available, or provided by stakeholders, an indication of the extent to which shortages are currently experienced is provided.

Table 5.2 Strategic Skill Needs in the Pharmaceutical Sector

Skill set / discipline	Level	Shortages (where reported)	Current Demand	Future Demand
Biological Skills				
Clinical pharmacology/ translational medicine	Graduate PhD Post-doctorate	Relatively small numbers required, but demand is thought to be in excess of supply	Current demand as specified but is expected to grow in the future	In the future, depending upon the breakthroughs in biotechnology, these types of skill are likely to be increasingly in demand.
Pharmacokinetics/ADME				
In vivo research skills				
In vitro research skills				
Toxicology				
Pathology				
Molecular biology				
Biochemists		Demand increasing with shift to biotechnology		
Pharmacy	Graduate		Overall high level of demand currently	Trends expected to continue in future.
Chemistry				
Spectroscopy	Graduate PhD Post-doctorate	Generally considered hard to recruit by industry	Well rounded chemists considered to be difficult to recruit.	Demand from the Bio-medical sector will increase, but supply is also increasing.
Analytical chemistry				
Synthetic chemistry				
Physics				
Bio-medical imaging	Graduate / post-graduate			Whether shortages emerge in the future is dependent upon the increase in the number of physicists. Physics has not proved as amenable to increases in the number of graduates as other science disciplines.

Table 5.2 (continued) Strategic Skill Needs in the Pharmaceutical Sector

Skill set / discipline	Level	Shortages (where reported)	Current Demand	Future Demand
Mathematics & Statistics				
Statisticians	Graduate	Demand increasing Strong demand from other sectors	Current demand strong and increasing	The demand for simulation and the increased use of bioinformatics will increase the demand for people qualified in these subjects. This will need to be allied to an understanding the phenomenon they are studying
Simulation	Graduate/PhD/ Post doctorate			
Bioinformatics				
In silico modelling				
Engineering				
Chemical engineering	Graduate	Strong competition from other sectors High labour turnover also depletes stocks	Not much evidence of severe shortages currently	The main barrier in the future may be that of attracting engineers into the sector – especially medical technologies
Instrument engineering/process control	Mixed (graduate/ non graduate)			
"omics"				
Multidisciplinary approaches including: Genetics molecular biology, mathematics , IT, etc		Emerging discipline, but highlighted in the literature as a potential source of shortage	Skills sets just beginning to emerge	The multi-disciplinary approach involving team work will become increasing to the fore
Generic Skills				
Scientific literacy		Skills which need to be allied to technical disciplines – generally considered to be in short supply		
Leadership/management		In general employers report shortages of these type of skills		
Quantitative skills		The demand for increasingly sophisticated generic skills may stimulate shortages		

Source: SEMTA (2006); APBI (2009), Edwards (2007); IER Stakeholder Interviews

Several of the stakeholders interviwed commented on the convergence of technologies and disciplines and the need for multi disciplinary teams to include engineers, bio scientists, bio engineers, data manipulation and ICT people, materials experts and people to work with living materials, electronics and design, regenerative tissue engineering, miniaturisation of devices – nano technology. This multi disciplinary working environment raised a demand for communication skills.

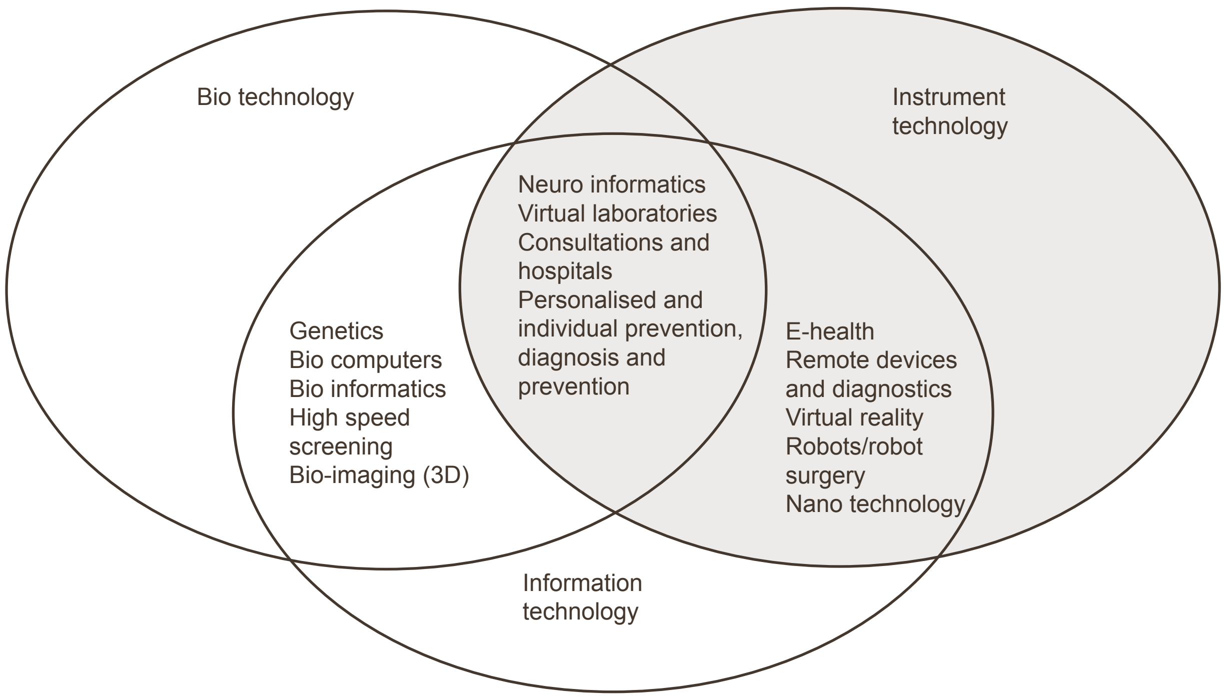
The skill needs of the sector have been defined very much with respect to emerging technologies which, in many instances, are yet to develop into new products being brought to market. Hence, the available data give no indication of the quantity of skills required, simply that more are required. It is also apparent that some of the skills required relate to disciplines or occupations (e.g. clinical pharmacology) whilst others relate more to generic, cross-cutting skills such in vivo research skills.

Data specifically for the biotechnology sector suggests that around 45 per cent of employment in this sector is in R&D jobs, compared to around 40 per cent in the USA and 50 per cent in Germany (Critical I, 2006).

5.4 Specific Skill Needs in Medical Technologies

At a strategic level the skill needs of the medical technology sector have been viewed with respect to the coalescence of skill in instrument engineering, IT, and biotechnology. It is a sector which there is a range of high level skill needs which are depicted in Figure 5.7.

Figure 5.7 Inter-industry linkages in Medical Technologies and Associated Skill Needs



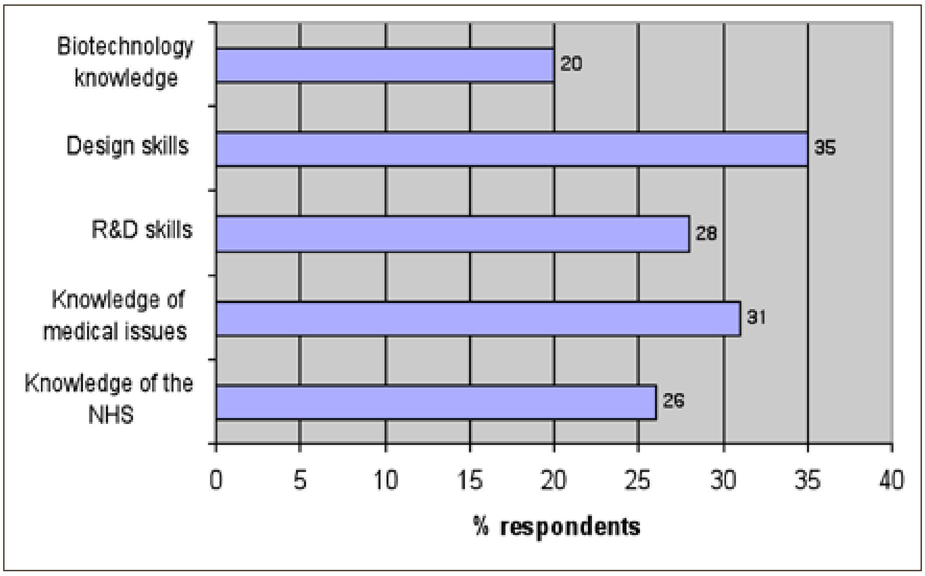
Source: Medico/Sundhed – en erhvervsanalyse, Erhvervsfremmestyrelsen, 2001 (Denmark), based on the example of Medicon Valley

Surveys of engineering companies in the West Midlands which were engaged in the production of goods with a medical application reveal this skill needs to be a little more generic (Hogarth et al., 2004; Hogarth et al., 2005). The skills employers For the most part, these related to:

- Basic computing skills;
- Engineering skills;
- Communication skills;
- Customer handling skills;
- Problem solving skills;
- Management skills;
- Medical device regulations;
- Experience of dealing with NHS;
- Numeracy skills;
- Literacy skills;
- Personal attributes;
- Technical/practical skills.

The critical skill sets which employers identified in relation to the constraints on business development in the medical technologies cluster are outlined in Figure 5.8.

Figure 5.8: Critical skill needs in relation to medical applications and markets



Source: LSC/ESF Medical Technologies Skills Survey 2005 (IER/IFF); Hogarth et al., 2005 –

In another, older study of the skill needs of the medical technology sector in the West Midlands Byre Associates sought to identify the skill needs and skills gaps in companies in the West Midlands medical technology sector and to map learning relevant provision in the region. The study identified three main areas of need for medical technology businesses. These were:

- medical engineering;
- project management; and
- new product development.

The report concluded that skills gaps were of secondary importance compared to other business issues (such as short-term profitability or the impact of legislation and industry regulation). Insofar as skills development needs were identified, these needs were for supervisory and project management skills, business and commercial skills for technical managers and for Level 4 process and electronics engineering skills. The report also concluded, after mapping provision in the region, that there was adequate provision in further and higher education institutions to meet the learning needs identified by companies in the medical technology sector.

The findings of the Byre Associates report are echoed to some extent in the findings of the ATL survey of medical technology businesses (cited in Gibney, 1998). The ATL survey reported that employers in the medical technology sample identified a number of skills related weaknesses relating to:

- an inadequate supply of professional engineers;
- a lack of production skills in the medical diagnostics/devices area;
- a general lack of bioscience skills in the region;
- a lack of knowledge of working directives and standards required for medical technology device manufacture and production;
- a shortage of laboratory technicians;
- a lack of entrepreneurs in the medical technology field.

5.5 Specific Skill Needs in Biotechnology

Many of the skill needs mentioned in the medical technology sector are the same as those required in pharmaceuticals (see Table 5.3). The nature of the biotechnology sub-sector – typically micro-enterprises pursuing an innovative new idea – suggests that their skill needs are at a high-level and, often, at the cutting-edge of scientific progress (in vitro and in vivo research skills, pharmacokinetics, bioinformatics and simulation, etc. Perhaps the key issue here is that there has been, with the shift towards the use of biological agents rather than chemical ones in pharmaceuticals, a significant shift in the science base. This potentially creates a skill or professional development demand amongst those already working in the pharmaceuticals industry, and a requirement for an inflow of scientists and engineers with differing skills sets from previous cohorts. It is easy to overstate this – biotechnology as a discipline has been around for several decades – but it has created a significant shift in skill demand.

5.6 Skills for Diversification into Medical Markets

In the pharmaceutical and biotechnology sub-sectors companies tend to be focused solely on pharmaceutical or biotechnology activities. This is not the case with medical technologies, where engineering companies are likely to be engaged in the production of a range of goods only some of which are medical related. Indeed, some may have only recently diversified into the medical market. A survey of mainly engineering firms in the West Midlands revealed substantial potential for companies to diversify into medical technologies. This tended to take the form of taking an existing process or product and modifying it so that it had a medical application (Hogarth et al., 2005). The study found that over 50 per cent of current medical technology businesses had diversified into medical technologies since the business was first established. This stands in contrast to medical biotechnology firms which tend to be established with the sole purpose of producing a medical application (Critical I, 2006a). Hence, there is considerable potential for companies, typically engineering ones but others too, to diversify into the production of medical technologies and equipment. The West Midlands survey also revealed that around 20 per cent of businesses not currently engaged in the production of medical technologies and equipment felt that their existing products had potential medical applications. This raises the whole issue of the strategic and tactical skills required to diversify into medical markets. The evidence suggests that where companies diversify into medical markets this can exacerbate any skill shortages, because the process of diversification tends to increase the level of skill demand in the organisation, principally in relation to engineering design skills. In addition, knowledge of the NHS procurement system is also a barrier those diversifying into medical technologies need to surmount and, the West Midlands study revealed, this can be a substantial barrier.

5.7 Generic Skill Needs

There are a number of generic skill sets which emerge across both sub-sectors. These relate principally to management and the skills managers need to acquire if they are sustain their position in the product market. To some extent, the skills needed relate to product vision and obtaining an alignment between the needs of the product market and the capability of the organisation to respond to those needs. These types of skill needs are common across most sectors. At the cutting-edge of the sector this relates very much to being innovation driven. There are a range of skill needs here relating to the capacity to lead multi-disciplinary teams. Given the amount of outsourcing which now appears common across parts of the sector, especially in some of the high-value, cutting edge sub-sectors, there are a range of management skills which relate to:

- managing a network of teams across companies and sometimes across countries to deliver to the specification;

- being able to deepen and strengthen relationships so that they deliver more than the sum of their parts.

For a large section of the sector this relates more to managing a relatively mature product in markets which are subject to strong price competition. As noted in Chapter 3, parts of the sector are under considerable pressure to reduce costs. The key management skills which emerge relate very much to:

- Lean management;

- Six Sigma[32];

- design of new products which can use existing production machinery.

There are also a set of skills which relate primarily to SMEs given their important role in developing new products in pharmaceuticals and biotechnology, and their critical mass in the medical technologies sub-sector. Hence one of the stakeholders pointed out that bbusinesses, not least SMEs, lack strategic skills. They are good at day to day survival but they are not good at forecasting the future; they are not good at identifying market opportunities; they don't understand how the sector

[32] Six-sigma is a well established process in manufacturing for identifying errors and minimizing variability in production processes.

works; they don't know who the key decision makers are. Another respondent pointed out that the difficulties for SMEs addressing marketing skills and the tendency to outsource marketing and sales representation, or to develop partnering arrangements for marketing and sales; but they typically then do not manage such partners well and become exposed to the vagaries of the quality of the partner skills and effort.

5.8 Conclusion

Chapters 3 and 4 revealed the direction of technological change in the bio-medical sector. The data on skill demand demonstrates the more cutting-edge technological breakthroughs are dependent upon high level scientific skills in the biological sciences. Indeed, much of the discussion about future skill needs in the bio-medical sector is based around, almost exclusively, developing a strong skill capability in the emerging areas of new therapies. The study has tried to identify as far as possible what these skill needs are likely to be.

While the skills allied to the latest technological breakthroughs are clearly important for the future of the sector in England, the review has also identified a more everyday, though important group of skills related to maintaining, or incrementally developing the existing range of products. These relate to graduate level skills in biology and engineering but also intermediate level skills typically associated with skilled trades jobs. The study has pointed towards the potential for, typically, engineering firms to capture an increased share of the medical technologies market but to do so they require the skills which allow them to enter this segment of the market. These skills sets relate very much to acquiring the knowledge to navigate the NHS procurement system but also developing the engineering design skills to allow products to be adapted to the needs of the health service. As chapter 3 revealed there is considerable potential for engineering and software solutions to be applied to a range of issues with which the health service is faced.

Though there is a clear distinction to be made between the skill needs of the cutting edge versus the more steady performers in the sector, the evidence as a whole points to the skill needs of the sector increasing, both qualitatively and quantitatively, over the medium-term with much of this being dependent upon having a technologically / scientifically literate workforce.

6 The Supply Side and Skills Mismatches

6.1 Introduction

The pace of technological innovation in the bio-medical sector is such that it places substantial pressures on the supply side to keep pace. There appear to be both quantitative and qualitative changes in the demand for highly skilled people to work in the sector. At the highest skill levels, the market for people is an international one with the best and most capable people attracted to centres of excellence around the world. But the remainder of the workforce is unlikely to be so mobile hence the importance of creating and maintaining a local supply.

In general, there are two types of skills supply which are of interest:

i. supply from the education system, especially higher education but not exclusively so; and

ii. continuing professional development and training.

Available statisitical evidence on the supply side is quite limited, but it is possible to discern some key points.

6.2 Supply from the Higher Education System

Assessment of supply from the higher education system is based on: (a) the supply of people qualified in subjects germane to the medical technologies sector (mainly engineering related); and (b) the supply qualified in science subjects more generally and which are of particular relevance to the pharmaceuticals sector. These data are indicative of the supply of people with the skills required by the bio-medical industry.

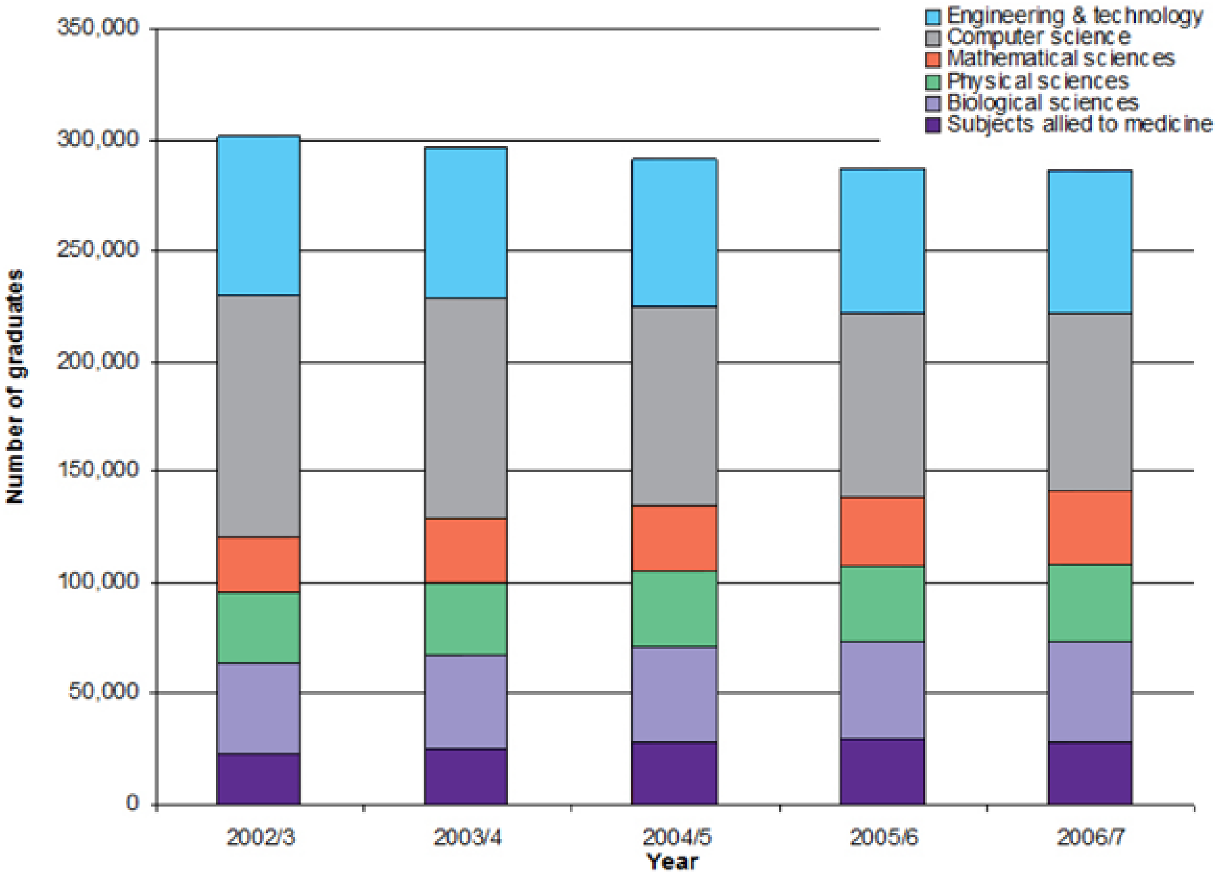
Figure 6.1 provides an indication of the trend in supply of people with degrees in subjects close to the interests of the medical technology sub-sector. The general trend is one of supply in decline though the rate of decline is quite modest.

Table 6.1 shows the change in the number of people studying degrees in the range of sciences germane to the bio-medical sector over the period 2002/3 to 2007/8. In contrast to the data relating specifically to medical technologies, the figures demonstrate that there has been an increase in the number of people taking these qualifications. This may be evidence that students are responding to signals being sent by the market that there is a strong demand for people to work in the biosciences. In Biological Sciences, however, much of the growth relates to an increase in the number of people studying Sports Science and Pyschology which may be less directly applicable to the bio-medical sector than some of the other Biological Science degrees.

It should be also be noted that the industy is a major investor in educationand training with the pharmaceutical sector hosting around 670 PhDs each year (ABPI, 2008).

In relation to the pharmaceutical sector, Cogent has noted that overall the pharmaceutical sector takes on about 1,300 graduates every year which represents a small fraction of the overall population of STEM graduates thereby indicating that increasing the supply of gradautes is a weak lever of direct supply to the industry (Cogent, 2009, p. 34). This is a critical question: is the extent to which increasing the supply necessarily leads to more people entering sectors such as the bio-medical one. An indication can be obtained from the extent to which people who hold, for instance, a degree in Biology are engaged in scientific employment. From a quantitative perspective the Biological Sciences has a fairly successful conversion rate of people qualified in Biology entering a scientific profession or assoicate profession (see Table 6.2), but the situation is much more varied in relation to other scientifc subjects. Of those with Biology degrees, 64 per cent were employed in scientific or health occupations, compared to 24 per cent of those qualified in Physics.

Figure 6.1 Number of People Graduating with First Degree Relevant to the Medical Technologies Sector



Source: BERR Medical Technologies Metrics; HESA

Table 6.1 Students Studying Degrees Germane to Bio-medical Sciences, 2002/3 to 2007/8 absolutes

absolutes

	Total Number of Students 2007/8					**Change 2002/3 to 2007/8**				
	Total HE students	**Full-time graduate**	**Full-time under-graduate**	**Part-time post-graduate**	**Part-time under-graduate**	**Total HE students**	**Full-time post-graduate**	**Full-time under-graduate**	**Part-time post-graduate**	**Part-time under-graduate**
Medicine & dentistry	**61810**	**7670**	**43820**	**10160**	**160**	**12895**	**10475**	**2210**	**205**	**5**
Subjects allied to medicine	**287125**	**11690**	**143910**	**35165**	**96360**	**20710**	**12950**	**4400**	**7920**	**-4565**
Pharmacology, toxicology & pharmacy	21615	2775	13715	3950	1175	**5955**	3475	1490	300	690
Medical technology	8335	380	5445	1780	730	**1740**	1740	185	-450	265
Biological sciences	**161600**	**16650**	**111690**	**9940**	**23320**	**35740**	**19350**	**3910**	**-2625**	**15105**
Broadly-based programmes within biological sciences	765	10	720	0	35	**-260**	-165	-55	-65	20
Biology	26360	3390	18405	950	3615	**1950**	1015	275	-1125	1785
Botany	620	335	195	25	65	**-225**	30	50	-105	-195
Zoology	3810	300	3390	30	90	**-55**	225	5	-145	-140
Genetics	2100	510	1480	75	30	**-595**	-310	-5	-260	-25
Microbiology	3375	655	2225	310	185	**-820**	-130	-290	-455	55
Sports science	32870	1060	29365	855	1590	**15285**	13610	535	145	995
Molecular biology, biophysics & biochemistry	10315	2120	7280	360	555	**1035**	595	585	-390	245
Psychology	72570	7150	44625	6580	14215	**21790**	8830	2515	-35	10480
Others in biological sciences	8815	1115	4005	760	2935	**-2370**	-4345	280	-185	1875
Veterinary science	**4850**	**490**	**4080**	**225**	**55**	**1010**	**915**	**90**	**-15**	**15**

Table 6.1 (continued) Students Studying Degrees Germane to Bio-medical Sciences, 2002/3 to 2007/8 absolutes

absolutes

	Total Number of Students 2007/8					Change 2002/3 to 2007/8				
	Total HE students	Full-time graduate	Full-time under-graduate	Part-time post-graduate	Part-time under-graduate	Total HE students	Full-time post-graduate	Full-time under-graduate	Part-time post-graduate	Part-time under-graduate
Physical sciences	**82130**	**13900**	**52685**	**3890**	**11655**	**11090**	**5175**	**1875**	**-2445**	**6485**
Broadly-based programmes within physical sciences	**965**	0	910	0	60	**35**	0	0	0	40
Chemistry	**18815**	4240	12515	310	1745	**-200**	890	-30	-1430	365
Materials science	**620**	340	255	20	0	**185**	30	185	-15	-20
Physics	**14870**	3225	10145	290	1210	**2040**	1100	630	-780	1090
Mathematical sciences	**34120**	3600	22770	1520	6225	**7930**	3300	755	-1220	5090
Broadly-based programmes within mathematical sciences	**85**	0	55	0	30	**-450**	5	0	0	-455
Mathematics	**29620**	**2420**	**21045**	**935**	**5225**	**9500**	**4190**	**525**	**-45**	**4840**
Operational research	**855**	355	415	80	5	**40**	-15	155	-55	-45
Statistics	**3435**	800	1215	495	930	**-505**	-465	240	-1010	740
Others in mathematical sciences	**125**	30	40	15	45	**105**	20	30	15	45
Computer science	**95575**	**13425**	**55700**	**6520**	**19935**	**-38460**	**-29835**	**-975**	**-3450**	**-4195**
Engineering & technology	**139435**	**23875**	**80425**	**11800**	**23335**	**7860**	**3570**	**3825**	**-4690**	**5150**
Chemical, process & energy engineering	**7715**	1660	4405	1010	640	**2130**	1230	285	125	490
Biotechnology	**1025**	495	460	55	20	**890**	335	485	55	20
Economics	**29850**	**5310**	**22155**	**725**	**1660**	**710**	**270**	**1060**	**-1350**	**735**

Source: HESA statistics; own calculations
Note: shaded cells show where numbers have decreased

Table 6.2 Occupational Characteristics of People with Science and Mathematics Degrees, 2007

	Degree Subject						
	Biological Sciences excl Sports Science / Psychology	Other Physical Sciences	Chemistry	Physics	Mathematical & Computer Sciences	Engineering	All
Corporate Managers	7	20	16	19	17	20	9
Managers & Proprietors	1	2	5	13	2	2	2
Science/Tech Professionals	2	19	0	6	19	31	3
Health Professionals	3	3	1	0	1	0	1
Teaching/Research Prof.	3	13	7	9	13	7	4
Business/Public service Prof.	2	5	4	0	7	6	3
Science/Tech Associate Prof.	1	5	2	4	4	4	1
Health Associate Prof.	54	1	0	2	2	1	3
Protective Service Occs	0	0	0	2	1	0	1
Culture/Media/Sport Occs	0	2	0	2	2	1	2
Bus/Public Serv. Assoc Prof.	2	6	24	10	7	5	4
Any kind of Science / Health / Teaching occupation	**61**	**40**	**10**	**21**	**39**	**43**	**11**

Source: Labour Force Survey 2007; own calculations
Base: All with a current occupation

From the supply side, available information suggests that in the fields of life sciences / medicine, three of the world's top 20 universities are located in England, though most of the top 20 are based in the USA. There is always disagreement about how these types of ranking are constructed but they nevertheless give an indication of the relative positioning of UK based universities (see Table 6.3).

Table 6.3 2009 Top 20 Life Sciences Universities

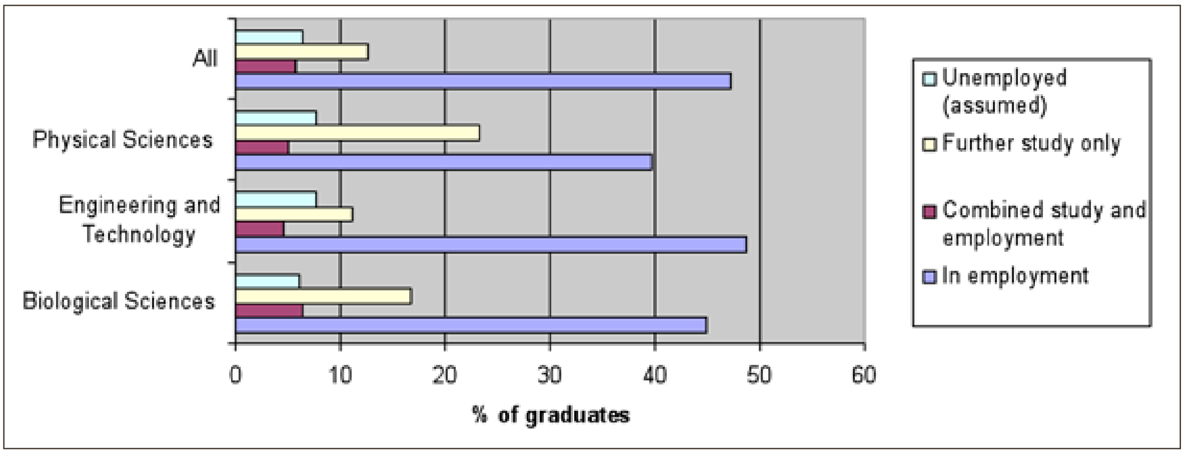
Rank	School Name	Country
1	Harvard University	United States
2	**University of Cambridge**	**England**
3	**University of Oxford**	**England**
4	University of California, Los Angeles (UCLA)	United States
5	University of California, Berkeley	United States
6	John Hopkins University	United States
7	University of Tokyo	Japan
8	Massachusetts Institute of Technology (MIT)	United States
9	Yale University	United States
10	Mcgill University	Canada
11	University of Toronto	Canada
12	University of California, San Diego	United States
13	University of Melbourne	Australia
13	Kyoto University	Japan
15	University of Sydney	Australia
16	University of British Columbia	Canada
17	**Imperial College London**	**England**
18	University of California, Los Angeles (UCLA)	United States
19	Peking University	China
20	National University of Singapore (NUS)	Singapore

Source: http://www.topuniversities.com/world-university-rankings

A key question relates to the incentives for people to study subjects germane to the needs of the bio-medical sector. With respect to the destinations of first degree holders leaving university in 2006/8, there is relatively little difference in the percentage going on into employment with first degrees in Biology, Physical Sciences, or Engineering & Technology compared to the entire population of graduates (see Figure 6.2). Biology graduates are more likely to go to further study compared to the population of graduates, but less so than those with degrees in physical science. The wage returns for scientists (excluding mathematicians) appear to be around the average for all graduates. The data in relation to wages suggests that science graduates tend to earn around the same level as social science graduates after being in the labour market for around four years, but less than those who graduated in medicine, engineering, or mathematics and computing (Purcell et al., 2005).

These data suggest that the overall level of demand for scientists is no greater than that for all graduates, though the evidence suggests that recently qualified graduates enjoy a wage premium over their counterparts who are not graduates. This does not take into consideration qualitative differences between graduates. From the interviews conducted as part of this study and from some of the background literature, there are concerns that science graduates are sometimes lacking the basic scientific and social skills which companies require (see section 6.4).

Figure 6.2 Destinations of Graduates in Selected Subjects, 2007/8



Source: Table 3 - Destinations of full-time UK and Other EU domiciled first degree graduates by subject area of degree and gender, 2007/08, 2006/07 and 2005/06 - http://www.hesa.ac.uk/dox/fsr137/fsr137_table_3.pdf

6.3 Supply of Intermediate Level Skills

As indicated elsewhere in this report, the industry as a whole is also dependent upon the supply of intermediate level skills. Evidence suggests that the supply of Apprenticeships is constrained in part by the lack of supply of training places provided by employers (HoL, 2007). But where employers do invest in Apprenticeships they can recoup their costs relatively quickly and achieve a number of benefits such as: a having a cadre of people from which to select future supervisors and managers; or having the values of the firm instilled in the employee from an early age (Hasluck et al., 2008). In relation to the bio-medical sector the two Apprenticeships of particular interest are: (a) Engineering; and (b) Chemical, Pharmaceutical, Petro-Chemical Manufacturing & Refining Industries, respectively. In 2007/8, there were 200 new starts (the same as in 2006/07) in the latter (the same as in 2006/07),[33] and 13,900 in the former (up 2,600 on 2006/07). Across Engineering and Manufacturing Technologies as a whole there were 43,100 new starts in 2006/07 compared to 34,700 in the previous year.

6.4 Supply from the School System

Many of the critical skill demands employers reported in Section 5 (the demand for skills) were often at a graduate and post-graduate level. It was also evident that a key requirement was a strong quantitative knowledge (mathematics and statistics) and a good level of understanding in many cases of sciences allied to biological sciences, especially chemistry. Looking simply at the supply of graduates tells only part of the story since there have been a significant number of initiatives launched by Government to improve the science and mathematics teaching so that more school pupils will achieve GCSEs in the these subjects and potentially go on to study at A-level and beyond.

Level 5/6 is the level pupils are expected to attain in Mathematics and Science by the age of 14 (Key Stage 3). Figures 6.3a and 6.3b show the percentage of pupils attaining this level in Science and Mathematics between 1995 and 2007. The general trend is for an improvement in the percentage achieving this level. Figure 6.4 shows the percentage gaining a grade A to C at GCSE which shows a flatter trend.

[33] http://www.thedataservice.org.uk/statistics/sfrjun09

Figure 6.3a: Percentage of Pupils Attaining Level 5/6 at Key Stage 3 in Science

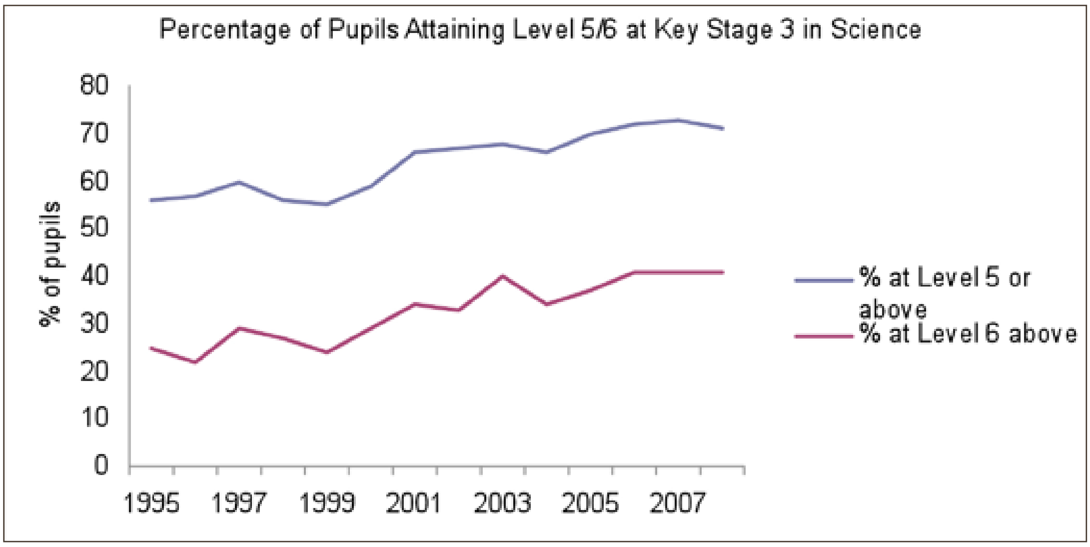
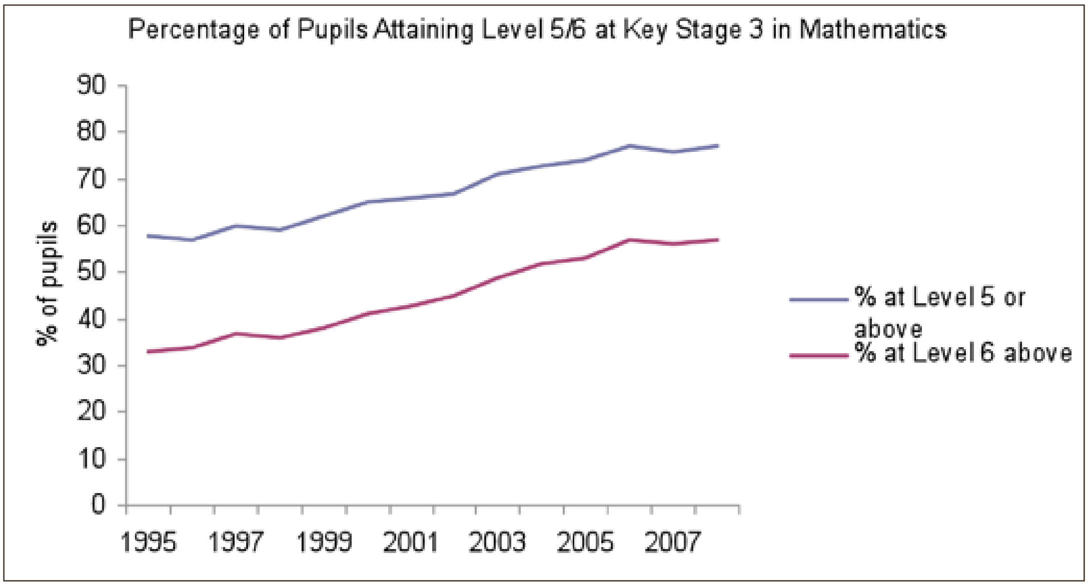
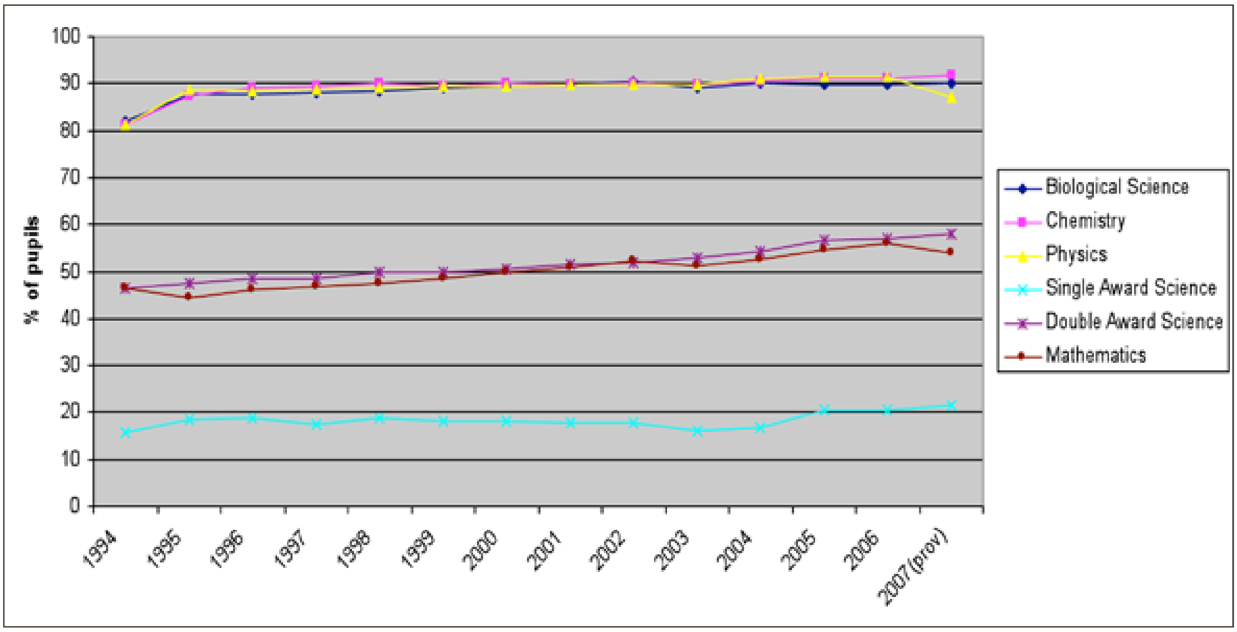


Figure 6.3b: Percentage of Pupils Attaining Level 5/6 at Key Stage 3 in Mathematics



Source: DCFS

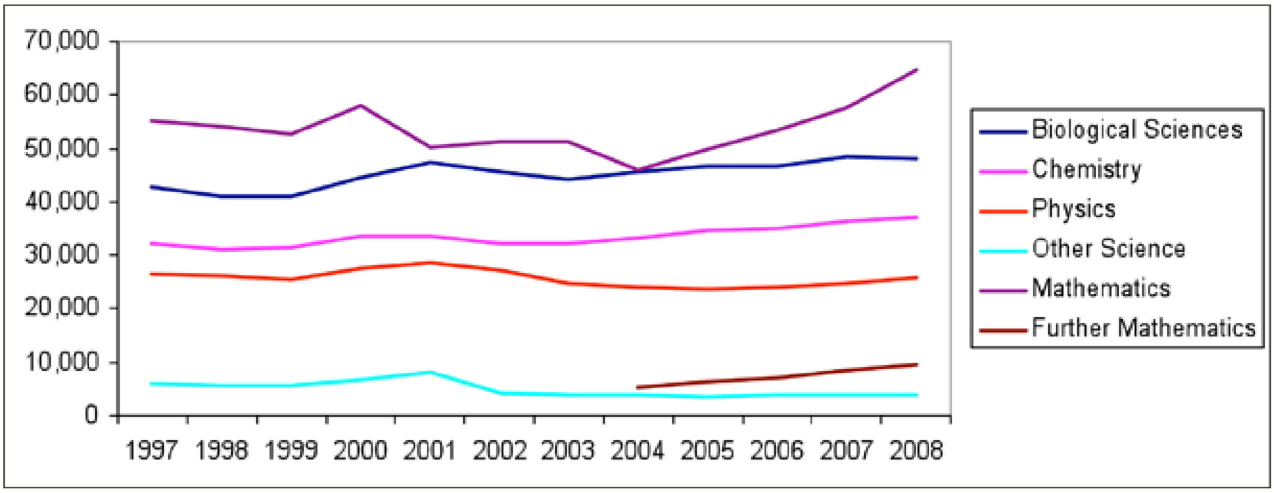
Figure 6.4 Percentage of Pupils Achieving Grades A*- C in Mathematics and Selected Science GCSEs 1994 - 2007



Source: DCFS
Note: Data for 2007 are provisional At KS4 (GCSE)
The National Curriculum allows for two alternative science courses: Double Award Science, which is equivalent to two GCSE subjects; Single Award Science, which is equivalent to one GCSE.

The data in Figure 6.5 shows the number of enrolments for A-levels in Mathematics and Science over time and shows that subjects such as Physics have struggled to reverse the decline in the number of students, while Biology appears to have been a relatively popular choice over time. Overall the evidence suggests that the number of people studying Biological Sciences has been relatively strong especially so compared to other scientific disciplines, but the evidence from the literature review and interviews with stakeholders reveals that employers are looking for a breath of scientific skills, not just those strictly classified to one discipline. In particular, they are looking for strong quantitative skills.

Figure 6.5 Number of Pupils Entered for Mathematics and Science A-Levels 1997 - 2008



6.5. Qualitative Mismatches

As well as calls for increases in the number of people who are studying degrees related to bio-medical sector, there have also been calls for the content of education to be modified in a number of ways. This is not just a recent phenomenon but a long-term, continuous campaign for the education sector to modify the content of the education and training it provides to meet the needs of the sector.

A key problem, or concern, appears to be how to instill the concept of multi-disciplinarity or the ability to function within multi-disciplinary teams, in the education and training individuals receive. As one report said: “The concept of disciplines per se may be a stumbling block for progress in sciences since all major challenges are multi-disciplinary” (Breimer, 2002). This report, drawing on the research of Triggle and Miller (1999), also revealed that pharmaceutical scientists in future will require training which provides them with:

- more scientific breadth to facilitate effective communication with other scientists;
- greater involvement in multidisciplinary research projects to aid better functioning on project teams;
- opportunities to refine written and verbal communication skills;
- greater access to computers/computing networks to better handle the explosion of new information;
- exposure to ethical issues that may be encountered in judgment based on performance;
- experience of industry to assist more intelligent career choices;

- international exposure to help develop the social and cultural skills needed in a globalised industry;
- Nearly ten years later, these are still some of the key priorities for skill supply for the sector.

There remains, however, a need for people in the pharmaceutical industry to have practical skills as the following makes clear:

> "For any area of the pharmaceutical industry… pharmaceutical scientists are needed who can problem solve on a foundation of science and practical, technical skills. The industry needs pharmaceutical scientists who can make scientifically sound decisions in a highly competitive environment, individuals who are able to separate the "need to know" from the "nice to know" without compromising quality. In relatively smaller, less vertically integrated companies, such independent generic companies and start-up biotechnology companies, pharmaceutical scientists need to be able to critically evaluate outsourced products…and services as well as handle a broad range of responsibilities within the organisation" (Till, 1997, p. 837)

6.6 Meeting Demand

In general, the evidence presented by industry groups suggests that supply is not keeping pace either qualitatively or quantitatively with the demands of employers. For example, a review of the skill needs across a variety of disciplines with respect to R&D and manufacturing in pharmaceuticals comments:

> "Having identified the types of career opportunities available to life scientists within pharmaceutical R&D, it is then vital to ensure that their education and training provides the requisite skills base. From the deficiencies described above, it is clear that this is currently often not the case. There are several commonly shared areas of concern across disciplines; 1) a lack of knowledge of the basics e.g. chemists who cannot describe what a mole of compound is, or clinicians with little knowledge of the principles of clinical trial design, 2) a lack of knowledge as to how to apply theory to actual practice e.g. graduates who can only follow a prescribed protocol and do not have the skills to develop new methodologies independently and 3) a lack of practical skills e.g. in vivo biology and toxicology or the awareness of the types, uses and applications of complex technologies." (Edwards, p. 31).

The ABPI also point out deficiencies they see on the supply side relating to the provision of skills (APBI, 2008):

- basic mathematical capability;
- practical skills;
- ability to apply scientific and mathematical knowledge.

With respect to higher level skills related to the key technological changes in the sector, the APBI comments:

> "...higher level critical skills have not yet enjoyed the focus, incentives or funding initiatives concomitant with their pivotal importance to key UK initiatives such as translational medicine. If the UK wants to compete in a global environment for Bio-medical research it must take seriously the competition in skills supply that is emerging in countries such as China, Singapore and India" (ABPI, 2008, p. 5).

Whilst it is important that employers are able to acquire the skills necessary to meet the demands of both current and future markets for bio-medical goods and services, it is also important that the industry is able to provide career opportunities which prove attractive to would-be recruits. Where shortages of some skills are cited, such as the demand for instrument and process control engineers, the underlying cause appears to be relatively high labour turnover in some instances. It needs to be recognised that many of the scientific and engineering skills – alongside the generic skills of management and leadership, and numeracy – the industry requires are also in demand in other sectors.

Cogent and SEMTA's analysis of the mismatches in the biosciences sector indicates that employers experience hard-to-fill vacancies across a range of scientific disciplines and technical skills (SEMTA, 2006).

6.7 Conclusion

The quantitative evidence suggests that there has been an increase in eductional attainment in mathematics and science over recent years. If one were looking to identify the key skill shortages in the scientific field, it would appear to be in mathematics and computing, and engineering, where the wage rates of graduates are relatively high (Purcell et al., 2005). Employers, however, are not complaining so much about the number of applicants so much as the specific skills they possess – it is not so much that there is a shortage of pharmacologists per se, rather those who are skilled in, say, clinical pharamacology. To some extent this is inevitable given the pace of change in the sector because it takes time for the signals from employers to feed through to the formal education system. The key issue is the speed with which the supply side can respond to the signals it receives.

7 Synergies and Spillovers, Collaboration and Networking, and the National Innovation System (NIS)

7.1 Introduction

The literature suggests that they are considerable gains to be obtained from the extent to which, on the one hand, companies agglomerate their activities, and on the other, the State encourages collaboration between organisations and agencies engaged in R&D activities. Where this works effectively, R&D activity is increased (e.g. spillover effects), and the pool of available skills is similarly increased through attracting people into a network or spatial agglomeration, sharing knowledge through the network, and potentially lowering the cost of training (via economies of scale). In summary, clustering / networking has the capacity to bring about a higher skill equilibrium or trajectory. As noted elsewhere in this report, there is evidence of clustering in the pharmaceutical / biotechnology sector relating to R&D – around Cambridge and the corridor to the west of London – and in manufacturing (e.g. in the North West). There is less evidence of clustering in the medical technologies sector, but there is evidence of regional agenices promoting this activity.

The chapter looks at the evidence relating to the agglomerative activities and the benefits this can confer on a sector, region, or country; assesses the evidence in relation to the bio-medical sector; and uses the West Midlands medical technology cluster as an example of how clustering or networking can develop capacity which can make use of the existing skills base.

Before providing national and regionional examples of networking, clustering, or synergy between organisations (companies, HEIs, the healthcare system), a brief summary is provided of different types of collaborative activities which firms engage in, especially those in R&D intensive sectors such as the bio-medical one.

7.2 Collaborative Activity

It is possible to make a distinction between activities in three areas – development, production and adoption – for example, the health service can adopt the use of MRI scanners without the UK necessarily developing or producing them. Equally, however, it seems obvious that there should be synergies between these three areas that make their associated activities more efficient and more dynamic. Potential areas of synergy and gain are manifold, for example:

- collaboration spreads knowledge along the supply chain of development, production and adoption. For example, knowledge of health needs and technology gaps that are not currently being met;

- skills produced by universities/university hospitals and the FE system, etc. which may be used in or transmitted to one or more of the three areas;

- the procurement activities of the NHS, acting as a stimulus to innovation and quality improvements amongst their suppliers and potential suppliers;

- the development of buyer-supplier chains, knowledge networks, quality agreements and regulations; etc.

Synergies can arise from “arms-length” relationships; for example, the presence of a high quality higher and further education system may result in an abundant supply of skills and knowledge relevant to the health system, reducing the need for training within the health sector and lowering the cost of employees and, thereby, the cost of the provision of health services. This group of synergies are largely market-orientated – e.g. the presence of a large and dynamic medical technologies sector may increase the supply of more advanced technologies to the health sector at a lower price – and largely take place through the traditional “input-output mechanism” (Leontief, 1941; Stone, 1947 and 1954).

The potential gains from synergies are likely to be significantly enhanced where the key actors (e.g. in development, adoption and production of new technologies) network and collaborate with one another. The literature suggests that networking and collaboration are sources of “spillovers” and “externalities”, which, in this particular instance, are likely to be significant sources of improvements in the rates of technological change, productivity growth and social welfare. The principal forms of collaborative or synerginistic activity that are interest in the context of the bio-medical secor are described below.

- **Spillover and Externalities.** Spillovers and externalities are perceived as largely non-market mechanisms whereby the actions of one organisation postitively (or adversely) affect the activities and outcomes of other enterprises. Spillovers come from the failure of enterprises to appropriate all of the benefits that accrue from their activities (see Griliches (1992) (Bosworth, 2009), Nelson (1959), and Arrow (1962)). Spillovers may be technological, spatial, or both;

- **Buyer-Supplier Relationships.** In the context of the present discussion, buyer-seller relationships take on a special importance. Any form of buyer-supplier relationship, even if short-lived, in some way extends the boundaries of the firm. They are a mechanism for the transmission of information flows, including new organisational or technological demands. In addition, buyer and supplier relationships form key elements of Porter’s five competitive forces relating to the emergence of sustainable competitive advantage (Porter, 1985). Procurement is one of the support functions (alongside firm infrastructure, human resource management and technology development) in the Porter model (op cit. p. 48). Management of the supply chain relationship is, thus, crucial to optimising the value chain of the buyer organisation. Oakey’s (1984, pp. 88-90) comparative study of small high technology firms in the South East of England, Scotland and the San Francisco Bay area, finds that buyers are essentially technologically dependent on their suppliers at each stage of the supply chain;

- **Government Procurement Activity.** In the present context, the role of public procurement in the innovation process is particularly important because of the size and importance of the NHS. The Government, however, and its various arms and agencies form the largest single “customer” in most economies.[34] In certain sectors, such as defence and pharmaceuticals, the government (directly or at arms length) is probably the single most important influence on the market. The Government can therefore be a force that either depresses or stimulates innovation. The argument extends far beyond government procurement, however, in that there are spillovers between all firms in the buyer-supplier chain. If buyers are producing low specification products that sell at a low price, then the demands that they place on their suppliers will also tend to be low specification and price;

[34] According DTI (2003, p. 82), public sector procurement amounted to £109 billion during 2001-2 – equivalent to about 10 per cent of GDP. By 2008, procurement expenditures are reported to have been about £150 billion. http://www.ogc.gov.uk/About_OGC_news_8440.asp.

- **Long-term Contractual Links.**Repeat orders and other long-term contractual relationships are a potentially important element of the organisation's intellectual capital (Brooking, 1997; Lynn, 1998). The contract itself is likely to be based on the formal product or service specifications prepared by the technical department of at least the buyer, but possibly both the buyer and supplier. A long-term contractual relationship can be distinguished from a long term contract, as in the former, even where contract lengths are relatively short, both firms expect the contract to be renewed (Ferguson, et al. 1993, p. 24). In the discussion of complex products and services it is clear that the continuing nature of the invention, innovation and design processes during the period of production, would entail ongoing discussions between the supplier and the buyer;

- **Research Joint Ventures (RJVs).** These involve two or more separate companies and are defined as:

  "… arrangements in which some firms agree to share the expenditures and the benefits associated with a given research project." (Tirole, 1990, p. 413)

  According to Kang and Sakai (2000, p. 33) the extent of international collaboration over the invention process more than doubled over the period 1980 to 1995. They report that the share of patents in OECD countries that involve two or more inventors based in different countries rose from 2.1 to 4.7 per cent over this 15 year period. Strategic R&D alliances tend to be concentrated in knowledge-based sectors, such as biotechnology, pharmaceuticals and ICTs (Kang and Sakai, 2000, p. 33)

  The literature on RJVs emphasises two principal factors:

  i. by bringing firms together, it is possible to internalise the benefits of the R&D amongst the participant companies. Where the firms act independently, spillovers occur that give rise to a free-rider problem, which reduces the private incentives to conduct R&D;

  ii. related to the previous point, RJVs result in cost savings because the costs of any given R&D project are shared (Röller, et al. 1997).

How all of the above might operate in a national and regional context is outlined below.

7.3 National Innovations Systems and Policy Intervention

The gains from "joined up" private strategies, public policies, with networking and collaboration (both domestically, across the different areas, and internationally), appear likely to improve the dynamism of the innovation system in meeting both health care needs and in the generation of domestic employment in the sectors supplying products and services to the health sector.

In the literature on the development of a critical mass of bio-medical activity there is considerable attention given to clusters or geographical agglomerations of companies. These often develop out of specific sets of historical circumstances so are not always readily replicated; for example, the cluster of IT companies in Northern California stems from the needs of the US military in the 1950s, the existence of military facilities in the area, the cheap availability of land, and the proximity of several universities and their research staffs (Finegold, 1999).

Clusters are normally viewed as "… geographically proximate groups of interconnected companies, suppliers, service provides, and associated institutions in a particular field, linked by commonalities and complementarities" (Porter and Ketels, 2003). According to Porter and Ketels, clusters generally influence competitiveness in three main ways:

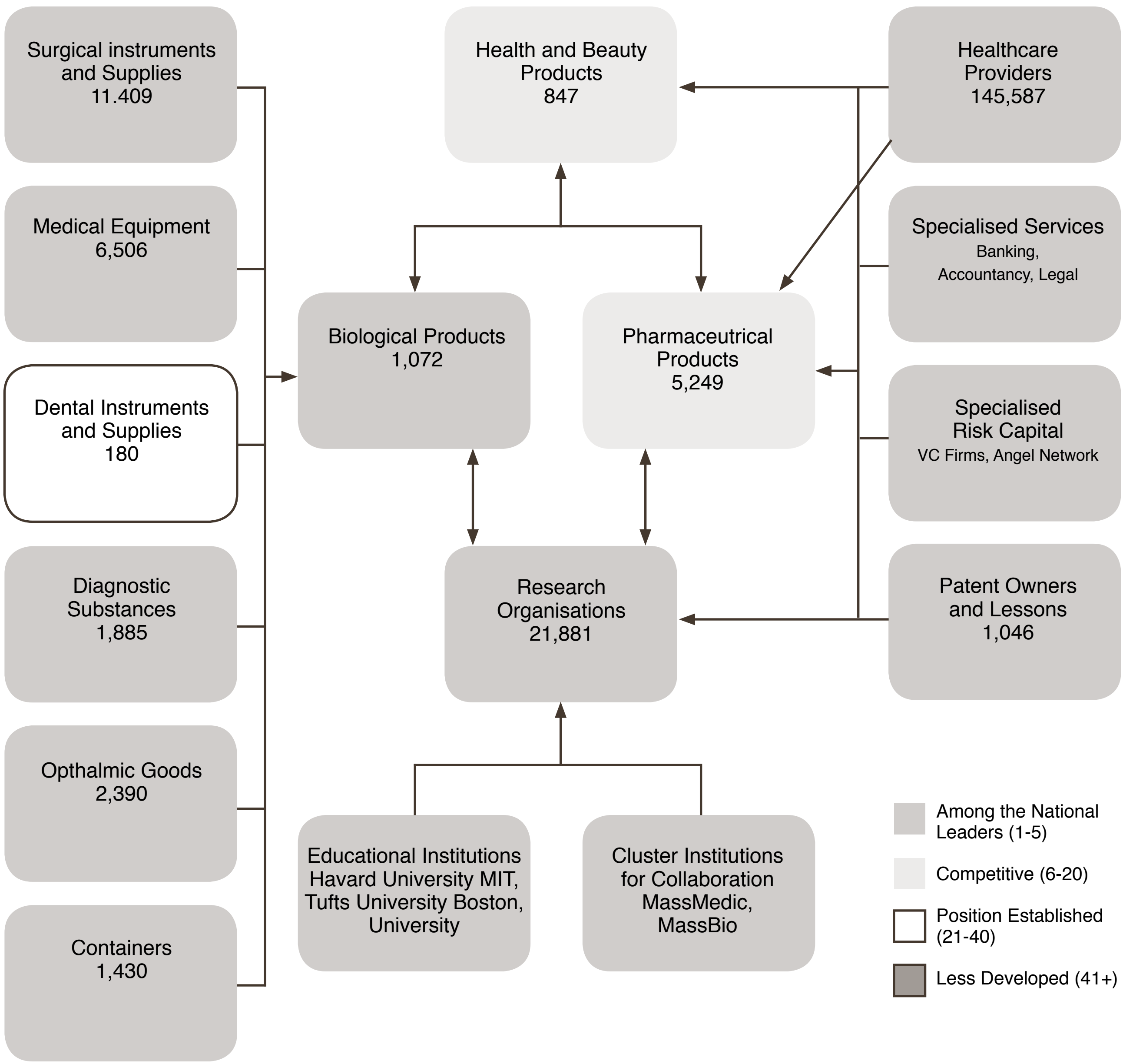
i. by increasing the **level of productivity** at which constituent firms can operate (i.e. carrying lower levels of stock due to local suppliers, reduce downtime because of access to local service providers, etc.);

ii. by increasing the **capacity for innovation** and, thereby, productivity growth;

iii. **enable new business formation**, which further enhances innovation (i.e. via the presence of experienced researchers, access to specialized venture capital, legal services, etc.).

With respect to the bio-medical sector, the Boston Life Sciences Cluster which includes "… world-class research universities, teaching hospitals, competing biotech companies, and cluster institutions that facilitate interaction among all these" is perhaps the most well known and successful (see Figure 7.1). It certainly has the hallmarks of a high-skill ecosystem (Finegold, 1999).

Figure 7.1 Boston Life Sciences Cluster



Source: Porter and Ketels (2003, p. 28).
Note: Employment numbers for 2000 given inside boxes when available.

It is clear that some clusters have grown organically because the institutional, economic and social framework was conducive to their formation and success, but the picture is not all positive, particularly with regard to the possibility of artificially creating the "culture" in which a cluster will develop and flourish.

Across Europe there are key clusters or agglomerations in the bio-medical sector, such as in Cambridge in the UK, Bavaria and Baden Württemberg (in Germany) and Medicon Valley (in Denmark) which share, to differing degrees, the characteristics of the Boston Life Sciences model. There are common features to these clusters or agglomerations which mainly hinges on the State policies which are designed to bring about the quick transfer of technology into the health care system with the State acting to bring companies and researchers together to promote research and successful product innovations. The agglomerations, to some extent, have developed organically and have been dependent upon the existence of key companies. In Bavaria, this relates very much to the location of Siemens Medical, and in Medicon Valley, presence of four fully integrated pharmaceutical companies (Novo Nordisk, AstraZeneca, H. Lundbeck and LEO Pharma), which attract highly qualified employees to the region (Vogler Ludwig, 2004; Thomsen, 2004). Similarly in Cambridge the university has been a hub of activity around which developments could take place.

The evidence from the UK suggests that there are concentrations, agglomerations, and clusters relating to the bio-medical sector, such as those which surround Oxford and Cambridge, and which exhibit many of the features of clusters found in Massachusetts, Denmark, and Germany which have also developed organically over time. Fostering links between the HE sector and industry, however, is not without difficulties as documented in the Lambert Review of Business – University collaboration (Lambert, 2003).

To show how agglomerative activity can develop – and the various facilitators and inhibitors – and the role of skills in this development, a case study of the West Midlands medical technology cluster is provided.

7.4 Case Study: Diversification into Medical Technologies in the West Midlands

Ten years ago in the West Midlands, a number of the public bodies with economic development arms were becoming increasingly concerned about the vulnerability of manufacturing sectors in general and several regionally based big companies in particular, not least in automotive. Medical and healthcare technologies were identified at regional and sub regional levels as a sector with significant growth opportunities given ageing populations, lack of technology in the NHS and the strength of OEM and supply chain companies in the region with the innovation and engineering skills to potentially be able to diversify their activities and address such opportunities.

Unlike other opportunities for SMEs, it was recognised at that stage that while there were mass market opportunities, there were also a multitude of niche opportunities in medical technologies and that the formalised hierarchical supplier tier structures typifying automotive and aerospace did not exist for many products, offering much greater potential freedom to a SME to be able to develop and exploit its own IP. Equally, the many barriers in the sector for SMEs were also recognised including the regulatory issues and the difficulties with routes to market and the many decision influencers.

The Regional Development Agency, Advantage West Midlands, encouraged a company led cluster to develop around medical and healthcare technologies and in similar timeframe, Medilink West Midlands was set up as a trade association to support SMEs in the region with healthcare technology interests under “franchise” from the originating Sheffield body. At almost the same time, some of the available ERDF resources in the region were used to support a £6m University led Health Tech programme to help SME companies with the many change management issues including the regulations and barriers to diversifying their businesses.

Skill sets were, are and continue to be a major issue in this scenario. SMEs are often owner managed and have originated from a variety of origins, but with the possible exception of family succession, rarely exist without considerable trauma for the owner who has had to be very determined to achieve success. In some cases, a larger company background may have provided the MD with the strategic thinking skills and competences to address the major company structure shifts and the different style of business operation required in the healthcare technologies sector but in most cases this is not the case and the first barrier to successful strategic change is the MD.

Given an enlightened, or open to change MD, the engineering capacity in such businesses is often strong and innovative but rarely structured to appreciate the level of evidence and development required in health care systems by the many decision makers and takers or the long timescales involved – particularly in the English system. In many cases SME companies set up a completely separate business, not just to distance the business risk, but to enable a completely different style of customised engineering with a supporting public face that relates to the expectations of the healthcare sector. That said, the engineering competences in the business can often adapt and bring significant levels of innovation into the medical technology sector by transferring their knowledge of materials, functions and devices from other sectors. But there still does need to be one or two engineering leaders with the flair for different functionality and design parameters in medical technologies.

The length of curve to develop manufacturing operations can be similarly long and protracted but there are many advantages in low volume niche markets to keeping this function in close proximity to the engineering and the development processes involved. Low labour cost is most unlikely to be a significant differentiator for a business in such markets, particularly if only available at a distance and in a different culture. Problem solving is likely to be the more important skill – not least in working with manufacturing systems that typically need to be far more agile, and more flexible, than for other sectors.

The complexity of the healthcare market has posed the largest set of difficulties facing diversifying SMEs – particularly those that were originally structured to operate in a matured, tiered supply chain, large OEM dominated sector. Thoroughly understanding the market and its decision structures is vital to the success of very different, and often extended, investment return models and the profitability of the business. There is also a major onus on the marketing leader to ensure that the very different business model required is understood by the rest of the managers in the team. There are a number of ways in which SMEs can and have acquired, or developed, these competencies but very few began diversification with this level of capacity in house.

Researching the SIC codes 10 years ago for designers or companies manufacturing medical technologies in the West Midlands revealed a grand total of six companies. This figure of course completely under represented the true picture as even then there were a significant number of companies who had a percentage of their activity in healthcare technologies but that was either not their main activity or their medical activity was classified under a different generic heading. Today, the clustering activity now reveals more than 1500 companies in the region with interests and activities in healthcare technologies, again most are not 100 per cent medical technologies.

The examples below illustrate how companies have developed within the cluster and how their skill needs have developed (see Boxes 7.1 and 7.2)

Box 7.1 Emerging Skill Needs in a Medical Technology Engineering Company

Electrical Equipment Company

Some six years ago a West Midlands company engineering and manufacturing electrical equipment took advantage of the Health Tech programme to look at some of the opportunities and issues involved in the healthcare technologies sector with a view to potentially expanding into that market. At that stage they had tried a couple of product ideas for people but had no level of regular sales or focus for those ideas in healthcare. In December 2008, when recession was biting hard, a review meeting was help with the MD: “Six years ago, we were 80/90 per cent automotive or general engineering, today we are 80/90 per cent healthcare technologies. We haven’t had a single order from automotive or our traditional markets for the last two months and if we hadn’t diversified into medical we wouldn’t be having this meeting today - because I wouldn’t be here”.

In November 2009, a further meeting revealed the continuing difficulties for the business in other sectors but that the healthcare sector was going from strength to strength and the company was in the middle of introducing new products for the healthcare market based on novel electronic components. Pressures on the business have been heavy, not least on the MD and the degree of change that he has had to accommodate as leader of the engineering and marketing effort; new skills and technologies have had to be acquired in the electronics field but many of the other business processes have been able to diversify through adaptation.

Box 7.2 Emerging Skill Needs in an Assistive Technology Company

Assistive Technologies Company

Many SME's have developed successful niches in healthcare technologies based solely on transfer of existing knowledge from other sectors but the opportunities that are presented by a rapidly developing sector such as healthcare are rich for innovation from a wider, and multiple sets of skills, competences and ideas. Already the region is seeing examples of companies achieving this. A manufacturer of assistive devices for the elderly began, and has very successfully grown the business largely based on stand-alone electrical and mechanical equipment. The company is now introducing electronic sensors and communication systems which will not only be able in the future to provide remote data on the functioning of the equipment, but will also be able to provide a communication platform for data related to the personal health and functioning of the equipment user. In this case, it is an excellent example of developing skill sets for short term pragmatic opportunities relating to the equipment functionality whilst at the same time putting in place flexible strategic skill sets and technology platforms that can deliver healthcare functionality to any of the potential private or public healthcare communication networks that will unfold in due course.

Diversifying into health care is not without its difficulties and the example of the West Midlands engineering companies suggests that negotiating access to the NHS procurement system – and that of other countries – is complex.

An important element of the West Midlands approach is to engage the region's HE sector in the development of medical technologies. In the West Midlands region there are nine Universities with research and other interests in medical and healthcare technologies; some with medical schools, some with health faculties of various types and some with medical engineering or related digital and software technologies. Over the last 18 months a group has come together under the title of Medical Interchange to represent their interests in increasing collaboration with other partners, typically in industry, in order to reduce the time to commercialise good ideas and to produce patient benefits and better healthcare economics more quickly. A key mechanism to achieve this is the use of trade sector events and expositions in order to promote University research, capability and innovation and to attract industrial partners to collaboration opportunities.

The company examples cited above focus on companies that offer the potential for significant numbers of jobs that can be created through conversion and adaption from the existing skills base in traditional engineering and manufacturing. As such, there are and have been strong clusters in product areas such as automotive and aerospace but also in a number of component technologies that are more generic and can be readily adapted to healthcare products including tooling and instrumentation, automation & robotic technologies, information & communication technologies.

Alongside such job opportunities, there is also growth in the West Midlands, as there is elsewhere, in companies and jobs related to genomic and bio database analysis and the provision of testing and a range of other similar services to the healthcare, research and knowledge based sector. In this context there are a number “hot spots” of knowledge that are strong in the West Midlands including software, media and related interactive technologies. Some 10 per cent of the world market for such interactive software originates in the West Midlands with much of the software traditionally being supplied to Sony, Warner and other big groups under sub contract for big budget entertainment films, computer games and other media. In more recent years the complexity of these projects has enabled the English companies to retain their own IP on the modules that they have been supplying. In turn they have been able to capitalise on this IP in the strategic use of this software for the development of Serious Games techniques – i.e. interactive software for training, simulation and predictive or forecasting scenarios for practical decision trees and the development of strategic planning. In this context the defence sector has now become one of the largest users of such software in the last few years but is rapidly being followed by the health sector where the potential life (or otherwise) outcomes can be equally concerning.

Programming and software skills are clearly a major requirement in relation to the development of the core processes and modules of a Serious Game and will continue to be so in healthcare applications. All the NHS teaching hospitals are potential customers for such software in their own training and development programmes and that all the clinicians are faced with similar issues such as: how do you realistically train a student in a surgical procedure which may only occur a handful of times during his or her career? The answer, in part at least, is to use Serious Games applications. Hence there is growing interest in the region from various agencies to apply Serious Games applications into the health sector. Again this raises skill issues in relation to being able to develop a product away from its initial purpose and gain entry into a system which has its own complex product licensing and product procurement rules.

7.5 Conclusion

There is a wealth of economic evidence to reveal the benefits which derive from spatially concentrated networks of companies, research and development centres, and State agencies. These benefits relate to increases in R&D activity, increased skill levels, and employment growth. The pharmaceutical and biotechnology sector provides examples of how has been successfully developed across Europe and North America. The West Midlands case study is provided as an example of how this type of approach can be developed in the medical technologies sub-sector through persuading engineering companies to diversify their activities into health care operations. With respect to the number of engineering companies now engaged in health care – even if this is not their primary market – there is prima facie evidence of success. Moreover the region provides evidence of positive spillovers given the potential for the serious games sector in the region to develop its applications for the health care market. What is apparent from the case study of the region is the need for concerted action between a range of regional partners to push the diversification agenda and then support its implementation. The principal skill needs which emerges is that of being able to access the procurement systems of the health service – either in the UK or abroad – and then meet the demanding product standard requirements.

What is less clear from the evidence which relates to a more embryonic cluster of activity is the extent to which long-term relationships are established between organisations of the following types:

i. intra-firm supplier – buyer relationships;

ii. industry-HEI-healthcare collaboration; or

iii. RJVs.

These are likely to be well established in more mature clusters of activity – such as the Boston Life Sciences cluster or the more established ones in England – but would appear to be dependent upon strategic intervention from public agencies to bring about their effective operation (e.g. through efficient information flows between organisations) where they are less well established.

8 Conclusion

8.1 The Sector

The bio-medical industry is one of strategic importance in relation to the nation's economic and physical well being. The global market for pharmaceuticals and medical equipment is huge and is likely to grow with the emergence, amongst other things, of new regenerative and preventative therapies, the convergence of pharmaceutical and medical technologies, and the use of information communication technologies allied to health care. All nations in the western world are investing heavily into this area of activity, and it is apparent that developing countries are also building a critical mass of expertise.

Several features of the bio-medical sector make it particularly important; not least is the likely strength of future demand for outputs of this sector. For example, increased levels of demand are likely to be driven by a wide range of factors, including the increasing need to:

- control the spread of diseases in an increasingly global economy;
- develop preventative therapies to keep individuals economically activity and in employment;
- meet the health needs of an aging and growing population;
- reduce energy consumption and waste;
- ensure that existing best practice is rapidly disseminated across the population in need, coupled with equality in access and treatment;
- meet the demand for more "bespoke" treatments.

The sector is one of the few remaining, relatively strong bastions of manufacturing in the UK. It is an important exporter of goods and, a number of the sub-sectors, such as the medical technologies sector, are net exporters of goods. Given the growth in future demand likely to be experienced by health providers, there is the opportunity for a significant proportion of the supply of bio-medical products which are used in health provision to be domestically produced, rather than imported.

The sector is diverse and is not easily categorised within the Standard Industrial Classification. Recent trends in and future opportunities for growth and employment are heterogeneous across different areas of activity within the sector. These areas seem likely, therefore, to require different policy approaches if they are to maximise the benefits that they offer to the UK economy. The key issues are how to sustain production in the more mature sectors which seem likely to be subject to pressures leading to contraction and to identify and provide appropriate policy support for areas where there is the potential for future growth. To this end, the Office for Life Sciences was established within the Department for Business Innovation and Skills in January 2009 to provide targeted intervention to help the sector realise its potential.

Part of this diversity stems from the fact that the bio-medical sector has been experiencing a period of major change and upheaval that has led to increased uncertainty about its future. Some of this change and uncertainty has been less than positive, such as:

- the decrease in the ratio of new products coming to market relative to investments in R&D in certain key areas, such as pharmaceuticals;
- the sorting-out and removal of relatively high risk, uncertain return activities caused by the bursting of the "dot-com bubble";
- the effects of economic slowdown, increased pressures to reduce costs and lower prices, associated with the need to outsource, network and/or strategically relocate different functions globally.

Conversely, other aspects of change and uncertainty give rise to new opportunities, although, admittedly challenging opportunities. These primarily, though not exclusively, stem from the enormously rapid rates of technological change in areas relevant to health, such as:

- the shift from chemical to biological based pharmaceuticals and the greater use of biomaterials;
- the rise of new technologies that enable existing functions, such as R&D or initial drug-testing to be carried out in entirely new ways;
- the rise of diversely different new technologies such as stem cell research, diagnostic techniques, medical equipment for use in the "home" rather than the hospital, etc. open entirely new avenues of treatment, change the balance between prevention and treatment, the location of treatment etc.

In much the same way that bio-medicine spans different sectors, today, different strands of bio-medicine span different areas of technology and the disciplines needed to be competent in them.

The detailed analysis of the patent data suggests that the extent of technological opportunities varies enormously by area of technology. Nevertheless, being at the forefront of technology is not enough, as there is an enormous degree of international competition to be involved with the bio-medical area. As noted earlier, there are few major industrial countries that have not developed a cluster of bio-medical activity, which is typically based around company – HEI collaboration and partnership.

Rather than discuss existing technologies and their continuing importance or the emergence of new technologies and the opportunity each offers, the discussion turns to two stylised example "sectors" which appear, at the present time, to be quite different, require different policies and support, and to meet the UK's needs in quite different ways. These example sectors are pharmaceuticals and medical technologies.

The first of these is the pharmaceuticals sector, which is an example of a relatively mature, R&D intensive technology which has been driven forward by advances in the science base, but is now threatened, at least in its more traditional lines of approach, by a rising difficulty of isolating effective new products per unit of R&D effort.

Historically, this area of activity has been driven forward by the employment of the most highly skilled individuals. Estimated employment is c73,000 and forecast to be static over the decade to 2020. As a generalisation, this part of the bio-medical sector not only places pressure on the supply of the very highest STEM skills by the public sector, has been able to attract the best talent to the UK from many parts of the globe and has contributed itself to the education, training and experience of staff at the highest level.

The trends in patent applications suggest that this area is far from exhausted, but, equally, there are other omens that suggest that this line of approach to health problems may be overtaken by other areas. If the latter is correct, then there is a need for government policy to assist this sector to sustain its high level activities for as long as possible. It should be noted that, even in a worst case scenario, existing patent protection for many of the pharmaceuticals will continue for the foreseeable future and subsequent generic production can still be profitable. However, a decline in this sector, given its work at the frontiers of science and its generally high skills demand, would have important implications for UK performance. The rise of biotechnology, however, provides the pharmaceutical sector with a substantial opportunity to develop the next generation of products.

The second sector concerns that of medical technologies. Employment levels are less precise here and estimated to be in the range of 40-60,000 depending on the source, with BIS/UKTI/DoH estimating 52,000, but are forecast to decline slowly. The upsurge in patent activity in this sector was perhaps more surprising, and not all of it was associated with the high-technology end of the spectrum such as diagnostic technologies (e.g. scanners). Some of the areas of technology where organisations were still actively patenting might be considered as being at the lower end of the technology spectrum (e.g. bandages and dressings).

Production based upon these technologies still has the potential to create employment for large numbers of individuals and, in particular, those down the skill spectrum. What is interesting is that a number of the component areas of medical technology, appear to require skills that may be available in more abundance (e.g. electrical, engineering and electrical-engineering skills), and a growth in this area might be able to off-set a decline in more traditional manufacturing areas, such as automotive production in the West Midlands.

8.2 Skill Needs

Analysis of patent data reveals the extent of research and development activity taking place in the bio-medical field. It also reveals; the importance of the USA relative to that of either Japan or the European Union; Japan's focus on IT developments, and; the sensitivity of the patenting activity to the economic cycle and the extent to which events such as the dot com bubble can have a negative impact on innovation and patenting presumably by limiting the availability of capital, especially venture capital, to fund innovation. A point made elsewhere in this report refers to the importance of SMEs in generating new ideas and prototypes which the larger corporations then acquire if these look as if they will result in a product coming to market. The impact of the recent tightening of the credit supply may have long run implications for innovation in the sector the effects of which only time will tell.

At the current point in time England is well placed to take advantage of future opportunities. This stems from the country's existing strong base in pharmaceuticals though less so in medical technologies where it lags behind both Germany and the USA. The strength of England's position results from its knowledge base – the supply of highly educated research scientists operating at the cutting edge of scientific endeavour. While the large corporations are significant investors in R&D and associated education and training, at least part of the country's enviable position is a consequence of a strong HE base with several universities regarded as amongst the very best in the world in several of the scientific disciplines germane the bio-medical industry. Ultimately the future of the knowledge-intensive sector of the industry is dependent upon the capacity and capability of the HE sector.

From a labour market and skills perspective there is also a need to consider the potential for the industry to create a large volume of employment in addition to the research scientists. In the UK it is estimated that around 110,000 people are employed in the Bio-medical sector, of which around 95,000 are employed in England and this, according to the Working Futures projections produced for this study, will remain more or less stable albeit with some modest reduction in numbers over the medium term. But there are challenges which may result in deviation away from this baseline projection. These can be summarised as such:

- mass manufacture of basic pharmaceuticals, especially those which are out of patent, becomes increasingly transferred abroad as pharmaceutical companies attempt to reign in costs in part because of the escalating costs of developing new products;

- niche manufacture comes more to the fore in pharmaceuticals as therapies become more bespoke and, accordingly do not require large volume manufacture.

The extent to which the latter can compensate for the former is a moot point and it is apparent that large scale manufacture is not that mobile. A switch from the mass manufacture of products to niche production has implications for skills – especially at the shop floor level - insofar as the latter is likely to be relatively skill intensive and less amenable to automation. It also has implications for investments in training if niche production is concentrated amongst SMEs, given the particular set of barriers they face when it comes to engaging in training.

It is unlikely that there will be a simple switch from one form of production to the other but the extent to which there is will result in differing types of skill need emerging. Both forms of production, however, are relatively reliant upon skilled trades workers (typically qualified to Level 3). The extent to which there is a large volume of employment engaged in the manufacture of bio-medical goods is dependent upon the supply of skills and strategic choices made by the principal companies in the market.

The medical technologies sub-sector has received relatively little attention compared to pharmaceuticals and biotechnology, in part because it is smaller and often concerned with the production of more mature products. The analysis of patent data, however, suggests that this is an area in which there is, globally, a large volume of innovative activity taking place. Germany and the USA are the principal players in this market. But has noted above there is considerable potential for producers in the automotive sector to diversify into medical technologies.

The future skill needs of the sector relate very much to:

- skills required by the R&D process (e.g.. highly qualified scientists able to translate scientific breakthroughs into products);

- the production process (e.g. engineers, technicians, and operatives);

- management (e.g. developing and managing inter-disciplinary teams, being able to diversify the product range, managing mature product ranges, etc.).

Many of the skills which the bio-medical sector will increasingly require are ones which are typically in short-supply across the economy (e.g. generic skills related to management and leadership, highly qualified scientists and engineers working at the cutting edge of product development). As noted elsewhere in this report, the nature of skill demand in the sector is such that supply will always struggle to keep pace. There are, however, a range of more commonplace skills which the sector is currently dependent upon and will continue to be over the period to 2020. These include a range of engineering and technician roles related to the production of everyday products and operatives who work on assembly lines.

In summary, Table 8.1 provides information about the industry's skill needs over the medium term. Without a strong supply of these skills it is likely that output will be constrained. But as noted throughout this report the supply of skills is not sufficient in itself to safeguard a large volume of employment engaged in manufacturing. This relates very much to the strategic choices which the large corporations make and the extent to which the networks, clusters, partnering and joint ventures of which they are part are concentrated in England rather than elsewhere. Nevertheless, skills supply is part of the overall attraction of England to producers and will influence the emergence of networks and clusters.

Table 8.1 Summary of Emerging Skill Needs

Skill Level	Type of skill required	Comments
Technical / Scientific Skills		
Ultra high Level Skill Needs	Post-graduate scientists in a range of biological and physical sciences	Generally required in small numbers with highly specialist skills, but critical to the future of the industry in England
High level skill needs	Graduate level scientists	Better laboratory skills Improved overall scientific and mathematical literacy
	IT Skills: Graduate level	Needed to develop improved communication between people and devices – a general requirement for the industry over the medium term
	Statisticians and mathematicians: Graduate and postgraduate level	Processing of data / use of simulation models, etc.
	Engineering	Nanotechnology skills, design and use of new materials / biomaterials ; software /IT – alongside the existing demand for chemical engineers, etc.
	Economists: Graduate level	Required to assess the cost-benefit of any new development and its application to the health care system
Intermediate level skills	Graduate / Level 3 Apprenticeship Skills	Required to support manufacturing process. Especially important in niche production if the future of the manufacturing sector is based on this form of production
Operative / Assembly line skills	Typically at Level 2	Skills at Level 2 are typically employed in the production of a range of bio-medical goods. A shift to more niche production is likely to limit the capacity of automation to replace these jobs. Though are at potential risk of being transferred to lower labour cost countries.
Generic Skills		
Management and leadership	Graduate level	Managing across multi-disciplinary teams
		Managing across organisations, networks, etc…where outsourcing used
		Procurement skills / negotiating with health care systems
All	All levels	Improved levels of scientific and mathematical literacy. Quantitative skills.

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Appendix 1: Interviews with key stakeholders

A series of interviews were held with key stakeholders in order to obtain an insider's views of developments in the sector (see Table A1.1).

Table A1.1 Interviews with Key Stakeholders

Type of organisation	Number of interviews
Government regional development agencies	1
NHS Trusts	1
Industry – health system liaison bodies	2
Trade organisations in healthcare	1
Industry representative bodies	1
Medical device companies	3
Pharmaceutical companies	2
Higher education institutions	2
Sector Skills Councils	2

Appendix 2: Patent statistics - a note

Some care needs to be taken with the interpretation of, and comparisons undertaken using, patent statistics (see Bosworth, 1986). For example, in the present exercise, patent statistics are drawn from a number of sources (based upon different jurisdictions – such as the US Patent and Trademark Office, the European Patent Office and the Japanese Patent Office. In addition, different sources compile their statistics in somewhat different ways – such as the OECD, which has its own definition of the biotechnology sector, which may not correspond identically that that used by other institutions, such as the SSCs, including Cogent.

The data reported in the present section were taken from two main sources:

- the OECD publications of patenting activity that form a part of their Science and Technology Indicators (STI) database;

- interrogation of individual patent data from the European Patent Office (EPO) ESpace database.

In the present exercise, all of the statistics reported in this Chapter are taken from the OECD database. However, the OECD data are only available up to a certain degree of disaggregation (e.g. the first four digits of the IPC). Hence, EPO data were used in the present report for two purposes: first to obtain a greater degree of technological disaggregation (which has been used qualitatively in reporting the results) and, second, to ensure that the patent trends from OECD sources correspond broadly with those from the ESpace database.

Given that ESpace contains worldwide information for over 60 million patent documents, a number of choices have to be made in the method of search, even bearing in mind that the international patent classes of interest only form a reasonably small proportion of the total. To simplify the search, the chosen starting point was to examine patenting application activity and, in the case of detailed interrogation of individual data, the focus was on applications to the USPTO.[1]

Here information is not only available about detailed areas of technology, it is, in principle, possible to recombine this information to explore the “technology platforms” that those operating within the sector (including the SSCs) recognise and believe to be important when examining future developments (see Appendix 3). In addition, other patent statistics contain other strategic information about countries (and, in principle, companies) that give some clue as the extent to which the UK can or should position itself as a leader or follower in different areas of technology. At present, this work is in progress and is not discussed in the present report.

Finally, certain areas of activity are much closer to the science base and might be more accurately tracked using information about scientific publications and the Science Citations Index (SCI). While exploratory work has been carried out in these sources, it is too early to publish results from this analysis.

Appendix 3: Technology Platforms

The technology platforms that Cogent and Semta appear to be currently working with include the biotechnology platforms that sit across the sectors:

1. Genomics

   Genomics as "the study and modification of genetic materials." Subject matter classified within genomics includes: pharmacogenomics, genetic medicines; gene therapy; gene probes; genetic engineering; DNA/RNA sequencing; gene libraries; genetic material/genes; gene expression profiling and the use of antisense technology.

2. Proteomics

   Defined proteomics as "the analysis of the expression, localization, functions, and interactions of the proteins produced by the genes of an organism." Subject areas classified as following within the field of proteomics include: proteins, peptides and enzymes; the isolation, purification, synthesis and sequencing of thereof; medicines containing proteins, peptides and enzymes; peptide/protein libraries; testing with enzymes; and biomarkers.

3. Metabolics (cell function)

4. Bioinformatics

   Defined bioinformatics to include the "construction of databases on genomes, protein sequences; modelling complex biological processes, including systems biology." The subject areas have been classified within this area include: libraries/databases with genetic information, genomes, genes and protein sequences and computer modelling of biological and chemical processes.

5. Synthetic Biology.

   Synthetic biology defined to include the redesign of biosystems, artificial genomes, regenerative and synthesis of bioparts. Subject areas classified as following under synthetic biology include: prosthesis; artificial hearts; artificial kidney; cell lines and tissues.

6. Biotechnology

   The term biotechnology has been construed narrowly to include health related aspects of life sciences that isn't part of the above categories. Subject matter classified within biotechnology includes: cell/tissue culture; tissue engineering; analysis of biological material; measuring or testing involving micro-organism or enzymes; vaccine/immune stimulants/antibodies; micro-organisms; and hormones & steroids.

These platforms can variously combine and lead to the following applications in health:

1. Therapeutics (new biopharmaceuticals produced in part or in whole by organisms, tissue engineering, stem cells, vaccines)

   Subject areas that classified under therapeutics include: genetic medicines; gene therapy; vaccines; medicines with proteins, peptides or enzymes; cell lines and tissues.

2. Pharmacogenetics (gene drug interactions combined with diagnostics and informatics to target ethnic and individual target groups for treatment)

   Subject areas that classified under pharmacogenetics include: genetic medicines/gene therapy; gene probes; gene libraries and gene expression profiling.

3. Diagnostics (in vivo and in vitro including genetic testing and biomarkers)

   Areas that categorized under diagnostics include: biomarkers; gene expression profiling & gene libraries; analyzing biological material; and measuring and testing involving micro-organism or enzymes .

4. Medical technologies

   Areas categorized under medical technologies include: prosthesis; artificial hearts and artificial kidneys. More traditional medical technologies have been classified under medical technology.

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Produced by the Warwick Institute for Employment Research for the UK Commission for Employment and Skills

UKCES
3 Callflex Business Park
Golden Smithies Lane
Wath-upon-Dearne
South Yorkshire
S63 7ER

T + 44 (0)1709 774 800
F +44 (0)1709 774 801

UKCES
28-30 Grosvenor Gardens
London
SW1W 0TT

T + 44 (0)20 7881 8900
F +44 (0)20 7881 8999

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ISBN: 978-1-906597-38-2