Michael J. Lynskey
is a researcher with several years' experience in managerial, consulting and non-executive directorship roles in business and industry. His research interests are in innovation, entrepreneurship, strategic management and technology management. He was previously in the Institute of Innovation Research (IIR) at Hitosubashi University, Tokyo; at the National Institute for Science and Technology Policy (NISTEP), Tokyo; and at the Research Center for Advanced Science and Technology (RCAST), University of Tokyo.

Keywords: *applied, basic, biotechnology, dualism, private, public, organisations, research, universities*

Michael J. Lynskey
St. John's College,
University of Cambridge,
Cambridge, CB2 1TP, UK

E-mail: mjl44@cam.ac.uk

The dismantling of redundant dichotomies: Biotechnology as an exemplar of university–industry collaboration

Michael J. Lynskey
Date received: 28th July, 2005

Abstract
This paper suggests that the established and distinctive dualisms invoked to describe aspects of research and forms of organisation are unravelling and becoming less meaningful in 21st century innovation, particularly as exemplified by university–industry collaboration in biotechnology. The *basic–applied* dualism to represent types of research activity and the *public–private* dualism to depict the nature of organisations are becoming redundant. Modern biotechnology draws on such an array of knowledge, from various disciplines and organisations, and with intricate, non-linear transfer mechanisms between actors, in order to deliver a broad range of applications, that conventional labels are becoming irrelevant. This has implications for the role and nature of the university in society.

The past is a foreign country: they do things differently there.[1]

INTRODUCTION

Twenty years ago, in May 1985, a Green Paper, entitled 'The Development of Higher Education into the 1990s', published by the Department of Education and Science, went much further than any previous UK government initiative to encourage universities to meet the needs of industry more closely, and by doing so attract private sector finance. The Green Paper painted a picture of the future in which universities would be much more responsive to the needs of industry by: (a) putting greater emphasis on the needs of science and technology; (b) encouraging industry to take an increasingly important role in funding and guiding university activities; (c) linking universities and industry to encourage the transfer of technology; and (d) fostering an entrepreneurial spirit for the improvement of economic prosperity.

A generation later, and after a review of various initiatives in the intervening years on the theme of university–industry linkages, one cannot help but be impressed by how much has been achieved. One is also struck by how many of the aspirations and antipathies prevalent today are similar to those in the 1980s and 1990s. Perhaps the past is not that foreign after all – many of the issues that motivated policy initiatives a generation ago remain with us, and various concerns in universities today result from the fact that we do not do things differently. *Plus ça change, plus c'est la même chose*. In particular, it seems that much of the debate throughout this period has focused on two abiding dichotomies: the 'public' versus 'private' nature of collaborating *organisations* and the permeability of that interface; and the 'basic' versus 'applied' nature of scientific and technological *activity* and the balance afforded to the two.[2] Maybe this is inevitable, since the use of mutually exclusive and jointly exhaustive aspects of debate are a feature of Western culture and philosophy.[3] One wonders, though, if these two dichotomies have become laden with assumptions to the point where they have become misnomers, and if progress might be easier if we could dispense altogether with such arbitrary categorisation. It is suggested in this paper that the symbiotic connections between academia and industry in modern biotechnology are doing precisely this – dismantling redundant dichotomies – and may provide an exemplar for other technology-based collaborations.

CHANGING ROLE OF UNIVERSITIES

A new social contract reflects the social accountability of university research and requires that it address social and economic needs

The *role* of universities has evolved considerably over the past two or three decades.[4] Universities were once regarded as focusing on two key roles – teaching and research – which were exogenous to, and independent from, specific economic and social development imperatives. This simple 'social contract' relied on a dissemination model of innovation whereby publicly funded basic research flowed to the economy through a 'Baconian' linear process. In this model, universities were seen solely as producers of knowledge;[5] firms then took forward those ideas the 'market' valued and launched them as products. This drew heavily on several aphorisms, worthy of Francis Bacon,[6] presented in a seminal report by Vannevar Bush.[7] The first of these aphorisms was that basic research is performed without thought of practical ends: 'Progress . . . depends upon a flow of new scientific knowledge . . . The responsibility for the creation of new scientific knowledge . . . rests on that small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research.'[8] The second was that basic research is the pacesetter of technological improvement; advances in basic science will be converted into technological applications by the process of technology transfer: 'Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.'[9] A third element in Bush's argument was that a nation would recapture the technological benefit of its investment in basic science: 'A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill'.[10] To this end, Bush recommended that, 'If the colleges, universities, and research institutes are to meet the rapidly increasing demands of industry and Government for new scientific knowledge, their basic research should be strengthened by use of public funds'.[11] Initially, this was well received. President Truman informed Congress on 6th September, 1945: 'No nation can maintain a position of leadership in the world today unless it develops to the full its scientific and technological resources. No government adequately meets its responsibilities unless it generously and intelligently supports and encourages the work of science in university, industry and . . . its own laboratories.'[12]

In time, however, the deficiencies of the linear model of innovation, together with increasing constraints on public funding for research,[13] led to new models of innovation,[14] and a new social contract that reflected the social accountability of university research and the requirement that it address social and economic needs.[15] Universities were asked to demonstrate the relevance to industry and society of their research and to act commercially by tendering for research contracts in the market, thereby contributing to the erosion of the distinction between public and private sector research.[16] As such, the political consensus in the UK in recent years has regarded university research as generating new products and processes whose commercial exploitation is a contribution of universities' research to wealth creation.[17]

Upstream biomedical research is likely to be 'private' in one or more senses of the term

Growth in all forms of third stream activities – patenting, licensing, consultancy and spin-outs – has occurred in major industrialised countries

Universities in the UK have responded to the call for 'a vigorous and commercial approach to the exploitation of university research'[18] which 'has been shown to have considerable commercial potential'.[19] Indeed, tangible manifestations of formal interaction and 'frequent and productive informal contacts between scientists and firms' as a means to commercialisation have been exhibited for many years.[20] Consequently, the University Directors of Industrial Liaison (UDIL) asserted that, 'research carried out in United Kingdom universities is outstanding in its innovative and commercially exploitable results'.[21] This view was reinforced when universities were described as developing 'constructive and outward-looking attitudes with a willingness to raise money from non-traditional sources, to engage in innovative projects and relationships with businesses and public sector bodies locally, nationally and internationally'.[22] Today, it is recognised that universities perform important roles as enablers, even leaders, of regional economic and social development and in regional innovation systems;[23] this has been captured in the notion of a third role – the so-called 'third stream' or 'third mission' – for universities.[24] There has been considerable growth in all forms of third stream activities – patents, licences, consultancy and spin-outs.[25]

Outside the UK, it was also popular to perceive universities and public research institutes as having a more entrepreneurial role than before, and one in which 'as university technology transfer shifts its emphasis from licensing to venture formation . . . talented researchers develop some ideas that may have great commercial potential'.[26] In America, the Stevenson–Wydler Technology Innovation Act and the Bayh–Dole Act, both passed in 1980, changed the law in two significant ways. The first act aimed at transferring technology out of the country's national laboratories and provided the means for others to access the laboratories' developments.[27] The second allowed universities, not-for-profit research institutes and small businesses doing research under government contract to keep the technologies they had developed and apply for patents in their own names.[28]

Responding to a shift in US government policy following the introduction of the Bayh–Dole Act, public research institutions and universities have created technology transfer offices to patent and license their discoveries.[29] At the same time, in the emerging field of modern biotechnology, new, dedicated firms sprang up in research and development niches between the upstream research conducted by academic laboratories and the targeted product development of pharmaceutical companies.[30] In the USA, the university was described as evolving 'into an enterprise capable of obtaining income from its research activities',[31] leading to 'a new commercial ethos associated with technology transfer'.[32] Today, upstream research in the biomedical sciences is increasingly likely to be 'private' in one or more senses of the term: supported by private funds, undertaken in a private institution, or privately appropriated through patents, trade secrets or agreements that restrict the use of materials and data.

Similar changes to those in the UK and the USA have also occurred in Japan over the past two decades.[33] The Ministry of Education issued an edict entitled 'Collaborative Research with the Private Sector and Others' in May 1983. This inaugurated the system for collaborative research efforts by national university researchers and those in the private sector on themes of common interest. Prior to this, certain barriers stood in the way of formal academic–industrial liaison, which did not even begin until the mid-1960s; and additional sources of finance, other than those provided by the government and for contract research assignments, were unwelcome.[34] Two decades later, the institutional environment has changed remarkably in Japan. In April 2004, the

Japanese government denationalised and gave administrative independence and corporate status to the 89 national research laboratories and 99 national universities – these became 'independent administrative institutions' or 'university corporations'.[35] The Japanese government also opened up the system of government-funded research for unprecedented cooperative ventures among various combinations of public and private universities, former national research centres and for-profit corporations. Universities are joining forces with venture capital firms in order to strengthen their financial bases, by building businesses from their research findings and turning them into viable sources of income.[36] This has caused some concern in Japan about what sort of research is valued. Joint projects with companies tend to be established to go quickly to market, which has caused some to complain about the abandonment of basic research.

Arguably, the transition in universities to a position of less dependence upon government support has occurred most significantly in the UK during the past two decades, but it can also be seen elsewhere, such as in the USA and Japan, despite being partially obscured by absolute increases in government research funding in selected research fields such as health.[37] Science is recognised as an alternative engine of economic growth to the classic triumvirate of land, labour and capital, the traditional sources of wealth.[38] Accordingly, changing the structure and function of universities – the wellsprings of many advances in science and technology – has become a crucial task to facilitate knowledge exchange with industry in order to develop new sources of innovation.[39]

Studies reveal substantial university-industry linkages in the UK and USA, but there are questions about its relevance and the commitment of both parties

ATTITUDES TO COLLABORATION

University–industry partnerships have existed for a long time. A number of studies by historians of science and technology show that close links between universities and industrialists date back to the mid-19th century.[40] Their diversity was certainly recognised decades ago: 'There are already numerous and varied contacts';[41] 'Individual academic scientists have a great variety of relationships with private firms'.[42] There is also evidence of the incidence of these linkages. Rothwell investigated small firms in the UK and found that 55 per cent had regular contact, with R&D activities being undertaken in universities and similar institutes, and 51 per cent had received technical inputs of use to their innovative activities.[43] A subsequent comparative study of science park firms revealed that 59 per cent had informal contact with scientists in universities.[44] In the USA, an early survey of industrial research firms and their interactions with federal laboratories identified workshops and seminars, laboratory visits and technical consultations as among the most frequently used interactions.[45]

More recently, research based on interviews with 800 small- and medium-sized enterprises (SMEs) in the UK and USA revealed that British universities enjoy substantial links with business.[46] Apparently, two-thirds of British firms use universities and higher education institutions as sources of knowledge, and almost a quarter of these businesses have research collaborations with them. The results also indicated that a third of SMEs in the USA enjoy similar links with universities, and that 14 per cent are involved in research collaborations. While the UK exceeded the USA in terms of the extent of university–business links, the study revealed that US collaborations tended to be deeper and more beneficial to companies. In all, 30 per cent of SMEs in the USA rated their links with universities as 'highly important' sources of knowledge compared with 13 per cent of UK firms. While one might reasonably question the high level of university–industry links found by the study, one interpretation of the low score for the importance of UK universities as sources of knowledge may be because university research in the UK is seen as less relevant to the needs of business, and university expertise is not valued as highly as in the USA. The words of Simon Davey, chief executive of Scientific Generics, probably ring true:

> UK university–business collaboration has been unsuccessful for too long. The UK has an exceptionally strong science and technology base, founded primarily in our university research capability. Yet business and academia consistently fail to translate this resource into profitable world-leading technologies and products made by companies with sustainable futures. Both sides are equally to blame.
>
> Business continues to limit its investment in university-led – and, in effect, state-subsidised – research and development. In the UK, business spends only 2 per cent of its available budget on university research. Academia, on the other hand, consistently refuses to acknowledge the link between research and profit.[47]

Reaction to university–industry collaboration has historically been varied. Some authors have suggested that academic researchers move easily between academic and commercial research.[48] Others have maintained that academics are essentially unwilling to become involved in commercialisation.[49] Concerns about collaborative work with industry have included constraints on the dissemination of knowledge, a drift from *basic* to *applied* research, the principle of individual *industrial companies* benefiting commercially from *publicly funded* research, and the belief that an academic's duty is towards scholarship and intellectual enquiry, which has little in common with the concerns of industry. These concerns lie at the heart of the dichotomies mentioned earlier. Louis *et al.* found that there was little evidence in their survey of American academics 'to suggest that most life scientists are more interested in commercial activities than traditional scientific endeavours'.[50] Other research has found mixed attitudes or evidence of greater willingness on the part of academic scientists to become involved with industry.[51]

Concerns about collaboration lie at the heart of the *basic-applied* and the *public-private* dichotomies

One explanation for the ambiguous or negative attitudes towards academic–industry collaboration appeared to be that most researchers considered the costs to their professional careers as greater than any potential rewards.[52] Others appeared to resent what they saw as an over-emphasis on R&D for commercial profit, rather than for intellectual returns.[53] This was echoed in Senker's interviews with over 100 UK university researchers and their commercial counterparts in biotechnology:

> many academic researchers would prefer not to have to take industrial contracts at all. They believe the role of the academic scientist is to do good, curiosity-driven, 'blue sky' research, whose potential significance for industry may not emerge for many decades. Reliance on industrial funding, they fear, may deflect them from doing basic research.[54]

One wonders, though, if the 'fear' expressed by academic scientists genuinely related to the prospect of science per se suffering gratuitously because of industrial funding or to the scientists' aspirations for secure, permanent positions. It is interesting to note that industry doubled its support for British university science during the 1980s.[55] The Committee of Vice-Chancellors and Principals itself acknowledged this in its 'State of the Universities' (1991): 'Increases in funding from industry and medical charities have more than made up for the lack of government funding over the past decade.'[56] The source of funding invariably affects the nature of its deployment. Industry funding is usually directed to discrete projects and to research positions of limited duration, but does not routinely endow permanent university positions.

Senker's findings corroborated other studies which found that academics deliberately placed constraints on their potential involvement in commercialisation, in part because few were strongly attracted by a profit motive,[57] and also because of the resentment shown to pragmatic, commercially-minded colleagues by 'pure science'-oriented faculty members, who:

> seem to think that any kind of business is self-serving and does not fulfil any useful role in the community.[58]

> The scientist comes to feel as if he is being treated as the enemy within . . . the perceived reaction of colleagues and university administrators to the sudden appearance of the seed of business within that environment.[59]

This dilemma is still faced by academic scientists today:

> Educators must use their own judgment in deciding when to pursue opportunities for profit. This is often hard to do when outside critics urge academic leaders to copy corporations, while sentiments within the academy resist anything that smacks of commercial methods and values.[60]

Part of this hostility is explained by cultural differences between academia and industry,[61] to the extent that 'managers and biologists inhabit quite different cultures'.[62] In a survey of UK industrial liaison officers, it was reported that 'academics tended not to be driven by personal financial gain and that the opportunity to carry on research unfettered by commercial sponsors and a desire to see the results of their work applied were more effective drivers'. Moreover, 'academic staff are required to focus in the main on publication success and on securing new grant opportunities rather than on taking old grant successes through to commercial application'.[63] More recently, the Royal Society of Chemistry raised the same matter in a report on science spin-out firms:

Biotechnology provides an exemplar of a new form of knowledge production

> Within universities, a mismatch exists between academic and commercial cultures. Universities by their very nature reward academics for their research and teaching efforts and do not generally encourage or reward entrepreneurship.[64]

There have, though, been some examples of countervailing evidence. For example, an early case study of the UK Plant Breeding Institute (PBI) touched on the vanishing distinction between basic and applied research, revealing that 'the early philosophy for the PBI was that plant breeding must integrate research and development, so that there is no arbitrary distinction between "pure" and "applied" research or between physiology, genetics, pathology . . . the staff themselves did not perceive their discrete activities in these simplistic terms . . . it was much more a matter of making deals that respected each group's specific language, skill and professional orientation to the job'.[65] More recently, there are examples of academic entrepreneurs who recognise the complementary aspects of academe and business. Professor Stephen Davies, the founder and chairman of an Oxford University spin-off firm, has stated:

> I have more money than I need to survive with the lifestyle I lead. But I, and my colleagues at VASTox, don't want to swap academe for business, however much money we make. I love chemistry and supervising PhD students. I love doing my full-time academic job. The business is a way to fund my research group and to employ PhD chemistry students.[66]

COMMERCIALISATION OF BIOTECHNOLOGY

Broadly speaking, the path to commercialisation of a new technology may be identified by three phases of evolution: phase one (*science-driven*), where primary emphasis is placed on scientific research; phase two (*technology-driven*), with primary emphasis on technology development and

The disjunction between understanding-inspired 'basic' research and use-inspired 'applied' research is little more than an abstraction

standardisation; and phase three (*commercialisation*), with primary emphasis on commercial development and application. Modern biotechnology perhaps provides an exemplar of a new form of knowledge production where university–industry collaboration has been evident in all three phases of this evolution since its inception, driven largely by scientific and commercial requirements.

Universities and other publicly funded research institutions were the birthplace of biotechnology, and the frontiers of knowledge remain largely in their domain. The fundamental science and techniques of biotechnology emerging from universities proved to be vitally important to the initial success of the biotechnology industry and its subsequent expansion.[67] Moreover, the unprecedented commercial rewards for universities were realised from the beginning:

> For the first time in basic biomedical research, the university has something extremely valuable to sell . . . potential profits from recombinant DNA and monoclonal antibody technology are enormous enough to make a substantial difference in the financial picture of any university lucky enough to have on its faculty researchers on the frontier of this science.[68]

There are two main reasons why university–industry interaction was fundamental to biotechnology, and this had a bearing on the subsequent nature of the public–private and basic–applied dichotomies. Firstly, the results of *basic* biotechnology research *activity* were very close to the form in which they were *applied*; and the closer basic research was to commercialisation, the greater the opportunity for the university to become involved. Secondly, the industrial *organisation* of biotechnology had not yet been determined. Biotechnology has *applications* in many industries, and no established industry – not even the traditional chemical or pharmaceutical industries – can be said to have been pioneers in this field.[69] In this industrial vacuum, start-up biotechnology firms emerged to become significant transfer agents through which scientific advances in university research laboratories were translated into commercial application in what has been characterised as 'one of modern history's best examples of technology transfer from universities to industry'.[70] Nevertheless, expertise in biotechnology remained substantially in the university. These two factors – the *nature* of the new technology (the *activity* factor) and the lack of a clear industrial *structure* (the *organisational* factor) – provided the opportunity for universities to become extensively engaged in the commercialisation of biotechnology.

Basic–applied dichotomy

Basic research in biotechnology is close to the form in which it is *applied*. Biotechnology is an exemplar of the new forms of knowledge production based on multidisciplinary approaches and problem solving in the context of *application*. The development of biotechnology, as a form of knowledge production, is characterised by the convergence of a diverse set of skills from a variety of disciplines. This convergence and the linkages between disciplines have eroded the boundaries between what traditionally has been called 'scientific activity' and 'technological activity'. The foundational *basic* research – most notably the discovery of recombinant DNA methods and cell infusion technology that creates monoclonal antibodies – drew primarily on molecular biology and immunology. Although these early discoveries had an inherent exclusivity, the science diffused rapidly over time as linkages between universities and industry expanded. Many new areas of science – such as genetics, biochemistry, cell biology, computer science and nanotechnology – have become inextricably involved in this process of knowledge production. Arguably, therefore, biotechnology is not a discipline or an industry per se, but rather a set of enabling technologies relevant to a wide range of applications.

In biotechnology, then, the disjunction between understanding-inspired 'basic' research and use-inspired 'applied' research is little more than an abstraction that is increasingly difficult to maintain.[71] Historical and cognitive evidence shows that the distinctions of 'basic' and 'applied' research are human constructions and, as such, have become a handicap to the emerging knowledge-based economy.[72] Again, this seems to have been recognised early on in biotechnology:

There has arisen novel forms of pubic-private linkages

> In reviewing the history and current state of industrial microbiology, we are struck by an abiding theme: mutually beneficial relations between what we have come to call basic research and applied research . . . This synergy between science and technology, we believe is the key to progress in industrial microbiology.[73]

Recognition of the congruence between *basic* and *applied* research vitiates the ideological separation of these activities. Until quite recently, academic scientists generally accepted that the advancement of knowledge was synonymous with pure, theoretical research. Recent examples of research, however, in which theoretical advances have occurred in conjunction with applied advances, have called into question the assumption of a unidirectional flow from basic to applied research and industrial innovation.[74] The acceptance of dualisms, such as patents versus publications[75] and 'basic' versus 'applied' research goals, were the obvious expressions of a theory of knowledge based on an underlying dichotomy that placed scientific advance in opposition to technological advance.

Public–private dichotomy

Increasingly, there is something of a myth about the two sectors – public and private

Biotechnology is a field in which public research is a significant source of external knowledge for firms.[76] It exhibits a high degree of formal linkage activity with universities and public research institutes, in terms of joint research and reliance on literature and other codified knowledge; and its researchers are also keen to be on the unpublished grapevine through informal networking.[77] These relations between laboratories and firms represent a techno-economic coordination between heterogeneous *public* and *private* actors, which links science, technology and the market in the production of scientific knowledge to economic goods. Such collaboration and knowledge transfer between public sector research organisations, especially university laboratories, and private firms has been intense since the early 1980s, and has given rise to novel forms of public–private linkages, such as the campus laboratory and university spin-off firms.[78] This has resulted in fundamental changes in the funding and conduct of research.[79]

In recent years, the biological sciences have developed more fluid and overlapping organisational boundaries, partly because of the expansion of funding by mission-oriented agencies on a project basis. As a new 'technological paradigm'[80] biotechnology involves 'specific search models, knowledge bases, and combinations between proprietary and public forms of technological knowledge'. That is, there is a 'specific balance between exogenous determinants of innovation (eg university-based advances in pure science) and determinants that are endogenous to the process of competition and technological accumulation of particular firms and industries'.[81]

> firms involved in biotechnology . . . have attempted to play an active role in shaping demand . . . by intervening in the public arena, encouraging institutional innovations or attempting to modify the regulatory and policy environment that influences demand.[82]

Increasingly, there is something of a myth about the two sectors – public and private. The accepted distinction between the two is losing meaning in reality, with the blurring of the interface. This is not simply because many functions previously part of the public arena have been privatised: 'A large, vital and expanding part of what is called the public sector is for all practical effect in the private sector'; it is also a function of the symbiotic relationship between industry, university and government in biotechnology.[83]

> Significantly, both public science and proprietary science have moved closer to one another in what interests them and what they can do. Both sectors are performing basic research and doing it well.[84]

The symbiotic connection between academia and knowledge-based industry is exemplified by the growth of new biotechnology firms emanating from universities; similarly, there have been changes in the nature and structure of biotechnology firms, some of which are moving towards an academic mode in operating as 'quasi-universities'. These firms employ postdoctoral fellows, undertake fundamental research that can be used to produce drugs, and share knowledge, which formerly would have been proprietary, with other firms in research project consortia. Universities, too, increasingly have corporate R&D facilities interspersed among academic buildings and departments as part of regional economic development strategies, and they resemble 'hybrid' organisations of academic–industry collaboration. They have also become marketeers of intellectual property and venture capitalist investors in their own spin-off firms, inspiring the notion of the 'entrepreneurial university'.[85] Thus, the distinction between the activities of universities and firms is coalescing in biotechnology.[86] As Robertson argued:

There remain some misgivings about combining the pursuit of the truth with that of profits

> The development of new information networks and the growth of centres of expertise outside universities open up the possibility that a new kind of learning market may be forming in which the campus-based residential university is merely one of a number of suppliers of higher education.[87]

In conclusion, the previous demarcations between 'public' and 'private' and between 'basic' and 'applied' research activities seem increasingly irrelevant; and innovation in biotechnology, together with entrepreneurship itself, appears to be diffused among diverse researchers, disciplines and organisations.[88]

'The academic–industry divide is a less clear-cut division than it has been for years. A lot of major pharmaceutical companies feel they need to address more basic science questions if they are to develop better drugs faster. Government agencies, too, are shifting towards the clinical end of the spectrum'.[89]

AN INSTITUTION FOR ALL SEASONS

This is a time of considerable public concern about the role of universities and the direction of science in society.[90] Pushing back the boundaries of knowledge is a hallmark of a free and civilised society,[91] but there remain some legitimate misgivings about the costs of encouraging researchers to combine the pursuit of truth and profit. Those costs are substantial. They include short-term profit undermining the commitment of universities to curiosity-driven research, that collegiality among scientists could collapse, and that proprietary science could threaten the open exchange of knowledge. These have triggered a series of exceptional scandals, from withholding data, through undeclared interests in supposedly objective clinical trials, to dismissing faculty who attempt to publish results that might upset a major corporate sponsor. The financial incentives are also substantial. Industry-funded research and development in US universities stood at nearly 7.42 per cent of the total in 2003,[92] but it is clear from surveys that in biomedicine a higher proportion of faculty consult for companies than this might suggest.[93] It is so high that in 2002 the *New England Journal of Medicine* weakened its stringent prohibition on conflicts of interest for authors of reviews and editorials.

More troubling were the results of a survey of university and government laboratories in the UK, which revealed that at least one in ten scientists has been asked by a commercial backer to tailor their research conclusion or advice to meet the sponsor's requirements. The survey showed that 7.9 per cent of all respondents have been asked to modify their results to suit the preferred outcome of a commercial sponsor. The figure rose to more than 15 per cent for female scientists. A further 1.2 per cent of all scientists had been asked to alter results to obtain further contracts and 1.7 per cent had been discouraged from publishing.[94] Likewise, researchers report withholding publication of results that reflect negatively on a commercial partner. A Stanford University study found 98 per cent of research papers sponsored by drug companies reported that the products studied are effective. In contrast, only 79 per cent of papers not commercially sponsored report positive results.[95] Conflicts of interest such as these that may arise for the academic scientist necessarily lead to the impression that commercial endeavours have transformed the 'ethical norms of scientific and medical researchers'.[96] Clearly, more arrangements need to be put in place to maximise transparency and clarify where responsibility lies, otherwise such behaviour will give sustenance to those who think, like Erasmus, that commercial activities are synonymous with 'lies, perjury, thefts, frauds and deception'.[97]

The purpose of the modern university: A sanctuary in which to cultivate the intellect for its own sake; or a mere forcing-house of the intellect and a product of corporatism?

To all intents and purposes, the modern university appears to have renounced Newman's quest of universal knowledge and the 'cultivation of the intellect' for its own sake;[98] in many ways it has become what Pusey warned in the 19th century it should not become – a mere forcing-house of the intellect. This is a trend against which later scholars also inveighed; Oakeshott, for example, argued that the imperialism of the modern university was encouraging fits of absence of mind about what was properly the purpose of the university.[99] By idealising individual independence and personal detachment in science, writers such as Merton and Polanyi articulated a common belief: scientists operate best under conditions of intellectual freedom and lack of coercion from non-scientific influences:

> We may affirm that the pursuit of science by independent, self-coordinated initiatives assures the most efficient possible organization of science.[100]

More recently, Graham has sided firmly with Newman: the university should be for the development of the critical faculty that allows one to 'see things as they are, to go right to the point, to detect what is sophistical, and to discard what is irrelevant'.[101] Graham recognises that there should be some institutions where 'the pursuit of truth and understanding are given special protection, not to the exclusion of useful or socially relevant subjects, but not principally in their service either'. He recommends, moreover, that these institutions will need to be controlled by scholars, and their independence buttressed by more and diversified funding than is the case at present.

Could it be, though, that universities are reverting to type? After all, the medieval universities were, in one sense, extremely utilitarian in conception, and often in a specialised way; and the 19th century revolt against this was sometimes, but not always, anti-utilitarian.[102] Even worse than the accusation of being utilitarian, the main concern today is that the university has become subject to quasi-scientific and quasi-economic beliefs about its technological, financial and social benefits.[103] The perceived danger is that, as university administrations take on more of the traits and practices of the corporate culture around them, 'we will have made the university another product of an industrial society instead of the ethical center by which culture is transmitted and in which independent thinking is done'.[104]

The rise of the entreprenurial university

There has undoubtedly been a marked transformation in universities in Britain over the past few years.[105] One of the watershed changes has been the rise of the entrepreneurial university, based on the 'market', with its emphasis on raising productivity and consumer-focused packages of teaching and research.[106] The 1997 *Dearing Committee of Inquiry into Higher Education* made clear that the driving force should be education for 'business'.[107] It made an appeal for forging alliances between universities and the economy, recommending that universities meet labour market needs and foster research aimed at attracting investment. Interestingly, though, Dearing was not able to show what the economic benefits would be from an increased investment in higher education. That argument has still to be won, and the victory will lie in the detail – in the particular fields of research and the quality of learning experience where investment leads to economic advancement.[108]

It is a moot point whether commercialisation is a spur for creativity

Commercialisation has certainly created new trends: the language of 'enterprise' and the 'needs of industry' now pervades higher education. It is a moot point, though, whether this is a spur for creativity. Arguably, intellectual inquiry depends on isolated activity and research free from the management and accountancy imposed by the new bureaucracies that universities have adopted.[109] Good scientific research, the kind of research that propels disciplines into new frontiers, is perhaps still viewed as the accumulation of creative *individual* efforts; external influence in choosing topics or objectives is counterproductive. According to Polanyi, 'Any attempt at guiding scientific research toward a purpose other than its own is an attempt to deflect it from the advancement of science'.[110] The idea that universities should operate along market principles has become hard to contest, though. There is a case for public accountability given the amount of taxpayers' money going into universities; and apparently worthy concepts such as 'accountability' and 'transparency' are difficult to oppose. But, in accepting them, universities help to sustain bureaucratic regulation of their activity. It is difficult for universities, then, to complain that what they do – education and research – has an intrinsic worth that relies on their independence from vested political and economic interests.

Given the current political ideology and economic constraints, it seems unlikely that the trend for increasing university–industry collaboration will be reversed or halted – if, indeed, that is desirable. In a pithy and informed account of the dangers to universities of putting too much emphasis on commercialisation, Bok also revealed some home truths about the nature of universities: 'Universities share one characteristic with compulsive gamblers and exiled royalty: there is never enough money to satisfy their desires'. In consequence, 'universities show signs of excessive commercialization in every aspect of their work'. Like individuals experimenting with drugs, 'campus officials may believe that they can proceed without serious risk', but 'the hoped-for profits often fail to materialise, while the damage to academic standards and institutional integrity proves to be all too real'. The pursuit of ephemeral profit leads to the sacrifice of essential values: 'Universities will find it difficult to rebuild the public's trust, regain the faculty's respect, and return to the happier conditions of earlier times'.[111]

These reflections on the nature and future of the university naturally affect biomedical research and commercialisation, which rely on close university–industry collaboration. The knowledge, technology, skills and resources needed in biotechnology rarely reside in one organisation – the 'locus of innovation' is a network in biotechnology[112] – so there is a growing convergence across the interests, capacities and practices of public and proprietary science. Consequently, the very university–industry relationships that some observers[113] see as undermining public science may be essential to academic research endeavours in basic biomedicine.

The context and contributions of academic science are changing

The context of academic science is changing. Of course, scientists may still see their research and its publication as 'gift-giving' to the larger community for which they receive the intangible benefits of recognition and prestige.[114] At the same time, however, the ideas and findings of academic science more frequently have greater commercial value than in the past. What were once simply contributions to the literature are now frequently seen as providing funds for the university or as forming the basis for industrial collaboration. The institutional and organisational arrangements that maintain these endeavours need to support an expanded concept of science for the public good, where efficacy stems from engagement rather than separation. This calls for the adoption of 'a biomedical research strategy combining the creativity and individual skill of traditional publicly funded programs with the technology investment and team tradition of the commercial sector'.[115] Policies that respond to conflicts of interest by prohibiting cross-sector collaboration – which, as we have mentioned, are becoming indistinguishable in any case – may dry the well for fear of poisoning it. Rather, there are likely to be benefits to universities and the public of academic engagement with industry. Academic researchers have contributed substantially to the development of new therapies to improve human health. Several universities, for example, hold patents on antiretroviral drugs used to treat HIV/AIDS. The legal power that ownership of such intellectual property affords universities presents the possibility of public-interest benefits.[116] One could also argue that universities, with their inefficiencies and the vested interests of many career academics (those with little or no experience of working in industry), have much to learn from the business world:

Benefits to universities and the public of academic engagement with industry

> The private corporation – guided by the marketplace, stimulated by competition, and regulated by government – seems to possess a set of incentives that drive its members to do remarkably well in responding to the desires of consumers and achieving high levels of productive efficiency. In contrast, the university strikes many critics as a kind of anarchy, ill-suited for any purpose other than securing the comfort and convenience of the tenured professors.[117]

In a recent article, Lord Broers suggested that a second industrial revolution occurred in the 1990s, brought about by enormous strides in new technologies.[118] While one may question if this was a second industrial revolution – others, for example, have suggested that we are living through a fifth industrial revolution – there are certainly 'creative gales of destruction' or 'long waves' of economic activity, in the sense conveyed by Schumpeter and Kondratiev, which seem to reflect present-day advances in science and technology.[119] As Vice-Chancellor of Cambridge University from 1996 to 2003, Broers saw the role of universities in society as organisations that focus on fundamental research, are effective at technology transfer, and apply the full panoply of their ability and resources to the needs of society – an institution for every situation or opportunity. He lamented, however, the results of a joint international review of universities which concluded that, while some researchers in UK universities were aware of the impact their work might have beyond university boundaries, many researchers 'were not well informed or motivated to produce external impact'. Broers stated that the UK must address these shortcomings if it is to maintain a university base that can supply business-led innovation.

Broers's comments about failings in UK universities are matched by even the best. In concluding their monumental history of Harvard University, Keller and Keller state that: 'No institution is without its warts . . . Its capacity to adapt to intellectual, social and cultural change has been the chief source of Harvard's success – and the chief source of its problems and discontents'.[120] While there have been improvements in the past two decades or so, much of the debate in universities during this period seems to have centred on finding an appropriate role in society vis-à-vis industrial collaboration. This has focused on striking the right balance between the two dichotomies of basic and applied research and public and private structures. Biotechnology arguably provides an exemplar of university–industry collaboration in an age when these dichotomies are blurring and losing meaning. Instead, perhaps the most contentious outcome of increased university–industry collaboration is that the context of academic science will change so that the university will find it has abdicated its role as an objective, independent critic, and forsaken or weakened its norms of openness and disinterestedness.

The university must preserve its position as an open, disinterested institution offering informed, detached critiques of society

This need not be the case. Ultimately, it is the obligation of the university to look beyond short-term financial incentives and take a stance in its long-term interest. While this most assuredly would include recognition that it is bound to contribute to the solutions of society's needs, the university must also preserve its position as the one institution capable of simultaneously producing knowledge, disseminating information and offering informed, detached criticisms of society. Whatever linkages universities forge with industry, and for whatever reason, the overriding consideration ought to be the furtherance of knowledge, both now and in the future. Universities can and ought to have a genuine affinity for, and important links with, the 'enlargement of knowledge'.

References and notes

1. Hartley, L. P. (1953), 'The Go-Between', Hamish Hamilton, London, p. 1.
2. A 'research collaboration' may be described as 'the working together of researchers to achieve the common goal of producing new scientific knowledge. . . . [It] has a very "fuzzy" or ill-defined border. Exactly where that border is drawn is a matter of social convention and is open to negotiation. Perceptions regarding the precise location of the "boundary" of the collaboration may vary considerably across institutions, fields, sectors and countries as well as over time'. See: Katz, J. S. and Martin, B. R. (1997), 'What is research collaboration?', *Res. Pol.*, Vol. 26(1), pp. 1–18.
3. For example: Aristotle's concept of the actual and the potential; Descartes' *Cogito* argument; Kant's *phenomenal world* of conscious experience and *noumenal world* of objective external reality. More recently, see Snow, C. P. (1959), 'The Two Cultures and the Scientific Revolution', Cambridge University Press, Cambridge.
4. Originating as medieval institutions for the conservation and transmission of knowledge, universities later took up the discovery of new knowledge as an explicit academic goal. See: Rashdall, H. (1896), 'The Universities of Europe in the Middle Ages', Oxford University Press, Oxford; Jencks, C. and Riesman, D. (1968), 'The Academic Revolution', Doubleday, New York.
5. Malecki, E. J. (1997), 'Technology and Economic Development', Addison Wesley Longman, London.
6. Francis Bacon (1561–1626), 'the father of modern science', primarily laid down the principles of inductive science in the early 17th century. Much of the second part of 'The Advancement of Learning' (1605) consists of a plea to King James I for state support of academic science: 'To the King . . . there is not any part of good government more worthy than the further endowment of the world with sound and fruitful knowledge' ('The Advancement of Learning', 1605, Chap. 1 Book 2). Bacon believed that pure science underpinned applied science and technology: If any man think philosophy and universality to be idle studies, he doth not consider that all professions are from thence served and supplied' ('The Advancement of Learning', 1605, Chap. 8). Technology, he thought, created wealth: 'The benefits inventors confer extend to the whole human race' ('Novum Organum', 1620). When reading Bacon's work, one should bear in mind that the state as we conceive of it today

did not exist in Jacobean England, and neither did the government. This might help to explain why all of Bacon's convoluted appeals for funding and support for his plans were directed at the individual with most access to money and authority in the land: King James I. While he was head of state, James was also, effectively, a private patron. Bacon therefore lobbied the King for support in the same way that the modern entrepreneur might lobby for funding from a venture capitalist – if you support my ideas, more wealth and fame will accrue to you.

7. Bush, V. (1945), 'Science – The Endless Frontier: A Report to the President', US Government Printing Office, Washington, DC. Vannevar Bush was an electrical engineer (PhD in 1916 from the Harvard/MIT joint programme) who rose through MIT to become Vice-President and Dean of Engineering, but he left in 1938 to become the President of the Carnegie Institution (a private body which was then the USA's largest science funding agency). Bush was appointed the first director of the Office of Scientific Research and Development in 1941 by President Roosevelt.

8. Bush (1945), pp. 5 and 7.

9. Bush (1945), p. 19.

10. Bush (1945), p. 15.

11. Bush (1945), p. 16.

12. Quoted in 'Science Policy Study Background Report No. 1' (1986), US Government Printing Office, Washington, DC.

13. The finances of US Ivy League institutions dwarf even the largest UK university budgets and endowments. The University of Manchester yielded an annual budget of £490m for 2002–03, the highest in the UK, according to the Higher Education Statistics Agency. The University of Cambridge had the largest endowments, at £413.4m, followed by the University of Oxford with £406m, for 2002–03. In June 2004, Harvard University's endowments were US$22.6bn (£12.6bn), some 25 times larger than that of the University of Cambridge. Harvard's endowments had grown by more than one-fifth from US$18.85bn in June 2003. Yale University and Princeton University had endowments of US$11bn and US$8.7bn in 2003.

14. See, eg, Jolly, V. K. (1997), 'Commercializing New Technologies: Getting from Mind to Market', Harvard Business School Press, Boston, MA; Nightingale, P. (1998), 'A cognitive model of innovation', *Res. Pol.*, Vol. 27(7), pp. 689–709; Padmore, T., Schütze, H. and Gibson, H. (1998), 'Modelling systems of innovation: An enterprise-centred view', *Res. Pol.*, Vol. 26(6), pp. 605–624.

15. Kline, S. J. and Rosenberg, N. (1986), 'An overview of innovation', in Landau, R. and Rosenberg, N., Eds, 'The Positive Sum Strategy: Harnessing Technology for Economic Growth', National Academy Press, Washington, DC, pp. 275–305; Lundvall, B.-A. (1988), 'Innovation as an interactive process: From user-producer interaction to the national system of innovation' in Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L., Eds., 'Technical Change and Economic Theory', Pinter Publishers, London, pp. 349–369; Guston, D. H. and Keniston, K. (Eds), (1994), 'The Fragile Contract: University Science and the Federal Government', MIT Press, Cambridge, MA; Geuna, A. (1999), 'The Economics of Knowledge Production: Funding and the Structure of University Research', Edward Elgar, Cheltenham.

16. Rappert, B. (1995), 'Shifting notions of accountability in public and private sector research in the UK: Some central concerns', *Sci.Public Pol.*, Vol. 22(6), pp. 383–390.

17. Advisory Council on Science and Technology (ACOST) (1993), 'A Report on Medical Research and Health', Cabinet Office, OST. HMSO, London; Office of Science and Technology (OST) (1993), 'Realising Our Potential – A Strategy for Science, Engineering and Technology', White Paper. HMSO, London. More recently, the British Government's Science and Innovation Framework 2004–2014 can be found at URL: http://www.hmtreasury.gov.uk/spending_review/spend_sr04/associated_documents/spending_sr04_science.cfm. The Higher Education – Business and Community Interaction Survey 2002 –2003, published on 8th February 2005, shows that the level and quality of interaction between universities and business is increasing, helping to boost the UK economy (URL: http://www.hefce.ac.uk/pubs/hefce/2005/05_07/).

18. Advisory Board for the Research Councils (ABRC) (1986), 'Report of the Working Party on the Private Sector Funding of Scientific Research', London, p. 130.

19. Lowe, J. (1993), 'Commercialisation of university research; a policy perspective', *Technol. Anal. Strategic Manage.*, Vol. 5(1), pp. 27–31.

20. Office of Science and Technology (OST) (1993), 'Realising Our Potential – A Strategy for Science, Engineering and Technology', White Paper, HMSO, London. Informal linkages between universities and industry have long been recognised as being important, but difficult to quantify, and hence tend to be reported anecdotally: 'There are already numerous and varied contacts' (House of Commons (1976), 'Select Committee on Science and Technology

Third Report: University–Industry Relations', HMSO, London, para. 5.10).

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25. In 2003, UK universities generated £31.3m from licences, and in 2004 ten university spin-off companies floated on the stock market with a total market value of £604m on flotation.

26. McMullan, W. E. and Melnyk, K. (1988), 'University innovation centres and academic venture formation', *R&D Manage.*, Vol. 18(1), pp. 5–12.

27. The Stevenson–Wydler Act, described at congressional hearings as 'a harbinger of an increasingly cooperative relationship between government and industry', considered universities as a contributor to the effort to revitalise America's economic condition. See: US Congress (1980), 'Summary of house and senate hearings on government–university–industry relations. Report for the subcommittee on science research and technology', US Government Printing Office, Washington, DC.

28. The Bayh–Dole Act was introduced to promote an increase in technology transfer from universities to industry whereby universities may elect to retain title to inventions developed under government funding, but must share with the inventor/s a portion of any revenue received from licensing the invention. Under the Act, universities are obliged to have written agreements with faculty and technical staff requiring disclosure and assignment of inventions. While many universities are distributing royalties arising through inventions, patents and licensing to the inventor/s based on their relative contributions to the work, this pecuniary reward frequently does not apply to inventions or copyrights arising through work prepared by an employee within the scope of their employment (eg Stanford University, 1998). If academic institutions were to be truly supportive of trilateral arrangements of science, then reward systems within would need to focus on the rigour, quality and outcomes of, rather than the field of, the research (ie basic versus applied research) or the ability to publish. See: Council on Governmental Relations (1999), 'The Bayh–Dole Act: A Guide to the Law and Implementing Regulations', Council on Governmental Relations, Washington, DC; Stanford University (1998), 'Research Policy Handbook', Stanford University, Stanford, CA.

29. During the period 1980–2003, 4,081 new firms were formed in the USA based on a licence from an academic institution. Research by Richard Nelson and colleagues suggests that the Bayh–Dole legislation was merely one of several factors that contributed to an increase in patenting and technology transfer from American universities. Based on a presentation by Richard R. Nelson, of Columbia University, entitled 'The contribution of American research universities to technological progress in industry', Research Institute for Economy, Trade and Industry (RIETI), Tokyo, 11th December, 2001. Also, see: Mowery, D. C. and Ziedonis, A. A. (2002), 'Academic patent quality and quantity before and after the Bayh–Dole Act in the United States', *Res. Pol.*, Vol. 31(3), pp. 399–418.

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31. Etzkowitz, H. (1983), 'Entrepreneurial scientists and entrepreneurial universities in American academic science', *Minerva*, Vol. 21(2–3), pp. 198–233.

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33. We mention Japan because it is the second-largest market in the world after the USA for the goods and services of biotechnology, although the characteristics of its market are different from that of the USA and the UK. See: Lynskey, M. J. (2001), 'Technological distance, spatial distance and sources of knowledge: Japanese 'new entrants' in 'new' biotechnology', in Burgelman, R. and

Chesbrough, H., Eds, 'Comparative Studies of Technological Evolution', Elsevier Press, Amsterdam and Oxford, chapter 5, pp. 127–205.

34. Phillips, G. O. (1989), 'Innovation and Technology Transfer in Japan and Europe', Routledge, London and New York. Actually, a formal system of academic–industry collaboration had existed from the late 19th century in Japan, but this was repressed during the allied occupation after the Second World War, and reduced to informal relations.

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37. See, eg, National Science Foundation (2002), 'Science and Engineering Indicators – 2002', National Science Foundation, Arlington, VA.

38. As identified by John Stuart Mill in his 'Principles of Political Economy' (1848). Also, see Freeman, C. and Soete, L. (1997), 'The Economics of Industrial Innovation', MIT Press, Cambridge, MA.

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46. See: Johnston, C. (2004), 'Business taps sector for ideas', *The Times Higher Educ. Suppl.* 3rd December, p. 9.

47. See: Davey, S. (2005), 'A lay-by on the road to market', *The Times Higher Educ. Suppl.* 8th July, p. 16.

48. Etzkowitz, H. (1983), 'Entrepreneurial scientists and entrepreneurial universities in American academic science', *Minerva*, Vol. 21(2–3), pp. 198–233; Webster, A. J. (1989), 'Privatisation of public sector research: The case of a plant breeding institute', *Sci. Public Pol.*, Vol. 16(4), pp. 224–232.

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64. See: Davis, C. (2005), 'Hefce failing to reward spin-offs', *The Times Higher Educ. Suppl.*, 11th March, p. 7.

65. Webster, A. J. (1989), 'Privatisation of public sector research: The case of a plant breeding institute', *Sci. Public Pol.*, Vol. 16(4), pp. 224–232. Ominously, perhaps, from the perspective of many academics, Unilever later acquired the PBI, partly because of its commercial success.

66. See Shepherd, J. (2005), 'Drug specialist doubles value', *The Times Higher Educ. Supple.*, 28th October, p. 7. Professor Davies is one of Britain's most successful entrepreneurs, having sold another spin-off firm, Oxford Asymmetry for £316m in 2000. VASTox is an Oxford University spin-off firm created in 2003, which develops drugs to treat rare diseases. It was floated on the London Stock Exchange in October 2004 and valued at £30m; thereafter it doubled its value to £58m in under a year.

67. On the importance of university–industry linkages in biomedicine, for example, see: Mansfield, E. (1991), 'Academic research and industrial innovation', *Res. Pol.*, Vol. 20(1), pp. 1–12; Blumenthal, D., Causino, N., Campbell, E. and Louis, K. S. (1996), 'Relationships between academic institutions and industry in the life sciences – an industry perspective', *New Engl. J. Med.*, Vol. 334, pp. 368–373; Cockburn, I. and Henderson, R. (1996), 'Public–private interaction and the productivity of pharmaceutical research', *Proc. Natl Acad. Sci. USA*, Vol. 93, pp. 12725–12730; Narin, F., Hamilton, K. S. and Olivastro, D. (1997), 'The increasing linkage between U.S. technology and public science', *Res. Pol.*, Vol. 26(3), pp. 317–330.

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dismantles the wall between understanding-inspired basic research and use-inspired applied research. Applying the linear understanding/use model to Louis Pasteur, Stokes determined that in this model Pasteur resides precisely in the middle. Pasteur's equal commitments 'to understand the microbiological processes he discovered . . . and to control the effects of these processes on various products and on animals and humans' reveal his motives as both understanding- and use-based, and incompatible with the linear model.

72. Vannevar Bush is credited with coining the term 'basic research'. He proffered the definition: 'Basic research is performed without thought of practical ends'.

73. Demain, A. L. and Solomon, N. A. (1981), 'Industrial microbiology', *Sci. Amer.*, September, pp. 66–75.

74. Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M. (1994), 'The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Society', Sage Publications, Beverley Hills, CA.

75. Sociologists have considered information and knowledge flows as 'gifts' that are exchanged within a community of practitioners sharing a similar set of scientific and technological problems. This 'gift and reward' exchange process has been identified as one of the primary mechanisms that enables science to function as it does. See: Hagström, W. O. (1965), 'The Scientific Community', Basic Books, New York; Merton, R. K. (1973), 'The Sociology of Science: Theoretical and Empirical Investigations', University of Chicago Press, Chicago, IL; Ziman, J. (1984), 'An Introduction to Science Studies', Cambridge University Press, Cambridge. Some scholars have seen a distinction between publishing and patenting; between the gift-exchange character of science, in its Mertonian tradition (which fosters publications), and the public good character of technology, in its economic tradition (which fosters patenting); this distinction lies in the social ethos of both worlds. See: Hughes, T. P. (1987), 'The evolution of large technological systems', in Bijker, W. E., Hughes, T. P. and Pinch, T., Eds, 'The Social Construction of Technological Systems', MIT Press, Cambridge, MA; Dasgupta, P. and David, P. (1987), 'Information disclosure and the economics of science and technology', in Feiwel, G. R., Ed., 'Arrow and the Ascent of Modern Economic Theory', New York University Press, New York.

76. For example, Nelson, R. R. (1986), 'Institutions supporting technical advance', *Amer. Econ. Rev.*, Vol. 76(2), pp. 186–189; Mackenzie, M., Cambrosio, A. and Keating, P. (1988), 'The commercial application of a scientific discovery: The case of the hybridoma technique', *Res. Pol.*, Vol. 17(3), pp. 155–170. Mansfield, E. (1991), 'Academic research and industrial innovation', *Res. Pol.*, Vol. 20(1), pp. 1–12; Mansfield, E. and Lee, J-Y. (1996), 'The modern university: Contributor to industrial innovation and recipient of industrial R&D support', *Res. Pol.*, Vol. 25(7), pp. 1047–1058.

77. Faulkner, W. and Senker, J. (1994), 'Making sense of diversity: Public–private sector research linkage in three technologies', *Res. Pol.*, Vol. 23(6), pp. 673–695.

78. Webster, A and Constable, J. (1990), 'Strategic research alliances and "hybrid coalitions"', *Ind. Higher Educ.*, Vol. 4, pp. 225–230. Despite the recent attention devoted to spin-off firms, they are, in fact, merely a modern manifestation of an old phenomenon. The formation of firms out of research activities occurred in the late 19th century at Harvard and MIT in the fields of industrial consulting and scientific instrumentation. See: Shimshoni, D. (1970), 'The mobile scientist in the American instrument industry', *Minerva*, Vol. 8(1), pp. 59–89. In the USA, 374 start-up firms based on an academic discovery were formed in 2003 as reported by 190 institutions, down 6.7 per cent from 401 start-ups reported by 183 institutions in 2002. Hundreds of spin-off firms have been launched in the UK during the past decade to exploit intellectual property that has been developed in an academic institution, but the Lambert review of university business links noted that, although universities were creating spin-off companies, few of them generated much value. According to one estimate well under 10 per cent have succeeded in generating wealth. Nevertheless, ten spin-offs obtaining public listings in 2004 had a total market value of £604m on flotation. This exceeded government spending to the end of 2004 – approximately £500m – on various initiatives promoting the commercial exploitation of research, including two Higher Education Innovation Funds and the University Challenge Fund. Arguably, the figures demonstrate tangible evidence of economic benefit for government funding of technology transfer from universities. See: Richard Lambert's review (URL: www.lambertreview.org.uk); Davis, C. (2005), 'Happy returns for floated spin-off firms', *The Times Higher Educ. Suppl.*, 4th February, p. 5; Davis, C. (2005), "Pompous' academics dampen fervour for spin-outs', *The Times Higher Educ. Suppl.*, 8th April, p. 9.

79. Etzkowitz, H. (1999), 'The Second Academic Revolution: MIT and the Rise of Entrepreneurial Science', Gordon and Breach, London.

80. Dosi, G. (1988), 'Sources, procedures and microeconomic effects of innovation', *J. Econ. Literature*, Vol. 26, p. 1138; Freeman, C. (1989), 'The diffusion of biotechnology through the economy: The time scale', in OECD, 'Biotechnology: Economic and Wider Impacts', OECD, Paris, p. 49; Walsh, V. and Galimberti, I. (1993), 'Firm strategies, globalisation and new technological paradigms: The case of biotechnology', in Humbert, M., Ed., 'The Impact of Globalisation on Europe's Firms and Industries', Frances Pinter, London, p. 175.

81. Dosi, G. (1988), 'Sources, procedures and microeconomic effects of innovation', *J. Econ. Literature*, Vol. 26, p. 1131.

82. Walsh, V. (1993), 'Demand, public markets and innovation in biotechnology', *Sci. Public Pol.*, Vol. 20(3), pp. 142–143.

83. Galbraith, J. K. (2004), 'The Economics of Innocent Fraud: Truth for Our Time', Houghton Mifflin, Boston and New York, p. 34. See also: McKelvey, M. D. (1996), 'Evolutionary Innovations: The Business of Biotechnology', Oxford University Press, Oxford; Etzkowitz, H. and Leydesdorff, L., Eds (1997), 'Universities and the Global Knowledge Economy: A Triple-helix of University–Industry–Government Relations', Pinter, London.

84. Kennedy, D. (2003), 'Industry and academia in transition', *Science*, Vol. 302(5649), p. 1293.

85. Etzkowitz, H. (2003), 'Research groups as "quasi-firms"? The invention of the entrepreneurial university', *Res. Pol.*, Vol. 32(1), pp. 109–121; Etzkowitz, H. (2003), 'The European entrepreneurial university: an alternative to the US model', *Ind. Higher Educ.*, Vol. 17(5), pp. 325–335.

86. For example, the author knows of one new university in Japan, created by Takara Shuzo, a biotechnology company, specifically for training scientists and technicians in biotechnology.

87. Robertson, D. (1997), 'Social justice in a learning market', in Coffield, F. and Williamson, B., Eds, 'Repositioning Higher Education', Society for Research into Higher Education and Open University Press.

88. Lynskey, M. J. (2002), 'Introduction', in Lynskey, M. J. and Yonekura, S., Eds, 'Entrepreneurship and Organization: The Role of the Entrepreneur in Organizational Innovation', Oxford University Press, Oxford; Chesbrough, H. (2003), 'Open Innovation: The New Imperative for Creating and Profiting from Technology', Harvard Business School Press, Boston, MA.

89. Professor Ed Bullmore, professor of psychiatry at Cambridge University, quoted in Fazackerley, A. (2005), 'Industry lures Oxbridge staff', *The Times Higher Educ. Supple.*, 4th November, p. 9. Professor Bullmore divides his time equally between the university and his role as the director of GlaxoSmithKline's Clinical Research Unit at Addenbrooke's Hospital in Cambridge.

90. One example here is the research into stem cells, where controversy arises over the provenance of embryonic stem cells, as it is necessary to derive these from an early-stage embryo.

91. Hamlyn proposed that one of the essential expressions of the university institution, and one of its enduring achievements since they were established in the Middle Ages, rested in what he called its 'enlargement of knowledge': 'If learning is to be pursued and if knowledge is to be enlarged there have to be institutions like universities, which have the double role of pushing back the frontiers of knowledge and of enabling future generations to carry on that process' (p. 216). See: Hamlyn, D. W. (1996), 'The concept of a university', *Philosophy*, Vol. 71(276), pp. 205–218.

92. Total sponsored research expenditures in fiscal year 2003 were US$38.525bn; sponsored research expenditures funded by industry were US$2.857bn. Association of University Technology Managers, Inc. (AUTM), AUTM Licensing Survey FY 2003.

93. See: Krimsky, S. (2003), 'Science in the Private Interest: Has the Lure of Profits Corrupted Biomedical Research?', Rowman and Littlefield, Lanham, MD.

94. Waite, R. (2005), 'Researchers pressured to tailor results for sponsors', *The Times Higher Educ. Suppl.*, 25th March, p. 2. Also, see, eg, Mangan, K. S. (2003), 'Medical-research ethics under the microscope', *Chronicle Higher Educ.*, 25th July.

95. Cho, M. K. and Bero, L. A. (1996), 'The quality of drug studies published in symposium proceedings', *Ann. Internal Med.*, Vol. 124(5), pp. 485–489.

96. Krimsky, S. (2003), 'Science in the Private Interest: Has the Lure of Profits Corrupted Biomedical Research?', Rowman and Littlefield, Lanham, MD.

97. Desiderius Erasmus (1509), 'The Praise of Folly (Moriae Encomium)': 'Most foolish of all, and the meanest, is the whole tribe of merchants, for they handle the meanest sort of business by the meanest methods, and although their lies, perjury, thefts, frauds, and deceptions are everywhere to be found, they still reckon themselves a cut above everyone else . . .'.

98. Newman, J. H. (Svaglic, M. J., Ed.) (1982), 'The Idea of a University', University of Notre Dame Press, Notre Dame, IN (first

published in 1854). Newman elucidates his idea on the aim of a university in the first line of the Preface to the text: 'The view taken of a University in these Discourses is the following:- that it is a place of *teaching universal knowledge*. This implies that its object is, on the one hand, intellectual, not moral; and, on the other, that it is the diffusion and extension of knowledge . . .'. Contrary to utilitarian beliefs, Newman did not see knowledge as the mere accumulation of useful facts that may enable their owner to provide himself with a living. The marketplace or the demands of industry should not dictate to the University what shall or shall not constitute knowledge that is worth pursuing. Education aims at nothing more than the cultivation of the intellect. 'Its object is nothing more nor less than intellectual excellence and culture' (Discourse VI). Knowledge, as it is pursued in the university, is an end in itself; it is not a means to some other end, for it constitutes the perfecting of the intellect itself.

99. See Oakeshott, M. (1989), 'Education: The engagement and its frustration', in Fuller, T., Ed., 'The Voice of Liberal Learning: Michael Oakeshott on Education', Yale University Press, New Haven, CT; Oakeshott, M. (2005), 'What is History? and other Essays', Imprint Academic, Exeter; O'Hear, A. (1987), 'The importance of traditional learning', *Br. J. Educ. Studies*, Vol. 35(2), pp. 102–114.

100. Polanyi, M. (1962), 'The republic of science: Its political and economic theory', *Minerva*, Vol. 1, pp. 54–73. Also see: Merton, R. K. (1942), 'Science and technology in a democratic order', *J. Legal Political Sociol.*, Vol. 1, pp. 115–126.

101. Graham, G. (2005) 'The Institution of Intellectual Values: Realism and Idealism in Higher Education', Imprint Academic, Exeter, UK and Charlottesville, VA, USA.

102. See: Hamlyn, D. W. (1996), 'The concept of a university', *Philosophy*, Vol. 71(276), pp. 205–218. It is worth pointing out, perhaps, that Newman did not deny the importance of professional knowledge, theoretical or practical. He merely wished that it be kept in perspective in the educated mind – like any other form of specialised knowledge – through the vision provided by other studies.

103. On this point, Miyoshi examines the neo-liberal principle at work behind the call to transform universities to make them respond better to the economic needs of industry in the global economy. Reflecting on the social impact of 'corporatizing' the university, Miyoshi points out how 'rationalizing' the academic disciplines considered redundant (most of the humanities and social sciences) renders more precarious than ever the ability of the university to function as a source of critical knowledge. See: Miyoshi, M. (2000), 'The university and the "global" economy: the cases of the United States and Japan', *South Atlantic Quart.*, Vol. 99(4), pp. 669–696.

104. Giamatti, A. B. (1988), 'A Free and Ordered Space: The Real World of the University', Norton, New York, p. 44. For a more recent, extensive treatment of the deleterious effects of corporatism and consumerism on the university, also see: Readings, B. (1996), 'The University in Ruins', Harvard University Press, Cambridge, MA.

105. See: Evans, M. (2004), 'Killing Thinking: The Death of the Universities', Continuum, London.

106. Handscombe, R. D. (2003), 'The promotion of an entrepreneurial culture in universities', *Ind. Educ.*, Vol. 3(1), pp. 219–222.

107. Dearing Report (1997), 'Higher Education in the Learning Society', HMSO, London.

108. On this and similar ideas, see: Wolf, A. (2002), 'Does Education Matter? Myths about Education and Economic Growth', Penguin Books, London.

109. See: Fuller, S. (2005), 'The Intellectual', Icon Books, Cambridge; Furedi, F. (2004), 'Where Have All the Intellectuals Gone?: Confronting 21st Century Philistinism', Continuum, London.

110. Polanyi, M. (1962), 'The republic of science: Its political and economic theory', *Minerva*, Vol. 1, pp. 54–73.

111. Bok, D. (2003), 'Universities in the Marketplace: The Commercialization of Higher Education', Princeton University Press, Princeton, NJ. Other titles in a similar vein, which are concerned that the university today has lost its ideals, are: Gould, E. (2003), 'The University in a Corporate Culture', Yale University Press, New Haven, CT; Kerr, C. (2001), 'The Uses of the University', Harvard University Press, Cambridge, MA; Kirp, D. L. (2003), 'Shakespeare, Einstein, and the Bottom Line: The Marketing of Higher Education', Harvard University Press, Cambridge, MA; Readings, B. (1996), 'The University in Ruins', Harvard University Press, Cambridge, MA; Rhodes, F. H. T. (2001), 'The Creation of the Future: The Role of the American University', Cornell University Press, Ithaca, NY; Slaughter, S. and Leslie, L. L. (1999), 'Academic Capitalism: Politics, Policies, and the Entrepreneurial University', Johns Hopkins University Press, Baltimore, MD.

112. Powell, W. W., Koput, K. K. and Smith-Doerr, L. (1996), 'Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology', *Admin. Sci. Quart.*, Vol. 41(1), pp. 116–145.

113. For example, Krimsky, S. (2003), 'Science in

the Private Interest: Has the Lure of Profits Corrupted Biomedical Research?', Rowman and Littlefield, Lanham, MD.

114. See: Hagström, W. O. (1982), 'Gift-giving as an organizing principle in science', in Barnes, B. and Edge, D., Eds, 'Science in Context: Readings in the Sociology of Science', MIT Press, Cambridge, MA, pp. 21–34.

115. Kennedy, D. (2003) 'Industry and Academia in Transition', *Science*, Vol. 32(5649), p. 1293.

116. On this point, the so-called 'commons model', which is based on free access to biomedical resources and knowledge and their widespread dissemination, lost so much ground to the 'private ownership model' that a 'tragedy of the anticommons' was thought to ensue, where, in the case of biomedical research results such as patents and genome data, too many owners have the right to exclude others from using a scarce resource, and the resource is prone to under-use. While such criticisms of the international trend towards patenting forms of life may be unduly pessimistic, they, nevertheless, set out the case against extended patenting *in extremis*. See: Heller, M. A. and Eisenberg, R. S. (1998), 'Can patents deter innovation? The anticommons in biomedical research', *Science*, Vol. 280(5364), pp. 698–701.

117. Bok, D. (2003), 'Universities in the Marketplace: The Commercialization of Higher Education', Princeton University Press, Princeton, NJ.

118. Broers, A. (2005), 'Wake up to the future', *The Times Higher Educ. Suppl.*, 8th April, p. 14.

119. See: Kondratieff, N. D. (1935), 'The long waves in economic life', *Rev. Econ. Statistics*, Vol. 17(6) (November), pp. 105–115; Schumpeter, J. A. (1934), 'The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle', Harvard University Press, Cambridge, MA (originally published in 1912 as 'Theorie der Wirtschaftlichen Entwicklung', Dencker & Humblot, Leipzig); Schumpeter, J. A. (1939), 'Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process, Vols. I and II', McGraw-Hill, New York and London.

120. Keller, M. and Keller, P. (2002), 'Making Harvard Modern: The Rise of America's University', Oxford University Press, New York.