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Berlin visitors put European

► *Sir William Stewart, FRS, FRSE (left), speaking to Mr Antony Ford, the Deputy Ambassador, who gave the reception at the Kempinski Hotel during the Foundation's event in Berlin.*

'COLLABORATION' was the keyword for the Foundation's event in Berlin organised jointly with the German-British Chamber of Industry and Commerce in London, with the Federation of German Industries, and with WIR, Wirschafts-Initiativen fur Deutschland E.V. The main event was held at the Kempinski Hotel in western Berlin, and attended by about 20 from Britain and 50 from Germany on 31 October 1996.

Sir William Stewart, President of the BioIndustry Association, and Professor C. Birr, Professor at Heidelberg University and managing partner of ORPEGEN Pharma GmbH, started with short talks on collaboration which led to a lively discussion under Lord Butterworth's chairmanship reflecting some similarities in approach to technology foresight and the spawning of SMEs.

Talks were then given by Dr C.H. Hahn, a Member of the supervisory Board of Volkswagen AG; Mr Peter Craine, a director of British Aerospace plc; Herr U. Heider, Director of Daimler-Benz Aerospace AG; and Mr R. Dziabas, Divisional Manager, British Telecommunications plc, all followed by further discussion. The British Embassy then provided a reception at the hotel. Mr Antony Ford, Her Majesty's Minister and Head of the British Embassy Office in Berlin, received guests.

Frau C. Yzer, Parliamentary State Secretary in the German Federal Ministry for Education, Science, Research and Technology, was the principal guest at dinner under the chairmanship of Herr J.C. Gehrels, Chairman of the German-British Chamber of Industry and Commerce in London, and also Chief Executive of Siemens plc, Bracknell.

Frau Yzer talked of collaboration and also of relationships with Brussels and the Framework Programme. She emphasised the different economic backgrounds of the two countries, stressing the importance of 'globalisation', an approach not always seen with favour in Germany.

Co-operation between countries is the keynote as Foundation helps stage German-British industry conference

She spoke of the German intention to establish internationally orientated pilot courses with English as the working language and with qualifications recognised by other countries. Frau Yzer reflected on some of the success of achievements within Europe in such schemes as EUREKA and JESSI, and hoped that European research funding might become more flexible, but that the programmes should be focused on the development of 'cutting-edge' technologies.

She noted that there are some 900 British firms accounting for more than 136,000 jobs in Germany, illustrating close collaboration between the two countries. Mr Antony Ford spoke briefly, describing some aspects of British policy towards collaboration and the European Union.

partnership into practice

▲ *Frau C. Yzer, Parliamentary State Secretary in the German Federal Ministry for Education, Science, Research and Technology, Bonn, talking to Lord Butterworth, CBE, DL, during the dinner held in Berlin on the subject How can German-British collaboration in industry really work?*

◄ *Dinner at the Kempinski Hotel, Berlin, during the event on How can German-British collaboration in industry really work?*

More news from Berlin overleaf; more Foundation News pages 11 and 12

Dinner and discussion

◀ *Dinner at the Kempinski Hotel, Berlin, during the event on How can German-British collaboration in industry really work?*

Members get the Rolls-Royce treatment

▲ *Reg Moore, Chief Engineer of BMW Rolls-Royce, Dahlewitz, explaining various aspects of the BMW Rolls-Royce aeroengines during a buffet lunch following a visit around the plant.*

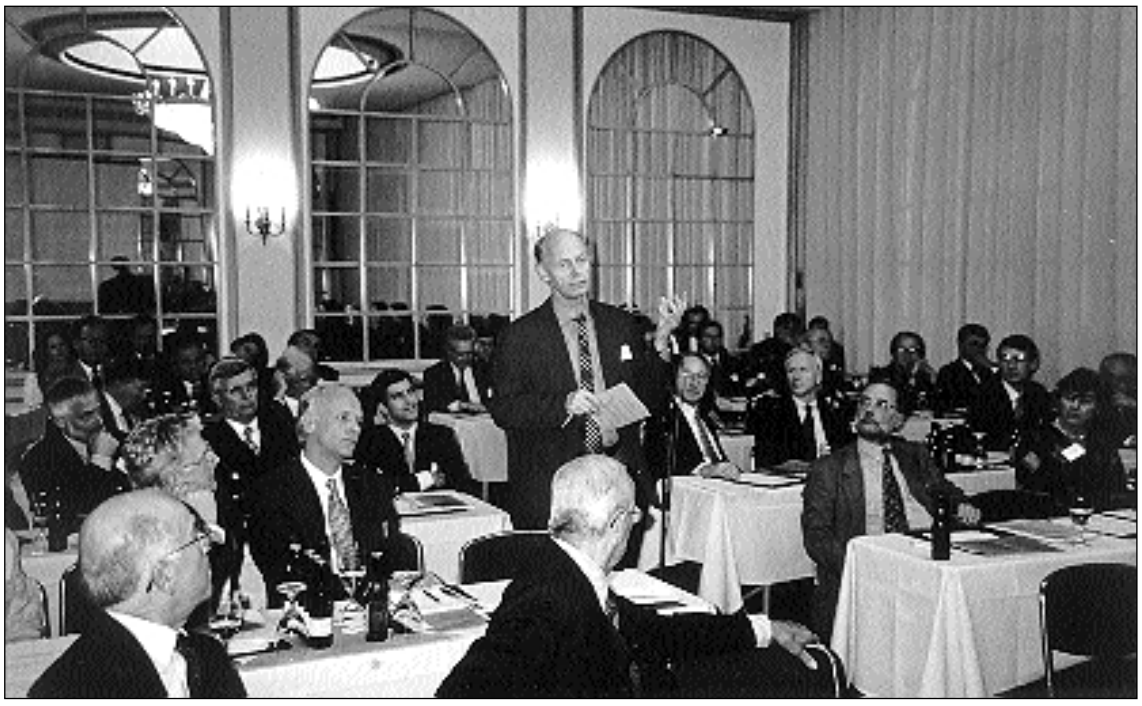
Site visit introduces group to family of aeroengines born of BMW collaboration with Rolls-Royce

SOME thirty of those who had attended the event in Berlin visited the BMW Rolls-Royce aero-engine site at Dahlewitz on the following morning, where they had an excellent presentation by Caroline Harris on the development of the BR700 family of engines designed through the collaborative arrangement between BMW and Rolls-Royce. The engines are designed for regional and corporate aircraft requiring thrusts of 14,000 and 23,000 lbf, and having greatly improved environmental performance.

The site at Dahlewitz had been built some six years before with especially-designed soundproofing for the two testbeds so that noise was reduced to an entirely acceptable level for the local population. The office blocks were designed especially in octagonal shape, with offices round the outer shell with an open space in the middle, meaning that there was maximum communication between designers and engineers. This was on the understanding that most good ideas stem not from sitting alone in front of a desk, but often from casual conversations and discussions. Recruiting of young engineers had been carried out carefully, and it was interesting to note that there were only about six women engineers - all from Britain. There were engineers from over thirty different nations working on the site, all working together and collaborating to the full.

Caroline Harris fielded many interesting questions before the group was taken on a tour of the site to see the construction of some of the engines and the impressive engine test facilities. Finally, Reg Moore, the Chief Engineer, held a discussion session over a buffet lunch.

► *Professor Sir William Stewart, FRS, FRSE, addressing guests in Berlin during the afternoon seminar on Biotechnology in Britain and Germany. Professor Dr C. Birr, Professor at Heidelberg University and Managing Partner of ORPEGEN Pharma GmbH, Heidelberg (right), also spoke. Lord Butterworth (left) chaired the afternoon session.*



◄ *Participants during the discussion stage of the seminar held in the Kempinski Hotel, Berlin, on the subject of How can German-British collaboration in industry really work?*

The sights, the sounds – and what the event was all about

SOME of the party from London – including Dr Klaus Wild, Science Counsellor at the German Embassy in London, who had been so helpful in the planning and preparations – remained for an extra day to take advantage of the opportunity to see something of Berlin and the immense developments in the east.

Most visited the impressive Pergamon Museum to the east of the Brandenberg Gate, and some attended the German Opera of Berlin for a performance of Mozart's *The Magic Flute*.

The event had been suggested by Dr Richard J. Haas, who had helped to organise it. The visit was in the 25th Anniversary year of the German-British Chamber of Industry and Commerce, and was the second event in Germany for the Foundation; the first, again proposed by Dr Haas, was in Frankfurt in 1993.

These collaborative events with individual countries of the European Union reflect the policy of the Foundation's Council to assist in establishing contacts and improving understanding between the United Kingdom and other partners of the Union. The event in Berlin also demonstrated clearly the many common interests between the two countries.

DISPOSING OF RADIOACTIVE WASTE

On 11 June 1996 the Foundation held a lecture and dinner discussion at the Royal Society on 'Disposal of Radioactive Waste – Two Sides of a Coin'. The Lord Butterworth, CBE, DL, was in the chair and the sponsor for the evening was United Kingdom Nirex Ltd. The speakers were *Dr John Holmes*, Director for Science, United Kingdom Nirex Ltd; *Professor Charles Curtis*, Manchester University; and *Sir Francis Graham-Smith, FRS*, Nuffield Radio Astronomy Laboratories, Jodrell Bank.

Dr John Holmes*

Summary: **Dr Holmes discussed the need for disposal, waste types and quantities, the disposal concept and the Nirex approach at Sellafield. It could well take over 2½ years overall to gain approval for the 'rock laboratory' (RCF) and a long public inquiry was programmed for any subsequent proposal to develop a repository for long-life wastes. Professor Curtis, noting that radioactive waste remained potentially hazardous to health for hundreds of thousands of years, said disposal should provide containment for similar periods. It was, however, difficult to demonstrate the safety case for a waste repository. He argued the case for finding solutions earlier rather than later.**

Introduction

The title for this evening's event and the flyer announcing it were no doubt designed to stimulate discussion and to set the scene. It is fair to say that, historically, there has been doubt and some necessary delay in implementing a national programme. However, the Government's clear backing for the Nirex programme - given in a major White Paper last year - gives us a robust framework within which to plan our very long-term task.

Need for disposal

Every industry produces waste. Some of these wastes are highly dangerous. For example, some heavy metals retain their toxicity and need to be kept from the human environment, effectively forever. Whilst carrying potential dangers, radioactive material is different, its activity does decay through time.

Radioactive waste exists now. It will continue to arise irrespective of the future of the nuclear power industry. We have an obligation to dispose of it safely and securely. Our research at Sellafield gives us good reason to believe that radioactive waste could be disposed of safely at the candidate site we have identified in the area. Safety for now and for forthcoming generations is our paramount consideration - Nirex would not wish it any other way.

Nirex's core role is the final disposal of intermediate-level waste or 'ILW'. The disposal strategy, supported by the Government, is for deep geological disposal. In the UK alone, there is today, on current packaging assumptions, the equivalent of 60,000 cubic metres of ILW held at the surface. To use a topical example: this would cover a football pitch to a depth of 30 feet. The same quantity again will be generated from existing nuclear plants by early next century.

But why dispose of these wastes in a deep underground repository? Why not store these wastes on the surface? This option would be available if we felt that, on the whole, we would rather leave this particular problem to future generations or there were some technical benefit to be gained by delay. It would be possible to postpone matters by holding wastes in interim storage at the surface for some decades before undertaking disposal.

Independently audited studies show that for a wide range of differing assumptions a 25- or 50-year deferment of disposal is seen neither to add significant cost nor to yield significant savings. However, in undiscounted terms, the costs of a 50-year delay are estimated as between six and seven billion pounds. Whatever view economists take, costs are surely not the driver anyway? Early disposal brings important benefits in terms of reduced risk to the public and to workers in the nuclear industry.

There are, I believe, other reasons to deal now with the radioactive waste which our generation has created. There is the important principle that 'the polluter pays', not the grandson or great-niece. Given the half-lives of many of the radionuclides concerned and the mixed character of some of the wasteforms in which they are found, there is no technical benefit from delaying disposal. The national commitment to sustainable development also points up the moral argument for not leaving the problem to our grandchildren. Today's problems should be solved and paid for by the present generation. We have taken the benefits of nuclear technology. We should clean up. We should pay.

The Government's 1995 White Paper on Radioactive Waste Management Policy was the culmination of what perhaps can be regarded as a textbook piece of open government. A consultative 'green paper' was published in 1994 and all with an interest had an opportunity to participate in an open process of decision-taking.

Government took a hard look at international developments, and the march of science, since deep disposal of intermediate-level wastes was first adopted as the national strategy in the mid-1980s. A key conclusion of the White Paper was reaffirmation of the deep disposal strategy.

Waste types and quantities

The main sources of radioactive waste are the nuclear power industry, the defence programme, medical applications and various industrial processes. About 80% of the annual arisings of radioactive waste is classified as low-level. including things like disposable clothing used in nuclear establishments. Most low-level waste goes for shallow disposal at a British Nuclear Fuels' managed site at Drigg near Sellafield.

High-level waste is not the responsibility of Nirex. The bulk of it arises from BNFL operations at Sellafield, where it is vitrified. There it will be stored in a specially-built store for at least 50 years to allow it to cool, before it is disposed of in a dedicated repository.

Disposal concept

The waste is held behind suitable barriers on the surface now and, with repackaging and investment in additional stores, this could continue for many decades.

* *Director for Science, United Kingdom Nirex Ltd.*

However, for long-lived radioactive waste we have to have a much broader historical perspective. They demand the right degree of containment for tens of thousands of years. Fortunately, whilst 10,000 years is an almost unimaginable period in terms of human history, it is just a moment in geological time.

Disposal needs to be designed to be safe without any need for human intervention. For disposal of ILW, our concept provides for excavation of vaults deep below the ground. The wastes would be held in stainless steel drums or concrete boxes set within a cementitious backfill in the vaults. The backfill is expected to hold pH - alkalinity - above 10.5 for more than a million years.

The overriding commitment has to be to deliver safety with confidence, without requiring future generations to intervene or even to monitor over the long term. Locked up in a long-lived natural system, the wastes will pose no significant threat. Crucially, the world will not be dependent on man's - frail - will and abilities to sustain that happy state of affairs

Over the first 1,000 years, more than 99 per cent of the radioactivity of the waste packed in steel or concrete packages will have decayed. The packages are expected to provide a very high level of physical containment during this period.

For about one million years, the conditions inside the repository will remain alkaline and reducing, ensuring that most long-lived radionuclides dissolve very slowly and are chemically contained while they continue to decay. After one million years, more than 99.99 per cent of the original radioactivity will have decayed. Only 0.01 per cent - one ten-thousandth - of the original radioactivity will remain.

Thus the vast majority of the radioactivity will decay within the repository. However, some radionuclides, Cl and I, are both long-lived (e.g. I - 16-million-year half-life) and mobile. Others - U^{238}: half-lives comparable to the age of the universe. Any disposal system must anticipate the eventual release of such radionuclides and ensure that they do not get back to the surface in concentrations that will pose a problem.

In addition to these chemical and engineered systems, the host rock also forms a barrier.

For the Nirex system in saturated rock, our research has established that the key hydrogeological parameters for a safe repository site are the annual flow of groundwater through the repository - and the dilution of any such flows in the surrounding rock, known as the geosphere.

The volume of groundwater flow must be sufficiently low to ensure that chemical conditioning by the backfill is not prematurely exhausted. Flow through the repository also determines the spreading time of the source term - the time taken for release of radionuclides in waste from the repository into the geosphere. That, plus the spreading in time during transit through the geosphere, determines the effective dilution of residual radionuclides released from the repository and hence the associated radiological risk.

From that potted account, it will be clear, I hope, that the basic physics, engineering and geology of deep disposal are simple enough in concept. We must, of course, model repository behaviour through hundreds of thousands of years. And modelling flows of relatively tiny quantities of water in rock fractures throws up challenges. But there is much knowledge that we can draw on. The Romans invented long-lived stable cements and our modelling of fracture flow draws on techniques initially developed in the oil industry.

At the end of the day we need a sufficient understanding of long-term system behaviour to have practical confidence in our performance assessment. We are not looking for a comprehensive understanding of every process involved, driven by intellectual curiosity for its own sake. There are aspects of our safety assessment where conservative assumptions - provided they are demonstrably conservative - are and will remain a perfectly acceptable tool.

The overriding commitment has to be to deliver safety with confidence, without requiring future generations to intervene or even to monitor over the long term. Locked up in a long-lived natural system, the wastes will pose no significant threat. Crucially, the world will not be dependent on man's - frail - will and abilities to sustain that happy state of affairs. But what will happen if some amazing new technology emerges? Very unlikely but just possible. Could the waste then be retrieved?

The access ways to the repository zone will be kept open throughout the planned operational life of the repository: 50 years or more. Final closure will itself require separate regulatory approval in the second half of the next century and a decision by that generation. That decision can take account of results from monitoring of the filled caverns and the evolution of hydrogeological conditions in the host rock. Stripped to its essentials, the repository programme can be seen as providing a future generation with a live option for safe, final disposal. It certainly does not foreclose other choices should society change its mind over the next 60 or 70 years.

Nirex approach at Sellafield

Most of the audience this evening will know that Nirex has concentrated its site investigations for deep disposal in the area of Longlands Farm, just inland of BNFL's Sellafield Works in West Cumbria. More than 60 per cent of the waste requiring disposal in the Nirex repository arises from BNFL operations at Sellafield.

Since 1989 we have made excellent progress with our investigations. Up to 1995, some £187 million has been committed to specific spending on Sellafield. This sum covered the cost of 27 deep boreholes and other studies which have enabled us to prepare a first-cut, risk-based, safety assessment for the groundwater pathway. It is that pathway which dominates risk calculations.

You may also know that earlier this year, on 1 February, we reached a milestone with the close of a 66-day planning inquiry into our proposals to excavate a Rock Characterisation Facility - the 'RCF' or 'rock laboratory' - at Longlands Farm. This research facility comprises twin shafts going down to depths of between 750 and 1000 metres. Lateral galleries will be opened up for data gathering and experimentation.

As the Royal Society and the Radioactive Waste Management Advisory Committee (RWMAC) agree, the RCF is an essential next step to provide the access and data we need in order to raise the confidence with which we can assess the potential long-term safety performance of a repository, and to decide whether to propose such a development.

To date our investigations have shown good promise. Our base case projections point to a flow volume and a dilution factor which, taken together, point to a peak level of annual risk for natural discharge within the tight regulatory target. That target is that the risk to a representative member of the critical group of developing a fatal cancer or a serious hereditary defect be kept below 10^6 - one in a million. As the environmental regulators have pointed out, the risk target is equivalent to between

$^{1}/_{100}$ and $^{1}/_{1000}$ of the risk implied by natural background radiation in the UK.

When and if we do propose development of a repository, the conceptual design provides for a drift tunnel, or tunnels, for waste movement and excavation of a suite of repository vaults at depth.

Subject to grant of planning permission for the RCF, the results we obtain from it and the progress through the regulatory and planning systems of any repository proposal, first waste emplacement could be in 2012, but probably not before. We can set no target until we have the Secretary of State's decision on the RCF.

In the flyer for this event the question 'What is happening in other parts of the world, and are there lessons to be learnt?' was posed. I would like to point up the extent of international consensus and collaboration in the arena of radioactive waste disposal.

There is world-wide and very open co-operation on civil nuclear programmes, radiation protection and waste disposal principles and practice. We see this multilaterally through the ICRP - set up as an independent body of experts nearly 70 years ago - and through the IAEA, Euratom and the Nuclear Energy Agency of the OECD. But there is extensive bilateral co-operation too, typified for example by Nirex's ties with its sister organisations in France, Canada, Switzerland and Sweden.

Let me report briefly where these other leading countries stand with their geological disposal programmes.

A Swedish Final Repository for low-level and short-lived intermediate-level waste has been in operation since 1988. Located near the Forsmark nuclear power station, it is excavated about 50 metres below the bed of the Baltic. Parallel tunnels run from the surface down to the repository. By 2010, about 90,000 cubic metres of waste will have to be accommodated. When the repository has been filled, the tunnels will be sealed with concrete to isolate the caverns and tunnels to prevent future access.

Sweden is also working to provide a deep repository for spent fuel. Initial site investigations are planned at various candidate sites before the end of the century. Subject to information obtained from exploratory excavations, consent for repository construction would follow and the target is to commence disposal by about 2010.

In the US, spent fuel, high-level waste and some civil intermediate-level waste are intended for disposal in a deep repository deep within Yucca Mountain in Nevada. Despite chronic political controversy in Congress and between the Federal government and the state of Nevada, geological characterisation is well in hand. An underground laboratory - or 'Experimental Studies Facility' - has been developed through a 25ft-diameter tunnel which has now been bored nearly three miles into the mountain. The US Department of Energy is giving increasingly upbeat indications of its confidence in the potential suitability of the site.

France, like the UK, has reprocessed its spent fuel. The primary waste form for deep disposal across the Channel is, therefore, long-lived intermediate-level waste. The repository containment concept is very similar to our own. Work on deep disposal is governed by special legislation adopted in 1991. Three potential siting areas are now being studied and, following public hearings, decisions regarding underground laboratories will be made in the next eighteen months. Depending on the results, and legislative sanction to move formally to final disposal, one of the laboratory locations would be chosen in 2006 for development of a repository.

Future/conclusion

I conclude with a brief reflection on what the requirements mean in practice. I note first that it may well take us more than 2½ years overall to gain approval for the RCF, which is purely a research facility. And a long public inquiry process is also programmed for any subsequent proposal to develop a repository. All that places a clear continuing responsibility on Nirex to provide information openly and to justify its proposals in public.

Indeed, in our experience we find that if people are informed and aware of our activities they tend to become more supportive. Our and others' research shows that once they are assured that the RCF is to be a research facility, a clear majority of people in Cumbria, and in particular in the Copeland Borough - the area of specific interest to us - were minded to support the development.

A recent initiative by Nirex to formulate proposals to enhance and put onto a regular cycle the publication of information about its scientific work and development of the repository programme has been welcomed by the Government. We are continuing to develop stronger links with scientific, academic and professional communities to ensure peer review and acceptance of our science and technology.

Nirex's responsibility must now be to carry the programme forward, respecting above all the scientific and engineering requirements to be met in demonstrating a robust safety case. Yet, for a major programme like the repository, modern society, through government in Brussels and Westminster, also puts in place a multiplicity of other checks and balances. These come in the shape of the planning and environmental assessment requirements. Like other organisations involved in sensitive developments, we respect those requirements.

We have in this country mechanisms which, in a pragmatic way, do ensure that society, local communities and individuals are all able to have their say. Within the present policy and legislative framework, we are able to make real progress, albeit sometimes at a frustratingly slow pace.

Professor Charles Curtis*

Introduction

In his opening talk, John Holmes outlined the disposal concept being developed by UK Nirex Ltd and its implementation strategy at Sellafield. He also commented on how the UK programme sits easily within the framework of collaborative international research. At the core of these international efforts lies a more-or-less agreed specification for the deep disposal safety case, specified in order to meet the real concerns of society in terms of acceptable or tolerable risk. This translates to a condition that the containment provided by the repository (the 'near-field') together with the surrounding geological formations (the 'far-field' or geosphere) shall be such as to prevent any significant return of radionuclides to the Earth's surface (where they would enter hence endanger the biosphere) for a period of 10^6 years.

Such a challenge is daunting indeed. As scientists and engineers, how can we possibly extrapolate from laboratory experiments (a few hours to a few years) to these extraordinary times - which are wildly beyond human engineering experience? One approach, briefly alluded to by Dr Holmes, is the study of natural analogues, and I shall develop this below. Before that, however, I would emphasize again that the Nuclear Powers have accumulated very large volumes of substances which are

* *Research Dean, Faculty of Science & Engineering, University of Manchester*

unquestionably dangerous to life: both radioactive wastes and new fissionable materials. Nearer to home, almost all of us benefit daily from the ready availability of electric power, some significant fraction of which is of nuclear origin. Collectively, we are responsible for this accumulation of dangerous material.

In this context, the two sides of the coin for me imply a delicate balance of judgment: is it better to postpone decisions about disposal (thereby avoiding the risk of bequeathing new and serious problems to future generations but accepting existing risks) or should we dispose now, thereby reducing the risk, some believe, for both current and future generations? This question is separate from that about the value/need/acceptability of future nuclear power generation and the global needs/reasonable expectations of the developing world. Separate though it is, it is easy to understand the concerns of those who see a solution to today's accumulated waste problem inextricably linked to a *carte blanche* for expansion of the nuclear industry.

Natural analogues

One approach is to step back a little and ask if studies of the Earth have yielded knowledge about the migration of chemical elements within the sub-surface over timeframes greater than the millions of years required for safe disposal - 'natural analogues studies'. The geological timescale has been calibrated precisely by radiometric dating. A range of complementary techniques has permitted interpolation to achieve a resolution of thousands of years in some periods of Earth history. More important, it is easy to demonstrate that certain geological materials have persisted unmodified for tens or even hundreds of millions of years. This becomes obviously relevant when mineral deposits of great antiquity (10^8-10^9 years) demonstrate that high natural, local concentrations of elements such as uranium have not dispersed over these enormous time periods. There is thus much interest in 'natural analogue' metalliferous deposits which allow transport processes under different environmental settings to be investigated in detail. Confidence in disposal design concepts should surely be enhanced by such studies.

I would like now to move to another area of geological knowledge which bears on the problem in hand, if not quite so logically nor so directly as studies of element migration in the subsurface. If a repository 'fails', the most likely pathway for escape is by dissolution of radionuclides in groundwaters and the transport to the biosphere in solution. Oil and gas are two different fluids which are found trapped in 'reservoirs' of porous rock where, for some at least, it can be demonstrated that they have resided for millions of years. In the North Sea a great deal of oil was generated around 30 million years ago and a substantial quantity remains trapped to this day (in spite of our very best endeavours to extract and burn it). It is not easy to get the oil out, in spite of the fact that there is a positive buoyancy drive towards the surface.

Normally, once located, the oil in a reservoir is produced from a well which terminates within the oil and gas accumulation. Hydrocarbons are then displaced by injecting water (usually sea water) through a second well which penetrates the pore water beneath the hydrocarbon accumulation. Natural buoyancy drive is thus augmented by displacement in order to produce oil and gas at an economically viable rate. Fluid emergence at the surface therefore requires a pathway from surface to depth, a different return pathway to the surface and a driving force. The absence of any of these leaves the fluid in place.

Decades of oil and gas exploration and production have demonstrated that there are probably thousands of oil and gas reservoirs within the sedimentary geosphere, each, by definition, a site where buoyant fluids have been naturally trapped and prevented from migrating to the surface for time periods of at least the same order as that required for a safe radioactive waste repository.

It would be disingenuous of me to imply that the hydrocarbon analogy is perfect. The positive buoyancy drive creates traps (the 'anticlines' in simple textbooks) which would not constrain the flow of pore waters which might transport radionuclide solutes. On the other hand, most pore water columns within the geosphere are salinity (therefore density) stratified. There is no simple upward drive for deep, saline ground waters. Even in open water bodies (i.e. unconfined within rock pore space) salinity stratification appears to persist for thousands of years in the deeper parts of enclosed or semi-enclosed marine basins.

In the most general terms, therefore, it is quite clear that in certain geological settings, metals have resisted migration (by whatever means) over enormous time periods. In other settings, it is demonstrable that deep subsurface fluids (probably including brines) are contained at depth for tens of millions of years. It thus seems to me that there ought to be lots of places where deep geological disposal would effectively isolate radioactive waste from the biosphere. The problems are two-fold: locating such sites and, within the democratic process, carrying the argument for disposal. The safety of the proposed Sellafield Repository remains to be proved: Nirex are actively pursuing the necessary geological and hydrogeological characterisation of the site and, with close international collaboration, research into repository design. An important part of both programmes, as John Holmes has outlined, is construction of the RCF (Rock Characterisation Facility).

Proving the negative

The oil industry has successfully located numerous geological formations within which hydrocarbon fluids have been isolated for millions of years. They have then, for the most part, successfully extracted valuable fluids. The big difference between petroleum engineering and repository design is that proof of success for the one is proof of failure for the other. It is easy to prove that you can get oil out of a reservoir, impossible to prove that deep fluids cannot migrate to the surface. There is a huge inequality here, not unfamiliar to those currently grappling with the problem of demonstrating that disease transmission by particular routes is impossible. The 'safety case' for a repository is fundamentally difficult to make.

Ethics and economics

The ethical stance of the OECD Radioactive Waste Management Committee is based on fairness and equity: *inter*-generational equity and *intro*generational equity (OECD, 1995):

> . . .our responsibilities to future generations are better discharged by a strategy of final disposal than by reliance on stores which require surveillance, bequeath long-term responsibilities of care. . .
> *(noting that for long-term safety considerations, the assumption of long-term care by future societies may not be wise).*

This is the adopted policy of H.M. Government.

Were nuclear power generation to be discontinued tomorrow, we would still have a legacy of waste from both military and civil sources. The problem exists, we should deal with it. This surely requires that we evaluate the various options available to us. One basis for evaluation is the quantification of risk, usually expressed in probabilities (1 in 10^3, 1 in 10^6) of suffering a fatal cancer. If the 'two sides of the coin' refer to disposal or storage, there are obviously risks associated with both options. Put very simply, long-term storage requires repeated re-packaging, with its risks to the workforce; there is an ever-present threat of accidental or terrorist-inspired disruption and there must be a real prospect of institutional control deterioration, as in the former Soviet Union. The principal concern about disposal must be that it would be difficult for future generations to correct

serious design/construction errors.

The risk-based approach is potentially helpful in this evaluation. Risks of very different kinds can be compared: smoking with driving, for example. But there are difficulties here. Simple numerical comparisons take no account of whether the risks are voluntary or imposed, under personal control, natural or man-made, or even familiar. We benefit from some risks taken but we may dread the possible consequences of others (Hiroshima, Chernobyl?).

Once this kind of analysis has been fairly attempted, further imponderables remain. There are seductive arguments in favour of delay. The first of these is scientific: *future improvements in technology and understanding will provide us with much better options.* This is certainly difficult to counter except in that advances in the last 30 or 40 years have been incremental rather than fundamental.

Another huge argument in favour of delay is the requirement to commit necessary resources - *it is obviously much easier to budget for something 25 rather than 5 years away!*

I have a great concern that the ethical argument in favour of dealing with this generation's problems as soon as we reasonably can is difficult to carry in the face of these arguments for delay. Most of all I worry that the trend we are seeing of societies less and less able (or willing, it doesn't matter which) to commit funds to long-term programmes. Those who counsel delay shoulder at least as much responsibility as those who counsel dispose.

Looking to the future

Surely we should strive to carry through what we consider to be the solution which is most sound, both ethically and scientifically. We must not allow the inequality of argument (proving the negative) or the fact that to sit on our hands and do nothing is so much easier than the alternative (less culpable and less expensive in the short term) to prevent us from addressing difficult decisions.

My personal concern goes beyond recognizing these inequalities. Democratic societies have finite resources and find difficulty in drawing on them for measures that are not seen to be of immediate and tangible benefit. The opposing trends of world population growth and non-renewable resource exhaustion would appear to make it less and less likely as time goes by that we shall have the will and capability to tackle these difficult problems.

That being the case, we should look to spend our money wisely. We know much more about the health risks associated with radioactivity and can monitor radioactivity levels very much more easily than we can most of the toxic wastes generated by our society. The costs of delay, once a good technical solution to deep disposal has been found, must be evaluated very carefully indeed.

PUBLIC PERCEPTION

Sir Francis Graham-Smith FRS*

Introduction

> An even greater effort by governments and the nuclear industry should be undertaken to secure the public acceptability of nuclear power, both by technological development and the wider dissemination of accurate information *(World Energy Council, Tokyo, 1995)*

As a member of the public, with no affiliation to the nuclear industry, I welcome this statement. The problem is growing: there are 450 nuclear reactors world-wide, generating 17% of the world's electricity. In the UK 25% is from nuclear power stations; in France it is 75%. World energy demand is growing and may double in the next half century. Resources of fossil fuels are finite and increasingly insecure; their use may be restricted by international agreement because of global warming. Nuclear power is efficient and in itself practically non-polluting, but it does produce radioactive waste, which is the main subject of public unease.

Complexity

The problems of nuclear waste may appear complex and confusing because of the variety of reactors which have been developed, each with their own particular fuel cycles. Furthermore, each reactor type is perceived to have associations: MAGNOX was developed for plutonium production, and has an inherent requirement for reprocessing; PWR was originally for submarine propulsion; CANDU requires a deuterium plant; the fast neutron reactor is expensive; RMBK is unsafe. There is also the complex question of reprocessing spent fuel from the PWR, which is the commonest type of reactor; THORP in the UK and a similar process in France produce uranium and plutonium for further power generation, either in a fast neutron reactor or in MOX fuel which can be used in PWR. Other countries, such as the USA and Sweden, do not reprocess spent fuel.

All this complexity may be simplified into three basic kinds of waste; low-, intermediate- and high-level. Low-level poses few problems; it is like domestic waste, but is kept separate because it contains some activity. Intermediate-level waste (ILW) includes seriously active material associated with fuel fabrication and reactor operation; this includes radioactive elements with very long lives. High-level waste (HLW) is a residue from reprocessing, it contains about 95% of the activity in spent fuel, it generates heat, and it must be kept in store for some decades. Spent fuel which is not due for reprocessing is also kept in store for cooling as the activity decays; this then is a waste stream similar to high-level waste. There are no proposals in the UK for the direct disposal of spent fuel.

Disposal

The bulk of the waste is ILW; it is unequivocally waste as there is no fuel to be extracted from it. Its disposal is the subject of the exploration adjacent to Sellafield, where there is at least a good chance of demonstrating that a deep rock repository will be safe and secure.

HLW is much less bulky, but needs greater care. There are at present no proposals for its ultimate disposal; the first stage is to incorporate it into glass blocks, and it may end up in the rock repository. Spent fuel which is not to be reprocessed is treated similarly, for example in Sweden, where there is no reprocessing: the spent fuel is cooled in wet store and will eventually be sealed in heavy copper cylinders in a deep rock repository.

Spent fuel contains plutonium, which is a particularly unpleasant and dangerous material. It is also a useful fuel, and the separation plant THORP was originally conceived as an essential step in the use of plutonium in the fast neutron reactor. Unfortunately, the development of the fast reactor has been indefinitely postponed,and the only use for the separated plutonium is in MOX, the mixed oxide fuel which now forms part of the load of many PWRs. Again unfortunately, this does not appreciably reduce the total amount of plutonium, since the part of it that is burnt is replaced by new plutonium generated in the uranium. The process does, however, give an improved

** Nuffield Radio Astronomy Laboratories, Jodrell Bank*

overall use of the original uranium, although not approaching the efficiency of the fast reactor.

The amount of plutonium in the world has in my lifetime increased from zero to 1200 tonnes. Of this most is in spent fuel, where it is relatively inaccessible. About 250 tonnes has been separated for military purposes, and 150 tonnes has been separated for the civil power programme. There are no proposals for the ultimate disposal of this dangerous material, apart from its slow use as MOX fuel, which at least has the advantage that it leaves spent fuel rather than separated plutonium.

Achieving public understanding

Public understanding, and public acceptance of, the proposals for nuclear waste disposal can only be achieved through complete openness of information and transparency of decisions. Beyond that, the difficulty of obtaining consensus may be illustrated by a proposal, current a few years ago, to bury waste under the deep ocean bed, dropping it torpedo-fashion some tens of metres down into the stable mud of a large ocean basin. There is a good geological case to be made for this, but the obvious difficulties of obtaining the necessary international agreement make it profitless even to start a full scientific and technical investigation.

It has also to be appreciated that the general public, myself included, is not wholly convinced by an argument that a new procedure, which is by its very nature unprecedented, has a quantifiable risk attached to it. If a process is reckoned to be safe, with only one chance in a million of disaster, my attitude is 'that damned chance keeps turning up time and time again'.

To quote from a recent editorial in *Nature*: 'Public confidence in today's sophisticated and media-rich world is no longer based on uncritical acceptance of "scientific" statements - however prominent those who make them -but on a more complex process that hinges on the question of trust.'

Footnote

The information and opinions expressed in this article were mainly gathered during my involvement in the following reports:

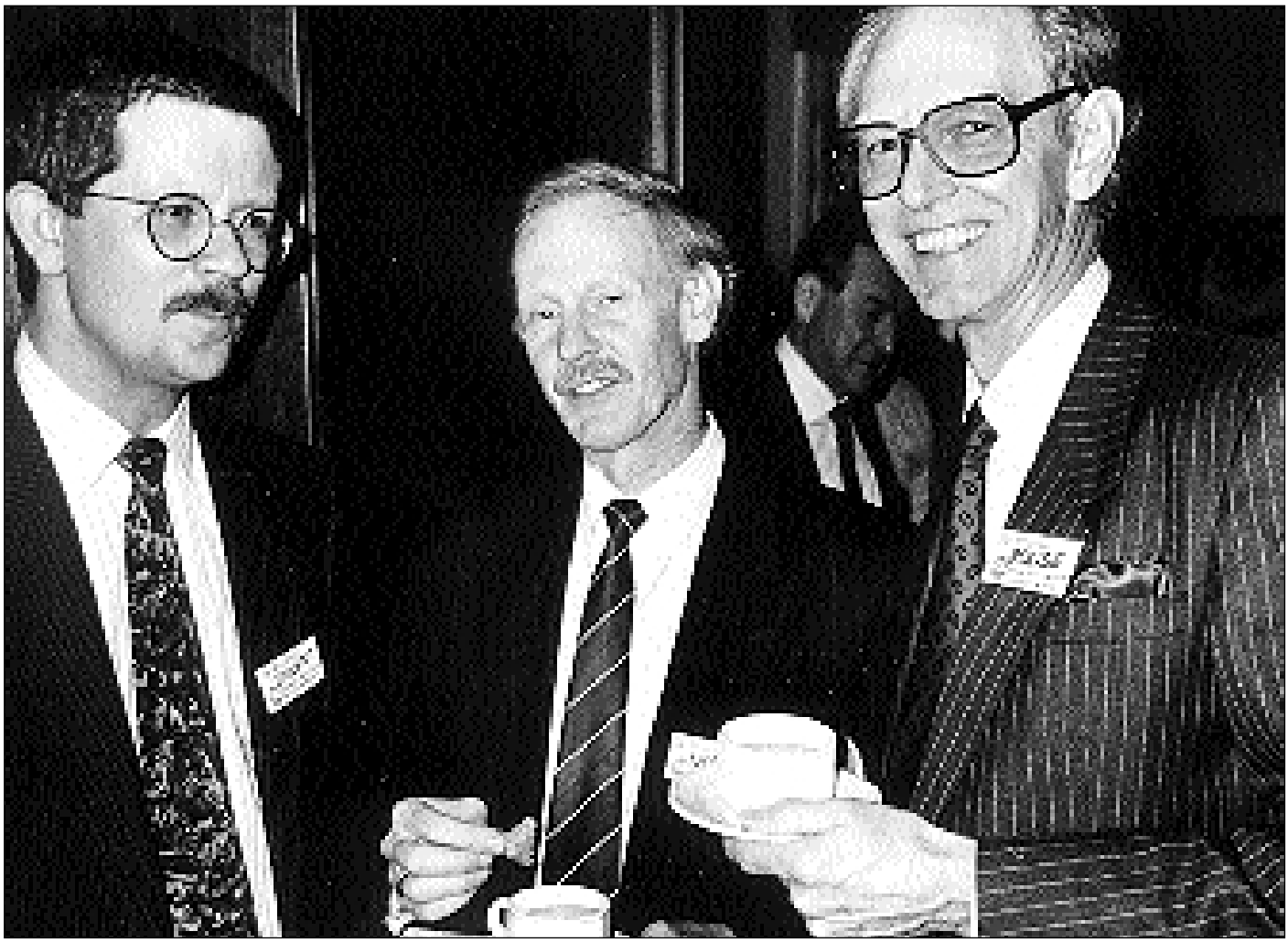
Energy and environment in the 21st century. NAPAG, 1995.

Disposal of radioactive waste in deep depositories. Royal Society, 1994.

Risk: analysis, perception and management. Royal Society, 1992.

MORE NEWS *in pictures*

Water lecture guests enjoy a coffee break



▲ *Thirsty work, talking about water: guests at the Foundation's event on UK Water Supply - Reliability versus Climate Change , sponsored by Generale des Eaux in the UK, may have enjoyed their tea- and coffee-break even more than usual. Pictured are, from left: Richard Vincent from the DoE, Dr Mike Norton and Michael Rouse.*

◀ *Julian Darley, Lord Haskel and Dr Eric Duckworth among others during the Foundation's visit to the Warwick Manufacturing Group in October.*

Technology visit to Warwick Manufacturing Group

PROFESSOR Kumar Bhattacharyya, Director of the 400-staffed centre, was host to a Foundation visit to the Warwick Manufacturing Centre on 14 October 1996 by about 30 members of the Foundation. The £50 million annual turnover organisation, situated in a new high-tech manufacturing centre on the campus of the University of Warwick, brings immense income to the university, and at the same time has centres in various parts of the world where the staff teach. The Group is based on 300 'member companies' including the Rover Group, whose representative was present at lunch after the visit to help take questions on their relationship with the Warwick Manufacturing Group.

The Group started as an experiment in 1981 when there were cut-backs in education, and no funding available to start such an initiative. So Professor Bhattacharyya approached some captains of industry to seek a mutually beneficial partnership on the basis of a dire need for a change in approach to British management in manufacturing industry. It is now working with partners in Thailand, Malaysia, India, South Africa, Hong Kong and China, with special units in Paris, Milan and Munich. The essence lies in the management approach, and training at all levels. The Group has some 1,200 master students, 2,600 doing diploma courses and short courses, and about 140 PhD students.

Much of the research is centred on ways of speeding up time to market, operations management, computer aided product development, Surface Science and environment issues. The Centre is looking, for example, at novel ceramics at lower temperatures. Industrialists and university staff work together in partnership. Partners, such as Sun, Computervision, Rover, Rolls-Royce, etc. bring their own technology to the site, and there is a good deal of security around certain sensitive areas, but there is also a working trust between academic and manufacturing staff. Naturally there is care not to have two competitors on site. The arrangements for IPR are simple, and work well.

'Risks have to be taken sometimes, and we recruit what we think is required, but not from other university departments,' Professor Bhattacharyya explained to the visitors over a lunch which itself reflected the high standard of the organisation.

Shared Sponsorship Scheme – an important way to help the Foundation

THE Shared Sponsorship Scheme for 1996 has assisted the Foundation over three events, making it possible to launch them with confidence and find good speakers for them. The Scheme has once again proved its value to the Foundation and has given the Director important flexibility in planning the Foundation's programme.

Those who have contributed to the Scheme since it was initiated were:

1992: **3i plc, 2 anonymous donors, Blake Resource Development, Comino Foundation, ICI Corporate Research & Technology, National Power plc, Unilever plc, United Biscuits (UK) Ltd.**

1993: **3i plc, Biwater Ltd, Glaxo Group Research, Kinkley Group, Loughborough University, MAFF, Premmit Engineering Services Ltd, United Biscuits (UK) Ltd, Zeneca Ltd.**

1994: **Biwater Ltd, Cookson Group plc, Esso UK plc, Glaxo Holdings plc, UK Nirex Ltd, Zeneca plc.**

1995: **3i Group plc, Biwater Ltd, Esso UK plc, Glaxo plc, Zeneca Group plc.**

1996: **Anonymous, Comino Foundation, Esso UK plc, Premmit Associates Ltd, RHM Technology Ltd.**

The scheme has the added advantage to the Foundation that the Inland Revenue agrees that the Gift Aid Scheme may apply to the Foundation's Shared Sponsorship Scheme. The Director welcomes inquiries.

New Associate Members and Major Donors

Perrots Group plc
Contact: The Lord Haskel, Chairman

Ernst & Young
Contact: Hugh Tinsley

A T Kearney Ltd
Contact: Patrick McHugh, Vice-President

Institute of Food Research
Contact: Catherine Reynolds

Engineering Training Authority
Contact: Dr Michael Sanderson, Chief Executive

INVESTING IN GROWTH ISSUES

The subject 'Investing in Growth Issues for Technology Based Firms' was discussed at a Foundation lecture and dinner discussion on 13 March 1996. The Lord Butterworth, CBE, DL, was in the chair and the evening was sponsored by National Westminster Bank plc and the Department of Trade and Industry. The speakers were *Mr Duncan Matthews*, Head of the Innovation & Growth Unit, National Westminster Bank plc; *Dr Bob Bishop*, Industrial Secondee to DTI Innovation Unit and Director and Secretary of Brax Biotechnology Ltd; *Mr Richard Drury*, Director, Maelor Pharmaceutical Supplies Ltd; and *Mr M. Powell*, Managing Director, Integrated Optical Components Ltd.

Dr Bob Bishop*

Summary: **Dr Bishop discussed how finance could be obtained for a technology based company, commenting that the UK had the largest capital industry in Europe. Smaller firms still had difficulty in raising finance; there was an `equity gap in the £150k to £3m area, most for investments below £0.5m. Dr Bishop went on the discuss what, from the point of view of potential investors, made a really exciting proposal, and the support available to young companies. Mr Matthews outlined the changes occurring in the world's technological base. If UK companies wished to penetrate the international market they needed to be capable of growth. There was a myth, he said, that there was a lack of finance for small growing businesses. However, three main areas required significant change: attitudes of both financiers and entrepreneurs had to change; methods had to be found to get expertise into the business right from the start and new ways must be found of appraising and funding businesses.**

Introduction

I was a scientist and technologist once, but if I have any credentials to be here this evening it must be on the basis of experience of growing technology-based businesses, firstly within a large UK public limited company (T&N), secondly in the form of a privatised government research laboratory (the Computer-Aided Design Centre), and now in a very exciting biotechnology start-up company (Brax Biotechnology Ltd).

DTI innovation unit

However, I was invited here today as an industrial member of the finance team of the DTI Innovation Unit. The Innovation Unit is a group of senior industrialists and DTI officials working to achieve public awareness of the importance of innovation, and the successful exploitation of new ideas in UK business, science base, education, government and finance.

Finance for growth

Finance for the growth of a technology-based company can come from a great variety of sources. Personal investment by the entrepreneur, grants, bank finance, factoring and private investors (Business Angels) are examples. However, I would like to highlight the importance of early business deals, before turning to Venture Capital as a main theme. The ability of a new business to 'bootstrap' its own growth, by doing early deals is a very important source of finance. It also ensures that the business is developed in a very 'customer-focused' way right from the start. Examples of early business deals are pre-paid development contracts, or the sale of options to the results of development, or down-payments to secure marketing rights.

Venture capital

Turning to Venture Capital; first, a definition. Venture Capital is medium- to long-term, unquoted equity, with a emphasis on capital gain rather than interest payments or dividends. Venture Capital seeks high potential returns on each project, since even in a portfolio of investments it is almost inevitable that some will fail. This means that the Venture Capital investor seeks businesses with substantial growth potential, not the 'lifestyle' type of business.

UK venture capital

Figures published by the British Venture Capital Association show that the UK has the largest venture capital industry in Europe, with 34% of the deals last year by number and 42% by value. Over £2bn was invested in over 1,200 firms. This was an increase of 43% on the £1.4bn invested in 1993. However, in relation to new, technology-based firms, it is very significant that only 5% of the funds were invested in start-up firms. Only 177 such firms were backed, a 25% fall on the 236 start-up firms backed in 1993!

Contrasts with USA

Comparisons are frequently made between the relatively greater success for new, technology-based businesses, of the US Venture Capital market. In addition to the large difference in market size, there are very strong and clear differences between US and UK business cultures. The USA is considerably more ambitious and entrepreneurial. Risk-taking is more acceptable, and experience gained in an unsuccessful venture is better regarded than in the UK! There does seem to be a greater willingness for large firms in the USA to do business with young companies. There are more of the 'classic' type of true Venture Capital firms in the USA, and it is easier to get a true valuation and market for new shares because of the success of the NASDAQ stock market. Finally, of course, there are far more examples of very substantial, technology-based business success in the USA.

Equity gap?

I have spent my first few months of secondment to the DTI looking at the difficulties which smaller firms, especially technology-based firms, have in raising finance. This is still the 'Equity Gap' identified in the 1931 Macmillan Report! Working with Dr Gavin Wonnacott of the DTI, we talked to the customers. During last Autumn we have talked to over 100 people who have a direct interest in resolving or reducing the equity gap. This included venture capitalists, business angel networks, academics,

* *Industrial Secondee to DTI Innovation Unit, and Director and Secretary of Brax Biotechnology Ltd.*

business support organisations like the new Business Links, companies, banks, accountants and academics. The people we consulted confirmed that there is an equity gap in the £150k to £3m area. Most thought that the main 'gap' is for investments below £0.5m. There are only about 20 Venture Capital (VC) firms in the UK, out of a total membership of the British Venture Capital Association of 108 who operate as 'classic' VCs. Only about 1% of the thousands of proposals which they see actually get funded. There is a total of only about 100 such investments per annum in new, technology-based firms in the UK. However, we also got the very clear message that 'really exciting' proposals will get funded. Although there is a shortage of institutional backing for some Venture Capital funds, in the main there are excess funds chasing too few exciting opportunities. We were repeatedly told that there is a shortage of good proposals.

▲ *Sir Aaron and Lady Klug (centre), with Professor Sir Frederick Crawford, FEng, Vice-Chancellor, Aston University (left), and Lord Renwick at the meeting.*

'Really exciting?'

The obvious next question is 'what makes a really exciting proposal?' The investors are looking first and foremost for a strong team, which includes some real international business management experience. The UK is a small market for most technology-based businesses. The team needs to be hungry for substantial growth and looking at a large potential market. The venture must have a credible marketing strategy to enable a new small firm to reach a substantial market. A good product is needed with excellent protected technology, but that is probably a 'given' since the UK has such a strong science base.

Issue 1: management is the key

This brings us to the nub of tonight's issues. A new business venture with excellent technology and an excellent business opportunity must show the investor that it has a world-class management team. However small and new is the venture, it needs star players to turn the opportunity into a big success, partly because of the need to win substantial international business, partly because all sorts of unforeseen hazards and pitfalls will be encountered along the way.

Issue 2: early stage support

There is already a variety of activities in the UK to provide support and guidance to young companies. This is also fertile ground for productive government policy. More early stage support could be expected to result in more business successes later. The most important role of such support is to make sure that there is a strong management team to create the business success.

Issue 3: risk/reward

We hear a lot about the high risk to investors of backing new, technology based businesses. The real risk takers are the entrepreneurs and managers. They are only backing one venture, with the risks not softened by the Venture Capitalist's 'portfolio'. This is the key issue for tonight. If more outstanding managers can be motivated, trained and rewarded for taking the enormous career risks of putting all their effort and all their effectiveness into a young, high-growth, technology-based business, then we will have more successes. In fact if you would like a (personal - not DTI!) controversial proposal, I would suggest 'negative Capital Gains Tax' for the entrepreneurs and managers who put their careers on the line to start a new, technology-based business. If they are clever enough and lucky enough to make a capital gain from this, then I suggest they should collect 40% more of a gain 'to encourage the others', not 40% less!

Mr Duncan Matthews*

Introduction

The topic for discussion this evening is 'Investing in Growth - Issues for Technology-Based Firms' - a large and complex topic. I should like to restrict my remarks to a more general overview of the problems facing growing businesses *and* investors, as seen from the perspective of a banker.

As a starting point, I would like to put my talk into context by discussing briefly some of the environmental and market factors affecting growth businesses. And I would like to focus on one main theme that I as a banker regard as fundamental to the topic - change.

Change

I was reminded of the overwhelming impact of rapid change a couple of weeks ago as I had lunch with a corporate financier who had just come back from Silicon Valley in the United States - where technological change is a way of life. He'd been on a three-month fact-finding mission, looking at the latest developments in technology and investigating US investment practices.

* *Head of Innovation & Growth Unit, National Westminster Bank plc-*

▲ *Mr Duncan Matthews (centre), Head of Innovation and Growth Unit, National Westminster Bank plc, with Mrs E.M. Bowman, W.S. Atkins Ltd, and Professor P.A. Bennett, FEng., CSE.*

We all recognise that the culture and in particular the investment culture of North America is different to ours. There is greater emphasis on enterprise and risk capital, and a greater willingness to invest in technology. I was once told by a very senior academic in the field of biotechnology that whereas a professor at MIT would be considered a failure unless he had a couple of successful businesses going on the side, his counterpart in the UK would be regarded as not taking his subject seriously. Now I don't know how apocryphal that is - you can judge better than I. But I think we would agree that America in general has a much more open approach to technology.

Let's not get hung up on the United States, however. Just as important is the Far East trading block of Japan and the so-called Tiger economies - rapidly developing countries who use technology as a commercial weapon in the creation of their sunrise industries. This is having serious consequences for Europe and the UK. Let me explain how.

Patents

The patent is an important link in the innovation process. It gets the technology out of the lab and into the market place and is often the first step in successfully commercialising an idea.

A recent report by the European Patent Office stated that Europe registers 245 applications per million inhabitants every year. The USA files 388 per million population. Japan files 2.665. Whilst we in Europe are still relatively well protected in traditional technologies, they tend to be those operating in stagnating markets. In certain hi-tech rapid growth sectors Europe and the UK are falling behind. Gradually, our ability to protect and profit from our technology in the future is being eroded.

Another example: the UK devotes 2.2% of its GDP to R&D; France and Germany 2.4%; the USA 2.7% and Japan 2.9%. We have fewer companies involved in industrial research and fewer researchers, scientists and engineers per head of population than our competitors. These gaps are widening. Is it a coincidence that our ranking in the world competitiveness tables is falling?

The point is clear. The world's technological base is changing, and so is the balance of technological power.

Technological change

Let me bring matters closer to home. Not only is the world's technological base changing, the UK's corporate base is changing in line with it.

One of the first things I recognised when I set up Innovation & Growth Unit was that NatWest's customer base was altering quite significantly. There are something like 50,000 IT businesses in operation in the UK which were simply not around twenty or even ten years ago.

This has serious implications for bankers. Our managers now have to deal with business propositions on anything from robotics to biotechnology, taking in multimedia, smart materials, photovoltaics and dozens of other new technologies on the way.

One of the services my Unit has established for our bank managers is a 'Hotline' information service. We provide them with information and advice on new technologies and new markets, and explain in plain English the technical detail that accompanies these business propositions. Take the Internet as an example of a current 'hot technology'. In any one week, we may handle up to ten inquiries about the Internet from bank managers - and that's just a fraction of the number of inquiries that walk through our doors. I would also say that in the brief life of the Internet so far, we have already seen a number of markets emerge - and disappear again. Such is the pace of technological change.

New technologies are also impacting on the way businesses operate. The advent of CAD, virtual reality and rapid prototyping means that manufacturers can now get new products to market in weeks not months. New communications technologies are changing the way companies set themselves up and carry out their day-to-day operations. And there is now even a new type of business emerging - the so-called virtual company. What is the result of all these technological and corporate changes? Well, they are leading to:

- an increasing globalisation of markets. Technology is a global product, and more often than not the key markets are not in the UK but are in Europe, or even further afield. If our businesses do not penetrate these markets quickly, they miss the window of opportunity
- technology-based enterprises must constantly innovate to stay ahead of the competition. This must by its very nature fuel growth. If you wish to innovate you have to put resource into research and development, and to finance this you must have a continuously renewed stream of products generating income. Organic growth is vital to the successful technology-based enterprise.
- and finally there is far greater opportunity for a new technology to have an overwhelming impact on the markets and industries it serves. These so-called industry breakpoints - Apple computers for instance - can revolutionise markets through vastly improved performance or cost reductions.

Growth capability

The corollary of all this is that if UK firms wish to penetrate the international marketplace, they must be capable of growth.

Some 380,000 businesses start up every year. Not all of them wish to grow into multinational conglomerates. Most of our customers are what we term 'lifestyle' businesses and will remain relatively small.

But new technology is empowering some companies to grow at almost unprecedented rates. Of all start-up businesses, an estimated 40% die within four years and about 55% remain

Dealing with technology businesses presents traditional bankers with a fundamental dilemma, stemming essentially from a failure to understand. We call this gap in understanding the empathy gap.

small. A mere 5% of all start-up businesses in any one year - something in the region of 19,000 companies - will achieve substantial growth.

The concentration of power is even greater than these figures indicate, however. Out of every hundred businesses, the fastest growing four will create 50% of all the new jobs amongst their start-up group over the next decade. A mere 15,200 firms will be responsible each year for major growth.

The result is a twin-track system - the majority of slower-growth businesses which we must of course not neglect, but running alongside them a group of rapid-growth, high-potential enterprises that we must first identify, and then actively nurture.

What are the issues facing these businesses? Based on my experience with this type of business I would describe the key factors as being:

- firstly, getting someone to listen to you. If you cannot find anyone willing to try and understand what you are saying, your cause is pretty well lost before you start. Let's face it, financiers speak financialese, and (if I dare say this in this distinguished company) scientists are more comfortable speaking what some call 'techno-babble'.
- Secondly, having got your listener, how do you turn him or her into a believer? How do you expect the investor to take a rational and fair view of your proposition if he or she can't understand the technical advances your innovation represents or the markets in which you are operating?
- thirdly, how do you get the skills into the business which will enable you to cope with the rapid growth you will face? And, finally, how do you get the right funding?

Getting over the obstacles

Understanding, appraising, signposting and funding. How can we help our technology businesses get over each of these Beecher's Brooks?

Dealing with technology businesses presents traditional bankers with a fundamental dilemma, stemming essentially from a failure to understand. At NatWest we call this gap in understanding the empathy gap. It is based on a two-way lack of knowledge and understanding:

- On one side we have financiers who understand neither the technology nor the issues facing technology and highly innovative firms, a situation which generates a high level of anxiety and an unwillingness to get involved.
- On the other side of the desk, companies themselves do not have the expertise or skills to present their proposition in the right way, or to implement their plan to its full potential.

Clearly, there is a gap between the technical financial criteria that a banker has to work by, and what he understands by a bankable proposition, and what the business can actually provide.

To get over this gap we need to provide the banker with more information about the technology involved and the critical factors that will determine the success of the business. We must recognise that these enterprises have different needs, and that they face different problems. And different problems demand different solutions.

It follows that we have to find an innovative way of appraising innovative propositions. Traditional due diligence methods are inadequate. They tend to focus on historic performance and existing opportunities. For appraising new products and new markets we have to develop new tools.

At NatWest we have developed a new type of appraisal methodology, unique to the bank, and designed specifically for our innovative and technology-based business. Called New Technologies Appraisal Service, or NTAS, it looks not just at traditional financial benchmarks or at the historical and present state of the business. Instead, NTAS assesses the commercial viability, technical feasibility and the future potential of the enterprise. And it assesses these factors against the market environment in which the new products will have to compete in the future.

The third fence to negotiate is management expertise, and the need to signpost these businesses towards the management skills and expertise they lack. I think this is one of the most significant areas of all affecting small businesses. If there is one thing that changes a good technical idea into a bankable proposition, it is first-class management input.

Currently, this professional expertise is simply not reaching its target. Our research suggests that only a fraction of our technology business customers approach any of the mainstream agencies to get advice and assistance before approaching potential investors. We try to tackle this problem by signposting our customers to our national and regional network of contacts in management, marketing, financial, technical and other areas. In this context, the Business Angels service we established just over a year ago is providing input to many businesses, as well as invaluable financial resources.

Funding

There is a myth that there is a lack of finance available for small, growing businesses. This is not the case. Numerous research studies and investigations confirm that there is no lack of funding in the market, certainly not from banks. Good ideas, backed up by good propositions, will find funding. We hear from our Business Angels as well as venture capitalists that the only thing that stops them investing more is not lack of tax incentives or available cash, but the lack of good propositions that are suitable for their type of investment.

The problem for businesses is finding the right type of finance at the right time. Entrepreneurs waste valuable time, resource and competitive advantage by trying to get finance from the wrong source, and when they do find the most appropriate one, by not having a good enough proposition to put to them. We see it as part of our role to make growth businesses more aware of the most appropriate funding methods for them, and then help them obtain it.

The needs of technology businesses change as the business

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We believe that businesses and investors should stop thinking about one source of funding and start thinking in terms of a package of funding, made up of various types and amounts from different institutions with very different criteria, exit routes and payback needs, and which is brought into the business over a period of time.

itself develops. In the past, businesses seeking funding in their earlier stages have gone either to banks, which traditionally provide debt finance, or, for larger amounts of equity, to venture capitalists. Now, the small number of technology-friendly venture capital funds are doing an excellent job, and we must congratulate them. But the venture capital industry itself acknowledges that it is focused on MBOs, MBIs and development funding. They simply cannot do more than touch on a fraction of the technology enterprises that need venture funding.

We believe that businesses and investors should stop thinking about one source of funding and start thinking in terms of a package of funding, made up of various types and amounts from different institutions with very different criteria, exit routes and payback needs, and which is brought into the business over a period of time.

By expanding the variety of funding types available to these businesses:

- we avoid putting them into a financial straitjacket that restricts their freedom to find other more suitable funds at a future stage, particularly in the medium- to long-term when second- or even third-stage funding is needed.
- it can leverage in other funds by sharing and minimising the risk amongst investors.
- it may often be cheaper. Taking the first funding offered may solve a short-term financing gap, but can prove extremely expensive, whether in terms of interest rates or loss of control of the business. A broader approach maximises use of all types of funds, whether from public, private or institutional sources, so that the most appropriate package can be built up.

Conclusions

I believe there are three main areas that require significant change if we are to improve the UK's technology business investment portfolio. As market leaders in technology business funding, NatWest started this process a number of years ago through a series of major initiatives which we believe can serve as a basis for further discussion.

First of all, attitudes must change - and that means the attitudes of both financiers and entrepreneurs. This will not be easy. But unless we develop a far greater mutual understanding of each other's problems and of the main pressures and issues facing the other party, we will continue to carry on a 'dialogue of the deaf'.

In this context, the DTI are making a great contribution through initiatives such as the Science, Engineering and Technology Week. But we cannot rely on government to do all the work - it is a problem we must work on together. Our approach has been to train our managers to appreciate the needs of these businesses, and then to place these trained Technology Business Managers around the country for easy access by our SME business customers. We supplement this with the Hotline information service I mentioned earlier, so that we can go some way to bridging the empathy gap.

We must develop flexible and sophisticated mechanisms to get expertise into the business right from the start. We have an extensive network of contacts that we use to put our customers in touch with specialist help. But the problem also urgently requires a new approach to professional management training for start-up technology businesses, the introduction of non-executive directors at a far earlier stage, and much greater support from existing agencies.

Technology business entrepreneurs must themselves take responsibility for upgrading their management skills so that they do not waste valuable time at the start of their venture by going down the wrong funding path, or putting together inappropriate marketing strategies.

Finally, we must develop new ways and tools for appraising and funding these businesses. The NTAS service I outlined earlier is a key component in our toolbox, helping us to appraise our customers' propositions far more rationally.

Our tools also include packaged funding, as well as a greater variety of funding especially for rapid growth businesses. We need to tap into new sources which do not penalise the entrepreneur but instead motivate him to greater levels of commitment. Our Business Angels initiatives, as well as the newly-launched Pioneer and Elevator funds, have been specifically designed for these growth business.

The Alternative Investment Market (AIM) is also an encouraging start, and we hope that it will develop into a major source of funding for our growth businesses. Similarly, the European automated share dealing system (EASDAQ for short) is being

Attitudes must change - and that means the attitudes of both financiers and entrepreneurs. This will not be easy. But unless we develop a far greater mutual understanding of each other's problems and of the main pressures and issues facing the other party, we will continue to carry on a 'dialogue of the deaf'

developed to provide a Europe-wide market for high-growth-potential enterprises. Based on the North American NASDAQ system, it is hoped that it will slow down the flow of UK technology businesses into the American investment community. Whilst North America remains the key market for these businesses, however, they will probably continue to raise investment there, and we must be prepared for this.

I would like to leave you with two quotations. One I am sure you recognise and is from a well-known scientist: 'There is no alternative'. Our ability to compete with the rest of the world is at stake here. We fail to support these businesses at our peril. The second is from one of the greatest-ever economic innovators. John Stuart Mill said this: 'No great improvements in the lot of mankind are possible until a great change takes place in the fundamental constitution of their modes of thought.' ■

HUMAN GENETICS

On 23 January 1966 the Foundation held a lecture and dinner discussion at the Royal Society on 'Human Genetics, Ethics, Society and Legislation'. The Lord Butterworth, CBE, DL, was in the chair and the evening was sponsored by the Kohn Foundation, The Office of Science and Technology, Pfizer Central Research, The Wellcome Trust and Zeneca Group plc. The speakers were *Sir Giles Shaw MP*, Chairman, House of Commons Select Committee on Science and Technology; *Professor Peter S. Harper*, Professor and Consultant in Medical Genetics, University of Wales College of Medicine; and *Dr Helen Watt*, Research Fellow, The Linacre Centre for Health Care Ethics.

Sir Giles Shaw MP*

Summary: **Sir Giles Shaw discussed the Government inquiry into human genetics which had revealed a number of practical and moral issues. On the basis of their deliberations, the Select Committee had put forward proposals to Government. The Government response had been encouraging but a number of the recommendations had been ignored, in particular the need to respond to public concerns about the possible misuse of genetic information and genetic science. Dr Helen Watt confined her comments to one issue, namely prenatal diagnosis with a view to termination. She believed that prenatal selection was due for a radical re-evaluation.**

Introduction

Let me commence by letting you down lightly. I am not a scientist. It is true that many years ago I was forced to dabble in physics and chemistry for a time and had a nodding nasal acquaintance with Kipps apparatus which I believe produced H_2S and I also met the brown ring tests for nitric acid, I think. But very early on I discovered that overhanging the excitement of science there lay the dread albatross of mathematics. It was that that finally and fully sunk any aspiration for further progress. I remain, therefore, non-numerate and barely literate considering I achieved a 2.2 degree in the Cambridge history tripos, starred for illegibility.

After the Select Committee on Science and Technology undertook its inquiry into the routes through which the science base is translated into innovative and competitive technology, the Committee had a view about how science was organised, how essential it was to our economy and the factors which encouraged and constrained the relationships between science and industry. When the time came to choose another major subject of inquiry in March 1994 it was clear that it was time for the Committee to look at a specific scientific field - the non-scientists would have to expose themselves to their colleagues' withering appraisal.

We chose human genetics, both because the research was of immense scientific interest and because, even before we undertook the inquiry, we considered it likely the research would bring a range of moral and political issues in its wake. Governments are often driven into belated action by the unexpected problems thrown up by scientific developments; perhaps the most famous example is the banning of DDT in the 1960s. We hoped that undertaking a thorough inquiry into genetics at an early stage would, for once, allow us to identify potential pitfalls early enough to avoid this.

Let me just say we began the inquiry prepared to be impressed by genetic science, and by the United Kingdom contributions to it, and ended it not just impressed but awed.

Nature and scale of the inquiry

I have not time to trouble you with an exhaustive account of the conduct of the inquiry, but I think I must outline something of the scale of the enterprise. We began with an informal chat with Sir Dai Rees, who confirmed our belief that the topic was both interesting and timely, toward the end of April in 1994. We appointed as two advisers Professor David Porteous (MRC Human Genetics Unit) in Edinburgh and Dr Bryan Sykes of the Institute of Molecular Medicine in Oxford and considered background papers on genetics over the summer, and called for written evidence on 3 November 1994.

We visited researchers in Cambridge, Oxford, Edinburgh and Cardiff. We were kindly given seminars which might have been entitled 'Genetics for Dunces' by many researchers at the forefront of the field. We took oral evidence from a range of witnesses: scientists, clinicians, theologians, genetic interest groups. We went abroad and discussed genetics with our colleagues in the European Parliament, with officials at the European Commission, with eminent scientists from France and America, with American businessmen (a class often identical to American scientists), and inevitably with lawyers. We brought our evidence home in crates, overwhelmed by people's willingness, even eagerness, to assist us.

What right did we have to conduct this inquiry? Well, the basic issue was that public money was involved, and Parliament has a right to examine public expenditure, even when the results of that expenditure are more limited that those of the Human Genome Project.

Our position as a Select Committee meant we were able to gather an enormous amount of information; people with all sorts of angles on genetics were willing to talk to us at length and to write to us - sometimes also at length. Most of what we have gathered has been published; any real glutton for punishment may even inspect the rest in the House of Lords Record Office.

The lessons we drew from the inquiry were, in my opinion, of two types. The first was that science today can develop quickly - *very* quickly. Whereas Gregor Mendel's work in the mid-nineteenth century was ignored for thirty-five years, today results are disseminated through international databases within weeks. Crick and Watson published their discovery of the structure of DNA in 1953 but it was not until 1977 that the sequence of the first genome was published by Frederick Sanger. Today the techniques developed by scientists like Sanger, Stanley Cohen and Herbert Boyer together with the power of the computer (which we should never forget is also continually refined and developed by scientists) means that within five months of beginning the work, the scientists sponsored by Merck to construct the Merck gene index could release 15,000 expressed gene sequences into the public domain. We do not know quite what will be discovered in the next few years, but recent estimates suggest the Human Genome in its entirety will be sequenced by 2005.

* *Chairman, House of Commons Select Committee on Medical Genetics*

Public policy

The speed of this research is exhilarating in scientific terms, but we must have a public policy framework which will enable us to deal with its wider consequences and to deal with them in good time. For genetic knowledge could transform our society.

So Genetics has tremendous power for good in all sorts of ways, but it also raises a great deal of ill-informed public suspicion. While the medical uses of genetics are acclaimed, there is a danger that too much is expected too quickly, and that the frustration of unreasonable expectations will lead to a backlash. Perhaps the opposite is true for the non-medical uses of genetics: it is quite possible that in the near future a great deal of information could be available which might be used to the individual's disadvantage. Once again 'genetics' might get the blame.

Add to this general public suspicion of biotechnology or anything smacking of 'genetic engineering' and you will understand why we ended our inquiry convinced that if the application of genetic science were not developed within a clear policy framework there was a real danger that public opinion could turn against genetics and that decisions about how genetic knowledge might be used would be distorted by suspicion and distrust.

Links between genes and disorder

Genetic science, as I have said, is advancing very rapidly. Perhaps the most significant fact, in policy terms, is that we are no longer dealing with genes for single gene disorders where the link between gene and disorder is simple and direct; we are now finding genes implicated in complex multifactorial disorders. While one can say that a person with a particular form of a particular gene is more likely to develop heart disease, say, than someone without it, this information does not tell us when the condition will develop, how serious it will be or even whether it will ever become manifest at all. In time scientists will improve their understanding of these complex conditions, but it will take time, possibly a great deal of time, and, however perfect scientists' understanding, we will never have certainty.

Moreover, this science is at an early stage. Those genes which increase the risks of one condition may protect against another. Even though the genome is being mapped at an enormous rate it will be some time before its complexities are understood. And while genetic knowledge should lead to great medical advances I am sure that we will be able to diagnose genetic defects, or, not to be judgemental, genetic configurations, long before we can alter them, if, indeed, this is desirable. I am also sure we all prove to have some 'bad' genes.

If society was entirely cohesive and rational maybe we could wait until genetics was fully understood before taking action on our genetic knowledge. But there are very good reasons why many sections of society wish to act on such knowledge now.

- Sections of the health service wish to offer screening and individuals wish to be screened.
- Insurers want to be sure that those who apply for cover are not concealing information about their health; they may also wish to use genetic information to vary the rates they offer.
- Employers might like to use such screening to avoid employing someone likely to develop major health problems.
- Pharmaceutical companies want to use genetic knowledge to develop therapeutic drugs.

Problems that arise

These perfectly natural wishes can throw up practical and moral difficulties. I will not attempt to enumerate them all but here are a few examples:

- How does one balance the benefit that genetic screening may bring to the individual against the costs to the NHS involved?
- Should the principle that screening is offered to allow choice about parenthood mean that pre-natal tests are offered for late-onset diseases?
- Should employers be allowed to discriminate against people who are perfectly able to work at the time a job is available, if their genetic profile suggests that they have a risk of developing some genetically-linked condition in future?
- Should insurers be allowed to use genetic information? If they are banned from doing so completely, there is risk that insurance will be taken out by those who have taken genetic tests which show they are at increased risk; all our premia will rise. If they are allowed to use genetic information fully, there is a chance that companies may 'cherry pick' and offer good rates to those with a good genetic profile; in that case the cost of insurance for others would also rise.
- The drug companies need patent protection to ensure they get a return on their investment, but that protection should not be so wide that it blocks subsequent scientific research and the development of new therapies.

We have a series of dilemmas, and in few of these dilemmas is there a clear-cut choice between right and wrong.

There are matters which cannot be easily resolved. How can genetic privacy be protected in practice? We are agreed that genetic information should only be given after proper counselling, to allow people to decide whether they wish to receive that information. Such counselling requires, firstly, that the medical professionals involved have a proper understanding of genetics, and of probability, and secondly, that they understand that genetic testing is not routine. We saw that the counselling already provided for pre-natal testing too easily became perfunctory, resting on the assumption that the tests would 'show that baby is all right' rather than facing the real question 'Do you *want* to know if baby is *not* all right?' The question will have to be turned around not just for pre-natal but for all genetic testing: 'This is what we can tell you: do you want to know?'

And we must be sure that genetic testing cannot be offered without appropriate counselling. It may be appropriate to offer testing for some genes by post, provided that counselling is available. What horrified the Committee was that there are no powers to stop any company that wishes from offering any test it wishes. This must be changed.

Proposals

The Committee made proposals aimed at Government, at the Colleges of Medicine, at industry. They were intended to address the most urgent problems; for example, on patenting the Committee agreed that the pharmaceutical companies had to be involved if the medicines based on genetic knowledge were to be developed efficiently. It costs £200 million over 10 years to develop a new product; patent protection is needed to ensure that companies can recoup their investment. However, the patenting system should not allow the holder of a patent using genetic information to block all subsequent uses of that information. For the record, our proposal was that:-

(a) only a combination of a gene and a known utility which is novel and not obvious should be patentable in the context of that utility; and

(b) a combination of the same gene and a further novel utility should also be patentable.

A Human Genetics Commission

However, although we could suggest some answers we considered that the development of genetic science would bring new posers for society to answer. Moreover, there were some issues which we felt it was wrong for politicians to pronounce on, such as whether it was appropriate to allow pre-natal testing for late-onset conditions. For these reasons the Committee recommended

that there should be a Human Genetics Commission. A, or perhaps even the, main task of this body would be to regulate the main use of genetic screening. It would monitor the availability of genetic services in different regions; advise Local Research Ethics Committees on research involving genetic screening; approve screening programmes before they were introduced; prescribe the circumstances in which particular types of screening or diagnosis should be provided or forbidden; regulate companies offering genetic tests.

The Human Genetics Commission would inevitably be thoroughly up to date with genetic technology, and know both its advantages and its limits. The Committee considered that it should accordingly also advise on wider public policy issues

In failing to respond to public concerns about the possible misuse of genetic information and genetic science, the Government Reply may have created the conditions for widespread mistrust of genetics

raised by the advance of genetic science. The main tasks we identified were:to define and monitor genetic disorders which were relevant to employment (if any); keep the law and practice of patenting under review; to monitor the effect of genetic medicine on the insurance market and suggest what regulation was needed, if any; to promote research into the ethical, legal and social issues raised by genetics; to encourage public education and debate.

We considered that the Commission's role in educating the public and fostering public debate was crucial. If genetic science is to be used for good, the public must know its limits, and must not fear it. Equally, scientists need to ensure they do not undertake research that a well-informed public - not a vociferous minority - would find repugnant. If they do so, they will put acceptable research at risk. In fact, the geneticists we met had been very responsible; however, it takes little to make the public question the whole science. For example, the patent on a method of germline manipulation of mice was widely reported, and raised a great deal of disquiet.

Government response

We received the Government Reply to our Report the day after Parliament returned from the Christmas recess. There is to be no Human Genetics Commission but a non-statutory Advisory Committee on Genetic Testing, which will report to Health Ministers, is to be set up. This will 'advise on the ethical, social and scientific aspects of genetic tests and establish agreed standards for efficacy and product information to be met by manufacturers and suppliers of genetic tests. The Advisory Committee will consider the use and potential use of tests, both in clinical practice and sales to the public. The Advisory Committee will be asked to produce an annual report of its activities which will be made available to Parliament and to the public' (para 65). It is to regulate, albeit on a non-statutory basis, commercial testing and screening. (44)

This is welcome, as far as it goes, but does it go far enough?

Loop-holes

The Committee recognised that a Human Genetics Commission *might* develop from a non-statutory body and the Government keeps open the option of statutory control (para 66). I am particularly pleased that the Government has responded to our concerns over commercial tests which are, at present, completely unregulated. It is *possible* that an active Committee on Genetic Testing might deal with most of the medical functions identified by the Committee, but it could do so only by stretching its remit.

There will be no independent overview of the non-medical implications of genetics, and no legislation to protect the privacy of genetic information. Although the Government is committed to keeping the need for legislation on insurance and employment under review it has rejected the proposal which would have given it an independent, authoritative source of advice on such matters.

The Government's view is that such problems are unlikely in the 'foreseeable future'. The evidence presented to the Committee, and reports of developments since we reported, make me believe that tests for the 'susceptibility genes' I mentioned earlier will be introduced within the decade. The future is not only foreseeable, it is advancing fast. Indeed, an American woman has already committed suicide in response to tests which showed she had a gene linked to Alzheimer's.

I cannot predict the Committee's final response to the Government Reply, but we have already made a most unusual announcement. Rather than leaving it to individual members to comment, the Committee has said that it intends to take further evidence on this matter and expects to report to the House. A subject of this importance needs Parliamentary debate; if and when a debate is held in the House I and my colleagues intend to pursue our case with vigour.

The greatest disappointment to me is that in failing to respond to public concerns about the possible misuse of genetic information and genetic science, the Government Reply may have created the conditions for widespread mistrust of genetics. Genetic science is not only about the problems I have raised in this talk; it will give people knowledge which offers them choices about their lives, and not just in obvious ways. For example, it could ensure that those with genetic susceptibilities to certain pollutants do not inadvertently set themselves at risk. It could revolutionise medicine through rational drug development, through gene therapy, through simple life-style counselling. But these benefits will only be gained if the public is happy with genetic science and bio-technology is unfortunately on the way to becoming the modern bogeyman.

The public sadly no longer trusts the man or woman in Whitehall, the scientist in the white coat or even the medical establishment. The public needs to understand both the limits and the efficacy of genetic testing. It equally needs to have confidence that the techniques being employed and the products being offered are scientifically appraised and reliable to use. Even before that, however, public opinion must be brought into this equation so that people may understand more of what may be at risk and perhaps, above all, what is not at risk. Many small and vulnerable groups may have high and unsustainable expectations. Many other smaller vulnerable groups may be provided with no expectation at all.

The individual whose genetic make-up includes a fault which may or may not develop into fatal or debilitating disease needs to have that information conveyed in a thoroughly acceptable and sensitive manner and to have the counselling and support necessary before such information is made available. He/she should have a firm right to privacy according to the Committee's view, but equally there are other organisations who may wish to be involved in the consequences of the information. It is in this area that we as MPs properly have a crucial role to play. Because we are in touch with the public, we are elected by them and to greater or lesser degrees we still receive and hopefully still earn their trust. It is up to us to ensure that in this particular arena of health and social science we do not let the public down.

Dr Helen Watt*

Introduction

I have been asked to speak on the ethical questions raised by the recent Report on Human Genetics of the Science and Technology Committee. There are, of course, a number of ethical questions raised by this comprehensive and informative Report, concerning such diverse matters as carrier testing, gene therapy, insurance and intellectual property. To attempt to cover all, or even several, of these issues in any kind of detail in the time at my disposal would be frustrating both for me and for my hearers.

I have therefore decided to concentrate on one issue only among those raised by the Report. The issue I have chosen may be described as controversial; however, for a controversial issue it is discussed surprisingly seldom in many educated circles.

Such discussion as there is tends to concern not the practice itself, but the fine-tuning of the practice; if change is recommended there is seldom any question whether the practice itself should be retained. The practice in question is (as you may have guessed) pre-natal diagnosis with a view to termination: a practice very firmly established today in the health care system and in social expectation.

Attitudes to parenthood

That this practice is so firmly established may be seen as a natural phenomenon. After all, parents cannot be expected to welcome the fact that their children may be born with serious disabilities. While some disabilities are relatively mild, other disabilities are more severe, and some may involve considerable suffering for the child, or in any case for his or her parents. Is it any surprise that now it is possible to diagnose some such disabilities pre-natally, doctors will want to offer tests to do this, and parents will want to accept them?

However, it should be stressed that the attitudes inherent in pre-natal selection are relatively new in Western society - at least on the scale in which these attitudes are found today.

There has always been, of course, a certain amount of unwillingness to accept disabled children, in that there have always been some doctors and some parents prepared to practise euthanasia and/or neglect of disabled children. However, the more widely adopted position, and in any case the position presented as the ideal, has been that children should be accepted unconditionally by their parents - accepted as a matter of course, not on presentation of a clean bill of health.

Some see the relationship between parental rejection of children and pre-natal diagnosis or selection as a relationship of cause and effect, if indeed there is any connection at all. They ask if pre-natal diagnosis will lead to the rejection or qualified acceptance of children by their parents and if it will lead to negative attitudes to the disabled on the part of society at large. Such questions are among those explicitly raised by the Report of the Science and Technology Committee: will pre-natal diagnosis have an adverse effect on attitudes to parenthood and to people with disabilities?

Such questions are entirely proper, but they cannot be properly addressed without addressing more fundamental questions. That is, they cannot be addressed without asking what pre-natal selection constitutes with regard to attitudes to children and to people with disabilities. It is only by asking what pre-natal selection *is* that we can ask to what extent it is likely to affect the post-natal attitudes of parents and others to those with disabilities.

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The foetus seen as a child

One of the more striking aspects of pre-natal selection is the extent to which it is admitted - in the case of the foetus, if not in the case of the embryo - that the unborn child is a *child*. Not only parents but doctors, nurses and counsellors are likely to refer to the foetus as a child and to act in many ways on the assumption that this description is in fact correct. Thus health care professionals will encourage women having abortions to grieve for their children, to hold them in their arms, to attend cremation services for them, and so on. Yet despite all this, if the handicap is seen as sufficiently serious - Spina Bifida, Cystic Fibrosis or even Down's Syndrome - the parents - and particularly the mother - are seen as having absolute control over whether the foetus lives or dies. The foetus is thus a child for the purpose of being held and grieved for by the parents, but not a child for the purpose of being protected, either by the State or by medical professionals, from his or her deliberate destruction.

Here I should stress that I am not intending to pass a judgement on the individuals involved in pre-natal selection - whether the parents themselves, the genetic counsellor or other health care professionals. I am well aware of the emotional effect that the fear of disability can have on parents; I am also aware that some parents sincerely believe that they have, not simply a right, but a *duty* to screen and abort for some particularly serious conditions. What I am concerned with is not the level of responsibility of the parents or others for pre-natal selection, but the rightness or wrongness of selection itself, and the social context in which it takes place.

To this some will object that there *is* no right and wrong across the board when it comes to pre-natal selection. Parents must simply discover what is right for them, in the light of the needs of the child, their own needs and the needs of the rest of the family. The role of the genetic counsellor is to help the parents, without pressure in either direction, to come to their own decision with regard to screening and abortion. The role of health care professionals in general is to help the parents to carry out whichever decision they make, whether this is screening or not screening, abortion or giving birth.

But here it should be noted once again that a similar attitude would not be tolerated in the case of a born disabled child. If the parents were unable or unwilling to care for a born disabled child, it would be seen as a matter of course that the child should be passed to the care of others - such as foster or adoptive parents, or (where the handicap was especially serious) health care professionals. While paediatric euthanasia is, of course, defended by some, many would still deny that a born child can be *killed*, simply because he or she has disabilities and the parents do not feel that they can cope.

The good of life

In discussing this question, it is important to remember that the embryo and foetus is the same individual as the infant and the adult, and not a separate entity entirely. A human being is not a purely spiritual entity - a ghost who haunts a separate living body; rather, he or she is a living human organism, who passes through a number of different stages in the course of his or her life-span. It is for this reason that we can correctly refer to the future life of the embryo and foetus after birth, and postulate that he or she should not be deprived of this life, however limited it may be.

Few of those here tonight would be comfortable with the notion that the lives of the disabled have no value. However, we should remember that when we end the life of an embryo or foetus on the grounds of disability, we are depriving that

individual of the same kind of life experienced by older disabled children and by adults. If we are reluctant to deny the value of the life of an adult with (for example) cystic fibrosis, why should we assume that we may deprive a foetus of precisely that kind of life? If, on the other hand, we are prepared to make the claim that the life of the adult has literally no value, what justifies us in making - much less acting on - a claim of this kind?

It should be remembered that a person can be deprived of what is in his or her interests, even if he or she is entirely unaware that he or she has been deprived. What is in our interests does not, after all, depend on what we happen to value at some particular time. Health, knowledge and friendship, for example, are good for us - in our true, or objective interests - even if we are too depressed, too sick or too young to take an interest in these 'human goods'. It is for this reason that a doctor can act in the best interests of a newborn patient, despite the fact that a newborn baby has no idea of what his or her interests might be. Moreover, one of the interests of human beings is, it can be argued, the good of life itself: the value inherent in the sheer presence of a living human being.

To say that life itself can make a moral claim on us is not, of course, to say that life should be prolonged at all costs. The moral claim of the good of human life is, above all, that we not do something; that we not deliberately attack a human life - at least in the case of an innocent human being. The positive demands of the good of human life will depend on such variable factors as the costs and burdens of (for example) medical treatment, and what human goods in addition to life can be expected from the treatment. In contrast the negative demands of the good of life are not affected by these variables; life always has a certain objective value, and may never be deliberately attacked on the grounds that it does not.

Of course, the demands of the good of life go further than the demand that life not be deliberately attacked on the grounds that it is worthless. To endanger a person's life without sufficient reason is also morally wrong. And, here again, we see that pre-natal selection raises another very serious moral question, which is the risk of miscarriage. The risk of miscarriage is sometimes quoted in deceptively optimistic tones; we are told, for example, that the risk with chorionic villus sampling is 'no more' than one in a hundred. However, while such a risk might well be acceptable in the case of an otherwise fatal disease for which some treatment was available, it is surely not acceptable in the case of a disease for which no such treatment is available. What would we say about a diagnostic procedure carried out on a newborn child which had a one-in-a-hundred chance of killing that child, and whose only real benefit was to relieve anxiety in the parents, should the child be found to be healthy?

Impact of selection on women

This takes us to another moral aspect of pre-natal diagnosis, which is the emotional effect of pre-natal diagnosis on the parents, and particularly on the mother. Tests are often presented as relieving maternal anxiety; however, before they relieve anxiety in the case of many women they raise it to significant levels as women wait first for their tests and then for the results. Women are unlikely to refuse pre-natal tests if tests are presented as a normal part of pre-natal care, despite the fact that a positive result may confront them with a choice they would rather have avoided. If a miscarriage follows from pre-natal testing this is clearly a painful experience for the woman. And of course, abortion for handicap is for many women a shattering experience, not least because they regard the unborn child as a child, not as any kind of subhuman entity.

Quite apart from these emotional effects, however, there is the effect on women's attitudes to parenthood, which has already been referred to. The very fact that women must wait first for the tests and then for the results of these tests, means that they are likely to try to 'hold back' from bonding with, and commitment to, their children. More than one study has found that women waiting for the results of tests are less likely to report foetal movement; they are, it seems, subconsciously attempting to prevent themselves from bonding with a child who may be aborted.

Nor should we assume that such disruption of bonding with, and commitment to, the child will not spill over into the period after birth. It should be remembered that however many tests are carried out, the parents may still have a child who is disabled, either because the results of the test are deceptive, because no test was available for the child's condition or because the child is disabled due to some incident after he or she is born. Will it be any easier for parents to accept and care for a child with disabilities when they were prepared to abort at 20 weeks had similar disabilities been discovered?

Here it might be remembered that parents of disabled children will sometimes defend euthanasia as 'post-natal abortion', and ask why they should be prevented from ending the life of a child merely because that child has been born.

Attitudes to the disabled

The Report of the Science and Technology Committee rightly points out that 'providing a pre-natal screening test for a genetic defect, in the absence of any treatment for that defect, gives a signal that many people, at least, may consider the condition so serious it justifies termination of pregnancy'. Disabled people and their families will often react with understandable anger and distress to signals from others to the effect that life with disabilities is 'not worth living'. For many disabled people it is perfectly clear that their lives are worth living, not merely in the presence of multiple handicaps but even in the presence of chronic pain. Moreover, the disabled are all too often regarded simply as a burden on their families - as if they were not also a source of happiness for their families and indeed, in many cases, of a profound change in values.

It is often said that families and individuals differ in the degree to which they cope with disabilities. However, if this is the case, the difference would appear to lie less in the level of disability than in the system of values of the family or individual, which in turn is affected by the encouragement and practical help which they receive from others. Simply to assume that disability is the problem, and not the support which the disabled receive, is to send a most unfortunate message to the disabled and able-bodied alike. Moreover, it is no more permissible to end the lives of disabled children on the basis that support for them is inadequate than it would be to end the lives of those in any other group which is inadequately supported. Disabled children are entitled *both* to live their lives *and* to be supported in living their lives; to end their lives on the grounds that support is inadequate is to add insult to injury.

Conclusion

I am ending, then, on this controversial note, not because I want to be controversial at all costs but because I believe pre-natal selection is due for a radical re-evaluation. Pre-natal selection is harmful not merely in its impact on attitudes to parenthood and to the disabled, but in what it constitutes in terms of attitudes to parenthood and to the disabled. While I recognize that it may be difficult to question the existence of a practice into which so much time, money and emotional energy has been invested, I believe this is essential if we are not to misdirect our time, money and emotional energy. It is time to pay more than lip-service to the notion that every human being has a fundamental value, such that the presence of any human being can never be an undisputed evil. ■

PROFILES OF COUNCIL MEMBERS

Dr Bridget Margaret Ogilvie

It has been said of Dr Ogilvie that she holds the influential position of Director of the Wellcome Trust despite three apparent disqualifications: she graduated in agricultural science and not in medicine, she is female not male, and she is Australian not British!

Bridget Ogilvie was born in New South Wales with parents deeply committed to family values and the importance of education. Living on a sheep property gave her freedom combined with responsibility from an early age. After a year studying science at the University of Queensland, Dr Ogilvie went on to the University of New England in New South Wales to take a course designed to give an integrated understanding of the sciences underlying successful animal husbandry. She then won a Commonwealth Scholarship to the Veterinary School at Cambridge, where she obtained a PhD for the study of the immunology of helminth parasite infection. From there Dr Ogilvie went as a research fellow to the Medical Research Council's National Institute of Medical Research in Mill Hill and joined its scientific staff in 1965.

In 1979, after many happy years at Mill Hill, Dr Ogilvie was persuaded by Dr Peter Williams, the then Director of the Wellcome Trust, to spend a sabbatical year running the Trust's tropical medicine programme on a half-time basis whilst continuing her work at the NIMR. To her surprise, Dr Ogilvie enjoyed this role so much that she decided to make a permanent commitment to the business of funding others to undertake scientific research and joined the staff of the Wellcome Trust in 1981. At that time the Trust was a small organisation but almost immediately it began to grow in parallel with the increasing success of the pharmaceutical company owned by the Trust, known then as the Wellcome Foundation Ltd.

Dr Ogilvie's responsibilities within the Trust changed and grew until in 1991 she succeeded Dr Peter Williams as its Director. The Trust's income doubled from £90 million to approximately £200 million per annum in the first ten months of her Directorship after a further sale of its shares in Wellcome plc, and even further in 1995 when the Trust's remaining holding was sold to Glaxo. Thus Dr Ogilvie has had a challenging time over the past five years administering the increased funds of the Wellcome Trust and coping with the resulting expansion of the organisation.

Surprisingly, she manages to fit other activities into her busy schedule, as she is a trustee of the Science Museum and a non-executive director of the Lloyds TSB Group plc. She has appeared on David Dimbleby's *Question Time* and was recently named as one of the fifty most influential women in Britain by *Woman's Journal.*

One of the nominators for this latter honour was Kay Davies, Professor of Genetics at Oxford University, who said of Dr Ogilvie: 'She's dedicated to science and concerned about its influence on society. She's also helping to transform the Government's attitude, ensuring it takes British science more seriously.' Dr Ogilvie very much appreciates the recognition given to her by the academic community, reflected in the award of honorary degrees and fellowships by many different universities and professional organisations in the UK, Ireland and Australia. She especially values her Distinguished Alumnus Award from her alma mater, the University of New England, to which she feels particularly loyal because of the excellence of her experience as an undergraduate there.

Notwithstanding all of the above, Bridget Ogilvie has retained her links with her Australian background and has not lost sight of either her sense of direction or great humour. She still finds time to talk to the many people who seek her advice and guidance and, indeed, she lists one of her main recreations as 'the company of friends'. ■

Dr Bridget Margaret Ogilvie has appeared on David Dimbleby's *Question Time* and was recently named as one of the fifty most influential women in Britain by *Woman's Journal.*

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