Commercialisation and spin-out activities of the Institute of Biotechnology

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Keywords: *biotechnology, knowledge-based economy, spin-off company, multidisciplinary science*

Abstract

Knowledge is now recognised as a prime driver of innovation, productivity and economic growth. The new economies will require heavy investment into research and development, education and training and the development of novel flows and relationships among the key players, government, academia and industry. The higher education sector will play a key role in furnishing the novel ideas and skilled personnel to enable this transition, but will require organisational and cultural change to be effective. The Institute of Biotechnology at the University of Cambridge exemplifies a route by which the seamless exploitation of its pure science base to create knowledge-based spin-off companies may be achieved in a single organisation.

INTRODUCTION

It is fashionable these days to insert the prefixes e-, nano- and bio- ahead of many nouns such as medicine, society or economy to create the impression of state-of-the-art knowledge or understanding of particular advanced technology disciplines and their fulsome integration into a holistic vision of the future. These prefixes now represent a confluence of thinking which embodies the paradigm shifts from the agrarian societies of pre-history, through the industrial revolution of the 18th and 19th centuries, to the information (e-), bottom-up manufacturing (nano-) and sustainable and eco-friendly biological (bio-) societies of the late 20th and early 21st centuries.

Over the past 20 years, these inchoate technologies have been slowly transforming the way we live, learn, work and play, and the way in which governments tax, spend and provide services to their citizens. It is not too surprising therefore that both the advanced economies of the world and many of the developing nations are becoming increasingly dependent on knowledge and information derived from the physical, chemical and biological sciences. Knowledge is now recognised as a significant driver of innovation, productivity and economic growth and the role of these 'prefixual' technologies in the 'knowledge-based economy' and economic performance promoted.[1] Businesses and consumers in the USA have been quick to take advantage of these new knowledge-based opportunities and, as a result, US businesses became much more competitive and enjoyed spectacular and unprecedented growth during the 1990s. However, what about Europe? Five years ago at the Lisbon Summit in March 2000, European heads of state and government recognised that Europe could not afford to miss out, and set a challenging new goal for the European Union, to become the most competitive knowledge-based society in the world by 2010.[2] There is no doubt that the EU's success in achieving this goal will impact on all aspects of the quality of life of its citizens, the working conditions of its employees and the overall competitiveness of its manufacturing and service industries.

The new knowledge-based economies will be based on the production,

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distribution and application of knowledge and information and be mediated by growth in high-technology investments and industries, an increasingly skilled labour force and associated productivity and value-added gains. Not surprisingly, therefore, heavy investment in research and development, education and training and new manufacturing and managerial structures are essential. Equally important is the reconfiguration of innovation routes away from the classical linear model towards novel flows and relationships between the key players, industry, government and academia, in the development of science and technology as an economic vehicle.

THE UK SCENE

The UK has not been slow to appreciate the importance and impact of knowledge and information exchange on economic performance. One of the key planks in the Government's industrial policy has been the supremacy of the 'knowledge-driven economy', exemplified by the change in attitude away from traditional capital assets such as land, factories or hardware, towards human assets such as the skills and vision of the workforce. When populous developing nations, particularly those of China, Indonesia and India, can manufacture goods cheaper than any British firm through paying lower wages, economic survival will depend on brand loyalty, 'customerisation', innovation and technology, rather than cost.

Human assets are becoming more important than capital assets

Recently, the Chancellor, Gordon Brown, revived one of his favourite themes, making the economy more science-based, with a series of measures designed to boost innovation. He recently told MPs 'to succeed in the global economy, Britain should build on our strengths – our stability, global reach, scientific genius and world-class universities'. The UK's university system lies at the heart of this new thinking. Controversially, and far-removed from their traditional role of existing solely for the pursuit of knowledge, the universities' role has been redefined as two-fold: to produce a workforce with the skills required to safeguard the future competitiveness of British industry, and to act as 'hubs' driving the knowledge and information economy. A new twice-yearly forum between scientists, industry, the chancellor and the trade secretary, designed to improve the UK's research and development performance, has recently been instituted. Gordon Brown has also committed £2.5bn to a 10 year science plan to ensure that the UK leads in pharmaceuticals, biotechnology and the life sciences. A further aspect of this programme is Gordon Brown's desire to encourage universities and scientists to commercialise their discoveries, in some cases mediated via Deputy Prime Minister John Prescott's Northern Way growth strategy involving the establishment of 'science cities', starting with Newcastle upon Tyne, York and Manchester. Over the next six years, the three cities will share £100m to develop their science activities and create up to four world-class research centres in life sciences, nanotechnology and other key areas of research. However, the cash is destined for branding the cities as science cities rather than building business parks.

UK Government is promoting the knowledge-based economy with several initiatives

Universities are becoming 'hubs' in regional economics

BIOTECHNOLOGY IN THE UK

The desire to convert regional universities into 'hubs' of the knowledge and information economy has started to show some signs of success. The experience of the key US institutions of Harvard, Stanford and the Massachusetts Institute of Technology (MIT) in converting scientific achievement into successful companies, prompted the UK Government to create the University Challenge Fund Scheme to fund early stage start-up companies arising out of publicly funded university research. Three notable successes include the continued development of 'silicon fen' around Cambridge, the combination of Manchester and Liverpool hospital trusts to spin-out innovative healthcare

products in the 'North West Health Corridor' and the 'White Rose' consortium of the Universities of York, Leeds and Sheffield spinning out a number of high-technology companies. Other notable clusters include Oxford, the London region, the North East, the South West and, rather belatedly, the Southern region.

THE CAMBRIDGE CLUSTER

The Cambridge bio-cluster is still growing

The Cambridge cluster is generally regarded as the jewel in the crown of the UK's effort to foster a knowledge-driven economy emanating from a university hub and as such is probably the best known of its kind in Europe. Only the clusters around Munich and Copenhagen–Malmö–Lund (Medicon Valley) can be regarded as serious competition, although other clusters mushrooming around major conurbations such as Paris, Uppsala, Heidelberg and Nice have ambitious plans to expand. The Cambridge bio-cluster claims a full complement of services for business development, ideas generation, management training, research, innovation, incubation, communication and legal, patent and business resources. There are at present 11 science, business parks and incubators, 3 university and hospital incubators and 3 new business parks under construction. The number of biotechnology companies in the region doubled between 1995 and 2000 and was mirrored by a similar increase in the number of business service providers, such as venture capitalists, patent agents and lawyers. There are about 350 bioscience companies directly employing ~6,000 people, with almost 50 per cent claiming R&D as a core activity. However, in most cases, the companies are relatively small, with a median size in the range 20–49 employees and the largest cluster in the 5–19 employee bracket. Since 1999, the biotechnology growth rate has been +7 per cent per annum, compared with the East of England growth rate of +1.9 per cent and the national growth rate of +0.75 per cent. This business-rich environment supports a dynamic and highly networked industrial culture and a local workforce characterised by high levels of expertise and achievement. A crucial node of this world-class cluster is the University of Cambridge, which is now recognised as the leading European university and in the same league as Harvard and Stanford in the world rankings.[3]

UNIVERSITY OF CAMBRIDGE

The University of Cambridge was founded in 1209 when groups of scholars congregated at an ancient Roman trading post for the purpose of study. It is one of the oldest universities in the world and one of the largest in the UK. Cambridge's reputation reflects the intellectual achievement of its students, and the outstanding work of the academic community of the University and the Colleges, to make it one of the world's leading universities. Throughout the last 800 years, its contributions to the development of the world have ranged from the discovery of the mechanism of blood circulation to the structure of DNA, from the great philosophers of the early 15th century, to the groundbreaking work of its many Nobel Prize winners. It trains doctors, veterinary surgeons, architects, scientists, engineers and teachers. At all levels, about half of the students at Cambridge study arts and humanities subjects, many of whom have subsequently become prominent figures in the arts, print and broadcast media. The University's achievements in the sciences are measured by the 60 or more Nobel Prizes awarded to its members over the years.

The University of Cambridge[4] offers a wide range of expertise in bioscience and biotechnology across many of the departments in the Schools of Biological Sciences, Medicine, Physical Sciences and Technology. The Graduate School of Biological, Medical and Veterinary Sciences alone supports about 1,500 graduate students in 40 different

departments and affiliated institutes, while the Departments of Chemistry, Physics, Computer Science, Engineering, Chemical Engineering, Materials Science, Manufacturing Engineering and the Judge Institute of Management Studies all profess some interest in biotechnology. The Institute of Biotechnology is a department within the School of Technology and is the only part of the University dedicated solely to biotechnology.

INSTITUTE OF BIOTECHNOLOGY

The Institute of Biotechnology is a centre of excellence in biotechnology research. It was established in 1988 to meet growing demands for highly skilled research personnel and to develop the new knowledge necessary for continuing expansion of the science platform upon which biotechnology innovations are based.[5] Its vision is to sustain and enhance a unique world-class centre of excellence for research, training and entrepreneurship in biotechnology. It aims to attain the highest quality in science, and to promote exploitation of basic science platforms. It seeks to provide its staff and students with a stimulating environment providing opportunities to develop their scientific and creative insights and to improve their analytical, communication and professional skills. Ultimately, its commitment is to produce the highest calibre science, and to create the academic, business and financial leaders of the future.

The Institute of Biotechnology is a multi-faceted organisation with an ethos of entrepreneurship

The Institute of Biotechnology is probably the only organisation in the UK that has fulfilled the vision set out by the former UGC's 1982/83 Biotechnology Initiative. Since its informal foundation in 1984, it has evolved from a prototype idea with an original recurrent grant of £50,000 per annum to an established financially sound and sustainable institute with a reputation for the quality and innovation of its science and its ethos of entrepreneurship. The Institute now has a small core of academic staff and, together with administrative and technical staff, currently supports over 120 people in an exciting, well-integrated and highly active Institute of the University.

Twenty years after its foundation, the culture of the Institute still reflects the motivation and innovation of the staff and an uncompromising quest for world excellence. From the outset it was not constrained by any existing university departmental structure and was able to consider new ways to create an environment of innovation and provide world-class training for graduates. This has allowed the Institute to seize the opportunity and build on the 'ideas' and initiative of its small core of permanent staff. It has successfully addressed several key challenges, ie how to:

- promote science of the highest international standards while developing sufficient breadth and depth to provide a firm basis for future developments;
- develop and sustain a reputation as a first class academic postgraduate organisation;
- encourage and nurture multidisciplinary research;
- provide core equipment and specialist facilities;
- provide opportunity, where appropriate, to transition from underpinning fundamental science to exploitable technology within one organisation;
- create an ethos of achievement and entrepreneurship.

The Institute occupies laboratories, purpose-built in 1991, and housing in excess of £15m worth of modern equipment to support its multidisciplinary research programme. It has the highest *per capita* external income in the university, averaging £410,000 expenditure per

university teaching officer (UTO) per annum over the past six years, despite receiving less than 20 per cent of its funding from university sources. It has recruited a critical mass of highly skilled, independent and lateral-thinking researchers from a wide spectrum of primary disciplines, all of whom are maintained on short-term contracts. It offers highly sought after graduate-training programmes leading to MPhil and PhD degrees and, more recently, hosts a one year taught master's course in Bioscience Enterprise, funded initially by the Cambridge-Massachusetts Institute of Technology (CMI).

The Institute is more than a specialist research organisation

The Institute cannot be regarded as a 'conventional' university department, but believes that it has achieved a highly successful formula that offers a platform to build future developments. In a world where much lip-service is paid to 'multidisciplinarity', the Institute has created unique interfaces between disciplines that have catalysed organic growth of new research and innovation, combining leading science in a wide range of applicable fields with a training experience that prepares doctoral and postdoctoral researchers for their future career aspirations.

This paper examines the factors that have led to the Institute's present success and that provide a platform for building a vision of the future for the Institute of Biotechnology.

CREATION OF A MULTIDIMENSIONAL ENVIRONMENT

The founding principle of the Institute of Biotechnology was to create a multidimensional environment, crossing not only the traditional boundaries between scientific disciplines and forming a bridge between pure science and technological applications, but also integrating other business, teaching and training activities into an entrepreneurial culture that embraces interactions with industry at all levels and promotes a seamless transition for exploitable research from the laboratory to the marketplace.

This philosophy can be portrayed in bipyramidal space emanating from a focus of science, and with x, y and z-axes representing the continua of multidisciplinarity (chemistry, biology, physics, materials science, engineering, technology), business activity (local, national, international industry, entrepreneurial start-ups) and postgraduate training respectively (Figure 1). Activities of the Institute occupy all eight quadrants of the bipyramid and this leads to the ability to address new landscapes and spawn innovation in any of the constituent areas.

The Institute believes it is more than simply a specialist research centre because of the unique opportunities created by the overall spheres of operation. The environment is truly exciting, since it not only traverses the boundaries of traditional scientific disciplines with a breadth that is itself probably unique within a single institute, but also creates an interface with the commercial world that stimulates and broadens the experience and appreciation of students and researchers. The structure is able to promote cutting edge science, while also responding to UK Government and European Commission aims for an entrepreneurial economy based on knowledge-based industries in which biotechnology will play a leading role.

This environment has been successfully created because the Institute is a small, independent and flexible organisation, which is not constrained by existing internal structures. It has grown organically from a small core, by appointment of individuals who share both a common vision for the Institute and a strong belief in, and commitment to, its development. Given the highly diverse nature of its research activities, the strong cohesion that arises from this shared vision is essential for the continued functioning of the Institute. For this reason, the Institute could not function as part of a larger department, nor can it expand indefinitely, since the essential

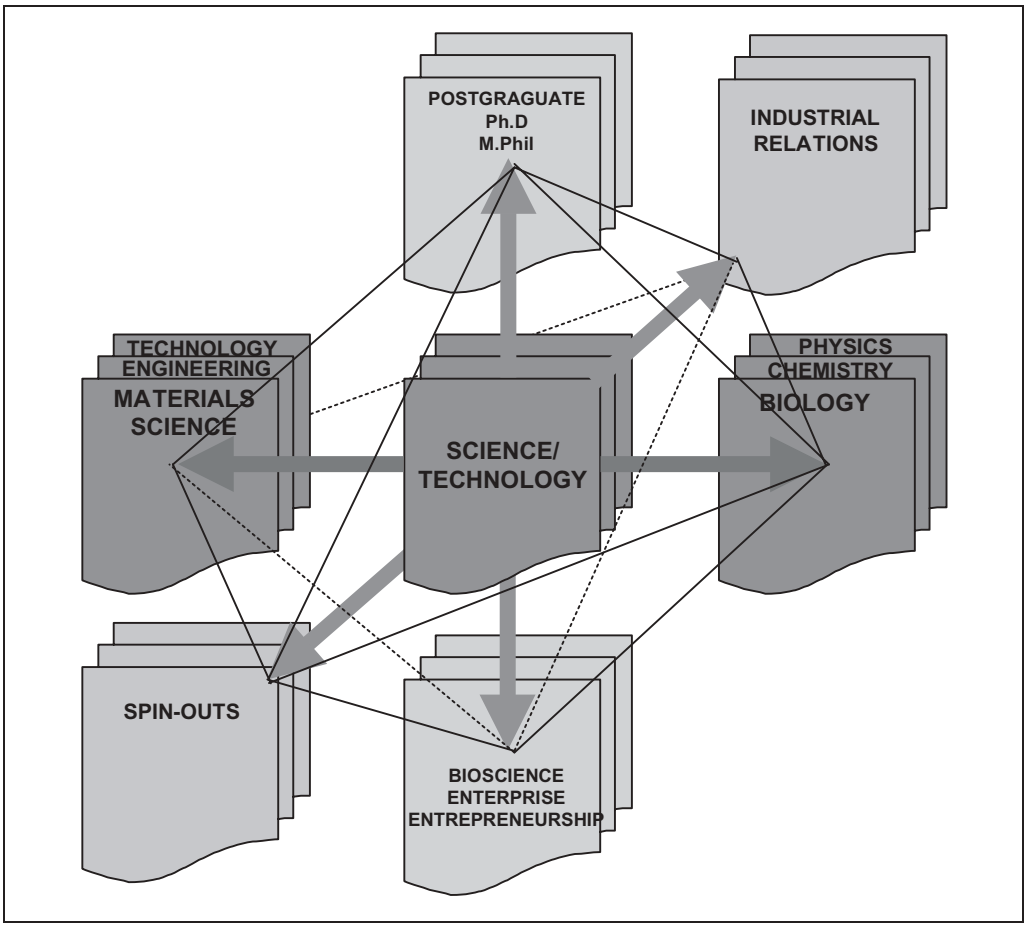

Figure 1: The multidimensional environment created at the Institute of Biotechnology

loyalty and internal cohesion would be lost.

The Institute has endeavoured to redefine biotechnology, and since its creation has consistently challenged and extended the conventional perception and boundaries of the subject and how it should be integrated into a university department. For example, a primary focus of the Institute from the outset was the biosensor/sensors area, at a time when biotechnology was almost universally regarded as lying exclusively in the domain of molecular biology. This broad view of biotechnology has allowed the Institute to continue to grow and prosper, while most other biotechnology departments created at the same time have either been subsumed back into biochemistry or biological sciences, or ceased to exist.

Promotion of an 'enterpreneurial environment'

Over the past five years, the Institute has heavily promoted the concept of an 'entrepreneurial environment', a move driven by its belief in the benefits to the whole organisation of such a culture imbuing all activities. It also concurs with Government and European thinking, and fulfils a real need for training outward-looking, broad-minded scientists with an understanding of the operation and role of science in the commercial world. It should be emphasised, however, that the Institute sees this ethos as supplementing the strong science focus it already has and, indeed, all research groups have consolidated their positions as world leaders in their respective fields during this period. The entrepreneurial environment is stimulated not only through the creation of strong links with local, national and global industry, but also by the formation of spin-out companies exploiting research initiated within the Institute. The most recent, and particularly critical, part of this strategy has been the establishment of the Masters in Bioscience Enterprise course, which is

housed within the Institute, and which forms a key part of the future strategy of building a multidimensional environment.

The nature, achievements and future plans of the Institute are explored below in more detail, but the key goals are summarised here. They are to:

- undertake research of the highest quality in biotechnology;
- deliver a unique training experience for graduates from a variety of disciplines;
- create an environment that encourages the exploitation of research through an entrepreneurial ethos.

Research activities

Research, training and technology transfer are the three key interlocking activities

The key axis in the Institute's multidimensional environment, which is integral to all its activities, is research. The Institute supports a broad research programme in the biological sciences (plant biotechnology, microbiology, anhydrobiosis, enzyme and protein engineering, biopharmaceuticals and, most recently, in neuropsychiatric disorders and prion protein research), but is also at the forefront of research in the physical and applied sciences (nanotechnology, biosensors, analytical and surface chemistry, high-frequency acoustics, water engineering). This has been achieved by attracting outstanding group leaders, postdoctoral associates and students to join the Institute, who have an unusual breadth and depth of expertise, and an eagerness to explore new areas outside their immediate experience. The academic and research staff of the Institute have diverse backgrounds in the biosciences (molecular biology, cell biology, genetics, microbiology, biochemistry), medicine (psychiatry), physical sciences (organic and physical chemistry, physics, materials science) and technology (biotechnology, chemical engineering, electrical engineering).

The Institute currently houses a total of 65 research workers in five main groups. Each group has its own separate and independent programmes driven solely by the interests of the individual group leaders. Nevertheless, particularly remarkable is the breadth of activities within individual research groups, and it is a feature of the Institute's research environment that it stimulates not only interactive collaborations between groups within the Institute, but also completely new activities within groups. The experience of the Institute has shown that successful interfaces of multidisciplinarity are initially often not obvious and therefore cannot be designed or forced. Rather, they need to grow organically from a genuine desire and enthusiasm for new opportunities and directions created by a shared culture of enquiry and discovery and an interest in the processes of application. All groups have adopted significant new research directions within the last ten years, either as a result of intra-Institute collaboration, external collaboration or by capitalising on new funding opportunities.

External collaborations both within Cambridge University and outside are also numerous. Interactions in Cambridge exist at a variety of research levels with the Departments of Biochemistry, Plant Sciences, Genetics, the Veterinary School, Engineering, Chemical Engineering, Materials Science and Metallurgy, the IRC in Nanotechnology, Chemistry and Physics. Recent innovations include the establishment of links with the Medical School and the creation of the Cambridge Centre for Neuropsychiatric Research (CCNR).[5] All groups are members of one or more EU network programmes. The Institute has a high profile on the international stage and is engaged in multiple external collaborative programmes.

Teaching and training activities

The second key axis is that of training; the Institute currently has approximately 35 students enrolled in its MPhil and PhD programmes by research and 25 on its

newly introduced taught Master's in Bioscience Enterprise (MBE) course, the latter course being initially pump-primed by the CMI, but soon to become self-financing. The MBE course covers science and technology, business and transitionary modules and a four to six week internship. Students enrolled on this course and from the MBA programmes from the Judge Institute of Management Studies and Institute for Manufacturing have proved particularly valuable in assessing the potential marketability and in establishing spin-off companies arising out of research emanating from the Institute of Biotechnology. The Institute provides training at the postgraduate level and has sought to expand the programme available to develop both research expertise and excellence, while also providing the essential transferable skills to prepare the students for careers in both industry and academia. In order to maintain world leadership, it is important to provide a background and training of the highest academic standard and with an understanding and familiarity of business, commerce and ethics that will equip the students for leadership and judgment in their future careers. The most unique aspect of the Institute is its multidisciplinary approach, which fosters and encourages interactive research and provides the core strength of the graduate training programmes. Through the research environment, both inter- and intra-disciplinary activity is stimulated and the development of a special combination of skills and expertise is fostered through an exciting and stimulating learning environment. Hence, research projects are offered with a primary focus in the areas actively being pursued within the Institute and cover a remit defined within the environment encompassing a programme allowing fundamental, strategic and applied research, including training at the interface of academia and industry.

The Institute's programme offers a much sought-after opportunity to obtain real understanding and expertise in both the science and business sectors and some emphasis is therefore placed on the business–science interface. This unique environment of cutting edge science and business entrepreneurship is at the core of the training environment. Underpinning this environment, the Institute hosts the Master's Programme in BioScience Enterprise in conjunction with the MIT. The Master's Programme in Bioscience Enterprise aims to provide a cross-disciplinary education for future leaders of the life science sector. It consists of a range of modules covering the broad areas of:

- science and technology;
- business management;
- science communication;
- ethics, regulation, law and policy.

In addition, it addresses a number of the issues arising from the integration of bioscience and business, such as informatics, technology transfer and the commercialisation of science.

Technology transfer and exploitation

The third key axis of the seamless multidimensional environment is designed to facilitate the process of technology transfer from the fundamental research platforms being pursued in the Institute to commercial reality. The Institute has established extensive links with local, national and international industry and is acutely aware of most of the fundamental issues facing the commercialisation of science and technology from an academic habitat into sustainable knowledge-based industries. Initially, this process was conducted on a largely *ad hoc* basis, but in the current more pro-active entrepreneurial climate, the University of Cambridge has established extensive procedures and capabilities via the Research Services Division, the Technology Transfer

Office, Cambridge University Technical Services Ltd, the Corporate Liaison Office and the University of Cambridge Challenge Fund, now collectively referred to as Cambridge Enterprise. The Institute now takes full advantage of these new advice and practical services to bolster its technology transfer and exploitation approaches.

The guiding principle is to establish novel and exploitable science emanating from the research programmes, recognise its value in diverse market niches, protect it via patents, investigate the possibilities for exploitation via established or spin-out companies and then proceed to commercialisation by the most appropriate route. Students from the Master's in Bioscience Enterprise and from the MBA programmes of the Judge Institute of Management Studies have proven particularly valuable in helping to assess the potential marketability of the work. Since the Institute of Biotechnology was formally established in 1988, about 60 patents have been filed and seven companies founded:

The Institute aims to proceed to commercialisation by the most appropriate route

- Affinity Sensors Ltd;
- Cambridge Biotechnology Consultants Ltd;
- Cambridge Sensors Ltd (formerly Environmental Sensors Ltd);
- Lumora Ltd;
- ProMetic BioSciences Inc. (formerly Affinity Chromatography Ltd);
- Purely Proteins Ltd;
- Smart Holograms Ltd.

These companies have raised substantial angel, corporate and venture capital (VC) funding, collectively employ ~200 people, have a current market capitalisation of ~£200m, and have been established with a research budget of ~£20m, of which only 50 per cent was from UK public sources. One of these companies (ProMetic BioSciences Inc.) is now quoted on the Montreal stock exchange and employs skilled scientists on both sides of the Atlantic. A second of these companies (Lumora Ltd) has recently arisen out of the integration of the Institute and members of the MBE course, while other joint activities have resulted in Institute students winning the £50,000 business plan competition (bSure Inc.), a £1,000 award and one of the not-for-profit prizes in 2004.

Each of these companies have been funded via different mechanisms: Affinity Sensors Ltd was established following a collaboration between the Institute, Fisons Ltd and Plessey Research (Caswell) Ltd and funded from an in-house investment from Fisons Ltd. Cambridge Sensors Ltd was funded initially via equity and R&D contracts from two blue-chip companies, British Nuclear Fuels Ltd and Anglian Water plc, prior to raising £3.5m from the City of London. Purely Proteins Ltd raised its finance from VC sources, while Smart Holograms Ltd was financed by an investment from the University of Cambridge Challenge Fund and subsequent VC input from Partnerships UK and Porton Capital Ltd. ProMetic BioSciences Inc. arose out of a merger between Affinity Chromatography Ltd and ProMetic Pharma Inc. of Montreal and is now quoted on the Montreal and Toronto stock exchanges and employs skilled scientists (~150) on both sides of the Atlantic. The Institute and Affinity Chromatography Ltd jointly won a Queen's Award for Technological Achievement in 1996 in recognition of the scientific advance and commercial success for novel protein purification technology from the Institute. Only five academic organisations have ever won such a prestigious accolade in the history of the Queen's Award scheme. Lumora Ltd has recently arisen out of the integration of the Institute and members of the MBE course. Members of the Institute actively participate in a number

of local, national and international entrepreneurship and exploitation activities.

These developments are clearly in line with current UK Government thinking of ensuring the universities should engage with the business world. Interestingly, a recent survey of 164 higher education institutions by the Higher Education Funding Council for England has revealed a dynamic sector which is more business-orientated, better at conjoining its research to the needs of industry and more cost-effective than equivalent American universities. UK universities created one spin-off company for every £17m they spent on research, compared with a ratio of 1 to £60m spent in the USA. The Institute of Biotechnology's ratio of one spin-off company per every £7m spent on research attests to the success of the paradigm pursued at the Institute.

Creating spin-offs is good value for money

However, more recently, in 2002/2003, the number of spin-off companies established by UK universities has fallen, while the number of patents granted has almost doubled in the same period. An issue that arises within the university sector and that may explain the trend is the fact that most universities in the UK do not back their spin-outs with appropriate resources, and consequently there is a high attrition rate. While venture capitalists expect 10–15 per cent of the new businesses they back, albeit out of a larger pool, to create wealth, the proportion of successful university spin-outs is much lower. In the case of the Institute of Biotechnology, the companies are pre-incubated within the relatively protected environment of the university laboratories, prior to allowing the company to emerge as an 'imago' when adequate funding is in place. Technology transfer is achieved by transferring key individuals with the move to new premises. The Institute promotes an ongoing dialogue with the newly formed imago companies by applying for joint grants, creating three-way interactions with third party companies and having pipeline agreements to exploit future research in the relevant areas. Figure 2 outlines the general *modus operandi* of the Institute and shows its location within the University surrounded by a 'halo' of spin-off companies with ongoing dialogue with the parent Institute, the third party relationships and the funding routes through the academic and commercial channels.

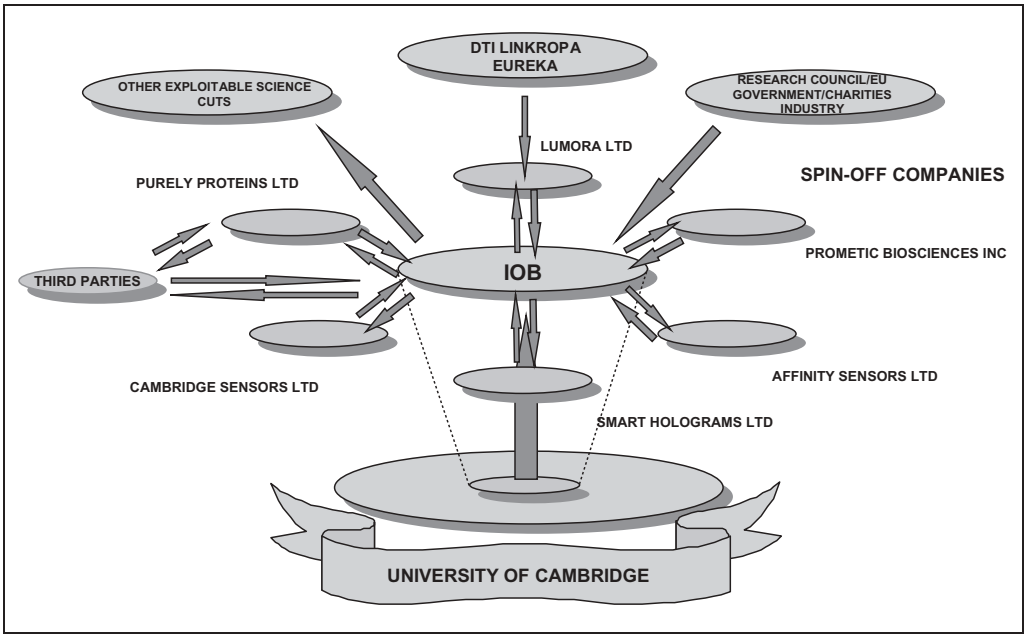

Figure 2: Operational model for the Institute of Biotechnology (IOB)

SUCCESSES, CHALLENGES AND ORGANISATIONAL HURDLES

What have been the elements that have contributed to the success of the Institute in spinning-out a number of sustainable companies? The key factors are at the frontiers of biology and other scientific and technological disciplines, strong independent and innovative research programme, a broad interpretation of biotechnology, the appointment of dynamic and visionary individuals with total commitment to the concept of a truly multidisciplinary institute, the fostering of new research directions between groups and a strong sense of identity as a pioneering entrepreneurial organisation.

'Multidisciplinarity' is difficult to achieve

To be successful, however, there are a number of other significant and, at the time of writing, ongoing challenges in creating spin-outs from a university environment. These other considerations reflect strongly on the underlying research and exploitation culture in the UK. A key one relates to the challenges involved in multidisciplinary research *per se* within a traditional university environment. The Institute of Biotechnology cannot be regarded as a 'conventional' university department in that it has developed its scientific programmes along lateral scientific trajectories rather than vertically integrated routes. In a world where much lip-service is paid to 'multidisciplinarity', the Institute has created unique interfaces between disciplines that have catalysed growth of new research areas and their subsequent exploitation in spin-off companies. One example of this approach is the development over several years of physically-, chemically and biologically sensitive holograms for application in biomedical diagnostics, high-throughput biology and security/packaging. This programme has involved the participation of biologists, chemists, physicists and engineers, and has resulted in a new and well-funded spin-out company, Smart Holograms Ltd, targeting lucrative multi-billion dollar potential markets.

This multidisciplinary philosophy does not sit well on a typical vertically integrated university organigram comprising department, faculty and school structures, nor on the classical distribution of academic expertise on national committees, professional bodies and societies, research council and other funding bodies, government departments or, for that matter, industrial sectors. For example, there are well-established professional organisations for the promotion of science, medicine, engineering and industry, but no suitable organisation to promote technology in general. Furthermore, multidisciplinary technology is notoriously difficult to assess in the classical peer-reviewed process in the UK, with a limited number of individuals in the country able to appreciate the breadth and depth of such proposals in their holistic entirety. The same can be said of research assessment exercises (RAE), where technology, which is neither science nor engineering, is universally perceived as being disadvantaged, compared with conventional and well-populated academic subject streams with an established large cohort of players.

A second key issue relates to the difficulties experienced in attempting to publish multidisciplinary science in mainstream academic journals, where common experience suggests that acceptance is more likely in journals of lower impact rating, especially if the work perpetrates the physical or engineering worlds, or is considered 'specialist'. Furthermore, it is not often appreciated that multidisciplinary technology is expensive to perform in terms of finance, space, personnel and administration: it is perceived to be a 'short-term' problem-solving activity. Current approaches to fund such research within the UK are wholly inadequate, both in terms of total funds available and the longevity of the funding timetable. A current and ongoing dilemma within the Institute is how to fund a multidisciplinary team comprising, for example, biochemists, organic and polymer chemists, physicists and

engineers, working contemporaneously in the same laboratory with parallel funding from multiple sources. A normal pattern of funding covering multiple sources and different overhead rates and intellectual property rights (IPR) exploitation rules can create substantive issues further down the value added chain if not carefully managed from the outset.

ATTITUDINAL BARRIERS

A second substantive issue relates to the attitudes of senior academics, government officials, industrialists and financiers to exploitable science. These attitudes are often enshrined within the traditional professional organisations noted above. However, although of late there has been a sea change in the culture of industrial collaboration and exploitation in the UK, residual cultural and demarcation impediments to wealth creation still remain. There is no doubt that the clearest factors that promote spin-outs are the dedication and commitment of the founding academic to the process of commercialising the technology. However, universities need to provide greater career support and entrepreneurial training to those academics who wish to exploit their work and reward them accordingly, rather than lauding them solely for research perceived to be of internationally competitive standard. In this context, 'a senior UK Treasury source' was reported as saying that the government was unwilling to increase substantially the funds towards universities for fear the money would be 'wasted' on academic salaries. With these views being expressed, it is no wonder that the only true asset most universities have, 'fine minds', is not being used to best advantage to the nation.

University's principal asset of 'fine minds' is not being used to the best advantage of the nation

With the university sector being nudged more and more towards ideas' generation and wealth creation, traditional territories are being encroached upon and will require a realignment of appropriate factions to ensure seamless exploitation of university-derived research. For example, universities should recognise that resources spent wisely on exploitation yield untied returns and are an investment rather than expenditure. Furthermore, the traditional file-and-license approach to patents, where the IPR is filed as a provisional patent and then licensed to a prospective exploiter prior to incurring serious maintenance costs, will have to give way to a more mature approach requiring the construction of patent portfolios to maximise returns on the research work. This route requires input of early-stage funding to ensure packaging of the technology into an exploitable portfolio.

One of the Institute's spin-off companies, Smart Holograms Ltd,[6] has now acquired a patent estate equivalent to 20 patents, which with substantial VC funding becomes a sizeable asset for the company. As noted above, an additional consideration is that funding of multidisciplinary teams through various organisations and regimes can result in multiple ownership, co-ownership and layered royalty payments in the event of exploitation of the results. All of these issues have to be carefully considered and resolved prior to any successful exploitation of the technology.

THE FUTURE

The Institute of Biotechnology has been uniquely successful in creating novel research opportunities at the interfaces between the biological, chemical, physical and engineering sciences, in building strong and truly interactive relationships with commercial sponsors, in creating an innovative and entrepreneurial training environment and in exploiting its technology for wealth creation within the UK via licensing and spin-off activities. In the future, it plans to consolidate these elements, by enhancing the research base, the training opportunities and the entrepreneurial and physical infrastructure. The Institute's vision is to create a new 'research-to-exploitation' (R2X) concept for biotechnology as an outward looking organisation offering solutions to complex research, development and exploitation challenges.

'Innovate or perish' is a new academic paradigm

This approach is the cornerstone of the current model (Figures 1 and 2) and it is proposed to extend it to the wider academic, business and service community in order to create a regional hub for biotechnology in the Eastern region. The old adage that academics 'publish or perish' is slowly being eroded and replaced by a new paradigm 'innovate or perish' where the future health of the nation as a knowledge-based economy is clearly at stake.

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