A Picture of Health 2030

Engineering the Future of Health and Medicine

Engineers Ireland

The Irish Academy of Engineering

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April 2006

Acknowledgement

This report was prepared by a Taskforce convened jointly by the Irish Academy of Engineering and Engineers Ireland, which are all-island engineering organisations. It forms part of an ongoing programme of study and research into matters of interest and concern to the engineering profession.

The project was sponsored by Enterprise Ireland.

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Acknowledgement

Engineers Ireland and the Irish Academy of Engineering thank Enterprise Ireland for supporting this project. The views and the opinions expressed here remain those of the Taskforce, however, and do not necessarily reflect the views of Enterprise Ireland, Engineers Ireland, and the Irish Academy of Engineering.

Contents

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Foreword

Ireland has developed a world-class manufacturing industry over the past 25 years, supplying pharmaceutical, medical device and information and communications technology products and services to the global market. Coupled with our rich history of discovery and innovation in science, engineering and medicine, this industry base provides a very sound platform for future economic development founded on continued investment by multinational companies and increasing investment in indigenous enterprise. It is also a sound base for achieving the vision of a knowledge economy, which has become clear Government strategy.

Given our recent economic success, each one of us now has a greater than ever expectation of a good quality of life. 'Your health is your wealth' is an old saying that is as relevant today as it was in previous centuries. Rapid progress in medical discoveries, new materials and manufacturing technologies, computer power and information and communication systems will continue to drive tremendous innovation in healthcare and should lead us away from reactive care of the sick to promoting wellness through preventative medicine. However, living longer, changing social structures and our rising cost base will pose challenges to achieving our ambitions.

This report has set out to paint a picture of patient needs, medical knowledge and technology advances, opportunities and challenges across the broad healthcare area in the year 2030, set in the global context, with a special interest in the role that the engineering profession can play. It has generated a set of recommendations to be undertaken to achieve success not just in creating world-class healthcare for the people of Ireland, but also in bringing with it further economic success by converting our achievements into commercial ventures for the global market.

The project is a joint venture between Engineers Ireland and the Irish Academy of Engineering, sponsored by Enterprise Ireland. I would like to acknowledge the active participation of the Task Force members in contributing the foresight, information and data needed for the report and to acknowledge the input of many others in the healthcare field consulted either by interview or by written contribution. On behalf of the Task force I want to thank Engineers Ireland staff, Máirín Ní Aonghusa, Grace FitzGerald and Yvonne Lynch for their assistance. Finally I want especially to acknowledge the work done by consultant science editor Mary Mulvihill, in reading, compiling and editing the many contributions, and finally writing the report.

Paddy Caffrey

Dr Paddy Caffrey

Summary and Recommendations

Ireland has the potential to build a world-class health-care system for the country, and a world-class health-care sector for the economy, to the benefit of us all. We outline in our Prognosis the future potential of health and medicine, and the many diverse opportunities for building a stronger, smarter healthcare industry. In our Prescription, we identify the many initiatives and measures needed across the board if we are to achieve our vision.

In particular, our healthcare system needs to move to promoting wellness, rather than merely treating the sick, shifting from costly late-stage intervention to early cost-effective detection and prevention. We need to 'mainstream' concern for health across all aspects of national planning and policy, and be committed to research and to improving our healthcare system. Our healthcare industry must switch from being investment driven to being innovation driven. And our tax incentive schemes must change from promoting property to promoting intellectual property. Innovation is the key to this healthy future, generating the ideas that will form the basis of future healthcare treatments, and helping to anchor multinational R&D teams here.

Many of the next generation of medical and technological breakthroughs, devices and therapies will come from a convergence of diverse technologies and from collaborations between different disciplines. For this to happen we need to create ways for interdisciplinary collaborations to develop, both formally and informally. The problems we face are too big for any one team or company alone, and progress will happen only if we can bring together researchers, industry and those in clinical practice. We must also build the requisite infrastructure: in IT, in education and research, and in clinical practice and translational medicine. Our desire is for every patient to receive the best possible care.

Achieving this by 2030 will take long-term vision and investment, for this is a marathon, not a sprint. We need to continue to build on past and present initiatives, particularly in funding research and education. But this in itself will no longer be enough, especially if we are to grow our healthcare sector in the face of increasing international competition. To survive and prosper, we need to act smart and be clever. And we need to start now.

Policy and planning

Recommendation: Health and healthcare should be a core element in every aspect of Government planning, policy and activity. Prevention rather than cure must be the objective, moving from treating the sick to keeping people well. To arrest soaring health costs, long-term vision and implementation are called for. We believe that this report and its recommendations are a valuable first step towards this end.

Actions: To protect and improve the population's health and well-being, concern for health and healthcare should be mainstreamed across all Government departments. We need a 'grand coalition' for healthcare. The Department of Health and the Health Services Executive (HSE) should establish an innovations and policy think tank or foresight forum to ensure that this happens, and the engineering profession should be represented on this body.

‘Health impact assessments’ should be a requirement in all policy and planning initiatives. There may also be a need for a Cabinet sub-committee on health and healthcare, similar to that established for science and technology. The Government should fill the position of chief scientist as a matter of urgency, as a cornerstone of our national scientific and policy infrastructure.

Education and training

Second-level education – Recommendations: We need to increase the numbers of students taking science, engineering and technology subjects at second- and through to third-level.
Actions: Invest heavily in resources and training for the new Primary School Science Curriculum so that children are imbued with the excitement of scientific discovery. Ensure that all schools can offer all science subjects to higher Leaving Certificate level. Incentivise and support science teachers (e.g. support for further education and training, and work-placement and exchange programmes with industry and academia). Increase the emphasis on science and engineering in Transition Year. Double SFI’s STARs programme, with more emphasis on collaborations in engineering, healthcare-related and biomedical research. Implement fully the recommendations contained in the report of the Taskforce on the Physical Sciences. Modify the Leaving Certificate points system to give a bias towards subjects such as mathematics, physics, chemistry and biology.

Third- and fourth-level education – Recommendations: Dramatically increase the numbers studying the relevant science and engineering subjects at third-level, and the numbers of graduates who proceed to fourth-level (Masters and PhD). Review the structure and nature of engineering and IT training and courses.
Actions: Review and revise undergraduate courses, and create new inter-disciplinary courses to address specific skills needs (some of these will be of the new Bologna-style five-year Masters degree). Increase the output of science and engineering graduates by 7% annually over the next 15-20 years. Increase the funding and places available for Masters and PhD students by 10-15% annually over the next 20 years. Examine the reasons for the better conversion rates to postgraduate programmes in Northern Ireland, so these can be replicated in the Republic. Increase the stipend for PhD and Masters students, so that those who proceed to research do not overly lose out financially. Explore the possibility of IRCSET funding for engineering PhDs in industry. Establish graduate schools and structured PhD programmes. Foster and reward excellence in science, engineering and technical teaching with financial incentives, and the opportunity to participate in innovative programmes. Make greater efforts to attract women into engineering.

The research environment

Recommendation: Develop expertise in the new and emerging sciences, foster inter-disciplinary research, create a supportive research environment with a commitment to long-term funding, encourage collaborations across industry, academia and clinical medicine, and drive an expectation or belief in the realisation of commercial benefit from the research effort.

Summary and Recommendations

Actions: Continue Ireland's ongoing commitment to expanding our research capability and funding. Promote Ireland as an R&D location for MNCs, and as a venue for major international research conferences and events. Develop expertise and research programmes in key areas and establish a centre of excellence in materials science. Foster interdisciplinary networks and research. Encourage and reward excellence in research. Ensure that researchers have the support, time and resources to engage in research. Institute ready mechanisms to assist and support researchers and academics to translate their technical success into commercial benefit. Encourage exchange of personnel between industry and academia. Publish guidelines for successful industry-academia collaborations. Continue to expand funding and support for fundamental and basic research.

The global and business environment

Recommendation: Foster an innovative and entrepreneurial culture, and create a supportive tax and legislative environment that will encourage involvement and investment, and stimulate research, industry and business. Switch from property development to 'intellectual property development'.

Actions: Create new and innovative tax incentive schemes to attract and reward those who invest in research and in new technology-based companies here. Maintain and publicise the existing tax exemption on patent royalties. Broaden and expand the existing tax credits for R&D. Enterprise Ireland and the higher education and research institutes should work to identify and aggressively exploit new intellectual property. Establish a €100 million applied research fund and an IP commercialisation centre with a €10 million patent fund. Allow industrial researchers to lead SFI projects.

ICT Infrastructure

Recommendation: Build and install the requisite advanced IT infrastructure, both within the healthcare and medical systems, and across the country as a whole.

Actions: Upgrade and expand Ireland's broadband network, and ensure that we reach and remain in the upper quartile of the OECD rankings. Establish an integrated healthcare and medical information system.

The healthcare system

Recommendation: There must be a commitment in the health service to research, innovation and development, with defined career structures for all the professions who play a part in its delivery from research clinicians, doctors and nurses, on the one hand, to engineers, IT specialists and technical support staff, on the other. We need to develop our capability and infrastructure for clinical trials and clinical and 'translational' research.

Actions: The HSE should commit the healthcare system to research as a core activity. Use engineering principles and skills to convert good ideas into workable solutions. Facilitate career-long learning. Create defined career structures for research clinicians and clinical research nurses. Develop a clinical trials infrastructure. Establish a Life Sciences Council and an all-island GeneLibrary. Anonymise archive tissue samples and make these collections available for research. Create a firm and friendly but speedy regulatory and ethical environment.

Welcome to 2030

It is a fine April day and the digital monitor is blinking 13. So that's the second time this month your grandmother hasn't taken her Alzheimer's medication on time, and as the system dials her mobile you start to worry what it might mean. When she answers, it's reassuring to hear that the delay was because she spent the past hour Skyping with some old friends in Korea. A false alarm then, but not a wasted call – it's good to hear she's well and looking forward to the 100th birthday party the family is planning for her next month. And if the monitoring and sensor system means she can live independently at home at her age, it's worth the occasional false alarm.

You check your own wrist 'watcher' then, and see that your heart rate and blood sugar and cholesterol levels are normal. The day's readings will be streamed to the network tonight as always, adding to the data set that has been accumulating since the GP first diagnosed your diabetes 15 years ago. Not that you ever bother viewing the graphs yourself, relying instead on the MD system to spot any abnormal readings and alert you and the doctor. Indeed, the whole thing is now so unobtrusive you forget it's there. (Though watching the online video of the high-definition SPECT scan is kind of fun!)

Which reminds you: it's nearly time for another 10-yearly health check. But should you go local? Or go back to the Dublin clinic where you had the previous one? These check-ups have to be done in person – long-distance tele-consulting won't suffice here – but at least the new high-speed train has cut the journey from Cork to just one hour. Oh, decisions, decisions. And then there's the groceries to pick up on the way home tonight, if traffic isn't too bad on the outer orbital road.

As if you hadn't enough to do, worrying about the knee injury you got last month riding that avalanche in Wicklow. (The upside of climate change – or you wonder, as your knee twinges, is it a downside? – is that skiing in Ireland is now much better than ever.) Still, the tissue regeneration therapy seems to have taken, and while it will be another two months before it is fully repaired, at least you are not going to need a new knee or be faced with arthritis. Already the joint feels easier, but maybe it is a bit early to go back jogging, you think, putting away the trainers. Best to join the other clinical engineers for the lunchtime discussion instead, to hear about the new navigational instruments for the keyhole surgery team. And marvel again at how healthcare has improved since you were born in 2006.

. . . With apologies to George Orwell.

The Diagnosis

Just how healthy are we? How healthy is our healthcare system? What about our healthcare industry? And what national and international factors must we take account of as we look to 2030?

Young or old, rich or poor, sooner or later . . . At some stage in our lives, we will all need healthcare. Indeed, access to healthcare, especially in developed countries, is increasingly seen as a basic human right, while the existence of a sophisticated healthcare system is one of the ways we judge a country's success as a society.

Development of healthcare

Tending the infirm and elderly in the community was the earliest form of healthcare, and still the most basic. We know from archaeological remains that early humans and even Neanderthals took care of their sick and wounded, and it is one trait that distinguishes us from other animals. (The first healthcare service in Ireland was arguably the infirmaries provided for the most part by religious orders and monasteries, until closed by Henry VIII.)

> *Health is a state of complete physical, mental and social well-being, and not merely the absence of disease*
>
> *World Health Organization*

The second level of healthcare – medical intervention – developed over the next 400 years, with the emergence of modern professional medicine and specialisations and a growing scientific understanding of the causes of disease and infection. Developments included procedures such as vaccination, surgical techniques to remove and repair body parts, and a pharmacopoeia that was a significant advance on earlier herbals. In the 20th century in particular, medical intervention became increasingly sophisticated so that today spare part surgery, organ transplants and IVF are commonplace and unremarkable.

The third and perhaps most fundamental level of healthcare, is promoting well-being and preventing illness. This more inclusive view is reflected in the WHO's definition of health as 'a state of complete physical, mental and social well-being, and not merely the absence of disease'. Health prevention and promotion measures taken at community level include the provision of clean water supplies and sewage systems and initiatives to improve air quality, as well as childhood vaccination programmes. But much of the onus for well-being also lies with the individual and factors such as lifestyle choices, physical and mental exercise, nutrition and diet, behaviour and hygiene, and maintaining a healthy level of stress.

Medicine and healthcare are continuing to evolve. The sequencing of the human genome is powering the new field of genomic research, and already yielding new gene-based therapies, such as tests to identify which cancer patients will respond well to certain chemotherapy drugs. New drugs, new formulations of established drugs, new and more powerful screening and diagnostic techniques, sophisticated software that can analyse our vital signs, safer and less invasive surgical techniques, new and improved implants, the advent of digital imaging, and remote- or tele-medicine technologies . . . all are helping to improve the standard of our healthcare, to keep us well and fit for longer, and to cure and repair us faster and more safely when we fall ill or breakdown.

The Diagnosis

In parallel with these developments, are growing expectations of what modern medicine can achieve and what a patient-centred system should deliver. Where an older generation accepted their lot, more people today expect sophisticated world-class treatment at local level and access to every possible treatment regardless of the cost to the community. In Ireland, healthcare has become increasingly politicised, with issues-based independent candidates standing in general elections. However, local solutions are seldom ideal for the country as a whole, and while it is right that everyone should have excellent care at local level, expert treatment is best centralised in specialised high-tech centres. The Health Service Executive (HSE) recent moves in this direction, such as the decision to rationalise tertiary paediatric care into a single national centre of excellence, are welcome. There are many examples of similar inefficiencies of scale in specialist clinical services nationally. For example, gynaecological cancer services are currently provided in all three maternity and in several general hospitals in Dublin, yet it is unlikely that internationally recognised excellence will evolve in gynaecological cancer or reproductive medicine or perinatology while the expertise is so diluted. Examination of other specialities may reveal similar problems.

Recent years have seen a general trend towards greater testing, and safer medicines and devices. Of course, all medical interventions and therapies still come with potential side-effects and associated risks, yet increasingly, patients expect high-tech modern medicine to be risk-free. Fear of litigation may mean that clinical researchers are wary of taking risks, creating the kind of climate that stifles innovation. New research tools, such as cell cultures to test the toxicity of new drugs, and virtual (or *in silico)* experiments may help us to break through this barrier and find new ways of innovating that minimise the risks to patients.
As our healthcare services have grown in sophistication, so they have come to rely on many diverse disciplines and specialist staff. Gone are the frontier days when one general factotum could be the doctor, undertaker, coroner, dentist, barber and surgeon. Healthcare today is a complex web of interconnected technologies and businesses. The staff of a modern hospital will now include clinical engineers, medical physicists and biochemists, imaging and IT specialists, for example, while nursing and medical staff must now be expert in a wide range of techniques, materials and instrumentation.

Engineers are playing a growing role in the design, supply and delivery of healthcare services, equipment and systems. It is a role that dates at least from the 19th century, when they were instrumental in delivering the clean water supplies and sewage systems that did so much to improve urban health. The new disciplines of

Take your brain for a walk

IT WAS the Roman writer Juvenal who said, *Mens sana in corpore sano* (a healthy mind in a healthy body). Research has confirmed that he was right: mental and physical well-being are inextricably linked, and exercise promotes both mental and physical health and fitness. New research also suggests that people with mentally challenging jobs live longer generally than manual workers, and that mental activity can help older people to remain active and functioning. So, perhaps today Juvenal would be recommending a workout in the gym followed by a crossword puzzle and some sudoku!

clinical and bio-medical engineering, and the growing importance of areas such as nanotechnology and materials science mean that more and more engineers will be employed directly in the hospitals and healthcare companies of the future.

Healthcare in Ireland

As medicine has become more sophisticated, so it has become more costly, and the developed world is spending more than ever before on healthcare. Ireland is no exception: our total healthcare budget has grown significantly, from €2.9 billion in 1995, to €5.4 billion in 2000 and an estimated €10.5 billion in 2005 (source: HSE). Despite more than trebling our health spend in the past decade – and at a time when general inflation remained low – the system has many ailments of its own. Patients and their families frequently despair at the conditions and bottlenecks in Accident & Emergency, at the number of patients on trolleys, at the waiting lists, at the seeming inability to maintain basic hygiene and control MRSA infections. One of the major healthcare breakthroughs in the 19th-century was realising the importance of hygiene and asepsis, yet a national hygiene audit of 54 acute hospitals (HSE, 2005) rated only 9% as ‘good’ (a score of 85% or more) and 48% as poor (scoring 75% or below).

Then there are the seemingly preventable errors that can arise in screening, diagnosis, treatment and drug prescription. International surveys (notably *To Err Is Human*, the 2000 US Institute of Medicine report), conclude that significant numbers of serious medical errors can occur, and in the USA, it was estimated, 98,000 people die every year because of drug and other preventable medical errors. If a similar situation obtains here, then such errors could be implicated in the deaths of as many as 1,400 people a year here.

Our healthcare system is also hugely reliant on non-national staff, and up to 40% of nurses in some of the major Dublin hospitals are recruited from overseas. While this may mean that Ireland can benefit from staff whose training we did not have to pay for, and while these professionals can benefit from higher wage levels here than at home, it raises the ethical question of how the health system in their home countries is managing.

Ultimately, everyone wants to reshape the Irish healthcare system for the benefit of all, in terms of improved healthcare and well-being, not to mention value for our own hard-earned taxpayer’s money. Yet the diverse

nature and complexity of the problems, and the huge scale of the healthcare system, mean that this task will not be easy. Simply throwing money at the problem is not the answer: Ireland already spends about 7.4% of GDP on healthcare, and while this is below the OECD average of 8.8%, the USA spends 15.5% – double the Irish rate – yet has a grossly inequitable healthcare system, and life expectancy there is less than would be expected based on its national income (source: OECD *Health at a Glance*, 2003). If we want a better health system, we must also address social inequity, as economic and social disadvantage can seriously damage your health: a major five-year study, recently completed by a multi-disciplinary team from UCD and NUI Galway reported that Irish people who are well-off enjoy better health than those who are socially, economically and materially disadvantaged (see Kelleher *et al*, *Ir J Med Sci*. 2002, 171(3):134-8).

It is widely acknowledged that ‘prevention is better than cure’, and historically most of the major improvements in public health have come from preventive measures, and from social and public engineering works – witness the provision of clean water in the 19th century, which made cholera epidemics a thing of the past; polio and other childhood vaccination schemes, and the switch to smokeless fuels in the 20th century; and most recently, the smoking ban. Prevention has never been a primary focus in healthcare, however, and much of the existing system is in truth more about ‘sick care’ than ‘health care’. That said, Britain’s NHS is introducing the medical equivalent of a motor vehicle’s NCT, offering people health checks at five key points throughout their lives, and focusing initially on children and middle-aged people in disadvantaged communities.

Along with most of the Westernised world, Ireland is now facing two new epidemics, both of which are arguably preventable: obesity, and Type II diabetes. These debilitating conditions place major burdens on our healthcare system: an estimated 10% of the Republic's healthcare budget is spent on diabetes and related illnesses (source: International Diabetes Federation, European Region, 2006). The prevalence of diabetes in the Republic, at 3.4% of the adult population, is among the lowest in Europe (Germany has the highest rate at 10.2%), but the numbers of Irish people with diabetes is expected to double by 2010. Type II diabetes accounts for nearly 90% of all diabetes here, and people with this disease die on average 5-10 years earlier than those without diabetes. Yet this could be prevented.

A nation’s health is not constant, but continually changing and evolving. In addition to rising incidence of diabetes and obesity, the reported incidence of depression, mental illness and dementia are also increasing, though this may reflect better diagnosis and screening, rather than any true increase in the prevalence of these conditions. The arrival of new residents from outside Europe introduces many previously unknown diseases and conditions and poses special challenges for physicians and pathologists – sickle-cell anaemia, for instance, prevalent among those of West African origin, was once unheard of in Irish hospitals, but is now increasingly seen. By 2030 climate change may also have added to our medical problems: malaria could return (the last outbreak in Ireland was during the 1850s in Cork city), skin cancer could become more common, harsher winters might mean more deaths from hypothermia, while hotter, drier summers may mean more deaths from heat stress and dehydration. Factors such as globalisation, better communications and even cheaper air travel, usually seen as changing the international context for industry, can also impact on health ‘consumers’. Irish people don’t just travel to Belfast for cheaper dental treatments – these days they also fly to South Africa for safari and cosmetic surgery holidays, and India for laser eye treatments.

Ireland Inc

Ireland has enjoyed unparalleled economic success over the past 15 years, so that today this small island on the edge of Europe can boast one of the highest levels of GDP per capita in the EU. Our GNP grew by over 7% a year in real terms between 1994-2004 – double the US rate and nearly three times the rate seen in the euro zone. Net outward migration – over half of those born in Ireland between 1841–1961 left the country – has become net inward migration (see panel below). With nearly 2 million people at work, Ireland now has almost full employment and at a time when unemployment levels remain high in many other European countries.

The foundations for this economic success were laid as early as the 1950s and '60s: when Ireland pursued an open economic policy, funded free education, introduced attractive corporate tax rates, established the IIRS and later the IDA, joined the EEC (now the EU) and aggressively marketed Ireland as an ideal industrial location. We benefited hugely from EU structural funds, we chased jobs that might keep some of our people from emigrating, and we switched out of farming and into industry, manufacturing and services. In 1973, agriculture accounted for 24% of all jobs in Ireland, today that has fallen to 7%. Just as we moved jobs up the value-chain then, into pharmaceuticals and IT, so we will have to do so again as we move towards 2030.

Our previous industrial strategy proved highly successful: we offered the right conditions and the right people at the right time to the right multinational corporations. Over 1,000 multinational corporations now have operations here, 480 of them from the USA, and they employ 128,900 people directly, with perhaps as many again working for support firms. In particular, we have grown a thriving industry to support the medical intervention aspect of healthcare, through providing goods and services to the pharmaceutical and medical device industries. Today, in the pharmaceutical sector alone, we are home to nine of the world's top 10 pharma and 15 of the top 25 medical device companies. It's a roll call of world brand names: Wyeth, Pfizer, Schering Plough, Johnson & Johnson, Glaxo SmithKline, Medtronic, Boston Scientific, Stryker …

Our medical technology sector is growing at 10% a year, and we have achieved a critical mass in medical devices, cardiovascular and orthopaedic products, ophthalmics and hospital products. Some 80% of the world's coronary stents and 30-50% of artificial hip joints are made here. We can boast a similarly rich ICT sector (information and communications technology) employing nearly 100,000 people, with over 1,300 companies, including seven of the world's top 10 corporations. Taken together our pharmaceutical, chemical, medical devices and ICT sectors accounted for 72% of all exports in 2004, and were worth over €60 billion (source: *International Trade & Investment Report*, Forfás 2005).

The new Irish

IN THE early 1990s, Ireland was the only EU country with net outward migration, but by 2004 we had the second highest level of inward migration, after Luxembourg. In the 12 months to April 2005, an estimated 70,000 immigrants came to Ireland, the highest number on record; the number of emigrants in the same period was also the lowest, at 16,600, bringing net inward migration to 53,400. Returning Irish emigrants are the largest single group, followed by Poles, who account for 17%; one-third of immigrants are from the 10 new EU accession States. By the end of 2005, there were an estimated 253,000 non-Irish nationals aged 15 or over in the Republic. According to some estimates, as many as 10% of residents here may now be non-Irish nationals. (Sources: *CSO Population & Migration Estimates*, 2005; Immigrant Council of Ireland)

The Diagnosis

These successes helped nurture the ‘Celtic tiger’, but past successes should not make us complacent about the future. Other countries are adopting the Irish model and we face competitiveness challenges on several fronts. We have a rising cost base, and new EU limits to State aid will take effect after 2006. Countries outside the EU, notably Puerto Rico and Singapore, are competing with us for inward investment and offering even lower corporate tax rates. Within the enlarged EU there are real threats from well-educated and lower-cost countries such as Poland, Latvia and Lithuania. Then there’s globalisation: many of our industries, such as the pharmaceutical sector, are effectively global and therefore insulated from, and essentially independent of the local climate and conditions. China and India, with their low costs and ample supply of skilled labour (a combined population of over two billion), are increasingly attracting jobs and inward investment. India is a particular challenge, with its highly-skilled English-speaking workforce, increasing numbers with PhDs, a reputation for productivity, and tighter intellectual property protection under the latest World Trade Agreement.

Today, Ireland is a world manufacturer of pharmaceuticals and medical devices, but 30 years ago we had no manufacturing reputation. Low-cost countries such as China are in a similar position now, though they are already gaining a reputation for manufacturing generic drugs, and will soon be noted for their medical devices. Once products mature and are commoditised, it becomes easier to manufacture them in low-cost locations. And many Irish jobs are arguably over-reliant on mature products that are liable to move abroad. The tendency is to view these changes and challenges as a threat to our industrial base. But it is smarter to view them as valuable opportunities – opportunities that allow us to leverage our manufacturing and create the space to move jobs up the value chain into high value-added areas, such as product and process development, where we have already demonstrated our ability to compete with our flexibility, innovation and ‘can-do’ attitude. These up-and-coming economies are also hotbeds of innovation, and we should view them not as competitors, but as potential collaborators.

A Golden Era in Irish Medicine

COULD Ireland lead the world of medical research again, as it did in the early 19th century? Then, students came from around the globe to study at the world-renowned school of medicine in Dublin’s Meath Hospital, and men such as Robert Graves, William Stokes, Dominic Corrigan and Sir William Wilde combined their medical practices and ward rounds with clinical research.

They revolutionised patient care, making the patient – and not the medical man – the centre of attention. They pioneered the practice of taking a patient’s pulse as a simple way of assessing their condition and championed the use of the stethoscope. Irish doctors were the first to propose categorising cancer cells according to their microscopic appearance, and the instruments they invented included the hypodermic needle and the modern stethoscope. Their names are immortalised in the many diseases they investigated and explained – Graves’ disease, Corrigan’s pulse, Stokes-Adams syndrome, Colles’ fracture . . . – and their innovations remain standard medical care. This golden era could also be the future of Irish medicine and healthcare, but achieving this will require investment in expertise and staff, resources and infrastructure, training and education.

Great men in Irish medical history: Dominic Corrigan, Robert Graves, William Stokes

Moving forward

To continue to grow as an economy at the pace of recent years, the value of our output must treble in absolute terms by 2030. High-end, value-added production will be the engine of future growth. In other words, our economy needs to switch from being investment-driven to being innovation-driven. Manufacturing alone will no longer suffice, and already foreign direct investment is falling: from €31 billion in 2002, to €20 billion in 2003 and €9 billion in 2004 (source: *International Trade & Investment Report*, Forfás 2005). Research and development (R&D) will be crucial, as we look for new and better products and services, new and better ways of working, and new and better ways of delivering and marketing goods to the global market. We will need smart people and smart infrastructure to produce innovative ideas and to turn those ideas into jobs and wealth.

We Irish have a world reputation for literary creativity, but our entrepreneurial successes in the past decade reveal that we can also be technologically, scientifically and industrially creative, with an ability to see through problems to solutions . . . the very kind of creativity we now need to bring to bear on our healthcare system and healthcare industry. In the 19th century, our health-care system was renowned internationally for patient care, education and research (see panel opposite). We need to recreate that golden era.

It takes all the running you can do just to stay in the same place. To get somewhere else, you must run at least twice as fast

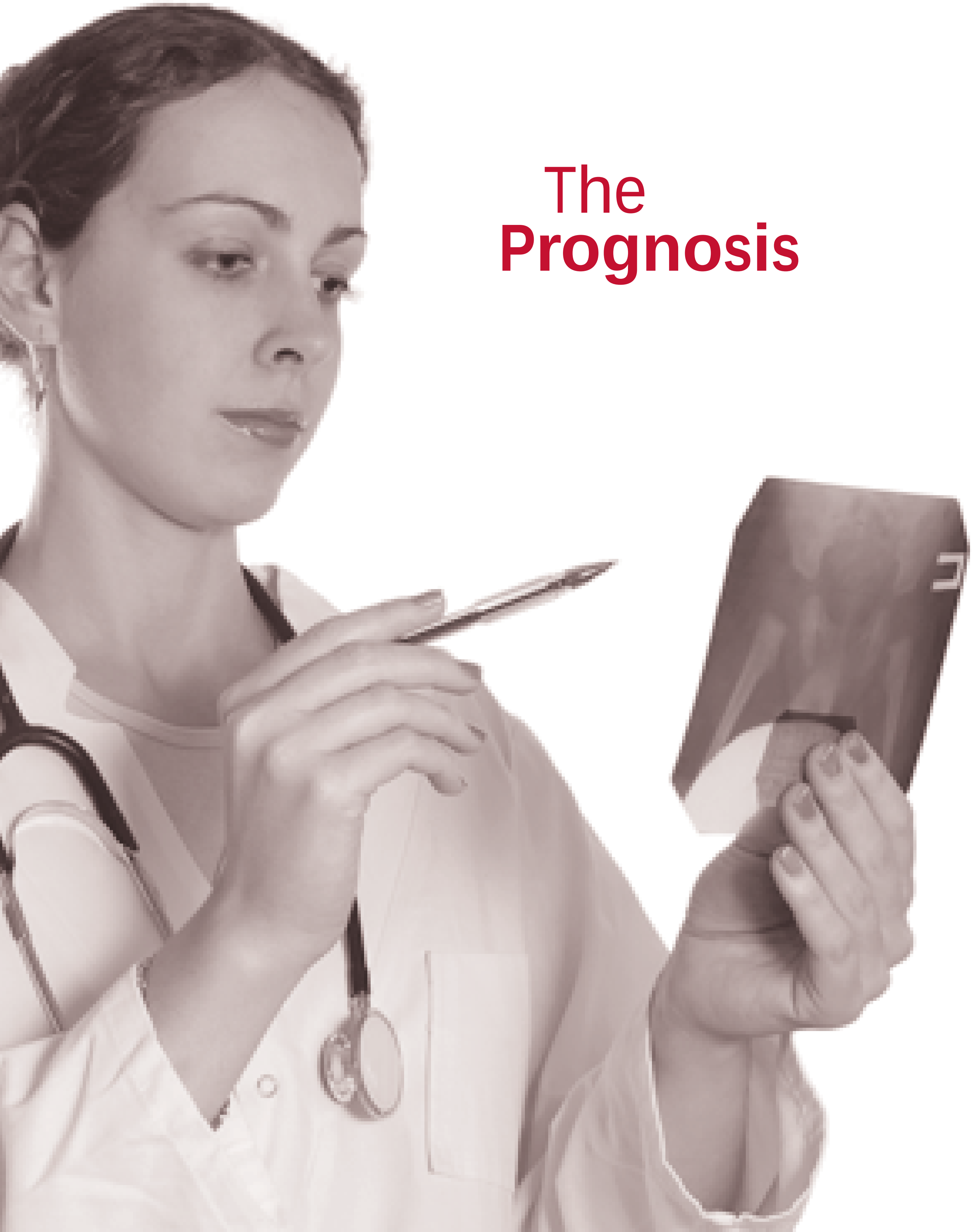
Thanks to work by Enterprise Ireland, IDA Ireland and others, we are already starting to see a shift towards new added-value jobs, while more mature and traditional jobs are moving to low-cost competitors. Witness the announcement in February 2006 by the world's largest biotechnology company, Amgen, to build a $1 billion process development, bulk manufacturing and fill and finish facilities at Carrigtwohill, Co Cork, creating more than 1,100 jobs by 2010, alongside the announcement of several closures and job losses across a range of sectors– notably NEC Semiconductor, Saehan Media, Fruit of the Loom, and Magee of Donegal.

If we are to compete successfully in the new globalised, 'always-on' information world, then the innovative thinking and the initiatives and investments that have brought us to where we are today must continue or we will fall behind internationally. In particular, we need to continue to invest in research and education. Our past success does mean, however, that we are well-placed to compete in the future, but we will need to find ways to anchor higher-value jobs here by driving quality into design and manufacturing, and crucially, by encouraging multinational corporations to conduct more R&D here, and put down long-term roots. Ireland's small size is one of our greatest assets, and should be exploited to facilitate networking and clustering, and to encourage fast and flexible research and development initiatives, with close connections, cohesive links and strong partnerships bringing together industry and entrepreneurs, research institutes and academics, clinicians and the healthcare system in a way that can rival Boston's medical technology cluster. It is reassuring that the combined efforts of the various research and development State agencies, such as SFI and IDA Ireland are focussed on these objectives.

The pharmaceutical, chemical, medical devices, diagnostics and ICT sectors provide the opportunity for growth. Happily, they also hold out the promise of tremendous improvements in national health and well-being.

As the Red Queen explained to Alice in the *Through the Looking Glass*, it takes all the running you can do just to stay in the same place – 'If you want to get somewhere else, you must run at least twice as fast.' Science and engineering can help companies, the economy and our healthcare system to run faster and get places.

The Prognosis



New and emerging technologies and social changes are among the factors that will shape healthcare over the next 25 years. Here we identify opportunities that Ireland could exploit, to be part of this exciting future, and to ensure that Irish healthcare in 2030 is among the best in the world

What will life, technology and even the human race be like in 25 years' time? Will we be living longer, healthier lives, and keeping old age at bay? Will we be increasingly bionic? And what kind of healthcare technologies will we be using? Writer William Gibson believes that 'the future has already happened, it just isn't very well distributed'. If that is so, then many of the developments in medicine and healthcare that we might look forward to in 2030 are probably already in use, albeit on a limited basis, just as much of what we now think of as modern was discernible 25 years ago. There is the potential here to improve our healthcare system and grow jobs and, if we can develop innovative solutions to generic concerns – Irish solutions to global problems – there is tremendous potential for Ireland Inc to contribute to healthcare improvements internationally and at the same time to grow our exports and earnings potential. Successful and innovative solutions are highly saleable.

The future has already happened, it just isn't very well distributed

William Gibson

The future foretold

Forecasting future developments, even broad trends, is notoriously difficult. Seemingly small changes can have disproportionately big impacts: the introduction of the freight container – essentially a big box – dramatically changed the world's docklands and the movement of goods and did away with the job of docker

Ireland in 2030

There will be more of us: there could be 6 million people living in the Republic of Ireland by 2030 (following CSO projections of a 2% growth rate), and at least 10% of us (some say even 20%) will be non-Irish nationals.

We will be increasingly urban: over 40% of us will live in the 'greater Dublin area' alone (counties Dublin, Kildare, Meath and Wicklow).

We will be living longer: life expectancy is likely to reach 80 for men and 84 for women, so those retiring at 65 in 2030 can expect to live another 15 to 20 years.

We will have a relatively high dependence ratio: with more 'old' people (22% will be over 65), and more 'young' people (30% will be under 14) the dependence ratio will hit 53%.

We will be increasingly overweight: if the USA is a guide, then half of us will be overweight, and 30% will be obese, with many people suffering chronic ill-health as a result, and susceptible to diabetes and cardiovascular diseases and related conditions such as blindness, kidney failure and gangrene.

New diseases and health problems: climate change may mean that diseases such as malaria and West Nile virus become established here, and that winter hypothermia and summer dehydration are increasingly common, especially for the growing numbers of older people in the community.

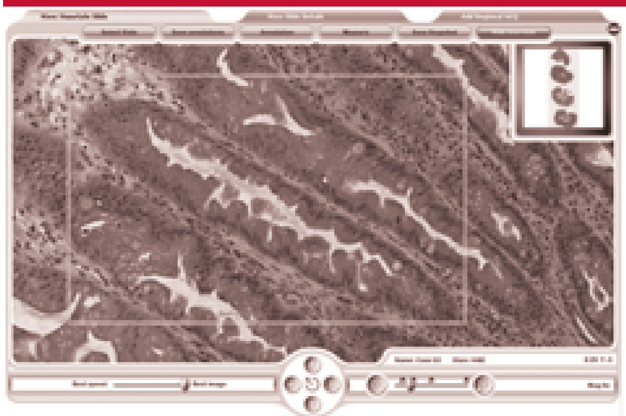
Sources: CSO projections and yearbooks, OECD *Health at a Glance* 2005 that had existed for centuries. In 1943, IBM's then chairman, Thomas Watson, famously said that 'there is a world market for maybe five computers' – which may have seemed logical at the time, but neither he nor IBM have been allowed to forget it. In the 1980s, all the talk was about video-phones – something we've forgotten about in our rush to embrace camera-phones. And in 1980 no one was predicting the Internet or a World Wide Web, never mind anticipating their impact, yet the basis for these already existed in the US military's DARPA Net (Defense Advanced Research Projects Agency).

When it comes to forecasting the future of healthcare we must also factor in social change and the vagaries of human nature. Society's attitude to smoking has changed dramatically in the past quarter century, for instance – and our attitude to alcohol may well become more prescriptive by 2030 – yet we are not necessarily more health-conscious, witness our insatiable appetite for junk food and the growing problem of obesity.

Remember too, that the future can be slow to arrive, especially when it has to make the long, circuitous journey from the laboratory to the hospital bedside and the GP clinic – biotechnology, for instance, is only now delivering on promises that were made 20 years ago, though admittedly, the lag time with medical devices is usually shorter than for pharmaceuticals. Even in computing and information technology, where tremendous progress has been made, researchers are still discussing how to harness these technologies to improve decision-making . . . something that was being discussed at least as early as the 1960s.

What we can do, however, is ask what might be possible, and what might be desirable, and how best to make the desirable possible. And one thing that is both desirable and possible is for Ireland to become a world leader in healthcare. Since our small open economy cannot compete in all areas, however, we must identify the niches where we can expect the greatest return – just as in the 1950s and '60s Bord na Móna led the world in peat extraction, exporting Irish technology to countries such as Finland and the then USSR, and the Aer Lingus personnel and project services subsidiary, PARC, developed a sizeable export business in the 1970s and '80s supplying staff and IT systems to hospitals in the Middle East.

3D action replay for pathologists



From Slidepath's Replay Suite; Viewing a serrated polyp of the ascending colon.

MICROSCOPIC examination of tissue samples is part science and part skill, and that makes it difficult to teach. After all, how can trainees know precisely which parts of the slide a pathologist viewed when they arrived at their decision? New software, developed at DCU under Dr Donal O'Shea with HRB funding, is changing all that. Their ReplaySuite exploits the power of new digital imaging, to capture the 3-D detail of microscopic samples, and track where a pathologist 'visits' as they view a slide. This can be relayed, around the world if need be, to trainee pathologists, colleagues providing a second opinion, or for quality control assessment. A spin-off company, Slidepath, is marketing a range of services, such as master classes with world experts. So, simply by tracking where a pathologist looks, an elegant Irish idea is helping to improve the quality of medical diagnoses.

Following three decades of developing a substantial chemical and pharmaceutical industry here, we have created many indigenous support companies that are now well established and increasingly selling their services overseas – PM (Project Management), and Mercury Engineering, among others – particularly in project work such as designing and building factories and facilities. To make similar progress in the healthcare sector, we need to identify potential niches and foster indigenous small-medium sized enterprises (SMEs) and entrepreneurs. This entails identifying areas where we can develop or already have a position of competitive strength, differentiation and critical mass. (For a detailed survey of the relevant industrial sectors, notably biotechnology, engineering and ICT, we refer you to the sectoral analyses that accompanied the Enterprise Strategy Group report, *Ahead of the Curve*.) And in companies such as Cork-based biotech support company, Luxcel, and SlidePath at DCU (see panel opposite) there is evidence that Ireland is now ready to do business.

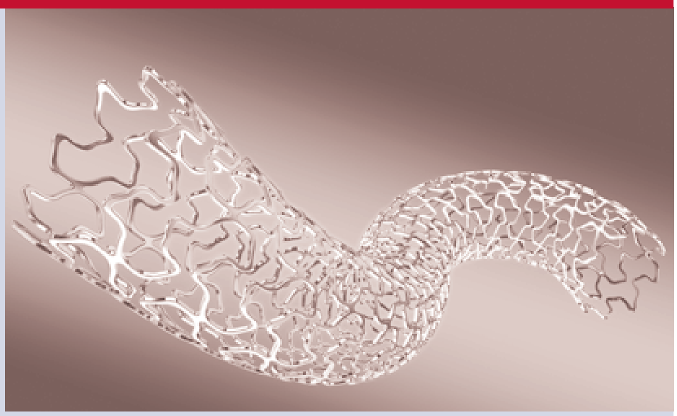
Perhaps the single most important point to remember here is that the 'picture of health in 2030' is one that will be shaped largely by a convergence of diverse technologies, and that this calls for new interdisciplinary structures and approaches. Witness the success of Boston Scientific's new taxus stent (see panel below), that combines a medical device with a drug. This novel product is an example of the kind of thinking and approach that Ireland should be following. And what else might we look forward to in 2030?

Social Landscape & Climate

Start planning your 100th birthday party! By 2030, there will be many more of us in Ireland, and we will be living for longer. Our life expectancy at birth continues to improve: from an average of 70 in 1960, to 78 in 2003, and probably reaching 82 by 2030. That's an extra two months every year, or ten seconds every minute. Meantime, scientific research is shedding light on the molecular changes that take place in our bodies as we age: how time, and wear and tear take their toll, leaving us prey to osteoporosis, arthritis, cancer, dementia and heart disease. The more we learn about ageing, the more some people believe we will devise anti-ageing therapies to keep old age at bay – even, some mavericks think, live forever. Futurologist, author and inventor Ray Kurzweil

Ireland – where drugs and devices converge

THE TAXUS project is a new approach to tackling blocked arteries: it combines a conventional stent (a cylindrical metal device used to hold an artery open and maintain blood flow) with an established atherosclerosis drug (Paclitaxel), and uses a special polymer to ensure the drug's release is controlled. Far more effective than either a stent or drug used alone, it's an elegant example of the type of novel solution that can emerge from the convergence of diverse disciplines, in this case pharmaceuticals, materials science and medical devices. Launched by Boston Scientific in 2003, this new drug-eluting stent netted nearly €1.5 billion in sales in the USA in its first nine months, and it now generates €1 million every hour. And it was developed by an award-winning R&D team at Boston Scientific's Galway campus.



TAXUS Liberté™ is Boston Scientific's second generation drug eluting stent.

The Prognosis

Average life expectancy is increasing by 10 seconds every minute

believes that by 2030 humans and machines will have converged: we will use computing prosthetics to enhance our brain power, forming a hybrid bio-mechanical being that he calls 'the singularity'.

Living longer does not necessarily mean we will spend those extra years being ill and disabled: international studies suggest that 80-year olds now are healthier and fitter than they were 40 years ago. Better medical treatments mean that people can now live reasonable lives with problems such as heart disease that, in 1960, would probably have killed them. Elderly people who can continue to live independently in their own home are generally healthier and happier, so we need to develop appropriate technologies to enable our elderly citizens in 2030 to live independently in security and comfort. As families become smaller and family members more geographically distributed, there will be fewer people to care for elderly relatives. New monitoring and sensing devices and advanced IT will be important in this regard. The increased care needs, and the higher incidence of age-related diseases such as Alzheimer's, will place additional burdens on our healthcare system. As a result these are also some of the opportunities that Irish researchers and companies could be pursuing. Major corporations such as Intel have already prioritised the development of such technologies in their Digital Health initiative.

Other factors can also impact on our health. Climate change and depletion of the ozone layer pose direct health threats. Increased global air travel exposes people to more diseases, and increases the speed at which infections can spread, and even how we design our buildings and cities can be important. Disease surveillance and epidemiology become ever more important in our globalised world.

Preventive measures such as exercise and a healthy diet are important for maintaining fitness and mobility not just among the elderly, but for us all, and especially our children, where already there is increased incidence of obesity and Type II diabetes. OECD figures reveal that the health costs of obese people are one-third higher, and their medication costs 70% higher than people of normal weight. For our health services this is perhaps the biggest time bomb. Prevention is better than cure, and so we must invest in our future health by introducing more preventive measures that encourage well-being and keep ill health at bay. This may call for legislative change, and educational and social initiatives. But then, a healthy population is the foundation for a healthy economy.

Opportunities: research the science and diseases of ageing, such as osteoporosis and neuro- degeneration, as well as how best to assist older people to remain healthy and independent. Explore new technologies such as RFID and related developments in information and communication technologies that would allow more older people to live at home independently. Study disorders that are prevalent in Ireland such as cystic fibrosis, coeliac disease and haemochromatosis. Invest in disease surveillance, and in training epidemiologists. Find innovative ways to encourage our children to eat a healthy diet and take more exercise, including mental exercise. Develop monitoring technologies and diagnostic devices that focus on wellness rather than illness.

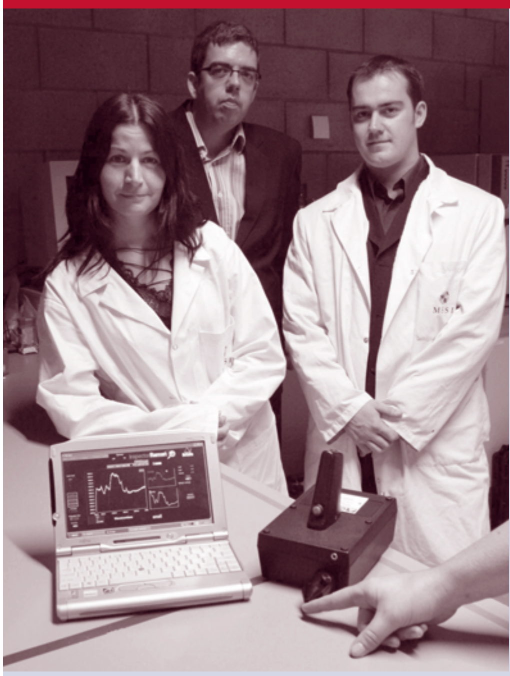
Pharmaceuticals & Biotechnology

We will still be taking the tablets in 2030, as we have done for centuries, but the tablets of the future should be safer and more effective, with fewer side-effects and even tailored to suit our individual make-up. We should have a better understanding of why a particular drug works for some people and not for others – one such puzzle is the current generation of IL-1 blockers that relieve rheumatoid arthritis in only some patients – so that drugs and treatments will become more targeted, and less 'hit and miss'. This kind of information should flow from the latest cell and molecular biology research, such as that underway at UCD's Conway Institute. A small number of targeted drugs are already on the market – e.g. Herceptin, which is aimed at a particular form of breast cancer – but this number will grow dramatically over the coming decades. To be able to tell if 'this drug is right for you', future pharmaceuticals may well incorporate or be sold with some kind of diagnostic test. This combination of therapeutics and diagnostics ('theranostics') is likely to become common-place.

Our future drugs are more likely to be proteins or small molecules that have been designed rather than stumbled on, and produced by applying increasingly sophisticated chemistry allied with advanced biotechnology techniques. It currently costs between $1-2 billion to develop a new drug, so drugs aimed at subsets of patients will be more expensive unless we develop more efficient drug discovery and design programmes, and cheaper ways of testing drugs. We believe there are opportunities here for Ireland.

New and better systems for testing the toxicity of candidate drugs that will reduce our reliance on animals, minimise the risks involved in drug testing, and hopefully yield safer and more effective therapies, would also be desirable. Time was when the main subjects for medical research were the poor and those on death row, and in the 20th century we relied predominantly on laboratory animals. New cell and tissue culture systems should allow us to test drugs more accurately, more efficiently and more cost-effectively.

An Irish test for bone fragility



Innovative UL researchers: Dr Niamh Rushe, Dr Mark Towler and Anthony Wren.

OSTEOPOROSIS affects 35% of women and 20% of men over 50, and bone fractures cost the Irish exchequer at least €12m each year, not including the costs of physiotherapy, drugs and social welfare. Happily, many osteoporotic-style fractures can be prevented if early action is taken, but diagnosing poor bone health currently involves an expensive and time-consuming DEXA scan.

Now Dr Mark Towler, a materials scientist at the University of Limerick, is developing a cheap, quick and easy test to determine bone health that could be more accurate than all existing non-invasive tests. His bone quality test uses a handheld device and Raman spectroscopy to measure the disulphide bonds in a person's fingernail, believed to be a reliable guide to bone quality. Ultimately every GP clinic could have one of these new handheld devices. The system, developed in association with Crescent Diagnostics Ltd, was recently short-listed for the UK's Medical Futures Innovation Awards. It's the kind of innovative thinking that can emerge when materials science meets medicine.

The Prognosis

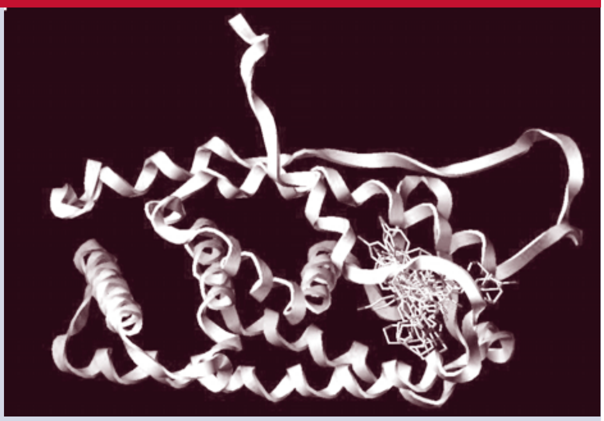
Opportunities: The entry barriers to pharmaceuticals are especially high and effectively preclude our developing an indigenous pharmaceutical industry. Instead, we should encourage indigenous SMEs to explore niche areas and sub-supply opportunities, especially in the medical devices, process-development and biotechnology sectors. As an example, consider Luxcel Biosciences, a young biotech company spun-off from UCC in 2002: its projects include an early warning system that can spot toxicity in new drug compounds as they are tested in cell cultures, and which is being used by Pfizer. Possibilities identified by the Enterprise Strategy Group include software for development processes, rational drug design, assay kits and drug delivery mechanisms.

Chasing such niche opportunities will require specialists, with at least PhD training, who are able to make connections and work in interdisciplinary teams. There may also be opportunities to exploit intellectual property which is not part of a multinational corporation's core business. The new Wyeth neuroscience research collaboration with UCD's Conway Institute is an attractive model of what can be done: under this deal, any resulting IP will be owned by the institute, but Wyeth will have an exclusive option on it. We welcome the new €90 million National Institute for BioProcessing Research & Training (NIBRT), a joint venture by UCD, TCD, DCU and Sligo IT, and with IDA support, which will provide important infrastructure, training and facilities, and address key shortages of skilled personnel in the high-value biotechnology sector.

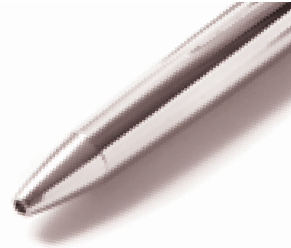
Ireland is well placed to exploit the new computer-based *in silico* techniques. In these, pharmaceutical chemists use powerful software, DNA sequence information, and 3D images of the target protein, combined with detailed chemical data about how existing drugs work, to produce new or improved drug designs for testing in the lab. This can yield new drugs that will greatly benefit patients, and valuable intellectual property that can generate jobs and revenue. A small number of projects are already underway in Ireland (see panel below), but more should be encouraged. We also welcome research such as that being conducted at UCD by Prof Michael Ryan, who is building an artificial kidney system as an alternative to laboratory animals for testing the toxicity of new drugs.

Designer drugs

AT TCD, pharmaceutical chemist Dr Mary Meegan uses computers to design a new generation of breast cancer drugs that will be more effective or with fewer side-effects or cheaper to make than one of the current drugs, tamoxifen. Tamoxifen acts by binding to oestrogen receptor proteins in breast cancer cells. In HRB-funded work, Meegan and her colleagues assess computer *(in silico)* models of hundreds of new chemicals and how they interact with the oestrogen receptors. They can test the most interesting compounds on breast cancer cell lines in the lab, and have already identified several hopeful candidates, new would-be tamoxifens.



The computationally generated superposition of a series of designed antagonist molecules in the ligand binding site of the oestrogen receptor protein.



Surgery

Better engineering and new materials will lead to improved surgical instruments and techniques that should greatly ease matters for surgeons, patients and hospitals. Patients recover from keyhole surgery quicker and with fewer side-effects than if the same procedure is performed using conventional 'open' surgical techniques. But keyhole surgery is highly skilled and requires considerable practice. New navigational systems, better design and engineering, and new ways to cauterise and suture, mean that the next generation of instrumentation will be 'skill independent' and easier to use, so that more surgeons will be able to perform keyhole surgery, and for a wider range of procedures and with less training than today. The result: improvements for patients, faster procedures, faster turnaround times and faster recovery.

An example of the kind of development from materials science that would greatly facilitate keyhole surgery, is a tough yet flexible bag that could be inserted into a patient through a ‘keyhole’, and into which a growth or cyst could be placed and then macerated using a keyhole-sized blender. The bagged tissue could be easily removed through the 'keyhole', which would be a tremendous improvement on the current technique, whereby a piece of tissue has to be tediously cut up and removed piece by piece.

Surgical techniques are also crucial for the success of an implant. New, less invasive and better surgical techniques and equipment will improve the ‘spare parts service’ – better navigational systems with reference points to position a joint, for example, and tele-medicine facilities that will allow an expert to guide the procedure even if they are located on the other side of the country, or even the other side the globe. By removing some of the human element, the procedures can be increasingly automated and improved, so that replacing a knee will become as easy as landing a plane! While much of surgery will become increasingly sophisticated, happily, some surgical techniques may disappear: for instance, if the new vaccine against human papilloma virus (HPV), announced in 2005, becomes widely used, then cervical cancer and the surgery used to treat it may become a thing of the past.

Opportunities: There is potential for Ireland to develop innovative technological solutions for operating theatres. The key components already exist here, notably a successful medical devices sector, a body of experienced clinicians, and a diverse ICT industry. Technologies which might be developed include navigational systems for orthopaedic surgery, an area which is just opening up; and voice-activated instruments for surgeons.

Spare Parts

New hips, false teeth, replacement knees . . . we have become used to the idea of replacing failed body parts. Yet orthopaedic surgery remains brutal and invasive, and the limited 10-12 year lifetime of many implants means the procedure is often delayed as long as possible. Happily, new and better tissue engineering, genetic and cellular therapies, hold out the promise of treating damaged hearts, joints and cartilage earlier, with less invasive, less intrusive techniques. Multidisciplinary research at centres such as NUI Galway’s National Centre for Biomedical Engineering Science (NCBES), which marries smart materials, biomolecules and cells, with engineering approaches, is leading the development of novel engineered tissues for vascular, cartilage, and orthopaedic applications. Nanotechnology and materials science may also have a role to play here. It might even be possible one day to fully restore joint function in many cases without recourse to replacements, something that should greatly improve treatment options for osteo-arthritic patients, among others. We will hopefully become better at harnessing the body’s own healing mechanisms, exploiting our disease-fighting immune system, our endogenous pharmaceuticals and painkillers, and especially our stem cell repair systems. This approach holds out considerable promise in terms of encouraging natural repair and regeneration of tissues rather than their replacement by artificial alternatives or devices. Already, adult stem cells have been successfully used in experiments to repair heart muscle in people who have suffered a heart attack, and muscle damage in racing horses. Other diseases that might one day succumb to such treatments include spinal injury, orthopaedic problems and even neurological disorders. Indeed, among the projects under way at NUI Galway's Regenerative Medicine Institute (REMEDI) is a study looking for ways to persuade damaged spinal cord to repair itself.

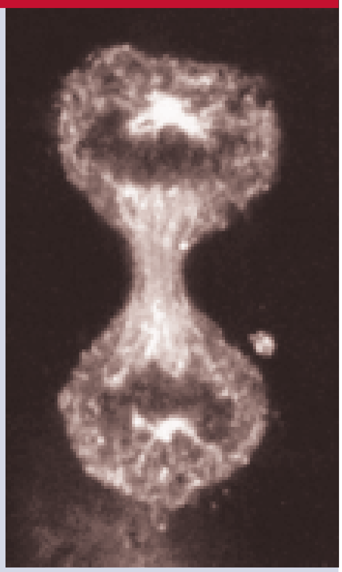
We will still have to resort to spare parts – heart valves, hip joints, even artificial organs – but replacement will be the last resort. When a joint replacement is finally called for, new high-wear bearing materials, and implants with three-dimensional porous metal structures which, combined with bio-materials, will encourage bone to grow onto the implant, should lead to better, longer-lasting replacements. We will also see a wider range of 'spare parts', especially for the smaller joints such as the shoulder, elbow and fingers. Among the exciting engineering technologies being developed for orthopaedic surgeons by the medical devices industry is selective laser sintering (SLS), which might one day allow us to quickly fashion complex shaped devices for individual patients. SLS has already been successfully used by Prof. Peter McHugh and colleagues at the NCBES for rapid prototyping, to construct models for the design of maxillo-facial implants in engineering-assisted surgery.

Opportunities: Develop a research base, expertise and manufacturing cluster in orthopaedics. Ireland already has an international reputation in the field, thanks partly to the work of orthopaedic surgeon James Sheehan, who pioneered the arthroscopy technique that is now the international standard. Significantly, after training in medicine and surgery, Sheehan gained an MSc in bioengineering and a PhD in mechanical engineering, and thus embodies the cross-disciplinary approach that will be crucial to the future development of healthcare. There is scope to develop an orthopaedic device industry cluster in Cork, centred on the two world-leading multinational corporations already located there (Stryker and DePuy Johnson & Johnson), and modelled on the successful cardiovascular cluster that has been nurtured in the Galway region.

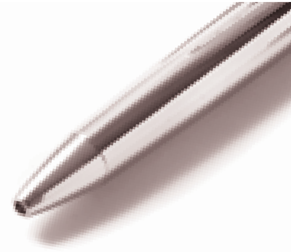
New Irish test for cervical cancer

CERVICAL cancer is notoriously difficult to diagnose: in the conventional test, thousands of cervical cells are smeared on a microscope slide, then someone laboriously examines the cells looking for abnormalities. It is tedious and depends on the individual's subjective judgement, so some laboratories ask two or even three people to examine every slide, yet even then, an abnormality can be missed, and a woman told she is clear, when in fact she may have cancer.

Pathologist Prof John O'Leary and his team at the Coombe Women's Hospital, Dublin, invented a radical new test that is fast, effective and not dependent on an examiner's judgement. Their antibody-based chemical reaction detects the genetic changes that occur in an abnormal cervical cell: simply add p16 antibody, and if any cells are abnormal, the mixture changes colour. The test takes a few hours, and can be automated. Testing for four additional genetic markers will allow the abnormality to be categorised as low, medium or high risk. International trials are under way to refine the procedure, and to design an automated test. It is a fine Irish success story which should improve the detection rate of cervical cancer, facilitate a nationwide screening programme, and save thousands of lives.



Cervical cancer cell about to divide.



Diagnostics & Devices

We expect considerable change and improvement in diagnostic techniques and technologies over the next 25 years, and believe that these will bring tremendous benefits for patients and for the healthcare system. By 2030, wearable diagnostic equipment and wireless technology could be more common – your wristwatch, for instance, might also monitor your heart rate, blood pressure and blood sugar levels, and transmit the information to your mobile phone or computer. This will empower people to monitor their own health and wellness, and allow more people to self-administer drugs in their own home. In GP surgeries we are likely to see more 'near patient testing' and ‘point of care’ devices, with rapid bedside tests replacing hospital ones. As genomic science matures over the coming 25 years, the information it yields should also impact on diagnostics – already, thanks to genetic studies, we know for instance that there is no such thing as lung cancer, rather, there are many different lung cancers, each one subtly different. And to tell if ‘this drug is right for you’, future pharmaceuticals may well incorporate some kind of diagnostic test, thus eliminating much of the ‘hit and miss’ problem of many existing drugs. Personalised medicine is certain to play a big part in our future.

> *If I had asked people what they wanted, they would have said faster horses*
>
> *Henry Ford*

New diagnostic technologies should allow us to detect problems early and intervene promptly. We particularly need early, accurate and ideally cheap and easy diagnostic tests for cancers, such as the promising new Irish test for cervical cancer (see panel opposite). These would save thousands of lives worldwide, as well as avoiding much pain and late surgery, while also saving money and releasing scarce resources for other medical needs. The lung cancer survival rate in Ireland, for instance, is reportedly 9%, among the lowest in the Western world. This is overwhelmingly due to late presentation, as currently there is no accepted screening test for lung cancer. Encouraging results are now being seen in CT imaging trials, however, and the hunt is on for an effective biomarker.

Opportunities: There are significant opportunities for Ireland in the broad area of diagnostics and sensors. We welcome the establishment last year of the Medical Technologies Council and SFI’s establishment of a Biomedical Diagnostics Institute at DCU. The BDI (www.bdi.ie) involves a large, multidisciplinary team of academic and industrial researchers working together to develop next-generation diagnostic devices especially for self-test, home-use. The inter-disciplinary Medical Technologies Council, established by IBEC and the Royal Academy of Medicine in Ireland, is a valuable initiative that aims to create a coherent medical technology platform in Ireland by 2010, and foster networking and an innovative culture in this area (*Vision 2020: delivering proactive medical care*, 2005). Future opportunities for Irish innovation could lie in developing cheap 'generic' medical devices (similar to generic medicines), for the home and world markets. This kind of valuable innovation might emerge where we can constructively bring together the disciplines of engineering, materials science and medicine.

There is tremendous global need also for cheap disposable ‘bits and kits’ – currently, many machines are relatively cheap, but the disposable items used with them are expensive, which limits their use and impact. New materials may help in developing cheaper alternatives – as happened with the move from glass to plastic syringes some years ago – which would benefit not just Ireland but the substantial healthcare markets of countries such as India and elsewhere. Finally, there is no reason why researchers in Ireland should not develop early and accurate diagnostic tests for some of the major killer cancers – as well as greatly benefiting patients and healthcare here, these would find a sizeable worldwide market.

Probiotics, GM Medicines & Nutraceuticals

Functional foods, probiotics and nutraceuticals (e.g. edible vaccines) are proving extremely popular and in many cases commercially successful. They are also welcome indicators of a greater public and corporate interest in preventive medicine. Sales of functional foods in Ireland are growing at a phenomenal 20% per annum, according to Bord Bia; sales of probiotic yoghurts alone were worth €46 million in 2004, and when other functional foods such as cholesterol-reducing spreads and Omega-3 milk are included, the total market value here could be as high as €180 million.

Perhaps Ireland's greatest probiotic success to date is the new therapeutic based on a bacterium isolated and developed by researchers at UCC and which has been shown to alleviate the chronic symptoms of inflammatory bowel disease. The probiotic was launched late last year in capsule form in the US, where it is being test-marketed under licence by Procter & Gamble (the Alimentary Pharmabiotic Centre at UCC, web: apc.ucc.ie).

While acknowledging the consumer and public antipathy towards many genetically modified (GM) crops and foods, we believe this powerful technology has much to offer healthcare, such as new and better ways of producing vaccines and medicines.

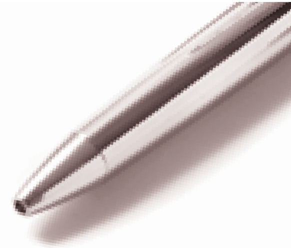
Opportunities: Ireland is already a world leader in the food industry, witness the supreme position held by the Kerry Foods Group. There is tremendous potential to build on our food science expertise to create new functional foods and probiotic healthcare products, and for GM medicines. As recommended by the Irish Council for Bioethics, proposals for GM products should be evaluated on a case by case basis (*Genetically Modified Crops and Food: threat or opportunity for Ireland?* 2005)

Magnetoencephalography machine for brain imaging.

Imaging

Technologies such as magnetic resonance imaging (MRI) and computerised tomography (CT) scanning would surely seem like magic to an earlier generation. Now, thanks to these and parallel improvements in software and imaging analysis, we can watch organs at work and even see the brain functioning in real-time. Imaging has become a vital source of information in healthcare, essential to many diagnoses and treatments, and increasingly used in procedures such as computer-aided and robotic surgery and to manage and display complex data.

Who knows what kind of imaging systems we will have in 2030? One target would be a safe alternative to x-rays, still the most common healthcare imaging technology. In the interim, additional information is coming from hybrid



systems that combine existing technologies, such as CT and SPECT (single photon emission computed tomography); these have the added advantage of requiring only one patient visit and are therefore more efficient. New mapping and registration techniques mean that data from pre-operative scans can be married to a patient's anatomy on the operating table, thus improving accuracy during, for example, navigation for cardiac treatments. As a result, surgeons are starting to use minimally invasive catheter technology to treat arrhythmia, instead of open-heart surgery.

One problem with modern imaging systems is the volume of information they produce: a single CT chest scan, for instance, can generate about 1,000 slices. So we need intelligent diagnostic and computer-aided decision systems to help clinicians and radiologists to analyse the data. Software algorithms based on expert knowledge could read cardiac ultrasound files, or compare scans and, for example, spot the nodule that might be cancerous – something that requires years of practice, and often second opinions and a biopsy – or determine the contours of a tumour, something that currently takes hours. Such systems would improve detection rates, help clinicians to make the best possible decisions for patients, catch problems early and avoid unnecessary surgery.

Given the valuable information that imaging technologies can generate both for patient care and patient-focused research, this task force welcomes the new HRB initiative to fund imaging equipment for clinical research. We especially welcome IDA Ireland's support for this programme, which gives the successful equipment suppliers an opportunity to collaborate in the research. The first two awards, which will be made this year, worth in all €8 million, will fund magnetic resonance equipment for a National Centre for Advanced Medical Imaging at St James's Hospital in Dublin (for research into adult illnesses such as cancer, and cardiovascular and neuropsychiatric diseases), and dedicated ultrasound machines at seven clinical academic centres around the country, as part of a new distributed National Obstetric Ultrasound Research Consortium to study problems of perinatal morbidity and mortality.

Opportunities: Imaging technology is a field where engineers and software engineers are playing and will continue to play important research and developmental roles. Ireland's expertise in software for imaging analysis, notably in astronomy and space applications (e.g. Captec Ltd), could be turned to analysing medical imaging data, where there is a growing market for sophisticated software systems and ultimately computer-aided decision systems.

Information Technology

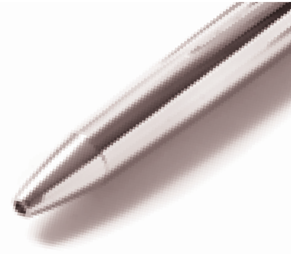
Of all the technologies that can impinge on healthcare, IT has the broadest reach. Used wisely and effectively, it has the potential to empower patients, aid GPs and clinicians, transform the delivery and efficacy of our health-care systems, and provide us with smart homes, smart clinics, smart hospitals, and smart health-care. New and more powerful IT systems should allow us to model the human brain and body, design better drugs, track patients and samples through hospital units, share files and information across departments and over long distances, analyse the enormous datasets being generated by the latest research, and prevent potentially fatal medical errors such as mis-diagnoses and the mis-prescription of drugs. Improved software and computing should also lead to more accurate interpretative systems for reading ECGs and scans, and for improved clinical decision making in general (for example, by comparing a person's test results against their previous results and results for the wider population). Just as we now have Internet banking, so we are likely to move to online Internet medical records. Just as in computing we moved from mainframes to personal computers, so we are likely to move from 'mainframe medicine' to personal medicine. IT can also empower patients, by enabling access to greater information. Thus we may see the emergence of sources of information that are mediated, with some people willing to pay for 'good information'. Doctors too will find it easier to keep abreast of the latest developments, and this should help address the current ‘voltage drop’ that exists between the amount and quality of information known at the top of the medical system, and what a patient actually receives. The result should be a more patient-centred system.

It is essential that our healthcare system be free of errors. This is true for the drugs and devices we use – where manufacturing control processes already ensure product quality – but it must also be true of healthcare delivery. International surveys (notably *To Err Is Human*, the 2000 US Institute of Medicine report), conclude that significant numbers of serious medical errors occur annually. An integrated and comprehensive digital or electronic health record (EHR), linked to electronic prescribing and evidence-based best practice clinical guidelines, should eliminate such errors by ensuring patients and their files are matched and that there is no scope for mis-diagnosis, or giving someone the wrong drug or the wrong dose. As a plus, a digital or electronic prescription would be faster to dispense and more difficult to forge. Also the EHR is a potentially rich source of clinical data for research.

Ireland is not rushing to adopt EHRs, nor is Britain’s NHS, but such systems are being developed in the US, and regional versions are being rolled out elsewhere, e.g. Germany, France and Italy. In Denmark, IBM is building what it calls a ‘national eHealth portal’, for both patients and physicians, that integrates electronic patient records, e-prescriptions, lab results and many more features (source: www.ibm.com). People with chronic illnesses, who typically need the services of a wide range of health professionals, would benefit particularly from an integrated medical record. Among Irish initiatives is a successful pilot scheme for epilepsy patients at Dublin’s Beaumont Hospital, now being expanded into a national epilepsy eHealth domain. By 2030, we believe these systems will be the norm. This is not to underestimate the difficulties involved in integrating disparate IT systems, as witness the problems that beset the HSE’s PPARS system, and we realise that the transition from paper to electronic records is problematic in all areas, but especially where one is dealing with personal and life-critical information. The challenge will be to make the information accessible to patient, doctor and hospital, possibly with patients controlling the level of access – your optician does not need to know if you had hepatitis for example – and for the system to be portable and readable from cradle-to-grave.

While to date most of a healthcare system’s IT budget has been spent on administration and accounting, that is likely to change once EHRs are implemented, and hospitals can move on to exploiting IT in medical decision-making (see also Imaging, page 28). Coupling advanced IT and broadband facilities should allow telemedicine to finally become the reality that has been promised for some years: using video-conference, intelligent sensors and IT technologies to bring medical expertise to where it is needed, and relieving sick patients of the need to travel long distances for consultations. Combined with robotics, this would allow surgeons to operate remotely, giving their expertise a wider reach beyond their physical location. Technologies such as these would greatly improve the standard of treatment and care available in Ireland at regional level, by making expertise more widely available.

In research, advanced IT systems should allow us to simulate the complex biochemistry of the human body, and to model the impact of diseases and drugs. Just as simulation revolutionised aeroplane design and engineering, so we believe it will revolutionise medical biology and healthcare. One such project currently underway is IBM’s BlueBrain collaboration with the Ecole Polytechnique Fédérale de Lausanne in Switzerland. Using one of the world’s most powerful supercomputers, the team is building a digital model of the human brain, starting with the neocortex. The largest and most complex part of our brain, and comprising about 85% of the brain's total mass, this is thought to be the centre for the cognitive functions of language, learning, memory and complex thought.



Opportunities: With our expertise in ICT and pharmaceuticals, Ireland is well-placed to develop digital or eHealth systems and services, much as several Irish companies have already successfully done for the financial services sector. There is a real opportunity for Ireland to develop advanced IT solutions for the management of complex and distributed biobanks. There are also particular opportunities in ICT solutions that would support ageing-in-place, tele-medicine and cradle-to-grave health records.

RFIDs & Sensors

The emerging technology of radio frequency identity (RFID) tags will mature over the coming years and by 2030 will probably be ubiquitous. Couple this with new and smaller sensors, IT systems and mobile telephones, and you can create a network that could be used, for instance, to unobtrusively watch over older people living at home alone. An automated system could then alert a family member or community nurse if, say, the person has not drunk sufficient fluids, and is at risk of dehydrating, or failed to take a pill. By facilitating more 'ageing in place' this could help elderly people to remain active and independent, reduce the need for long-term hospital care and move our healthcare system more towards 'promoting wellness' and away from treating illness. For this to be successful, it will need not just technology, but also for families and the wider community to be involved, and for all of us to address wider questions such as housing design and social environments.

IBM officially opened its largest R&D centre for RFID technology in March 2006 at its Mulhuddart campus near Dublin, one of only two such centres it has in Europe. Intel's research and development innovation centre, also based in Ireland, already has an international reputation with a number of projects exploiting RFID technology in healthcare settings, in particular matching patients to their files, and babies to mothers. In a project at St Vincent's Hospital in Birmingham, Alabama, their RFID technology cut admission and discharge time by over 80%; the time when a bed was empty dropped from eight-hours to under one hour, and throughput increased by 40%. The same project revealed that the hospital had up to 50% excess stock on its books, because when doctors and nurses could not find an item, as frequently happened, they ordered a new one. Thanks to RFIDs, staff can now locate equipment instantly (source: *Intel White Paper on RFID at St Vincent's Hospital (Alabama)*, 2005).
Since RFID technology can be used to tag products and even individual vials, it could help in tracking items and in facilitating product recall, as in the scheme pioneered at St James's Hospital in Dublin to track all haemophilia products from source to patient (see panel below). It could also be employed to tackle counterfeiting in the pharmaceutical industry, which currently costs an estimated $30 billion. It is thought that up to 50% of the anti-

Tracking haemophilia drugs

THE DRUGS that patients receive must be genuine and uncontaminated. It can be a matter of life and death: contamination problems in the supply of haemophilia care here left some 250 haemophiliacs infected with HIV and Hepatitis C. Following the Lindsay Tribunal report (2002), the National Centre for Hereditary Coagulation Disorders (NCHCD) at St James's Hospital, Dublin, successfully pioneered a system to track and trace the drugs administered to haemophilia patients. Their solution, a world first, uses barcodes and electronic product codes, plus the European global service relationship number (GSRN) to identify individual patients. Each vial of clotting factor can now be traced to when a patient is treated, the hospital can initiate a comprehensive product recall if needed, and the new system also reduced documentation errors and eliminated medical wastage, saving the centre €120,000 over the 2-year project. Result: logistical and operational excellence combined with clinical excellence. Currently, the product codes are added at the point of importation by Temperature Controlled Pharmaceuticals (TCP) in partnership with GS1 Ireland; it will be 12-18 months before the pharmaceutical industry is ready to add codes at the point of manufacture. The 'proof of concept' trial reported in February 2006, and will be rolled out to other hospitals later this year. Eventually, the system will incorporate RFID tags and low-cost RFID readers.

malarial drugs on sale in Africa could be bogus, with many of them containing ingredients that do not work or worse, are dangerous. In February 2006 the WHO announced a global task force to track down and prosecute people making and selling bogus drugs.

Opportunities: Ireland has considerable academic expertise in RFID and sensor technologies (e.g. the National Centre for Sensor Research at DCU), and is a recognised centre for software development. The presence in Ireland of IBM's new RFID centre, and Intel's IT innovation centre, which is championing RFID technology, are added pluses. We can build on this expertise to design innovative technological solutions and systems to benefit patients and the healthcare system as a whole, and to create a job opportunities for Irish SMEs.

Nanotechnology

Miniaturised devices, new materials, superior diagnostics and biosensors, improved imaging techniques and innovative technologies to enable tissue regeneration . . . Just some of the healthcare potential being promised by nanotechnology, arguably the most commercially exciting scientific and technological development in recent years. Nanotechnology refers to a radically new approach to building things from the bottom up by manipulating individual atoms and molecules, with scientists, technologists and engineers working at the scale of a nano-metre, or one billionth of a metre (the term *nano* derives from the Greek word for a dwarf). It is a cross-disciplinary and enabling technology with profound implications across many economic activities, including healthcare and medicine – indeed, the usual poster product for nanotechnology is a microscopic injectable robot that would perform operations inside the human body, such as scrubbing blocked arteries (though some nanotechnologists say such a device is unlikely).

This is likely to be one of the core technologies of the next 25 years, and it is important that Ireland be actively involved. Nanotechnology is, crucially, a new discipline that is neither physics nor chemistry nor biology, and we must therefore plan carefully how to train and educate nanotechnologists, and how to incorporate and interface this new field with existing educational and research structures. To be successful, it is also an area that will require considerable resources in terms of facilities and expertise, and possibly regulatory guidelines to ensure safe transfer of nanotechnology from the laboratory to the bedside.

The global market for nano-tools is currently estimated at €2.5 billion, and expected to reach €1 trillion by 2010, and not surprisingly, most countries are pushing nanotechnology R&D programmes (source: *NanoIreland Introduction*, 2005). Ireland has several research groups, variously funded under SFI, the PRTLI's dedicated nanomaterials and nanoscience interdisciplinary programme, and the EU's 6th Framework Programme: the Centre for Research on Adaptive Nano-structures and Nano-devices (CRANN) and the Sami Nasr Institute for Advanced Materials Science, both at TCD, the National Centre for Sensor Research (NCSR) at DCU, and the Tyndall National Institute in Cork. New Irish nanotechnology companies include Ntera and Deerac Fluidics, which sprang from research in UCD and TCD respectively.

The ESF European Research Medical Council believes that nanomedicine will become increasingly important in the coming 25 years (*Forward Look on Nanomedicine*, 2005), exploiting molecular tools and molecular knowledge of the human body. Miniaturised devices, chip-based technologies and ever more sophisticated nano-materials and chemical assemblies are already contributing to improved healthcare and we are likely to see nanoscience and nanotechnology impinging on areas such as analytical tools, imaging, materials and devices, and new diagnostics, therapeutics and drug delivery systems. Nanoelectronics-based biosensors, for instance, should speed and simplify measurements at the molecular level, and continue the revolution begun by the development of microelectronics.

Opportunities: There are undoubtedly opportunities in nanotechnology and nano-medicine for Ireland to exploit. We welcome the NanoIreland initiative established last year by Forfás, and welcome in particular that healthcare is a core consideration in its technology assessment exercise.

Concerns

Many of the future developments outlined above raise ethical and moral questions, the use of embryonic stem cells already being a case in point. New diagnostic techniques and tests will also generate more information, but this information, especially genetic information, could become a burden. Already, women with a family history of breast cancer are faced with a painful dilemma: take a breast cancer gene test, and possibly compromise their insurance rating; or have a preventive mastectomy instead?

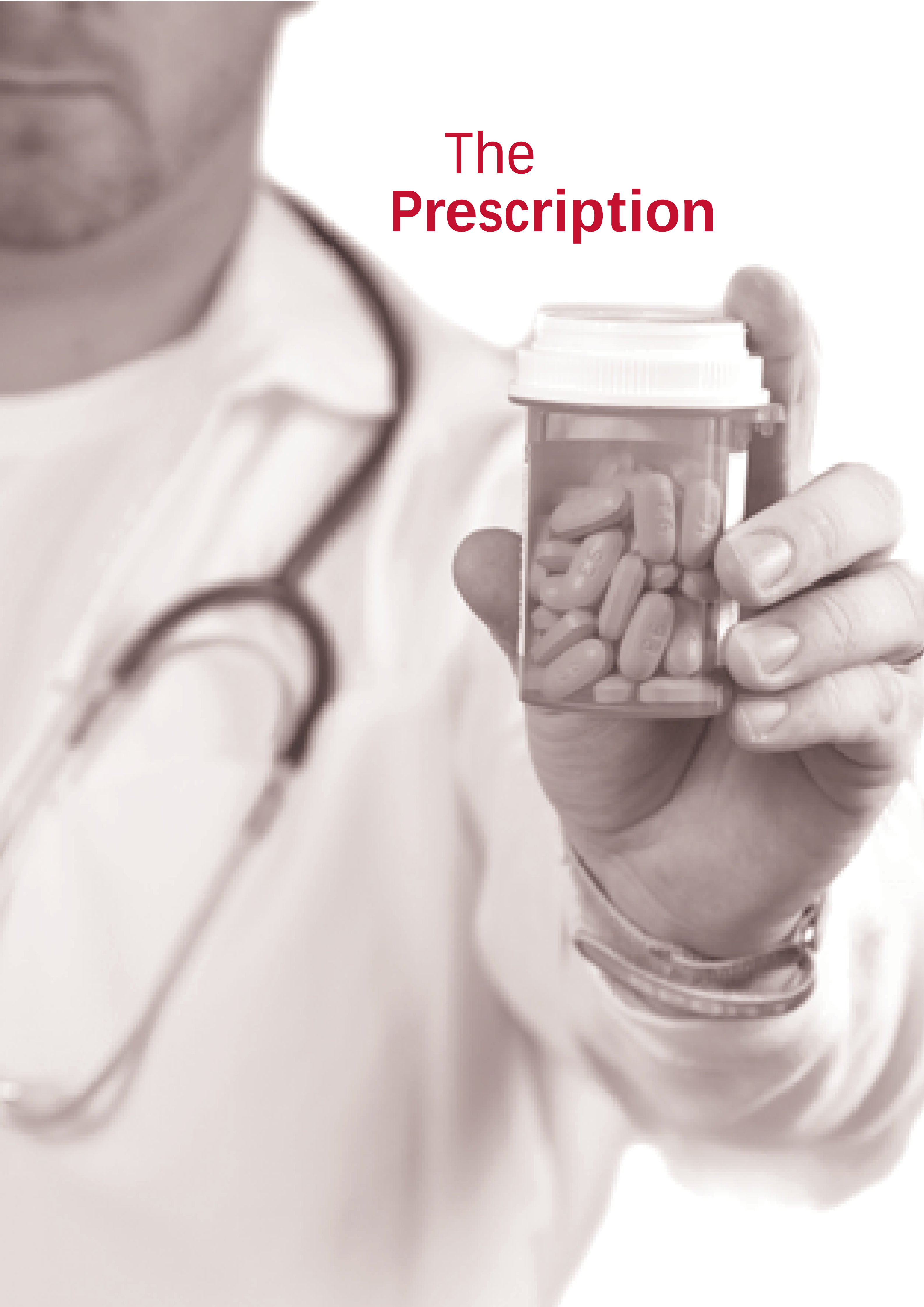
With more and cheaper tests possible, the more likely it is that something will be found. Not everything that is found needs to be treated, but does a patient need to be told if something has been found? In one recent US study, people who had one abnormal blood pressure reading and who were informed of the result, went on to become less well and to experience more absenteeism than those who had not been informed of their result. More information may well catch some illnesses early, but produce more neuroses and swell the ranks of 'the worried well'. And if a person opts for a follow-up investigation, will we be adding unnecessarily to the waiting lists, and committing some people to unnecessary surgery? These questions raise important ethical and resource implications. The British Medical Association has concluded, for instance, that most 'executive health checks' offer little value: an electrocardiogram, for example, is of little benefit to someone who has not been diagnosed with heart disease; a once-off blood pressure measurement will likewise have little value; and screening for cancer outside the high-risk groups is likely to produce more false positives.

Beyond the narrow focus of our own shores lie the major problems of diseases such as HIV/AIDS, malaria, polio and even diarrhoea in Third World countries. Proper use of anti-retroviral therapy can allow many infected with HIV/AIDS to lead normal, healthy, and productive lives, while many of the other diseases could be controlled with what seem like relatively simple preventive measures, such as clean water, mosquito nets and vaccines. But such seemingly simple measures can raise major socio-political issues. Yet here too we can play our part: leprosy has not been prevalent in Ireland since medieval times, but such is the serendipity of scientific research that Irish scientists discovered a powerful leprosy drug while chasing a cure for TB (see panel below). And then there are the fundamental ethical questions of who will pay for what may well be expensive treatment, and who will benefit – the wealthy few? Or can we in Ireland find a way to make this healthy future available to everyone?

Leprosy and serendipity

IN THE 1940s, Irish scientists began looking for a chemical cure for tuberculosis. They failed – but they did find a cure for leprosy, and one which is still recommended by the WHO. Led by Prof Vincent Barry (1908-75) and funded by the then Irish Medical Research Council (MRC), the scientists spent years making and testing thousands of chemicals. None was effective against TB, but fortunately antibiotics had become available by then. One compound, however, a modified form of a red dye originally extracted from a lichen, was also tested on the bacterium that causes leprosy, which is a close cousin of the tuberculosis bacterium. The results were spectacular, 22 countries asked to join the clinical trial, and in 1981 the new Irish drug, by then called Clofazimine, won the UNESCO prize for science. In recent years it has also been tested as a cancer treatment and to promote wound healing.

The Prescription



There is much that engineering and the application of science and technology can do to make Ireland's health-care system more patient-centred, more efficient and more effective for the benefit of all.

There is tremendous opportunity here for Ireland to produce innovative, commercial solutions that would maintain our healthcare industry at a world-class standard, helping to secure and grow new and better jobs and build a smarter, better healthcare sector. Many of these solutions could also be exported to help improve healthcare in other countries and provide an economic benefit for Ireland Inc.

With these opportunities come challenges, however – how to put in place the necessary enablers, how best to structure our commercial, business and research environments and educational systems, and how to facilitate the inter-disciplinary work that is essential if this bright future is to be achieved. The challenge is not merely the technology, but a well-thought out long-term vision and its implementation. In particular, we need to find ways to incentivise both involvement and investment.

Policy and planning

Recommendation: Health and healthcare should be a core element in every aspect of Government planning, policy and activity. Prevention rather than cure must be the objective, moving from treating the sick to keeping people well. To arrest soaring health costs, long-term vision and implementation are called for. We believe that this report and its recommendations are a valuable first step towards this end.

Rationale: Your health is your wealth – something that is as true for communities and countries as it is for individuals. Some of the many social and environmental policy areas that affect our health include waste disposal, energy use, air quality, public transport, even urban planning, IT infrastructure and broadband – the latter, by facilitating tele-working can, for instance, help to reduce commuting, stress and childcare worries.

It is neither the strongest species that survive, nor the most intelligent, but those that are best prepared for change

Charles Darwin

Some of the greatest improvements in public health have come from social and public engineering initiatives, such as the provision of clean water in the 19^{th} century, the switch to smokeless fuels in the 20^{th} century and the more recent smoking ban. Being preventive health measures, these were particularly cost-effective. Engineers played a major role in some of these developments. Major areas that remain to be tackled, and where engineers can again play a crucial role, are health and safety, namely: workplace safety, such as in farming and construction; improving the air quality in our towns and cities, particularly reducing particulates and emissions from vehicle exhausts; and improving road safety. By implementing good engineering practice and design it will be possible to 'engineer out' health and safety problems.

The Prescription

Most Government policy and planning ignores the direct and indirect health and healthcare implications. *Transport 21*, for instance, makes practically no mention of health and safety, despite the fact that road traffic accidents are a major cause of death and disability and a significant burden on the healthcare system. In the ten years planned for *Transport 21*, without a step change in our road-safety culture, we can expect 5,000 people to be killed on our roads and 50,000 people to be seriously injured. At a conservative estimate, road traffic accidents cost our health-care system €50 million a year (based on figures compiled by Goodbody Economic Consultants in 2000, and allowing for medical inflation in the interim).

> *As for the future, your task is not to foresee, but to enable it*
>
> *Antoine de Saint-Exupéry*

'Health impact assessments', taking account of all the factors that can impact directly and indirectly on the health of a community, should become a requirement in all policy and planning initiatives, just as environmental impact assessments have become standard as part of planning applications. The report on '*Traffic & Transport in Ballymun*', a health impact assessment (HIA) conducted by the then Eastern Regional Health Authority (2004), is a model of the kind of approach that should become the norm. We welcome the Department of Health & Children's commitment to introduce HIAs as part of the public policy process development (*Quality & Fairness: a Health System for You*, 2001). The Interdepartmental Committee on Science & Technology, which is currently preparing its strategy for promoting science, technology and innovation into 2013 (as part of the Government's action plan for investment in R&D, *Building Ireland's Knowledge Economy* (2004)), should include health research as a core consideration.

The engineering profession has much to contribute to planning and policy as it affects health and society, both through its comprehensive 'systems approach' to problem solving, and the technological solutions it can offer.

Actions: To protect and improve the population's health and well-being, concern for health and healthcare should be mainstreamed across all Government departments. We need a 'grand coalition' for healthcare. The Department of Health and the Health Services Executive (HSE) should establish an innovations and policy think tank or foresight forum to ensure that this happens, and the engineering profession should be represented on this body. 'Health impact assessments' should be a requirement in all policy and planning initiatives. There may also be a need for a Cabinet sub-committee on health and healthcare, similar to that established for science and technology. The Government should fill the position of chief scientist as a matter of urgency, as a cornerstone of our national scientific and policy infrastructure.

Education and training

Education is one of the main factors underpinning our current success, and it is also key to the future.

Second-level education – Recommendations: We need to increase the numbers of students taking science, engineering and technology subjects at second- and through to third-level.

Rationale: The numbers of students taking Leaving Certificate science subjects declined worryingly in recent years, albeit a trend seen in most other Western countries. It prompted the establishment here of the Task Force on the Physical Sciences, and its report (2002), recommended a wide-ranging strategy to address the problem at a cost of €178 million, plus an additional €66 million each year. A few of its recommendations have since been implemented and this current taskforce welcomes in particular the strengthening of the science and engineering public awareness campaign (now called Discover Science & Engineering, DSE), the commitment to establish a national science centre (the 'Exploration Station' beside Dublin's Heuston train station), and SFI's establishment

of the secondary teacher assistant researchers programme (STARs) which facilitates research links between teachers and SFI-funded scientists and engineers. The remaining recommendations in the Task Force report should be implemented, without delay.

In 2005, the numbers of students studying Leaving Certificate science seems to have stabilised, with 44% studying biology (up from 41% in 2004), 13% chemistry, and 14% physics. However, this compares with participation rates of 16% for chemistry in 1990, 20% for physics in 1990 and 52% for biology in 1988. Also, the numbers choosing honours (higher) chemistry and physics in particular remains low, at 11% and 10% respectively (source: www.examinations.ie).

Making science a core subject at Junior Certificate, while important in fostering scientific understanding and literacy, is unlikely to increase the numbers studying honours science subjects at Leaving Certificate and third-level (already at least 87% of Junior Certificate students study science). However, more emphasis on science, engineering and technology during Transition Year modules and activities could translate into a greater appreciation of the career and educational potential of these subjects. The STEPS to engineering programme for schools run by Engineers Ireland is a valuable initiative in this area. Disappointingly, there remain a number of schools that do not offer all subjects at Leaving Certificate level. If we are to have a national policy to foster science, engineering and technology, there should be a bias towards mathematics and science subjects in the points system.

Actions: Invest heavily in resources and training for the new Primary School Science Curriculum so that children are imbued with the excitement of scientific discovery. Ensure that all schools can offer all science subjects to higher Leaving Certificate level. Incentivise and support science teachers (e.g. support for further education and training, and work-placement and exchange programmes with industry and academia). Increase the emphasis on science and engineering in Transition Year. Double SFI's STARs programme, with more emphasis on collaborations in engineering, healthcare-related and biomedical research. Implement fully the recommendations contained in the report of the Taskforce on the Physical Sciences. Modify the Leaving Certificate points system to give a bias towards subjects such as mathematics, physics, chemistry and biology.

Third- and fourth-level education – Recommendations: Dramatically increase the numbers studying the relevant science and engineering subjects at third-level, and the numbers of graduates who proceed to fourth-level (Masters and PhD). Review the structure and nature of engineering and IT training and courses.

Rationale: Ireland currently produces about 3,800 science graduates (Bachelor degrees) 1,700 level 8 engineering graduates, 1,600 engineering technologists, and 2,600 computer science graduates each year. The numbers have fallen in recent times, yet these are the very types of graduates we will need for an innovation-driven economy. The Engineers Ireland / Irish Academy of Engineering report, *Engineering a Knowledge Island 2020* (2005), projects that by 2020 we will need nearly to treble the numbers of people with engineering and IT qualifications (from 40,000 and 42,000 respectively, to about 110-115,000), or a consistent 7% increase in output each year.

Many of the major future developments will emerge from the convergence of diverse technologies. To work creatively in, and to tackle the problems arising in healthcare and medicine, we need to train our scientists, engineers, technologists and medical professionals so that they can work and communicate in these new cross-disciplinary areas. And we need to produce a new generation of engineers who can think creatively in other disciplines, and work successfully in multi-disciplinary teams.

To meet the these future needs, we must increase specifically the numbers studying chemistry, process chemistry, biosystems and biomedical engineering, which currently account for a mere 12% of engineering students. Undergraduate courses should remain broad and disciplinary, but should include modules or projects that provide training in teamwork, communication skills, and business and entrepreneurship. (This could be as simple as introducing an inter-disciplinary team project in, say, third year.) Engineering courses in particular are short on the so-called 'soft' skills, yet two-thirds of graduates will end up working in industry – and we need to prepare them for that.

Ireland needs to develop an expertise in biomedical informatics, bio-informatics and epidemiology if we are to play an active role in analysing the next generation of data sets emerging from current DNA sequence and genomic research. The increasing complexity of biological and medical data sets will call for a quantum leap in computing power and in software for the analyses. Ireland should position herself to be ready for this next generation of petabyte databases which will require new and inter-disciplinary computing and programming styles.

We need to address specific skills gaps: in engineering, by providing courses and training in bioengineering and biomedicine; and in IT and informatics by developing new courses in bio-informatics, epidemiology, and combined mathematics and computing. These inter-disciplinary specialisations will require longer and more flexible training than conventional courses and would be best suited to the proposed new five-year Bologna-style Masters degree (see Appendix I on the Bologna-style degree).

Greater involvement by the pharma-chemical industry would assist in refining the curriculum of undergraduate courses, in sourcing work placements for students, and in attracting investment for research and facilities, and thus help make these courses more attractive to students.

If we are to produce the best engineering, science and medicine graduates, we need to continue to foster and reward excellence in teaching.

Most importantly, we need to increase the numbers of graduates who proceed to fourth-level (Masters or PhD), not least to meet the EU's Lisbon Agenda, which commits Ireland to increasing its R&D capability and to an R&D spend of 3% of GNP by 2013. Ireland currently produces 75 science and engineering PhDs per million population, compared to 180 in Finland. To meet our Lisbon commitment, and to drive the knowledge economy, we need to treble our Masters and PhD output by at least 2020 – effectively a 10-13% increase per year. Already there is a demand for more PhD places, with IRCSET admitting that good quality applicants are turned down each year due to a limited number of places.

Currently, just 10% of engineers in the Republic of Ireland proceed to an MSc, and only 2% to a PhD. This contrasts with 36% and 8% respectively in Northern Ireland. The transfer rate is better among science graduates, with an estimated 15% and 9% proceeding to Masters and PhD respectively (source: HEA First Destination Survey, 2004). The much lower transfer rate among engineers is not unique to Ireland and is partly due to the fact that engineers are more likely to find a job on graduating, and partly because there is relatively little R&D in

Irish industry. Better post-graduate funding, to ensure that students do not lose out financially by turning down a job on graduation in preference to research, will help to increase the numbers of engineers in particular who proceed to fourth-level. The maintenance allowance (stipend) for someone on an IRCSET PhD grant was a mere €12,700 in 2005, but rising to €16,000 in October 2006. In comparison, the starting salary for a engineering graduate is €29,000 (source: Engineers Ireland salary survey 2005). The research stipend is admittedly tax-free, and someone with a PhD will ultimately earn more than someone with only a primary degree. Nevertheless, to attract the best students into research, we believe the stipend should be increased to €20,000. The overall research budget must be increased to accommodate this, so that the same number of grants are awarded. Better financial incentives would also attract people in the workplace, and those who have left the workforce, into research.

Structured PhD programmes, such as the Integrative Graduate Education and Research Traineeship (IGERT) run by the USA's National Science Foundation (see Appendix II) would facilitate and foster inter-disciplinary research in areas such as bio-informatics and bio-medical engineering. Finally, we also need to establish Graduate Schools: these would offer the best opportunities to PhD students, and facilitate links with industry and foster entrepreneurship and other important skills.

To this end, this task force welcomes the Government's recent commitment to '4th Level Ireland' and the 2005 Budget allocation of €300 million for the new Strategic Innovation Fund and €900 million for capital funding and infrastructure. These measures should increase the numbers of Masters and PhD graduates, and ensure new core programmes, feeder pathways and life-long learning and skills initiatives.

In addition to attracting more school leavers into science and engineering, other sources of personnel include: those already working in industry, qualified graduates from overseas, people who have opted out of the workforce (e.g. for family reasons), and women. The success of SFI, HRB and other funding programmes mean Ireland is now an internationally recognised research location, capable of attracting researchers from overseas. India and China, while usually viewed as our economic competitors, could be a valuable source of research students, especially the elite Indian Institute of Technology. Women remain seriously under-represented in Irish engineering in particular – on average, some 15% of students on engineering programmes are women – and are a significant untapped resource. New courses in areas such as bio-engineering and medical engineering may be more successful in appealing to women than the more traditional civil and mechanical engineering, and already 50% of the students taking NUI Galway's bioengineering degree are women.

Actions: Review and revise undergraduate courses, and create new inter-disciplinary courses to address specific skills needs (some of these will be of the new Bologna-style five-year Masters degree). Increase the output of science and engineering graduates by 7% annually over the next 15-20 years. Increase the funding and places available for Masters and PhD students by 10-15% annually over the next 20 years. Examine the reasons for the better conversion rates to postgraduate programmes in Northern Ireland, so these can be replicated in the Republic. Increase the stipend for PhD and Masters students, so that those who proceed to research do not overly lose out financially. Explore the possibility of IRCSET funding for engineering PhDs in industry. Establish graduate schools and structured PhD programmes. Foster and reward excellence in science, engineering and technical teaching with financial incentives, and the opportunity to participate in innovative programmes. Make greater efforts to attract women into engineering. Demand more from and provide better rewards and career paths for engineering graduates.

The Prescription

The research environment

Recommendation: Develop expertise in the new and emerging sciences, foster inter-disciplinary research, create a supportive research environment with a commitment to long-term funding, encourage collaborations across industry, academia and clinical medicine, and drive an expectation or belief in the realisation of commercial benefit from the research effort.

Rationale: Successful and innovative research will be crucial to developing efficient, patient-centred healthcare for 2030. In recent years, Ireland has significantly ramped up its research programme and increased R&D spending – in particular with the HEA's €605 million capital funding programme for research in the third-level institutions (PRTLI), increased funding for the HRB and the establishment of SFI. To date, SFI has committed some €550 million in funding to over 600 projects, and succeeded in attracting world-class research teams to Ireland. Public funding of R&D is estimated to have hit a record €1.9 billion in 2005. This represents a substantial rise from 1.23% of GNP in 1995, to 1.5% in 2005, though still below the EU and OECD averages of 1.85% and 2.24 % of GDP respectively. (Source: Forfás, *State Expenditure on Science & Technology and Research & Development 2004-2005*).

This task force welcomes the Government's National Action Plan on R&D (*Building Ireland's Knowledge Economy*, 2004), and its commitments to further increase R&D funding to 2.5% of GNP and to double the number of researchers here by 2010. We also note Ireland's success in the EU's highly competitive Marie Curie programme – attracting some 220 researchers here from abroad, and funding of €42 million. We welcome too the recent initiatives by Enterprise Ireland and the IDA, along the lines of those recommended by the Enterprise Strategy Group (*Ahead of the Curve*, 2004), to increase research links and capability in industry and commercialise publicly funded research in the HEIs, namely: the Innovation Partnerships, the Industry-led Networks, and the Applied Research Enhancement Scheme. The new Irish Centre for High-End Computing (ICHEC), a consortium providing supercomputing facilities for research, and headquartered at NUI Galway, is another important element of the national research infrastructure.

A research location: These successes mean that Ireland is clearly an internationally attractive research location. We believe that Ireland can now be convincingly marketed as an R&D location for MNCs, capitalising on the

An Irish nicotine patch

THE WORLD's first commercial nicotine patch was developed in Ireland, by a team of chemists and pharmaceutical scientists from Trinity College Dublin and commercial researchers from Elan Pharmaceuticals. Their transdermal patch – a way of delivering nicotine across the wearer's skin – was designed, and the prototypes made, at TCD, and the clinical trials took place at Elan's Athlone centre. Their transdermal drug delivery work resulted in at least three US patents and over 20 publications, and a commercially successful product that was licensed in over 20 countries, with TCD benefiting from the royalties. It's a fine example of what can happen when a pharmaceutical company collaborates with solid state diffusion and pharmaceutical chemists. Read the details in US Patent No. 4946853 (1990). And take a bow, John Corish, Owen I. Corrigan and Yvonne Bannon (in the TCD corner) and Joe Masterson and Eddie Geoghan for Elan.

increasing globalisation and mobility of R&D functions. Significantly, a number of multinationals have established R&D units and relationships here in recent months – witness Wyeth's bio-therapeutic drug discovery research facility (at UCD), Bristol Myers Squibb Centre for Bioanalytical Sciences in association with DCU and NUI Galway, the Institute of Microelectronics & Wireless Systems at NUI Maynooth in partnership with Bell Labs, and the Vodafone Group's new innovation centre. Such R&D facilities, being costly and time-consuming to establish, can help to anchor MNCs in Ireland, because they are therefore less likely to be moved, and with the added advantage that they help to generate higher-value jobs and outputs. Promoting Ireland as a venue for major conferences would also raise our international research profile.

Fostering industry-research collaborations: Collaborations between industrial partners and higher education and research institutions are win-win situations for all parties. They bring a wide range of benefits, such as new intellectual property, commercial spin-offs, licences, jobs and revenue, and the research challenge of tackling real-life problems. They also improve networking and education, and increase our stock of codified knowledge.

Commercial and university collaborations may take many forms, as outlined in the UK report, *The Future of Engineering Research* (Royal Academy of Engineering, 2003): industry-sponsored undergraduate, postgraduate and foundation degrees; knowledge transfer partnerships; professional development courses run by universities for industry; secondment of academics to industry, and vice versa; industry-sponsored research projects, students and research chairs; major partnerships between universities and large companies; and joint ventures, such as centres and institutes. The exchange of personnel between higher education institutes and business can help transfer skills, knowledge and technology, and improve mutual understanding and awareness. All of which serves to enhance the health of research and facilitate the creation of wealth and other societal benefits.

Real interactions and collaborative research are already taking shape in Irish universities, research hospitals and industry, and there have even been some notable early successes (see panel opposite). It helps that universities and researchers are increasingly aware of industry's needs and aims, and concerns regarding intellectual property and especially confidentiality. SFI's €120 million campus-industry partnership programme (the seven Centres for Science, Engineering, and Technology, aka the CSETs, see panel below) has helped to structure substantial industry-research collaborations in a number of targeted areas. For example, the BDI CSET at DCU has six

Campus-industry partnerships

SFI's campus-industry research programme funds collaborations between scientists, engineers and industry. To date, seven Centres for Science, Engineering & Technology (CSETs) have been established, with funding of €120 million to address crucial research questions, foster new and existing Irish-based technology companies, attract industry that could make an important contribution to Ireland and its economy, and expand the educational and career opportunities in science and engineering here. The seven CSETS are:

Alimentary Pharmabiotic Centre (apc.ucc.ie), UCC
Digital Enterprise Research Institute (www.deri.ie), NUIG
Centre for Research on Adaptive Nanostructures & Nanodevices (www.tcd.ie/Physics/Crann), TCD
Regenerative Medicine Institute (www.nuigalway.ie/remedi) NUIG
Centre for Telecommunications Value-Chain-Driven Research (ctvr.tcd.ie), TCD
Irish Software Engineering Research Centre (www.iserc.ie), UL
Biomedical Diagnostic Institute (BDI, www.bdi.ie), DCU

industrial partners, each of which is placing researchers in the BDI laboratories. Another model for industry / academia collaborations is that recently developed by IDA Ireland, and exemplified by the Centre for Bioanalytical Sciences, established by DCU and NUI Galway in partnership with Bristol Myers Squibb.

Conversely, there are moves within industry here to conduct increasingly pure research, notably Boston Scientific's research and development team which successfully developed the new drug-eluting stent (see page 21), and the recent Wyeth initiatives. The time is therefore ripe to encourage further research and further collaborations. We need to encourage more exchange of personnel between industry and academia, and publish guidelines for successful collaborations to help eliminate misunderstandings and other obstacles. It is essential, however, that in the rush to support industrial collaborations, we do not stifle fundamental and basic research.

Inter-disciplinary research: Truly innovative research happens at the interfaces between disciplines. Future progress in healthcare, bio-medicine and bio-engineering will come only if there is interaction across these disciplines. To generate inter-disciplinary work, however, you first need to produce people who are expert in a particular discipline, and who can work in interdisciplinary teams. This calls for more PhD graduates in engineering, science and clinical medical research, and other highly qualified personnel (see: Third- and fourth-level education, above). We also need spaces where people from different disciplines can meet and collaborate. We need to break down the traditional subject barriers, and create forums, networks and research spaces where engineers, scientists and clinicians can meet, debate and work together.

The next generation of therapies (such as stem cell therapies, and targeted pharmacogenomic-based drugs tailored to a person's genetic makeup) will be more costly than current ones, and they will be targeted at smaller sub-groups of patients. We need to move now to develop expertise, courses and research programmes in the key areas – notably small molecule design, biocatalysis, medical devices, new materials, nanomedicine, biopharmaceuticals, diagnostics, bio-informatics, and the related IT areas – so that Ireland can make meaningful research progress here, and so that we will be able to afford these technologies for our healthcare service. Establishing a centre of excellence in materials science would be particularly beneficial, especially in the area of medical devices.

Support and reward research: Researchers face increasing administrative burdens and demands on their time. We need to design research funding and introduce support schemes (e.g. greater and easier access to sabbatical leave, and the provision of teaching assistants) so that scientists and clinicians have sufficient time and resources to engage in research. We should incentivise research (e.g. by providing access to equipment, to real problems, and to rewards). IBM's 'visiting scientist' programme, offering academics access to IBM Labs and real world problems, is a good collaborative model.We should also reward excellence in research (e.g. based on citation indices, or the tenure track system as recommended by the OECD).

Actions: Continue Ireland's ongoing commitment to expanding our research capability and funding. Promote Ireland as an R&D location for MNCs, and as a venue for major international research conferences and events. Develop expertise and research programmes in key areas and establish a centre of excellence in materials science. Foster interdisciplinary networks and research. Encourage and reward excellence in research. Ensure that researchers have the support, time and resources to engage in research. Institute ready mechanisms to assist and support researchers and academics to translate their technical success into commercial benefit. Encourage exchange of personnel between industry and academia. Publish guidelines for successful industry-academia collaborations. Continue to expand funding and support for fundamental and basic research.

The global and business environment

Recommendation: Foster an innovative and entrepreneurial culture, and create a supportive tax and legislative environment that will encourage involvement and investment, and stimulate research, industry and business.

Rationale: By 2030 Ireland will most definitely not be a low-cost manufacturing location. Already we are seeing the emergence of India and China as new industrial world economies and ever more manufacturing and service jobs moving to countries where labour is cheaper – witness, for instance NEC Semiconductor's decision in February 2006 to relocate to Asia from Co Meath. We need to view these changes not as a threat, but as opportunities for Ireland to move its manufacturing sector higher up the value chain. Moreover, we need to remember that competitiveness is not just about cost, but about identifying and capitalising on a unique selling point, and having the ability and flexibility to deliver what people want and need.

The Irish, as we discovered during the Tiger years, can be successful entrepreneurs. Indeed, in 2005 Mazars and the Global Entrepreneurship Monitor (www.mazars.com) ranked Ireland third, behind only North America and Australia (based on the per capita proportion of high-expectation entrepreneurs and 'business venturers' who declared an intention to hire at least 20 people over the next five years). To foster a high-technology manufacturing sector, we need to encourage these entrepreneurs and would-be entrepreneurs. Initiatives such as the annual Entrepreneur of the Year Award can help promote a greater awareness of our innate innovative abilities.

We need to switch from property development to 'intellectual property development'

Enterprise Ireland's successful programme to identify and support high-potential start-ups (HPSUs) has supported over 340 new businesses since 1998. These are a significant source of new high-value jobs: the 65 companies supported in 2004 expect to employ nearly 2,000 people by 2009. Among the many successes is Opsona Therapeutics, a TCD campus company that recently signed a collaboration deal with Wyeth Pharmaceuticals to research and develop new drugs to treat inflammatory diseases, including multiple sclerosis and rheumatoid arthritis. Enterprise Ireland's BioLink, Techlink and BioConnect programmes, to encourage networking and mentoring, and to entice potential biotechnology researchers and entrepreneurs to relocate to Ireland, are other important initiatives. The new IDA BioPharma Ireland facility in Co Galway – a fully serviced site with pre-approved planning permission for biopharma projects – and a similar campus for integrated circuit manufacturing and research at Grange Castle in Clondalkin, Dublin, are examples of a novel approach that should also enable fast start-ups.

To foster a high-technology manufacturing sector, we need to encourage investors and those who fund research and the start-up phase of new companies and technologies. Tax incentive schemes have already been used successfully to encourage investment in property development (e.g. Section 50). We support the Cork Seed Capital group's recommendation to establish similarly attractive, smart schemes to foster the development of Ireland's intellectual infrastructure and entrepreneurial activity. Switching from property development to 'intellectual property development' will foster the long-term economic growth needed to fuel the knowledge economy.
The transition to an innovation-driven economy depends directly on rapid commercialisation of intellectual property generated in the higher education institutions. We must become adept at spotting potential intellectual property, and in generating spin-off companies and licence opportunities. We need to maintain and publicise the existing tax exemption on patent royalties, and to broaden and expand the existing tax credits for R&D.

Intellectual property: IP, while not sufficient in itself, will be essential as we strive to move our health-care industry up the value chain. To date, however, our performance against a range of innovation metrics has been low to average at best – for example, Ireland submitted only 86 patent applications to the European Patent Office in 2001, compared with 367 applications from Sweden (source: *ICT: Creating Europe's Most Attractive Environment for Intellectual Property*, Engineers Ireland submission to SFI, 2004). Measures that would enhance our IP activity could include: increasing people's awareness of intellectual property issues and potential; establishing a sizeable applied research fund (€100 million over five years); establishing an IP commercialisation centre with a €10 million patent fund; and allowing industrial researchers to lead SFI projects.

At the end of the day, however, IP has a shelf-life, and being 'first to market' can be more important than owning the patent. IBM, in a counter-intuitive bid to speed up healthcare research, recently announced it is providing open, royalty-free access to thousands of its patents. The company hopes this 'health-share' move will accelerate the evolution of healthcare and promote open technology standards that will allow disparate IT systems to interact. (Source: www.ibm.com)

Actions: Create new and innovative tax incentive schemes to attract and reward those who invest in research and in new technology-based companies here. Maintain and publicise the existing tax exemption on patent royalties. Broaden and expand the existing tax credits for R&D. Enterprise Ireland and the higher education and research institutes should work to identify and aggressively exploit new intellectual property. Establish a €100 million applied research fund and an IP commercialisation centre with a €10 million patent fund. Allow industrial researchers to lead SFI projects.

ICT Infrastructure

Recommendation: Build and install the requisite advanced IT infrastructure, both within the healthcare and medical systems, and across the country as a whole.

Rationale: The potential of advanced IT, computing and communication technologies, should be harnessed to empower those working in the healthcare sector to greatly improve efficiencies, relieve staff to focus on the crucial role of healing, and to reduce errors. Information technology is a crucial enabler that will, if done right, make it possible to dramatically improve the efficiency and efficacy of our healthcare system, reduce costs, improve the care and conditions for patients, reduce human errors and improve patient survival, and transform our research capability.

This calls for: an integrated electronic patient record system, an integrated IT system linking GPs, diagnostic laboratories, hospitals and clinicians, pharmacies, and clinical and community care centres, and an advanced national broadband network that will facilitate file sharing (especially diagnostic images and videos), and tele-conferencing for remote consultations and ultimately even tele-surgery, allowing centralised expertise to be made available nationally.

Ulcerous feet and tele-medicine

PEOPLE with diabetes often develop foot ulcers which, if not properly treated, can result in amputation of toes, feet or even a leg. It's just one of the complications of a disease that affects 3-5% of the Irish population, and consumes an estimated 10-15% of the total health budget. Diabetic foot ulcers are generally treated in the community, not necessarily under the care of an expert. But international trials have shown that a real-time interactive telemedicine consultation, connecting the home-care staff to a hospital-based expert and using simple digital photography, can be highly effective. Such a system would be one of the benefits that could follow from installing an advanced IT network across Ireland.

Such a system would greatly reduce the time hospital staff spend searching for files – according to some estimates, as much of 30% of their time is wasted looking for files and equipment. Significantly, it would also dramatically reduce the frequency and severity of medical errors (mis-prescription of drugs, incorrect blood group transfusions, etc.). The use of 'point of care' devices and instrumentation will become increasingly commonplace and will require a communication system that is able to record, store, extract and manage data in order to provide ready diagnosis and treatment.

The recent controversy over the cost and implementation of the HSE's PPARS system shows that integrating numerous diverse legacy systems is non-trivial. Already, the UK's NHS system of patient management is increasingly paperless, and Irish trials are proving successful (as in diabetes management, where patients have switched from paper to electronic diaries). In the USA, patients can now create their own electronic health record, and growing numbers of companies there are offering to host these services. Essentially, all that is needed is a unique individual medical number – and the will to implement the system. Participation could initially be voluntary, to accommodate those concerned about confidentiality and privacy, but as internet banking has demonstrated, privacy and confidentiality are not technological issues.

We need to roll out an advanced broadband network across Ireland, and increase uptake of broadband services – in the latest Forfás survey (2005), Ireland ranked 25th out of 32 countries for broadband take-up. There would be indirect health benefits from an advanced IT network: the increased ability to tele- or home-work would reduce commuting, traffic, air pollution and stress, while the improved access to medical information and records would greatly empower patients and individuals. An internet-based medical record system would also obviate the need to develop a smart-card system, though an information card could be useful in emergencies for information on for example allergies and blood group.

Designing and building this integrated system would require tight definitions of standards and protocols so that all the data can be integrated across the healthcare system as a whole, and throughout a patient's lifetime. Archiving and readability of data, and compatibility of storage media will have to be addressed. None of this will be cheap – but the benefits are such that building this system is still cheaper than not building it. And if Irish researchers and firms can design an effective and elegant solution to this problem, then it would have tremendous export and sales potential.

Actions: Upgrade and expand Ireland's broadband network, and ensure that we reach and remain in the upper quartile of the OECD rankings. Establish an integrated healthcare and medical information system.

The healthcare system

Recommendation: There must be a commitment in the health service to research, innovation and development, with defined career structures for all the professions who play a part in its delivery from research clinicians, doctors and nurses, on the one hand, to engineers, IT specialists and technical support staff, on the other. We need to develop our capability and infrastructure for clinical trials and clinical and 'translational' research.

Rationale: Healthcare research: Vibrant research activity in the healthcare sector will lead to improved healthcare for all. We need to foster a culture of research in the healthcare sector, so that it becomes an integral part of care and treatment, so that clinicians and nursing staff can contribute to improvements, and so that patients and volunteers feel comfortable participating in the research. This is research that will benefit society as a whole and which has tremendous power for good. We need to find ways to reconcile the need to protect patient privacy and the right to consent, with the open access ethos that is essential for research. Essential to this will be closer relationships between research institutes and universities and hospitals (e.g. joint-management of research units and projects).

The rapid and continuous development of new technologies, processes and engineering solutions means that we need to make provision for on-going training and career-long learning, especially for those in clinical practice. This will speed up dissemination and implementation, and ensure that the best and latest information is available to both patients and students, with immediate benefits for the healthcare system and for medical education and training here. Curricula and syllabi will have to be reviewed and updated, and on-going training courses provided. Teaching hospitals will be central to this activity.

Currently, some 50% of graduates from Irish medical schools emigrate (due in large part to the high number of students here from outside the EU), and 20% leave medicine altogether. To address these issues, we welcome the new initiatives to revise and expand medical training in Ireland, with a doubling of the number of EU student places and the creation of graduate entry to medical school. Together, these measures should increase the numbers of medical graduates remaining here.

For innovative medical and healthcare research we also need to produce great clinicians and nurses, alongside engineers, scientists and technologists. There needs to be explicit career structures and funding for research clinicians, including the relevant MD and PhD programmes. This task force welcomes the HRB's move, begun in 2005, to fund research clinicians. We especially welcome the Department of Health's commitment to a 20% increase in the number of consultant academic shared positions between hospitals and universities (currently numbering 39), and the appointment as a first step of eight new academic clinicians this year. Medical consultant contracts need to be structured so that research clinicians working abroad can take up similar posts here. Effective clinical research also needs access to trained clinical research nurses who are skilled in taking samples, handling patient consent forms etc. There should be defined career structures and opportunities for clinical research nurses, so that this essential expertise does not evaporate at the end of each project.

Hospitals, and in particular operating theatres, can be hotbeds of innovation with surgeons and clinicians improvising and finding new ways of doing things. We need to find ways to harness and commercialise this potential source of innovative thinking and translate this into meaningful and commercial successes, and resolve any intellectual property ownership issues that might arise. Engineers and engineering principles can play a strong role in making this happen. We need to create fora where clinicians, nurses, engineers and scientists can meet to discuss key challenges and develop innovative solutions, and build on the informal networks already being developed by Enterprise Ireland.

Clinical research and clinical trials: Ireland needs to build new infrastructure to support clinical research, with dedicated clinical research centres (CRCs) for clinical trials, and especially pre-clinical research facilities (e.g. for animal studies). We welcome moves by the HRB, Dublin Molecular Medicine Centre (DMMC) and the Wellcome Trust to establish clinical research facilities here, such as the new ambulatory care units at Dublin's Mater and St Vincent's Hospitals. These will allow us to translate current scientific research into improved therapies and treatments for patients, and meaningful and commercial successes.

The Enterprise Strategy Group and others have identified clinical trials as a major opportunity for Ireland, neatly complementing our existing research and industrial strengths. We therefore support that group's recommendation for the establishment of a Life Sciences Council, modelled on the IFSC's Clearing House Group in the financial sector, and involving bodies such as the HRB, the Irish Medicines Board, industry representatives, state agencies, and higher education and research institutions. We also support the HRB's proposal to establish an all-island GeneLibrary, and the Irish Council for Bioethics recommendation that archive tissue samples be anonymised and made available for research, both of which would greatly facilitate clinical and biomedical research. Finally, the regulatory and ethical environment here should be firm but friendly, with a single national level of review (rather than multiple local reviews, which will otherwise delay research projects and increase the time to patent and the 'time to market').

Actions: The HSE should commit the healthcare system to research as a core activity. Use engineering principles and skills to convert good ideas into workable solutions. Facilitate career-long learning. Create defined career structures for research clinicians and clinical research nurses. Develop a clinical trials infrastructure. Establish a Life Sciences Council and an all-island GeneLibrary. Anonymise archive tissue samples and make these collections available for research. Create a firm and friendly but speedy regulatory and ethical environment.

Conclusion

Ireland has the potential to build a world-class health-care system for the country, and a world-class health-care sector for the economy, to the benefit of us all. We outline in our Prognosis the future potential of health and medicine, and the many diverse opportunities for building a stronger, smarter healthcare industry. In our Prescription, we identify the many initiatives and measures needed across the board if we are to achieve our vision.

In particular, our healthcare system needs to move to promoting wellness, rather than merely treating the sick, shifting from costly late-stage intervention to early cost-effective detection and prevention. We need to 'mainstream' concern for health across all aspects of national planning and policy, and be committed to research and to improving our healthcare system. Our healthcare industry must switch from being investment driven to being innovation driven. And our tax incentive schemes must change from promoting property to promoting intellectual property. Innovation is the key to this healthy future, generating ideas that will form the basis of future healthcare treatments, and helping to anchor multinational R&D teams here.

Many of the next generation of medical and technological breakthroughs, devices and therapies will come from a convergence of diverse technologies and from collaborations between different disciplines. For this to happen we need to create ways for interdisciplinary collaborations to develop, both formally and informally. The problems we face are too big for any one team or company alone, and progress will happen only if we can bring together researchers, industry and those in clinical practice. We must also build the requisite infrastructure: in IT, in education and research, and in clinical practice and translational medicine. Our desire is for every patient to receive the best possible care.

Achieving this by 2030 will take long-term vision and investment, for this is a marathon, not a sprint. We need to continue to build on past and present initiatives, particularly in funding research and education. But this in itself will no longer be enough, especially if we are to grow our healthcare sector in the face of increasing international competition. To survive and prosper, we need to act smart and be clever. And we need to start now.

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Glossary of abbreviations used

CSO	Central Statistics Office (www.cso.ie)
CT	computerised tomography
DCU	Dublin City University (www.dcu.ie)
DMMC	Dublin Molecular Medicine Centre (www.dmmc.ie)
HER	electronic health record
GM	genetically modified
HEA	Higher Education Authority (www.hea.ie)
HEI	higher education institution
HIA	health impact assessment
HPSU	high-potential start-up (company)
HRB	Health Research Board (www.hrb.ie)
HSE	Health Service Executive (www.hse.ie)
ICT	information & communications technologies
IDA	Industrial Development Authority, now IDA Ireland (www.ida.ie)
IIRS	Institute for Industrial Research & Standards, now incorporated in Enterprise Ireland
IP	intellectual property
IRCSET	Irish Research Council for Science, Engineering and Technology
IT	information technology
IVF	*in vitro* fertilisation
MNC	multi-national corporation
MRI	magnetic resonance imaging
MRSA	methicillin resistant *Staphylococcus aureus*
NCBES	National Centre for Biomedical Engineering Science (www.ncbes.ie)
NIBRT	National Institute for BioProcessing Research & Training (www.nibrt.ie)
NUIG	National University of Ireland, Galway (www.nuig.ie)
PRTLI	Programme for Research in the Third-Level Institutions (HEA)
R&D	research and development
RFID	radio-frequency identification
SFI	Science Foundation Ireland (www.sfi.ie)
SLS	selective laser sintering
SME	small-medium enterprise
SPECT	single photon emission computed tomography
TCD	Trinity College Dublin (www.tcd.ie)
UCC	University College Cork (www.ucc.ie)
UCD	University College Dublin (www.ucd.ie)
WHO	World Health Organization

I) Higher education and the Bologna Declaration

The Bologna Declaration was drawn up in the context of the development of a 'Europe of knowledge' through the enhancement of European higher education systems and the creation of a European Area of Higher Education, in which students can easily move from one programme to another and from one country to another. Underwritten by over 40 countries, the Declaration was first signed by 29 countries in 1999. Its six objectives are:

Adopt a system of easily readable and comparable degrees
Adopt a two-cycle higher education
Establish a system of credits
Promote the mobility of students and staff
Promote European co-operation in quality assurance
Promote the European dimension in higher education

The new two-cycle '3+2' higher education system is significant: it will allow for greater flexibility and for more inter-disciplinary training. Following extensive consultation, Engineers Ireland has proposed such a two-cycle structure for engineering education, which will effectively set a Masters-level qualification as the standard for professional engineers. This extended system will also greatly increase the flexibility in the engineering qualification, and enable a more inter-disciplinary approach to be adopted. Graduates of accredited programmes would be deemed by Engineers Ireland to have satisfied the educational standard for the title of Chartered Engineer; at the end of the first cycle, a Bachelor's degree may be awarded.

As an example of the type of degree possible, the first Bologna-style engineering qualification in Ireland is the 'Structural Engineering with Architecture programme' at UCD. A further suite of two-angle Bachelor-Masters programmes will be on offer in UCD from Autumn 2006.

II) The NSF's Integrative Graduate Education and Research Traineeship (IGERT)

This programme is described by the USA's National Science Foundation as having been "developed to meet the challenges of educating US PhD scientists and engineers who will pursue careers in research and education, with the interdisciplinary backgrounds, deep knowledge in chosen disciplines, and technical, professional, and personal skills to become, in their own careers, leaders and creative agents for change. The program is intended to catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. It is also intended to facilitate diversity in student participation and preparation, and to contribute to the development of a diverse, globally-engaged, science and engineering workforce."

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