

SCIENCE AND TECHNOLOGY

Trends and issues forward to 2015: Implications for health care

This paper highlights several expected future trends. On the one hand, a greater concentration of specialist expertise and equipment in a smaller number of larger centres is expected within health care services. At the same time, it will be possible to treat more conditions locally in small centres, and there is likely to be an increase in self-diagnosis and self-treatment or home care. Science and technology hold great promise for health and health care services in 2015 - increasing sophistication of medicine, improved potential for screening and treating serious conditions, and further reductions in hospital length of stay. Policy makers have to work with the growing demands and expectations of the public, the need to evaluate new health care technologies, and ensure that the health infrastructure and workforce can cope with developments.

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POLICY FUTURES FOR UK HEALTH

Edited by Charlotte Dargie

This paper is part of a series written for the Policy Futures for UK Health Project, which examines the future environment for UK health, with a time horizon of 2015. The full series is listed below.

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Trends and issues forward to 2015: Implications for health
care

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Charlotte Dargie

FOREWORD

Since its inception the Nuffield Trust has identified individuals and subjects that would impact on health and health care policy in the United Kingdom, with notable examples being *Screening in Medical Care* [1], Archie Cochrane's *Effectiveness and Efficiency: Random Reflections on Health Services* [2], Thomas McKeown's *The Role of Medicine: Dream, Mirage or Nemesis?* [3], David Weatherall's *The New Genetics and Clinical Practice* [4] and Alain Enthoven's *Reflections on the Management of the National Health Service* [5].

In keeping with tradition and reflecting the more complex issues in health and health care policy today, the Nuffield Trust established a Policy and Evaluation Advisory Group (PEAG), supported by the appointment of a Nuffield Trust Fellow at the Judge Institute of Management Studies at the University of Cambridge, to provide a research and intelligence capability for the Trust.

The Policy Futures for UK Health Project stems from the work of PEAG. It involves examining the future environment for UK health, with a time horizon of 2015. The first environmental scan has resulted in a series of 10 technical papers, which cover the following areas :

1. The Global Context
2. The Physical Environment
3. Demography
4. Science and Technology
5. Economy and Finance
6. Social Trends
7. Organisation and Management
8. Workforce
9. Ethics
10. Public Expectations

Each paper in the series is a stand-alone piece, but has also been used by the project to derive an overview report, which focuses on policy assessment in the light of the environmental scan. Entitled 'Pathfinder Report', the overview report is published separately and will be subject to external consultation².

The Policy Futures for UK Health Project and the work of PEAG are ongoing. Further reports and publications will appear in subsequent years. The technical papers will also be revisited and different subjects will be tackled.

The strength of the technical series is in providing a context for analysing health and health care policy for the United Kingdom. Each author has produced an independent piece of work that analyses trends and issues in their subject area, focusing on 2015. The papers enable one to read across the issues, in order to provide a general analysis of health and health care policy, which is lacking in the highly specialised debates that dominate the health world today. They have formed the basis for consultation and discussion as part of the Policy Futures for UK Health Project.

Finally, the Trust is grateful to the members of the PEAG, to Professor Sandra Dawson and Pam Garside of the Judge Institute of Management Studies and to the authors of the 10 technical papers. A particular thanks due to Dr Charlotte Dargie, Nuffield Trust Fellow at the Judge Institute of Management Studies, the author of the Pathfinder report.

John Wyn Owen CB

July 1999

ENDNOTES

1. *Screening in Medical Care: Reviewing the Evidence* A collection of essays with a preface by Lord Cohen of Birkenhead (Oxford: Oxford University Press for the Nuffield Provincial Hospitals Trust, 1968).
2. AL Cochrane *Effectiveness and Efficiency: Random Reflections on Health Services* (London: Nuffield Provisional Hospitals Trust, 1971).
3. T McKeown *The Role of Medicine: Dream, Mirage or Nemesis?* (London: Nuffield Provisional Hospitals Trust, 1976).
4. D Weatherall *The New Genetics and Clinical Practice* (London: Nuffield Provisional Hospitals Trust, 1982).
5. AC Enthoven *Reflections on the Management of the National Health Service: An American Looks at Incentives to Efficiency in Health Services Management in the UK* (London: Nuffield Provincial Hospitals Trust, 1985).
6. S Williams, S Michie and S Pattani *Improving the Health of the NHS Workforce* (London: The Nuffield Trust, 1998).

Each of the papers in the series is available from the Nuffield Trust.

² C Dargie *Policy Futures for UK Health: Pathfinder* (London: The Nuffield Trust, 1999). The Pathfinder Report is for wide consultation and invited comment. You can email your comments to policyfutures@jims.cam.ac.uk. You can also send your comments to Dr Charlotte Dargie, Nuffield Fellow in Health Policy, The Judge Institute of Management Studies, Cambridge University, Cambridge, CB2 1AG. You can also find this Pathfinder Report along with other technical papers in the Policy Futures series at the Nuffield Trust website: <http://www.nuffieldtrust.org.uk>. Please respond with your comments by Friday 19 November 1999.

ABBREVIATIONS

AIDS	acquired immune deficiency syndrome
CF	cystic fibrosis
CMP	Changing Medical Practice
DIPG	Drug Information Pharmacists Group
DIS	Drug Information Services
DoH	Department of Health
EWS	early warning system
GNP	gross national product
GP	general practitioner
HCHS	Hospital and Community Health Services
IT	information technology
MRT	magnetic resonance therapy
NHS	National Health Service
NICE	National Institute for Clinical Excellence
NPC	National Prescribing Centre
OST	Office of Science and Technology
SCID	severe combined immunodeficiency
SERNIP	Safety and Efficacy Register of New Interventional Procedures
SGHT	Standing Group on Health Technology
SMAC	Standing Medical Advisory Committee
UK	United Kingdom
US	United States (of America)

SUMMARY

Trends

- There will be a greater concentration of specialist expertise and equipment in a smaller number of larger centres dealing with complex cases, driven by the increasing sophistication of medicine (in areas such as genetics, biotechnology and bioengineering, image guided surgery, robotics and transplantation).
- The growing importance of technologies will allow self-diagnosis and 'self-treatment' (home care) with more complex care taking place at home, and the decentralisation of laboratory technology.
- An ever greater proportion of common conditions will be treated locally in small centres linked telemetrically to specialist centres (information technology [IT] and telecommunications) leading to increasingly blurred distinctions between primary, secondary and tertiary care.
- The potential for screening and treating serious conditions will be improved, with the potential of moving from the present operation of a 'sickness service' to the construction of a genuine 'health' service in which disease prediction and prevention are accorded higher priority.
- There will be further reductions in lengths of hospital stay as more diagnosis, treatment and monitoring is able to take place outside the hospital.

Policy issues

- There will be a growing demand for continuing care for frail elderly patients and those with chronic and multiple conditions (due to a further increase in life expectancy).
- Demand and need will increase for rigorous evaluation of new health care technologies, including their likely socio-economic impacts, in parallel with closer questioning of the role of science and technology in health care by society as a whole.
- Future training of health care professionals - educational programmes and undergraduate programmes - will be needed in new areas (for example, genetics)
- The ability of the health care infrastructure to cope with future changes in the organisation and configuration of services in terms of logistical issues, such as IT, will have to be ensured.

BACKGROUND AND CONTEXT

Recently, there has been increasing interest in the assessment of the effectiveness and costs of health care technologies. This interest has arisen from the need to justify the often high costs of technologies to governments and private insurance companies, and because of the implications that the introduction of such technologies may have for the organisation and management of health services (see paper no. 7 in this series: 'Organisation and management'). Such interest will grow as long as health care spending remains at 6 to 18 percent of the gross national products (GNPs) of developed countries [1]. In the United Kingdom (UK) these concerns have led to initiatives such as the National Institute for Clinical Excellence (NICE), the Commission for Health Improvement, and the growing clinical guidelines movement.

One manifestation of the increasing interest in the role of technology in health care has been the development of 'technology forecasting'. This discipline is a subsystem of technology assessment and futures research; it is an attempt to consider possible future relations between science and technology and the needs of society and industry. Initiatives are often undertaken at a national level with time horizons of five to 10 years or longer, and involve the systematic investigation of the future development and application of technologies. In the UK, for example, between April 1994 and January 1995, the Health and Life Sciences panel of the Office of Science and Technology's (OST) Technology Foresight Programme reviewed long-term trends in science, technology, health care, health-related industry and non-medical applications of the life sciences, and assessed the principal opportunities and challenges presented.

However, only a relatively small number of empirical studies (often using a combination of projection, extrapolation and pure guessology, augmented with surveys of reports and publications from other organisations) have sought to identify new health care technologies in a particular speciality or across health care as a whole. This paper presents an overview of major trends, themes and issues in science and technology forward to 2015. Existing predictions on advances in science and technology (as related to health care) are highlighted, with, where available, suggested realisation dates.

First some words of caution. Previously, excessive claims have been made for science and technology-related developments. Given the inherent uncertainties associated with technological innovation and adoption it is inevitable that some of the more specific predictions reported in this paper will prove to be wrong [2] [3]. The single most important caveat to many of these predictions (for example, in the areas of genetic engineering, xenotransplantation, robotics

and the potential for widespread access to personal health information) is whether some of the technological advances outlined in this paper will prove to be ethically acceptable (see paper no. 9 in this series: 'Ethics'). As Spilker suggests, 'simplistic futuristic views and projections that ignore human values and needs will almost always be wrong' [4 p392]. Ferguson reiterates this observation by pointing out that, 'unlike the past, the major bottleneck is unlikely to be scientific discovery, rather implementation, social acceptance, administration and finance' [5]. Against a background of scientific advance and technological innovation, there does seem to be a growing public fear of technology *per se*, often because of an accompanying perceived neglect of personal care. However, there is a dichotomy here as public opinion also strongly supports innovations in medicine as the 'hoped-for source of tomorrow's solutions to many of today's intractable medical problems such as AIDS, cancer and diabetes' [6 p3]. As well as the broader issue of the impact that science and technology may have on health and lifestyles, the rising costs of health care technologies have also led to concerns that social inequalities may increase. While the benefits of health care technologies can be substantial, they account for only part of the large increase in life-expectancy experienced since the beginning of the century [7]. Large residual differences in health may have something to do with our social lives, how many social contacts we have and whether we are part of one or more cohesive social groups (see paper no. 6 in this series: 'Social trends')

In spite of these important reservations, the aim of drawing on the results of earlier studies is to synthesise current thinking on likely major trends in science and technology, and their potential policy implications for health care, until 2015. Eight separate areas have been chosen for discussion but likely developments in some of the areas are closely related, and in some cases are interdependent. The selection is based largely on a review of earlier studies on the future of health care [8]. This paper also draws on ongoing work with which the author is involved to establish an 'early warning system' for identifying new health care technologies prior to their widespread adoption in the UK [1][9][10].

The chosen areas are genetics, biotechnology, bioengineering, minimal access and image guided surgery, robotics, transplantation, information technology and telecommunications, and home care.

GENETICS

Advances in molecular genetics have been identified as one of the two technological trends which will have the greatest effects on health care over the coming decades [11]. It is hoped that by 2010 the structure and function of almost all human genes will be understood. During the next five to 15 years

the Human Genome Project³ is forecast to offer, together with developments in biotechnology (see below), the prospect of [13]:

- potential cures in areas that are as yet untreatable
- a dramatic increase in the rate of drug discoveries (particularly in relation to cancer treatment, Alzheimer's disease, diabetes, heart disease and osteoporosis)¹⁵
- screening of patients to determine susceptibility to diseases
- treatment of underlying pathologies rather than symptoms
- targeting of treatment to the needs of individual patients.

More than 4,000 conditions, such as severe combined immunodeficiency (SCID) and cystic fibrosis (CF), are caused by inborn damage to a single gene [16] and there are a number of such monogenic diseases in which genes have already been identified [17]:

- Duchenne/Becker muscular dystrophy (1985)
- chronic granulomatous disease, retinoblastoma (1986)
- cystic fibrosis (1989)
- neurofibromatosis type 1, familial colonic cancers (1990)
- fragile X mental retardation (1991)
- polycystic kidney disease 1 (autosomal dominant), tuberculosis sclerosis (1994).

There is a growing demand for genetic services in the UK^C and it has been predicted that by 2010 genetic screening will be widely used [19]; in 1994 there was a tenfold increase in the number of cancer families referred for genetic counselling over the previous year [20]. In England and Wales there has been a 41 percent increase in molecular genetics tests during the period 1995 to 1997, and large increases in the use of other genetic tests [21] (see figure 1).

^a Phase one of this global project has been to define marker regions of DNA which together constitute a detailed map of the human genome. The second phase is to define the DNA sequence of all the 90,000-plus human genes [12].

^b Whilst in the past many drug targets were identified by 'pure serendipity', target identification is now being facilitated by a much more complete understanding of the molecular basis of disease [14]. Thus another implication of an increased understanding of the genetics of common diseases is that '...the search for new drugs will start with a much better understanding of the disease or disorder' [15].

^c Increasing availability of genetic tests and public awareness of genetic tests will have important implications for clinical genetics and primary-care services in particular [18].

The first person to undergo gene therapy³ was a four-year-old girl in the United States (US) who was treated for SCID in September 1990. In the eight years since this first human gene transfer experiment, about 30 gene therapy companies have been launched [22], more than 300 gene therapy protocols have been approved¹⁵ (over 3,000 patients have carried genetically engineered cells in their body) [23], and there has been a large growth in the number of research publications in this area. The Institute for Scientific Information in Philadelphia ranked genetic predisposition towards obesity, genetic causes of cell death and the BRAC1 gene in breast cancer as the top three areas of current biomedical interest in 1998^o. Such a growth of research in this area has led to claims that 'the new technology of gene therapy promises to revolutionise medicine in the next century' [23 p96]. However, respondents to a Delphi survey undertaken by the OST Technology Foresight Programme found little agreement as to when 'all common single gene disorders can be treated successfully by gene therapy', with responses ranging from 'by 2000-2004' at the earliest to 'never' [24].

As well as diagnosing serious monogenic disorders it is likely that it will be possible to identify individuals who have inherited a genetic predisposition to common diseases where there is also an environmental component in their aetiology. These polygenic disorders include coronary artery disease, hypertension, diabetes mellitus, auto-immune disease and dementia. It has been suggested that by 2015 the genetic links of all diseases will have been identified.

Unfortunately, progress in the development of suitable systems for delivering genetic material has not been so rapid. However, advances in gene transfer technology have led to novel drug delivery technologies being developed which have increased the prospect of gene therapy^d. Several different systems have been approved for use in human clinical trials: retrovirus⁶ (used in 56

^a Gene therapy is a term that can be applied to any clinical therapeutic procedure in which genes are intentionally introduced into human somatic cells [22].

^b Detailed information is available on the 232 protocols that had been approved in the US as of February 1998. The disease targets are/were: cancer (69 percent), genetic diseases (16.5 percent, mostly cystic fibrosis and other monogenic diseases), acquired immune deficiency syndrome (AIDS) (11.5 percent) and other (3 percent, including coronary artery disease) [23]

^c Using criteria such as (1) the number of people currently researching the issue, (2) the number of recent papers and (3) research funds allocated.

^d There are two main approaches to introducing genes: *in vivo* gene therapy (in which genes are delivered directly to target cells in the body), and *ex vivo* gene therapy (in which the target cells are genetically modified outside the body and then re-implanted). Most clinical activity to date has focussed on *ex vivo* protocols but much current research is concerned with systems that will permit highly efficient and accurate transfer of genes to target tissues *in vivo* [22].

^e Viral systems employ a virus from which the viral genes have been removed, allowing insertion of therapeutic genes.

percent of trials), non-viral³ (24 percent), adenovirus (10 percent), poxvirus (5 percent) and adeno-associated virus (1 percent) [9]. For cancer therapies, the main problem facing the gene therapist is how to get new genes into every tumour cell. If this cannot be achieved, then any malignant cells that remain unaffected will emerge as a resistant clone [25].

It may eventually be possible to deliver therapies across a wide range of conditions such as degenerative neurological conditions, vascular conditions and metabolic diseases as well as cancers. One futures study suggests that genetic engineering will enable the isolation of high risk groups for common disease during the period 1997-2007 [26]. The OST Technology Foresight Programme suggests that sometime after 2015 the 'practical use of gene therapy will be extended to the treatment of 30 percent of life-threatening disease' [24]. Perhaps the most significant change in medical practice that will result from progress in genetics is that whilst clinical skills are currently based on a model that aims to 'diagnose and treat', in the future, genetics will increasingly make the practice of medicine one of 'predict and prevent' [27 p31]. In cases where susceptibility genes can be identified there may be significant opportunities for preventive measures to be taken by the individuals concerned [9]. An individual's genome may be part of their medical record by 2015 [10]. The ability will exist to assess and act upon the risk of individuals developing certain diseases long before the symptoms of disease develop\

BIOTECHNOLOGY

Medical biotechnology is the use of biological processes to make useful products for medical treatments⁰, and is the means by which our increasing knowledge of human genetics (see above) can lead to the development of new medicines. In 1982, a genetically engineered human insulin was the first biotechnology medicine and the biotechnology revolution has now resulted in 54 new 'products'. In 1995, marketed biopharmaceuticals accounted for more than 12 percent of new medicines launched [16] (see figure 2) and it has been predicted that by 2000 between 10 and 20 novel medicines resulting from biotechnology will be launched every year [27].

^a Non-viral (or synthetic) systems facilitate the uptake of DNA into mammalian cells by condensing it with lipids, peptides, proteins, inactivated virus particles, or crystals of calcium phosphate. Some commentators suggest that non-viral systems will be the preferred choice in the future because of their safety and ease of manufacturing [23]

^b Through regular monitoring, lifestyle changes and/or preventative medicine.

^c Biotechnology products for medical treatments include natural products (such as erythropoietin, insulin and human growth hormone) produced by biotechnological processes, and second-generation hormones, vaccines, monoclonal antibodies and gene therapy products which are specifically designed to alter physiological processes within the body.

More than a third of the 350 new biotechnology medicines in development by the autumn of 1998 were for cancer, including 30 for melanoma, 20 for colorectal cancer and 13 each for breast and prostate cancers (see figure 3) [29].

Biotechnology medicines are being tested to enable patients to grow new arteries around obstructed coronary arteries, treat brain tumours more precisely and slow the progression of Parkinson's disease. In addition, five biotechnology companies are working towards manufacturing artificial blood which would overcome the world shortage of blood and the risks of infection; this development has been predicted for the year 2000 [10]. Biotechnology provides the means by which advances in genetics can be exploited; eventually (given the long development times involved when developing a new biotechnology product) a wide range of diseases will be treatable for the first time.

BIOENGINEERING

Bioengineering seeks to apply engineering principles to our increasing knowledge of human biology, through advances in areas such as cell biology and plastic manufacture. It has already led to the production of artificial skin and pacemakers [30]. Such innovations have led to the prediction that 'in the next three decades, medical science will move beyond the practice of transplantation [see below] and into the era of fabrication. The idea is to make organs, rather than simply to move them' [31 pi00]. Specific predictions include [10]:

- artificial ears (2000)
- electronic implants used to stimulate muscles in disabled people (2002)
- synthetic retinal implants for simple vision (2005)
- artificial heart (2010)
- artificial senses through sensors directly stimulating nerves (2012)
- artificial kidneys (2015)
- artificial lungs (2015).

In addition to newly available artificial organs, increasing longevity and activity are resulting in an ever increasing demand for existing implants such as hip replacements (as illustrated in figure 4). The rates of other implants such as knee replacements, shoulder and finger joint replacements, vascular grafts, heart valve replacements, pacemakers, breast prostheses and intraocular lenses are also increasing.

Increasingly practical biosensors are being developed which combine biofunctionalised surfaces with new microelectronic and fibreoptic sensing techniques. Predictions include that, in the next 20 years, there will be routine

monitoring of glucose in diabetics, of lactic acid in the shocked patient and of nitric oxide and oxygen for a variety of purposes [32].

Many biomaterials [33] (defined as non-biological materials destined for biological venues) in current use have a finite and limited patient-lifetime which leads to the need for repeat, or revision, operations [34]^a. Taking implant technology further will depend on researchers being able to develop materials and systems that can adapt to a biological environment, assimilate quickly, and then respond appropriately to a patient's molecular and cellular dynamics. The innovation of tailor-made materials, which mimic the mechanical performance of the adjacent tissue and produce an appropriate biological response (the principle of 'bioactivity'), has provided the basis for second-generation implants with an enhanced lifetime.

'Tissue engineering' is one such approach: living cells are combined with biologically friendly synthetic polymers, which ultimately dissolve, leaving behind new versions of functioning biological tissue that bears no trace of nonbiological material. For example, researchers in the US have developed tiny implants (small glass cones with a miniature electrode) that are put in patients' brains (inside the motor cortex) and allow severely disabled people to control a computer cursor by thought alone [36]. In time, the patient's own nerves grow inside the cones, encouraged by chemicals the team extract from the knees. Once the nerves have grown, they connect to the electrodes inside the cones, allowing the computer to detect brain signals via a small transmitter located just inside the patient's skull^b. Other applications under development include polymer-based replacement heart valves, implantable drug-delivery systems and a system for growing new collagen tissue such as ear pinnae. Tissue engineering also has enormous potential for treating trauma, burns, degenerative diseases and other types of organ failure.

MINIMAL ACCESS AND IMAGE GUIDED SURGERY

The general aim of minimal access surgery is to 'minimise the trauma of any interventional process but still achieve a satisfactory therapeutic result' [37 pi93]. In doing so the rapid development of minimal access methods of diagnosis and treatment (such as endoscopes, lasers and lithotripsy) has contributed, along with other developments in health care, to services moving away from traditional-style acute hospitals and decreasing lengths of in-patient

^a Increasing the lifetime of a prosthetic joint replacement is important as it has been estimated that in the future the proportion of total hip replacements accounted for by costly and technically demanding revision procedures may increase to 30 percent or more [35].

^b The American team implanted the cones in two patients, one a 57-year-old stroke victim and the other a woman suffering from a degenerative neurological disease. The woman has since died from her condition, but the man is now able to use the system to control a computer cursor to pick phrases on a screen, and communicate with the outside world.

stay [38][39][40]. The OST Technology Foresight Programme forecast that, by 2010-4, 50 percent of surgical techniques will be carried out by minimal access techniques [19]. In combination with these technological advances in minimal access surgery, safer (less toxic) anaesthesia has also increased the potential for outpatient and day case surgery, further emphasising the shift away from in-patient stays (see figure 5).

The use of robots (see below) in endoscopic, minimally invasive procedures without losing track of its orientation and position will also be of benefit in extending the range of endoscopic procedures [26].

Beyond minimal access surgery lies image guided surgery. Building on developments in magnetic resonance imaging (in particular the use of computers to construct three-dimensional images²), the concept of image guided surgery is not just to determine what is wrong with the body, but to instruct, guide and control the surgeon during the actual operation. Image guided surgery helps the surgeon see with better resolution, orientation and context setting, higher contrast, and vision inside 'solid objects', including the elimination of occlusion by the surgeon's tools or other external items [41].

One machine which has the potential to enable image guided surgery to be performed has already been developed: magnetic resonance therapy (MRT) has involved creating a new scanning machine which has a free and open space in which the surgeon can work, while simultaneously imaging the patient [42]. Examples of the application of such image guided surgery include the use of very high energy ultrasound beams to destroy imaged tumours (so-called 'trackless' surgery in which operations are conducted without touching the body at all) and image guided laser treatments in minimally invasive destruction of a wide range of tumours [43].

The possibilities of image manipulation and instrument development seem limitless, so much so that one commentator has suggested that 'open surgery with its hands-in approach will appear quite gross when viewed by the standards that will be set in the next 20 years' [42 pi43]. Such developments will blur the distinctions between surgery, medicine and radiology as well as between primary and secondary care. Fewer operations will require long hospital stays, and the application of robotics (see below) will allow some procedures to be done automatically and - with developments in virtual reality technology [44] - allow surgeons to perform operations by remote control [34].

^a Spiby suggests that three-dimensional dynamic imaging will be in widespread use during the period 1997-2007 [26].

ROBOTICS

Rehabilitation robotics^a is perhaps five years ahead of surgical robotics^b but the OST Technology Foresight Programme predicts that by 2010-4, 10 percent of surgical interventions will be carried out by robotic techniques [19].

The two most famous surgical robotic devices so far are America's RoboDoc, which performs total hip-replacement surgery^c, and a device in Britain which performs transurethral resections of the prostate^d. Robotic devices designed for surgery have three main advantages over humans [45]:

- they have greater three-dimensional spatial accuracy, especially when linked to scanning technology
- systems can be designed to be more reliable and produce more repeatable outcomes
- robots can achieve a precision at least an order of magnitude greater than that achievable by human beings.

Robotic technologies that may be available in the next decade include a computer-controlled endoscope that can 'follow its nose' to a predefined site, thereby avoiding damage to normal tissue while reaching restricted operating sites. Other potential developments include the skin of a device being coated with sensors that could not only measure force but also the concentration of a chemical or fluid flow, allowing the surgeon to know the position of the device and the nature of the surrounding tissue^e.

Convincing people of the safety of a surgical robot might prove to be the biggest challenge to their implementation. The first surgical systems have tended to be both passive (where the surgeon provides the physical energy to drive the surgical tool) and intrinsically safe (physically restricted motion). The wand is both passive and intrinsically safe and is used in head surgery to enhance three-dimensional spatial awareness. The current trend is towards more active systems (mechanisms with a degree of autonomy) [37] such as RoboDoc (see figure 6).

^a Spiby predicts that during the period 1997-2007 more effective treatment will be available for disability (via biological seromechanisms linked to computers and robotics) [26].

^b Within the context of surgical devices, it is more appropriate to refer to robotic devices rather than robots.

^c Current methods of femur preparation allow the prosthesis to make contact with the bone over only 18 to 20 percent of its surface. The robot can create a cavity to house any make of prosthesis with 90-percent surface contact.

^d Developed at Imperial College, London; thanks to its precision the robot takes 20 minutes to perform the operation, a third of the time it takes a human being.

^e Pearson and Cochrane predict that by 2010 devices will be roaming within blood vessels under their own power [19].

The benefits to be obtained from the use of robots in surgery will be in the high quality, consistent outcomes that can result from the ability of a robot to give repetitive motions with an accuracy of position and force that are beyond the capabilities of a human being [37].

TRANSPLANTATION

Transplantation is now established as a standard surgical technique (see figure 7) and several types of transplantation have been used [46]: solid organ (kidneys, liver, heart, lungs, pancreas), tissue (skin, cornea, heart valves, bone and veins) and cell (bone marrow, islet cells, myoblasts, adrenal cells and foetal brain cells).

The scale of transplantation is often limited by organ availability [47]^a (see figure 8) and effectiveness continues to be limited by rejection [49].

The future of transplantation depends on solving several problems which include [38]:

- the development of immunosuppressive agents that are more effective, more specific and less toxic
- the induction of specific immune tolerance to the transplanted tissue
- techniques to ensure the least perioperative damage
- the restoration of all vascular and neural connections
- finding a solution to the donor problem
- ethical and funding issues.

However, '...the early years of the next century are likely to see some further revolutionary advances' [48 p11], many of which will be closely linked to developments in bioengineering (see above). Spiby predicts that transplantation will be enhanced by the prevention of rejection during the period 1997-2001 [26]. The Steering Committee on Future Health Scenarios (STG) report in the Netherlands suggested a number of technological developments in the field of transplanted organs and tissues occurring from 1988 onwards [50]:

- with advances in the field of immunosuppressive drugs and with growing understanding of immune system functioning, such organs and tissues as pancreas, small bowel, and endocrine organs could be transplanted successfully
- cloning of skin and growth of retinal tissue and corneal endothelium could be achieved

^a As few as 5 percent of the organs needed in the US ever become available [48].

- organ and tissue replacements will more often combine living tissue with some artificial components.

Therapies to reduce the rejection of transplanted organs are likely to increase the potential for treatment of conditions that are as yet untreatable [6]. The first human hand transplant was performed in Lyons in September 1998, and a large number of clinical trials are ongoing throughout the world in which nerve cells have been transplanted into patients (especially Parkinson's disease^a). Thus the need for organ donors will continue to rise as more and new diseases are deemed eligible for treatment by transplantation. Over the coming years, progress in artificial organs and organ regeneration is predicted to occur beyond 2000 (see figure 9) [40]. Advances in xenotransplantation are described in more detail below. The development of artificial organs has been discussed in the bioengineering section above.

It is unlikely that human organ donors are ever going to be sufficiently numerous to fill the clinical needs of potential organ recipients. Xenografts (organs from other species) are a potential alternative solution and might be used as 'bridging' organs to keep patients alive until human organs become available. Pigs are the only animals being seriously considered today as a future source of organs for transplantation to humans. Several biotechnology companies are investing millions of pounds into developing such genetically modified animals. In August 1998 it was reported that a Cambridge-based company was within months of applying for a licence to use a pig's liver to provide dialysis until a human organ becomes available [52].

Improved understanding of the mechanism of rejection could make the possibility of xenotransplantation a reality in the foreseeable future [53]. Such transplantation of live animal tissues may soon become a practical treatment option, although this is matched by concern over the risk of new zoonotic infections in transplant recipients [36]. Given these difficulties it may be that the development of new mechanical devices will have greater influence than xenotransplantation in treating some forms of organ failure in the future [54].

IT AND TELECOMMUNICATIONS

Key areas for the use of IT in health care are: medical interventions, decision support systems, improving patient access to information, storing records and

^a Most recent patients are responding well to the transplants; many are reducing their drug levels and showing significant improvements in tests designed to follow the course of Parkinson's disease. As these patients are followed into the twenty-first century, time will reveal the success of this form of brain repair. Neural transplants, or perhaps more accurately cell replacement therapy, is being considered for many other neurodegenerative disorders [51].

images and telemedicine. It has been predicted that a number of specific developments in IT will take place [4] [18] [19]:

- linkage of computerised patient data between all hospital, community and primary care services and settings (1997-2007)
- artificial intelligence-based elderly and handicapped support devices (1998)
- picture archiving communication systems (1998-2000)
- full personal medical records on smartcard (by 2000)
- disability assistance devices using thought recognition (by 2000)
- personal wearable health monitor (2005)
- computers used by clinical departments for data collection (1997-2001)
- expert systems enabling diagnosis and defining the most applicable treatment (1997-2001).

The potential of computers to contribute to medical interventions in the body is extensive. To date, such interventions have been mainly concerned with rehabilitation and enablement: researchers have used computer signals to bridge damage to patients' spinal cords, and to develop electronic cornea implants and computer-assisted hearing. There are a growing number of projects that are looking for alternative ways for humans to communicate with computers and much of the work is aimed at helping the disabled.

IT can also provide 'decision support' to clinicians by allowing instant access to on-line libraries of medical information, diagnosis and treatment algorithms (i.e. 'automated diagnostics'), as well as patient instructional material.

Publicly accessible IT is fundamentally altering the relationship in health care between physicians, patients and advocacy/support groups [55]. As IT helps patients gain access to a wide variety of medical information sources, both professional and lay, they are becoming less and less dependent on the information provided by their own medical practitioner. This development may equip patients to take more responsibility for their own health and have more say in their clinical management. Therefore, the reliability of medical IT information is crucial.

Pooling information (i.e. the storing of medical records and medical images) will allow seamless access to pertinent patient records, radiographs, pathology slides and pharmacy information. Patient information will be able to be stored in archives that can be accessed by authorised medical personnel anywhere in the world.

Telemedicine is broadly defined as the use of telecommunications technologies to provide medical information and services [56], and is

commonly justified on the basis that it improves access for communities and provides access to specialist second opinions. It enables health care providers to see patients at remote sites by using a desktop workstation or laptop computer. In 1996, in order to take stock of the level and range of work in the UK, the Department of Health's Research and Development Directorate commissioned a survey of telemedical activity. That study identified the status of activity in the UK in telemedicine: the report provided details on 65 projects surveyed in the UK, of which 24 fall strictly into the category of telemedicine projects providing remote telematic health care services to patients [57]. Current services in the UK include some teleconferencing services, including mainland provision of trauma advice to oil rigs and remote foetal diagnosis on ultrasound images.

A *Lancet* editorial in 1995 commented that the recent resurgence of interest had yet to have a major impact on mainstream medical services and made a number of predictions as to the impact that telemedicine will have on medical practice in the year 2000 [58]:

- remote consultation will be commonplace in the image-based specialities (both for non-specialist centres to get specialist opinions and for specialists to get second opinions)
- in dermatology, accident and emergency and foetal medicine, concomitant videoconferencing will allow the doctor in the specialist centre to counsel the patient directly
- face-to-face video consultation will be used in undoctored areas and in psychiatry
- telemedicine will make an important contribution to the safety of out-of-hours care by junior hospital staff in areas as diverse as neurosurgery and obstetrics.

Another important potential use of telemedicine is telepresence surgery, where surgeons can operate at a distance from patients using robots guided by remote control. However, telepresence surgery is currently only in the experimental stages [59]^a, its future development unlikely in the next decade as our capabilities in achieving an adequate sense of touch are still rather crude and little understood [26].

The trajectory of telemedicine will be restrained by the lag in setting standards for computer interaction, the need for open computer-systems architecture, legislation and the regulation of medical practice, resistance by providers and

^a Arteriotomies involving incisions and various suturing techniques have been done successfully on swine. However, wound closure takes about twice as long as standard on-site techniques and the precision of the telepresence and on-site techniques has been the same.

reimbursement issues. However, in the US the number of programmes doubles yearly (see figure 10) and activity (number of consultations^a) trebled from 1995 to 1996 [61].

With video conferencing, virtual surgery and telemedicine already a reality, IT is blurring concepts like 'point of care' and 'care provider'. Expert advice can now be given remotely - in space and in time.

HOME CARE

Many of the likely developments in other areas already point to a dramatic increase in the provision of home-based care and services. One of the broad hypotheses used in the OST Technology Foresight programme was that 'current diagnostic and instrumentation technologies will evolve towards applications outside of specialist centres, towards uses in local clinics and in the home' [19]. The shift to home care is based largely on two trends:

- remote diagnostic equipment (such as heart monitors, electronic stethoscopes, blood glucose measurement devices and others)
- reduced size and portability of equipment (making it possible to provide other services closer to the patient so that diagnostic and treatment equipment can be brought to the patient's bed, the primary care centre or even the patient's home).

Furthermore, developments in information technology and telecommunications (see above) will make expert opinions and monitoring available in primary care settings, or to patients themselves. Also important has been the necessity to evolve technology-based devices which allow rehabilitation with only intermittent professional supervision, self-care and an easing of the burden of carers. Such developments, involving a transfer into the home, have clear links to the discussion on environment in paper no. 2 in this series: 'Environment'.

The possibilities for moving care outside hospital have already been demonstrated through techniques such as home dialysis for people with renal failure, home-based parenteral nutrition and self-monitoring by diabetics. Recent advances in dry chemistry technology and the integration of microprocessors (resulting in miniaturisation of equipment) have led to the development of desktop analysers. The implication is that, for the first time, chemical pathology and biochemistry tasks can be performed directly in the general practitioner's (GP's) office, with the results being immediately

^a Teleradiology is by far the most mature telemedicine application [60]. The most common specialities (in terms of number of consultations) in 1996 in the US were: radiology (13,653), mental health (3,460), emergency/triage (2,574), cardiology (2,017), dermatology (1,807) and surgery (1,351).

available to both the doctor and the patient [62] [63]. Home-based high technology care can broadly be categorised as [64]:

- home parenteral nutrition
- home enteral nutrition
- drug delivery systems
- intravenous antibiotics
- oxygen therapies
- renal dialysis and peritoneal dialysis.

Specific predictions that have been made include [10] [20]:

- Home (health) diagnostic systems with daily/real-time check up (by 1998)
- Virtual-reality based exercisers in the home (1998)
- Telemed link to home with home blood test kit (1998)
- Patient interviewing systems available in the surgery and in patients' homes (1997-2007).

POLICY IMPLICATIONS

Bearing in mind important reservations about the likely level of accuracy of some of the predictions that have been described in this paper, it seems likely that health care policy will be increasingly influenced by the following trends [6][65] in science and technology towards 2015:

- a greater concentration of expertise and equipment in a smaller number of larger centres dealing with complex cases, driven by the increasing sophistication of medicine (in areas such as genetics, biotechnology and bioengineering, image guided surgery, robotics and transplantation)
- the growing importance of technologies that allow self-diagnosis and 'self-treatment' (home care)
- an ever-greater proportion of common conditions being treated locally in small centres linked telemetrically to specialist centres (IT and telecommunications).

Underlying these general trends, new technologies are likely to lead to:

- improvement in the potential for screening and treating of serious conditions, which will lead to a move from the present operation of a 'sickness service' to the construction of a genuine 'health' service in which disease prediction and prevention are accorded higher priority [66]
- a further increase in life expectancy and demand for continuing care for frail elderly patients and those with chronic and multiple conditions

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- increasingly blurred distinctions between primary and secondary care, with more complex care taking place at home, and the decentralisation of laboratory technology
- further reduction in lengths of hospital stay as more diagnosis, treatment and monitoring takes place outside the hospital.

APPENDIX 1

SYSTEMATIC LITERATURE REVIEW

This review is reported on in greater detail elsewhere [8]. A summary of the retrieval from the literature review is shown in table 1.

In total, after extraction of duplicates, there were 4,160 references. Only references that specifically addressed the following were of interest:

- methods adopted in health futures studies that sought to identify new health care technologies, or
- scientific attempts at identifying new health care technologies.

However, the scanning and subsequent appraisal of a sample of the references enabled a four-way classification to be developed. The four types of papers were:

- Type I: methodological papers which assessed the processes and information sources by which health care technologies could be identified with a short-term perspective, whether set in the context of a national early warning system (EWS) or not.
- Type II: scientific attempts at identifying new technologies across a broad spectrum of health care, e.g. using formal and empirical methods (but which did not assess those methods).
- Type III: discursive pieces (often editorials or polemics) relating to future technological developments in health care but without any explicit description of their empirical methods or sources of information.
- Type IV: Delphi studies or scenario analyses of future trends in health or health care which were concerned not with likely technologies but with preferable 'futures' and/or related to a longer-term perspective than that with which this research is concerned.

No studies of the type I literature were identified by the literature search. However, there have been five studies which adopted formal and empirical methods to identify future health care technologies across the broad spectrum of health care - for example, a systematic review of the literature or some form of opinion gathering (the type II literature). Only two national initiatives have been reported on in the peer-reviewed literature (the EWS in the Netherlands and UK).

The bibliographic details of the five scientific attempts at identifying new health care technologies (the type II literature) were as follows:

- Food and Drug Administration 'Forecast of emerging technologies', US Department of Health and Human Services, June 1981.
- HD Banta and AC Gelijns (eds) *Anticipating and assessing health care technology. Volume I: General considerations and policy conclusions* A report of the Scenario Commission on Future Health Care Technology (Dordrecht: Kluwer Academic Publishers, 1987) [50]^a.
- J Spiby 'Advances in medical technology over the next 20 years' *Community Medicine*, 1988, 10(4), 273-8 [26].
- Technology Foresight Programme 'Notes on the Delphi survey: Companion paper B to the Health and Life Sciences panel report', unpublished working paper of the Office of Science and Technology, London, 1995 [24].
- A Stevens, G Robert and J Gabbay 'Identifying new health care technologies in the United Kingdom' *International Journal of Technology Assessment in Health Care*, 1997, 13(1), 59-67 [9].

The third category comprised the vast majority of papers: those that were discursive pieces, often editorials, about future developments in particular areas of health care (for example in one specialty or concerning one particular technology). These papers were often written from a single commentator's perspective in his or her particular area of expertise.

The final category of papers were those that used a method common to health futures (such as a Delphi study or scenario analysis) to predict trends in health or health care but which were not focused on identifying new health care technologies and often took a longer-term perspective. There are numerous examples of the application of futures methodologies to health care but these have often taken a very broad approach, examining demographic and scientific trends as opposed to specific technologies.

In summary, a small number of empirical studies have sought to identify new health care technologies in a particular specialty or across health care as a whole. Exemplar papers which together provide an introduction to this area are referenced in table 2 for readers who may be interested in the wider application of futures methodologies in health care.

^a Summarised in HD Banta, AC Gelijns, J Griffioen and PJ Graaff 'An inquiry concerning future health care technology: methods and general results' *Health Policy*, 1987, 8, 251-64; and HD Banta and AC Gelijns 'The future and health care technology: Implications of a system for early identification' *World Health Statistical Quarterly*, 1994, 47, 140-8. All these citations relate to the same project undertaken in the Netherlands during the mid 1980s.

APPENDIX 2

USEFUL INFORMATION SOURCES

There are a number of useful world wide web sites that provide an introduction to ongoing futures research and commonly employed futures techniques:

- OECD International Futures Programme (<http://www.oecd.org/sge/au>)
- World Future Society (<http://www.tmn.com/wfs>)
- Institute for Alternative Futures (<http://www.altfutures.com>)
- World Future Studies Federation (<http://www.fbs.qut.edu.au/wfsf/>)
- Resources for futures research (<http://www.well.com/user/leeshupp/future.html>)
- Futures techniques (<http://ag.arizona.edu/futures/fut/semtech>)
- Foresight research centre (<http://www.dur.ac.uk/foresight>)

Contemporary sources for early warning of new health care technologies in the UK

FORECASTING SECRETARIAT TO THE STANDING GROUP ON HEALTH TECHNOLOGY

In May 1995 the Department of Health (DoH) established a Forecasting Secretariat to the UK's National Standing Group on Health Technology (SGHT) and its panels.

The terms of reference for this Forecasting Secretariat were:

- to develop and operate an agreed mechanism for identifying new and emerging health technologies, as well as existing health technologies that are expanding in their use
- to develop and operate an approach to single out those health technologies that might have a significant impact on the National Health Service (NHS) in the near future
- to prepare briefings to the SGHT and its panels on those health technologies expected to have a significant impact on the NHS
- to explore, with relevant parts of the Department, the value of possible approaches to disseminating information on new, emerging and expanding health technologies to decision-makers in the NHS

This work is currently carried out as a collaboration between the Department of Public at the University of Birmingham (<http://www.hsrc.org.uk/horizon/>) and the National Prescribing Centre (see below).

SAFETY AND EFFICACY REGISTER OF NEW INTERVENTIONAL PROCEDURES

In 1996, the DoH gave its support to a new initiative being led by the Academy of Medical Royal Colleges to establish an 'intelligence centre' for new interventional procedures³ [67].

The Safety and Efficacy Register of New Interventional Procedures (SERNIP) registers new procedures and co-ordinates the experiences of clinicians developing new techniques in order to allow data to be rapidly accessed by other clinicians. This is a voluntary system, designed to support innovation and good professional practice in groups undertaking novel procedures. Information is invited from innovators of new procedures, those considering embarking on techniques learned from other doctors (often abroad) and from manufacturers of new devices. SERNIP was initially open to surgical, gynaecological, radiological and cardiological procedures but it is intended to widen the scope of specialties to include otorhinolaryngology and ophthalmology.

To April 1997 a total of 43 procedures had been considered. Twelve were considered safe and effective, 20 were of unproven safety and efficacy, 10 were still under investigation and one (intraoperative autotransfusion [Haemocell 350] IBS) has been proscribed by the committee^b.

STANDING MEDICAL ADVISORY COMMITTEE: CHANGING MEDICAL PRACTICE GROUP

The criteria for technologies to be included in the Standing Medical Advisory Committee (SMAC) advice to the DoH on 'changing medical practice' (CMP) are:

1. Categories of change will include:
 - 1.1. incidence, mortality, regional variations and distribution of disease
 - 1.2. developments in treatment and symptom control
 - 1.3. investigative and diagnostic methods
 - 1.4. methods of service delivery
 - 1.5. patient expectations and quality of care
2. A change in a technique should normally be included only if in SMAC's view it:
 - 2.1. is safe and effective
 - 2.2. has completed research and development and achieved some modest (say, 5%) diffusion into the NHS within the last two to three years, but not yet been fully diffused (say, 75%)

^a Source: information sheet from Academy of Medical Royal Colleges, June 1996

^b SERNIP newsletter, May 1997

- 2.3. will have a substantial incremental effect on the NHS in the next 2-3 years in terms of health gain or costs or both, OR
- 2.4. it would reduce clinical activity
3. Where possible evidence for the effectiveness of, and costs of, the change should be presented or referenced. Implications outside the speciality initiating a change should be indicated (e.g. for GPs)
4. Three of the categories of changes listed under paragraph 1 (items 1.2, 1.3 and 1.4) may be grouped together under the narrower heading of medical advance. There are potentially hundreds of these each year. The criteria for deciding which ones to review in detail should include:
 - 4.1. total potential health gain
 - 4.2. net (plus or minus) impact on total Hospital and Community Health Services (HCHS) spending over the next four years
 - 4.3. impact on other NHS spending
 - 4.4. the number of people likely to benefit and their prognosis without treatment
 - 4.5. likely speed/ease of diffusion
 - 4.6. medical productivity (i.e. health gain per £ spent)
 - 4.7. impact on other government spending
 - 4.8. impact on economy

DRUG INFORMATION SERVICES

The Drug Information Services (DIS) in the NHS exist to promote the safe, effective and economic use of medicine by providing up-to-date, accurate and evaluated information and advice on drugs and drug therapy. Specialist drug information centres were established in 1969 at the London Hospital and Leeds General Infirmary. By 1992 there were 20 regional centres providing a range of services [68]^a.

The UK DIS, co-ordinated through the network of regional DIS, has developed a structured approach to providing evaluated and rapid information on new drugs and medicines. The work for this scheme is shared between DIS throughout the UK (see table 3).

The outputs are cascaded down to local DIS and hence to commissioners of health care and clinicians.

The UK's Drug Information Pharmacists Group (DIPG) and the National Prescribing Centre (NPC) in Liverpool announced in April 1997 that they were to collaborate in a venture to provide advance information on significant

^a Such as general enquiry answering; evaluated information on new drugs; formulary support; current awareness bulletins; training in drug information; coordination of DIS

new drugs in development³. The initiative will build upon the UK DIS scheme entitled 'New drugs in clinical development' (see table 3, stage 3). Collaboration between DIPG and the NPC is intended to produce a package of information comprising enhanced content and presentation of the current DIPG monograph. It is intended to identify at the earliest opportunity (up to 18 months before launch) those drugs that could develop into important new medicines for the NHS.

Catalogue of world wide web sites with information on new health care technologies

With thanks to CCOHTA and Web Watch in the *Health Service Journal* for providing information on some of the Internet sites listed below. Many of the sites have links to other useful information sources on the Internet.

Reuters Medical News/Reuters Health Information Services (http://www.reutershealth.com/frame_about.html)

Highly recommended. Extremely easy to scan, useful categories, e.g. industry and regulatory. News archive to search news items for the past one to two years. Mainly US, with some Canadian and European coverage.

PRNewswire/HealthBiotech (<http://www.prnewswire.com/index.shtml>)

Free of charge. Useful links to health care associations. Contact information for each news story is included.

Doctors Guide: Medical Conferences And Meetings (<http://www.pslgroup.com/MEDCONF.HTM>)

Good news service. Particularly good for news of upcoming conferences and also has a conference highlights section from major medical conferences.

Centerwatch Clinical Trials Listing Service (<http://www.centerwatch.com>)

Free of charge. Search by disease category or for new drug approvals.

Us Food And Drug Administration (FDA) (<http://www.fda.gov>)

Information on new drug and device approvals.

^a further information on the collaborative venture can be obtained from Mrs Katrina Simister, NPC-DIPG New Product Co-ordinator, DIC, 70 Pembroke Place, Liverpool, L69 3GF, tel: 0151 7948112

Pharmaceutical Research And Manufacturers Of America (PHRMA)

(<http://www.phrma.org/>)

Free of charge. Useful tables of drugs in development and the level of clinical trial they have reached. Charts organised by major disease types showing new drugs undergoing trials in the New Medicines in Development section.

NIH Clinical Alerts

(http://wwwindex.nlm.nih.gov/databases/alerts/clinical_alerts.html)

Clinical alerts are provided to expedite the release of findings from the NIH-funded clinical trials where such release could significantly affect morbidity and mortality.

UK Drug Information Pharmacists Group

(<http://www.ukdipg.org.uk/newprod.htm>)

See above for details.

PHARMACEUTICAL INFORMATION NETWORK

(<http://www.pharminfo.com>)

Assessments of therapeutics and advances in new drug development.

EurekaAlert

(<http://eurekaalert.org>)

Latest research advances in science, medicine, health and technology. Average of 20 news releases each day.

Englemed

(<http://englemed.demon.co.uk>)

Latest reports about health and medicine (within previous four weeks). Stories are sourced wherever possible.

Doctors' Guide to the Internet: Medical news and alerts

(<http://pslgroup.com/DOCGUIDE.HTM>)

Designed to help doctors harness the resources on the Internet. Has medical news and alerts, new drugs and conference information.

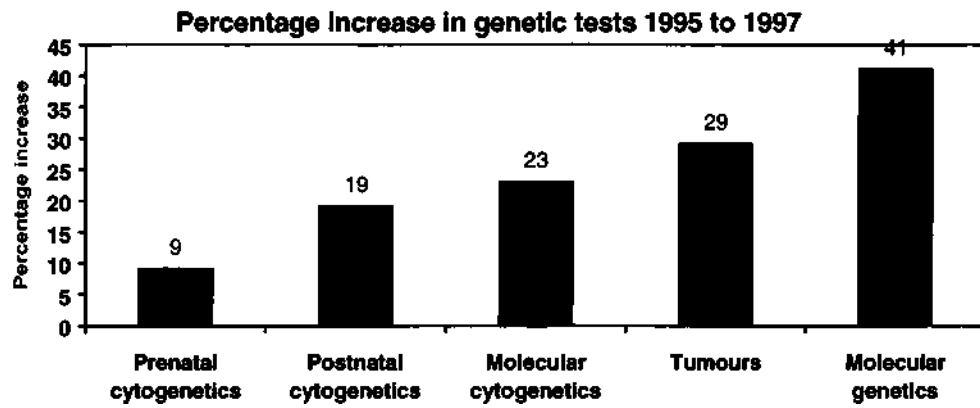
European Agency for the Evaluation of Medicinal Products

(<http://www2.eudra.org>)

The Agency aims to provide the EU Member States and the Community institutions with the best possible scientific advice on questions concerning quality, safety and efficacy of medicinal products for human and veterinary use. It co-ordinates single evaluations via a centralised or decentralised marketing authorisation system.

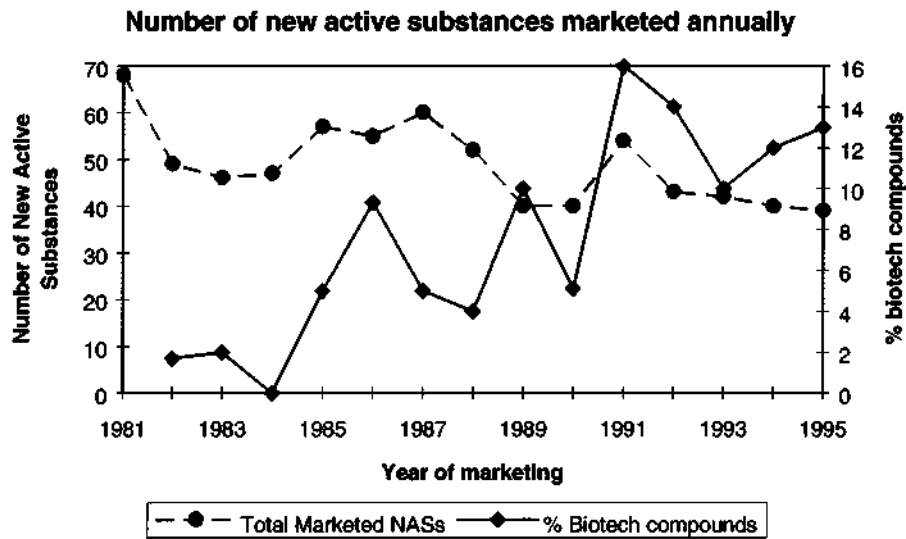
FIGURES

Figure 1



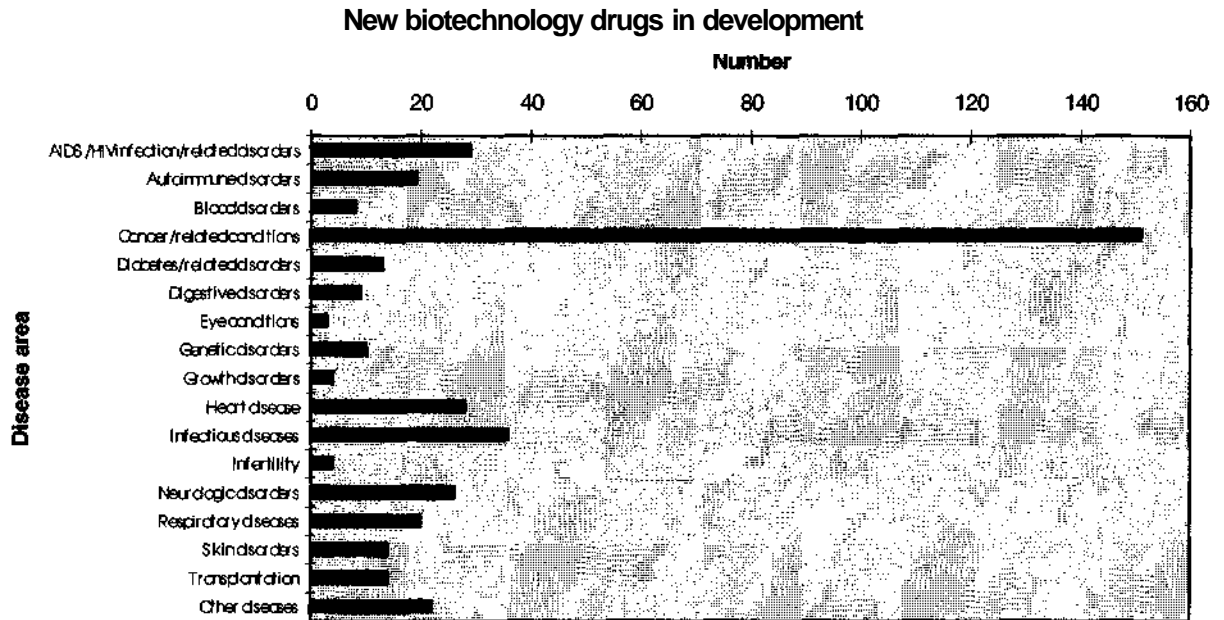
Source: Anonymous 'Higher purchase: Commissioning specialised services in the NHS', report by the Audit Commission, London, 1997 [21]

Figure 2



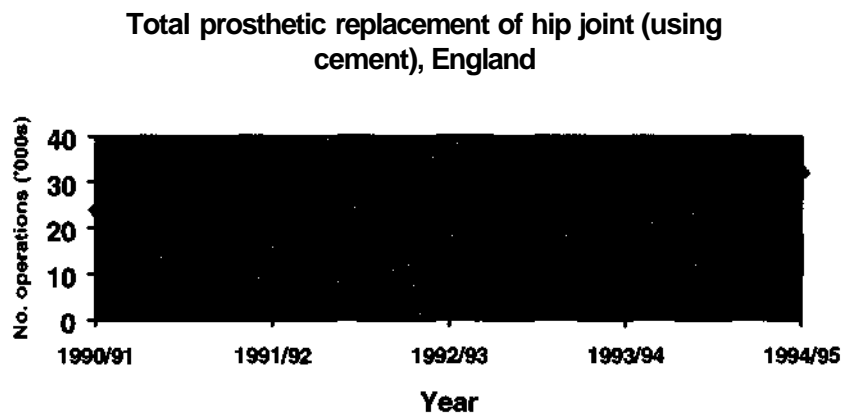
Source: B Kirkness (ed.) Agenda for Health: Biotechnology, a New Revolution in Health Care (London: The Association of the British Pharmaceutical Industry, 1996) [27]

Figure 3



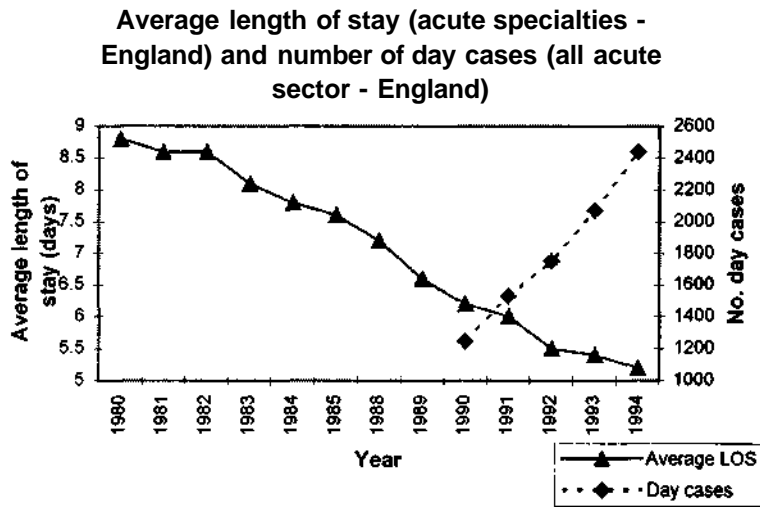
Source: Anonymous '350 biotechnology medicines in development', report presented by Pharmaceutical Research and Manufacturers of America (PhRMA). As cited in anonymous 'Biotechnology revolution gains momentum' Health Horizons, Autumn 1998, 35, 22 [29]

Figure 4



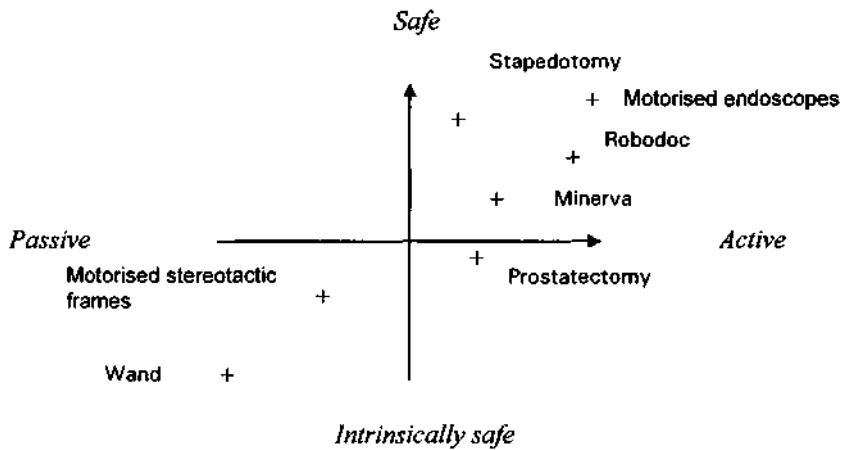
Source: Office of Health Economics Compendium of Health Statistics (London: Office of Health Economics, 1997 [10th Edition]) [39]

Figure 5



Source: Office of Health Economics Compendium of Health Statistics (London: Office of Health Economics, 1997 [10th Edition]) [39]

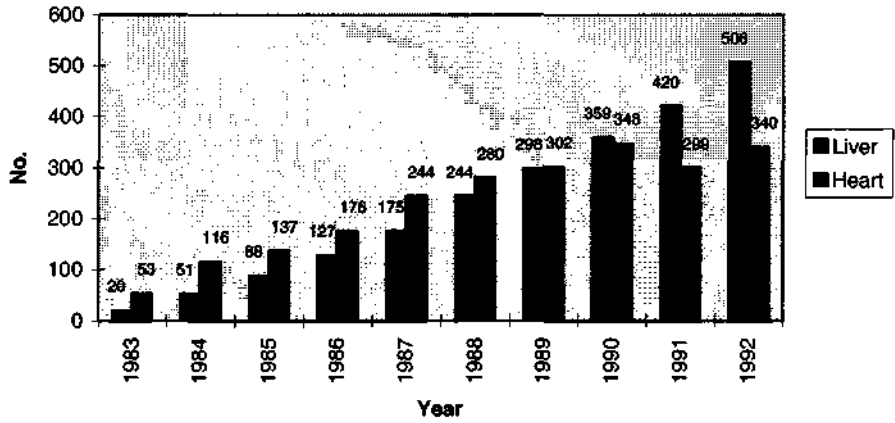
Figure 6 Trend towards active robots



Source: RA Buckingham and RO Buckingham 'Robots in operating theatres' *British Medical Journal*, 1995, 311, 1479-82 [45]

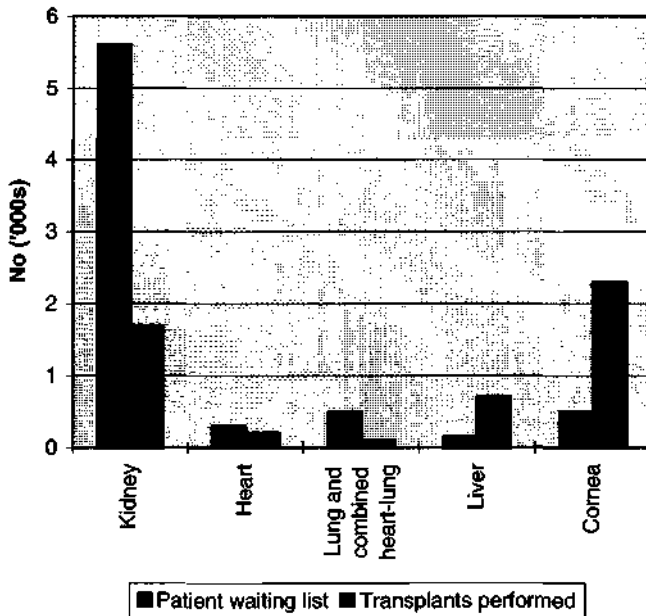
Figure 7

UK and Eire heart and liver transplants, 1983-1992



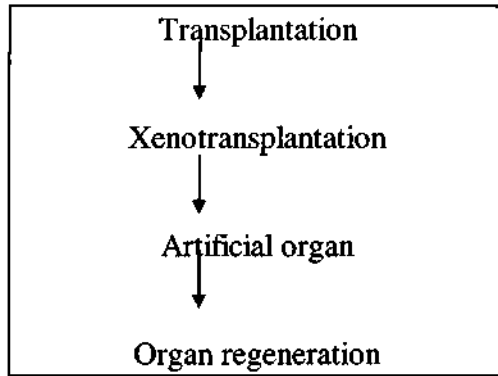
Source: Office of Health Economics Compendium of Health Statistics (London: Office of Health Economics, 1997 [10th Edition]) [39]

Figure 8 Major organ transplants in the UK in 1997 and the size of the waiting lists at 31/12/97



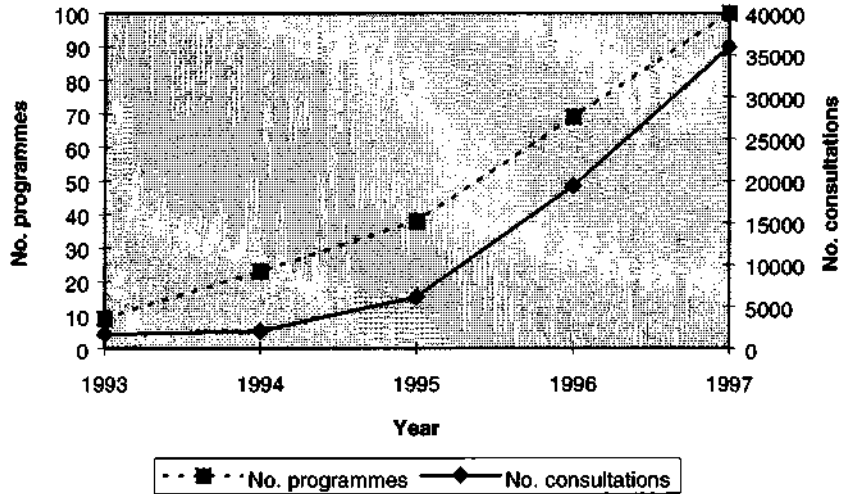
Source: RA Weiss 'Xenotransplantation' British Medical Journal, 1998, 317, 931-4 [47]

Figure 9 Possible development of transplantation



Source: PJ Lachmann, R Calne, TM Dexter, H Waldmann and D White 'New organs for old', Advances in Science and Technology: Implications for the NHS Conference, London, 23 January 1995 [49]

Figure 10 Tele-medicine in the US: interactive video-mediated programs, 1993-97¹



Source: B Grigsby and A Allen '4th Annual Program Review: A cooperative study by Telemedicine Today and the Association of Telemedicine Service Providers', Telemedicine Today, 1997, 5 (4), 30-8, 42

1. 1997 figures are projected from data from first four months of that year.

TABLES

Table 1 Results of literature review by database

Database	Years	Search strategy	Number retrieved
OVID MedLine	1966-9, 1998 ¹	[exp FORECASTING\] and [(TECHNOLOGY\ or technology.ti.ab.rw.sh) or (exp TECHNOLOGY\)]	1,214
OVID Core Biomedical Collection	1993-7, 1998 ¹	[future.ti.ab.tx.ct] and [technology.ti.ab.tx.ct]	2,186
HealthStar	1975-8 1998 ²	[forecasting (mh) or future (tw) or future (kw)] and [explode technology or technology (tw) or technology (kw)]	815
HTAIS (ECRI - US)	1990-6 ³	'Methods for identifying new health care technologies'	31

Source: Author's compilations

1. Final electronic search was carried out on 1 September 1998.
2. Final electronic search was carried out on 1 September 1998 and results exclude MedLine references.
3. Search was carried out on 11 March 1996 by ECRI.

Table 2 Examples of futures studies and introductory texts to the discipline

Title	Source
Futuring in health care	<i>Health Care Strategic Management</i> , 1985, 3, 26-9
Health care: Thinking ahead	<i>World Health Forum</i> , 1994, 15(2), 189-92
Scenarios for 21st-century health care in the United States of America: Perspectives on time and change	<i>World Health Statistics Quarterly</i> , 1994, 47(3-4), 126-39
The future of health futures	<i>Futures</i> , 1995, 27(9/10), 921-5
The future of medicine. A scenario analysis	<i>Journal of the American Medical Association</i> , 1987, 258: 80-85
Forecasting without historical data: Bayesian probability models utilizing expert opinions	<i>Journal of Medical Systems</i> , 1995, 19(4), 359-74.
Assessment of artificial neural networks in health futures research	<i>World Health Statistics Quarterly</i> , 1994, 47(3-4), 177-84
Events which will influence intensive care units in the future. A Delphi study.	<i>Technology and Health Care</i> , 1997, 5(4), 319-30
A way through the maze. What futurists do and how they do it.	<i>Futures</i> , 1993, 254-74
An introduction to national futures studies for policymakers in the health sector.	<i>World Health Statistics Quarterly</i> , 1994, 47(3-4), 101-17
<i>Scenario Development and Costing in Health Care: Methodological Accomplishments and Practical Guidelines</i>	Utrecht: International Books, 1996
Scenario analysis of the future of medicines	<i>British Medical Journal</i> , 1994, 29(309), 1137-40
A model for health projections using knowledgeable informants	<i>World Health Statistics Quarterly</i> , 1984, 37, 306-17

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Linstone HA	The Linstone lectures on technology forecasting and assessment 1. Technology-forecasting 2. Robotics 3. Technology assessment, risk analysis and the multiple perspectives concept	<i>Journal of Scientific and In</i> 46, 1-19
OnoR	Assessing the validity of the Delphi technique	<i>Futures</i> , 1994, 26(3), 289-
Pollock AM	The future of health care in the United Kingdom	<i>British Medical Journal</i> , 19
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Source: Author's compilations

Table 3 Structured approach of the UK Drug Information Services to providing evaluated and rapid information on new drugs and medicines

Title	Content	Timing
Stage 1: New drugs in research (list 1)	Early intelligence on all new drugs likely to reach the UK market; information content is brief as many products may never reach the market and early clinical information is scant; contains prediction of possible broad cost implications; approximately 300 drugs are continuously tracked	Continuous tracking up to 5 years before marketing
Stage 2: New drugs in research (list 2)	As stage 1 but restricted to selected drugs (up to 50) which are considered to have greater or closer market potential	Probably 6 months to 3 years pre-marketing
Stage 3: New drugs in clinical development	Comprehensive early intelligence evaluations of all new drugs, formulations and indications that are likely to have a significant impact on either prescribing practice or prescribing costs; information provides estimates of potential costs, uptake, and place in therapeutics, both in primary and secondary care	Continuous tracking from about 2 years pre-marketing; also uses drug companies as a source of intelligence
Stage 4: New medicines on the market	Comprehensive, in-depth evaluations of most new drugs which are marketed; currently excludes drugs in highly specialised clinical areas	Drugs identified through stages 1-3 and through product licence notifications

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