forthcoming in *East Asian Science, Technology and Society (EASTS)*

Before Biopolis: Representations of the Biotechnology Discourse in Singapore

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Abstract

Singapore's foray into biotechnology is generally considered an economic and scientific success, its most visible sign being Biopolis, launched in 2003 as an integrated cluster of research facilities in an urban setting. Biopolis, however, is itself the result of a long-term effort to build up capacities for biotechnological research. The present paper analyzes the early (pre-Biopolis) biotechnology discourse in Singapore, with special emphasis on its representations in the official media and on its strategic uses by the various stakeholders involved. Against the backdrop of the global emergence of biotechnology from the late 1970s onwards, the paper traces the motivations for Singapore's formulation of its own biotechnology policy, paying attention throughout to the dynamic between scientists and policymakers. It is this relationship, along with the ambiguities that characterize it, which is responsible for the sustained establishment of biotechnology in Singapore. At an interpretative level, an attempt is made to compare the case of Singapore's biotechnology policy with competing discourses of technology and modernity. The discourse on biotechnology can thus be recognised as a means of mobilizing its intended audience for the various stages in the country's path towards (real or perceived) modernization.

1. Introduction

Singapore's foray into biotechnology and the biomedical sciences has recently attracted the attention of researchers in the field of science and technology studies (e.g., Reubi 2010, Waldby 2009, Ong 2008, Holden and Demeritt 2008). Many of these analyses focus on the most recent phase of development, which is marked by efforts to turn Singapore into a centre for biomedical research and is intimately connected with the opening of the "Biopolis" biomedical hub, which was completed in various stages from 2001 onwards. The present paper attempts to expand the historical horizon by tracing

Singapore's biotechnological ambitions to the early 1980s. To this end, I draw on representations of Singapore's early biotechnological discourse, primarily in the news media and in published records by the relevant individual and institutional actors.

The structure of this paper is as follows: Section 2 relates the global biotechnology discourse from the 1980s onwards to developments and policy decisions in Singapore. Section 3 traces continuities and divergences between Singapore's emergent biotechnology policy and its earlier industrial policies, which were primarily aimed at manufacturing. Section 4 describes how scientists and educational institutions responded to the push towards biotechnology, and how they began to self-identify as stakeholders in this process. If, as some have argued, "the future of biotechnology is constructed in the discourse of society and the dialogue between a range of actors from science, industry, government, media and the public" (Doolin 2007: 5), then the same is very much true of its history; careful attention will therefore have to be paid to the alliances, interactions, and friction between different stakeholders. Section 5, finally, discusses the dynamic between scientists and policymakers, partly by comparing it with the ways in which Singapore's earlier technology discourse functioned as a means of mobilizing its intended audience for the various stages in the country's path towards economic modernization.

2. Early biotechnology and its reception in Singapore

Despite, or perhaps because of, its variegated meanings, the term "biotechnology" has seen an unprecedented rise in popularity in recent decades. The founding, by Herbert Boyer and venture capitalist Robert Swanson in 1976, of Genentech, sometimes referred to as "the first biotechnology company"[1], is often seen as marking the beginning of the commercial exploitation of the various advances in molecular genetics, genetic sequencing, and recombinant DNA methods. This was preceded by Stanford University's 1974 petition to the National Institutes of Health, regarding the acceptability of its application, together with Stanley Cohen and Herbert Boyer, for the patenting of a process of "gene splicing" that produced biologically functional molecular chimeras. Andrew Hess and Frank Rothaermel, writing from a management studies perspective and contrasting the new biotech ventures with (traditional) Big Pharma, argue that "the advent of biotechnology … represented a discontinuity for incumbent pharmaceutical firms, while offering a unique opportunity for start-up biotechnology firms" (Hess and Rothaermel 2012: 65). By longitudinal analysis of the publication and citation records of almost 300,000 scientists, and by tracking their institutional and corporate affiliations, Hess and Rothaermel demonstrate significant shifts in hiring patterns, including "a pronounced jump in star scientist hires in the late 1970s through the early 1980s" (Hess

[1] E.g., (Hess and Rothaermel 2012: 66).

and Rothaermel 2012: 72), which they attribute to pharmaceutical companies trying to jump on the bandwagon of the perceived biotechnological "discontinuity".

Gene splicing is but one of many techniques that were subsequently subsumed under the emerging label of "biotechnology". In a 1990 report, which aimed "to take stock of the current status of biotechnology and to assess the socioeconomic impact of biotechnology" across Asia, the Asian Productivity Organization (APO) gives a rather inclusive characterization of the field of biotechnology, when it writes that

> Recombinant DNA (rDNA) technology (i.e., direct manipulation of genetic material), monoclonal anti-body technology (i.e. preparation of complex molecules known as Mab), cell fusion (i.e. artificial joining of cells) and other techniques along with advances of in bio-process engineering are expected to find applications in several spheres like pharmaceuticals, agriculture, plant and animal breeding, specialty chemicals and additives, environmental applications, commodity chemicals, energy production and bio-electronics. (APO 1990: i)

The impact of the new technologies across Asian countries has been uneven. In a study that compares the biotechnology policies of Hong Kong and Singapore, Lai Si Tsui-Auch writes that, whereas Singapore's "biotech industry has achieved significant milestones in obtaining patents and commercializing products", the "Hong Kong biotechnology remains at the 'infancy stage'", even by admission of some of its leading proponents (Tsui-Auch 2000: 252). Different levels of government involvement were an important factor. Whereas "[t]he Hong Kong government made no plan and program for biotechnology" (ibid.: 262) – partly because pre-1997 governments had little incentive to develop long-term high-tech capabilities, given the foreseeable takeover of Hong Kong by China – the Singapore government set up science parks "to foster frequent exchanges and linkages between industry, academia and government" (ibid.: 258). An important aim of the science parks was "to create specific places for capturing globalising R&D activities", in an "deliberate and state-driven attempt to attract the location of R&D activities by global corporations" (Phillips and Yeung 2003: 709). There is, thus, considerable continuity between Singapore's courting of multi-national corporations (MNCs) as drivers of economic growth and its foray into biotechnology.[2]

A full discussion of the emergence, and rapid growth, of the biotechnology discourse in the 1980s, both at a global level and in Asia, is well beyond the scope of the present paper. Instead, I shall restrict myself to the more manageable task of analyzing how the discourse on biotechnology played out within Singapore. In doing so, it will be helpful, on occasion, to point out relevant contrasts with parallel developments elsewhere. Even more so than its limited geographical size, population, and natural

[2] On Singapore's strategy of attracting foreign direct investment from global MNCs, and leveraging on their presence and know-how for generating economic growth, see (Perry, Kong and Yeoh 1997; esp. chapter 5); for an analysis of the flow of biotechnology foreign direct investment to Singapore, see (Pereira 2006).

resources, the restricted number of political actors and "knowledge elites" (Menkhoff and Evers 2005: 9), along with its heavily moderated public discourse – especially during the period under consideration – make Singapore an interesting test case. This is underscored by the fact that Singapore is internationally regarded as having succeeded in the area of biotechnology. (See, for example, Van Epps 2006.) A close look at the conditions and dynamics of the early biotechnology discourse in Singapore thus promises to provide insight into how Singapore has functioned as an "echo chamber" for the global trend towards biotechnology as a cornerstone of science and technology policy. This might then help identify general features responsible for the success or failure of technology and innovation policies, including with respect to contemporary emerging areas of research.

As mentioned in the Introduction, most of the recent STS-informed literature on biotechnology in Singapore is concerned with ongoing programmes and current government efforts such as the Biomedical Sciences Inititative, announced in 2000, which led to the opening of Biopolis, aptly described by Catherine Waldby as "a high-profile space that brings key Singaporean biomedical research institutes together with global and local biotechnology and pharmaceutical companies and national governance bodies" (Waldby 2009: 368). The early history of the reception of biotechnology in Singapore, however, is typically glossed over or told in highly abbreviated form. Thus, Waldby turns her attention exclusively to Biopolis as a "particular moment in the biopolitical history of Singapore" (2009: 370), which she sees as indicative of "the current phase of biotechnology development", as opposed to the first "era" of biotechnology "beginning in the late 1980s" (p. 372). Thomas Menkhoff and Hans-Dieter Evers (2005) see a causal connection between the 1997/98 Asian financial crisis and the pursuit of "new, innovative technologies" – including biotechnology – since "it became clear that standard technology, like the production of mass storage devices, could no longer be sustained in the face of competition from China" (Menkhoff and Evers 2005: 5). Similarly, Sachin Chaturvedi (2005), in an article that uses Singapore as a case study of "the dynamics of a national system of biotechnology innovation (NSBI) in the wider framework of its role in economic development", focuses almost entirely on biotechnology efforts from the late 1990s onwards, subsequent to the adoption of the (second) National Science and Technology Plan (NSTP) covering the period between 1996 and 2000.

Since the present paper attempts to broaden the historical horizon of biotechnology efforts in Singapore, a brief timeline of key events is in order. While these events are merely indicators of broader trends, to be discussed later in this paper, they nonetheless illustrate that Singapore's recent systematic foray into biotechnology cannot be divorced from developments that predate the opening of Biopolis by some twenty years. When Biopolis was opened on 23 October 2003, this marked the completion of an important cornerstone of Phase One of the Biomedical Sciences (BMS) Initiative which, as legend has it, was "hashed out in an all-night session" by the "biomedical sciences

'Gang of 4'" – Philip Yeo, Chairman of the Agency for Science, Technology, and Research (A*STAR), Tan Chorh Chuan, then Dean of Medicine at the National University of Singapore (NUS), and oncologists John Wong and Kong Hwai Loong – and was announced in 2000, "one day before the unveiling of the human genome project" (Van Epps 2006: 1139). The BMSI, however, itself represents a refocusing of efforts, following a decade of broad-based investment in technology, through the NSTP (1996-2000) and the National Technology Plan (1991-1995), both of which were administered by the National Science and Technology Board (NSTB), A*STAR's predecessor, set up in 1991 as a statutory board under the Ministry of Trade and Industry (MTI).

Prior to this, in 1988, the Economic Development Board (EDB) had already established the National Biotechnology Programme (NBP) "to promote the fast-growing industry" (*ST*, 6/9/1988), as well as a National Biotechnology Committee (NBC), among whose recommendations was the creation of a Training in Biotechnology Scheme (TIBS) "to promote and speed up the transfer of knowledge, technology, and skills in biotechnology" (*ST*, 1/11/1989). The NBC was chaired by Chris Tan Yin Hwee, who was director at the Institute of Molecular and Cell Biology (IMCB), which was formally opened on 2 October 1987, but had already been operating for a year and a half. In 1986, the Economic Committee, a specially convened body tasked with reviewing the progress of the country's economy and with identifying "new directions for its future growth", had issued a report, *Singapore Economy: New Directions*, which, as David Reubi notes, "identified 'biotechnology' as one of the main drivers of Singapore's future economic development and called for the government to promote 'research and deveopment' in this field" (Reubi 2010: 149). Even earlier, in a series of articles in January 1985, the *Straits Times*, in broad brushtrokes, had laid out a blueprint for the promotion of biotechnology in Singapore. On 20 January, a prominently placed article on page 3 of the Sunday edition of the *Straits Times* declared that "Biotech takes centre stage", informing the public in bullet-point format of the imminent developments: "First LKY Distinguished Guest is a molecular biologist; Biotechnological institute set up; World conference will be held here in November; Microbiology now a separate subject at NUS; and grants offered under R&D assistance scheme." (*ST*, 20/1/1985.) This was followed up, in quick succession, first by a summary of the pronouncements made by "eminent British scientist" Sydney Brenner in a public lecture given under the Lee Kuan Yew Distinguished Visitors Programme (*ST*, 22/1/1985), and subsequently by a detailed sketch of the future Institute of Molecular and Cell Biology (*ST*, 24/1/1985). Interestingly, the first article in this series described the various activities as part of an ongoing "systematic programme" to "nurture" biotech, ever since "the government earmarked biotechnology as a priority industry two years ago" (*ST*, 20/1/1985). What this alludes to is a passing – yet nonetheless significant – reference in the 1983 budget statement by Tony Tan, then the Trade and Industry Minister, which was intended to prepare the country for a path of technological self-improvement. While the main focus was on computerization, Tan does

explicitly mention biotechnology when he speaks of a need "to encourage the development of knowledge-based services and activities involving biotechnology" (Tan 1983: 7).

The *Straits Times* was eager to reiterate this message – its leading article the next day declared that "Technology is the answer" (*ST*, 5/3/1983) – and quickly picked up on the reference to biotechnology. Less than two weeks after the budget statement, in a report on four biotechnological companies having declared an interest in setting up shop in Singapore ("Singapore on verge of being biotech centre", *ST*, 16/3/1983), the *Straits Times* refers back to Tan's speech which it claims "identified [biotechnology] as a growth industry of the future – thus Singapore's interest in promoting it". Interestingly, the EDB's position at this stage seems to have been not quite as enthusiastic. "The EDB", writes the *Straits Times*, "continues to promote biotechnology in the same way as it does other industries", and an unnamed EDB spokesman is cited as saying that

> At this point in time, it will be unrealistic for Singapore to get involved in the frontiers of biotechnology such as gene splicing. Rather, we are more interested in plant and food biotechnology companies. (*ST* 16/3/1983)

The EDB's equivocation between different kinds of biotechnology, and its reluctance to commit itself to "frontier" research, nicely reflects some of the concerns that would mark the subsequent discourse on biotechnology – not least the tension between pursuing research at the frontiers of science and translating biotechnology into tangible economic benefits (see Section 5 of this paper). Yet, as this episode clearly suggests, as early as 1983 the biotechnology "cat" is already out of the bag, demanding to be nurtured – as well as tamed. This finding extends the timeline of Singapore's substantive concern with biotechnology policy further back in time than recent studies have suggested, which tend to treat the "late 1980s" (Waldby 2009: 372; Tsui-Auch 2000: 257) or "mid-1980s" (Reubi 2010: 149) as historical cut-off points. It also challenges the notion, sometimes perpetuated in the more applied literature, that Singapore was late to the game of biotechnology policy.[3] For, as Mark Cantley has pointed out, at the European level too (specifically, at the level of the European Commission), the "first official mention of the word 'biotechnology'" did not occur until February 1983, and – as in the Singaporean case – it reflected "a perspective much broader than" simply recombinant DNA research (Cantley 1995: 530). Given that other major industrialized nations at the time were making equally tentative moves towards the formulation of an explicit biotechnology policy – with Canada's Science Council urging such a move in March 1983 (because "Canada is slipping behind") and Australia's opposition Labour Party, in the run-up to the 5 March 1983 elections, declaring biotechnology to be one of 16 "'sunrise'

[3] Often, in discussions of biotechnology policy in newly industrializing economies, this is coupled with the metaphor of "playing catch-up" with other, more advanced economies (see, for example, Cho, Hyun and Lee 2007).

industries" – Tan's inclusion, in his 1983 Budget Speech, of "biotechnology" among the list of priority technologies for Singapore was nothing but timely.[4]

3. Biotechnology as industrial policy

In order to understand the role of biotechnology in the economic modernization of Singapore, it is instructive to look at it against the backdrop of the country's long-term economic and industrial policies. The first thing that comes to mind with respect to Singapore's economy is, of course, its locational advantage as home to the busiest port in the world. Historically, as a British colony, Singapore – like Hong Kong – developed primarily as an entrepot, with local industries for a long time being treated as of lesser importance. Even today, Singapore's economy continues to rely on shipping and an expanded concept of entrepot trade, whereby raw goods are purchased and subsequently refined for re-export. What had historically proved to be a recipe for economic success, however, proved to be a hindrance after Singapore's independence in 1965. Not only did independence from Malaysia initially mean loss of access to the Malaysian market; other nationalist movements in the region also interfered with the entrepot model, given that they resulted in regional efforts at import-substitution industrialization. As a result, the Singapore government embarked on a path towards industrial development, in such diverse sectors as the textile industry, the petrochemical industry, electronics, and pharmaceuticals. By courting multi-national corporations, Singapore was able to attract significant foreign direct investment, in the process creating jobs in manufacturing. A continued rise in labour costs, however, necessitated a gradual shift up the value chain, which led to efforts to attract corporate and financial services, for example via the Operational Headquarters (OHQ) Scheme in 1986, which offered a low 10% tax rate for corporate income for approved services.[5]

However, the economy remained vulnerable to uncertainties in global trade arising from economic recessions and protectionist trends in individual countries. At the time the decision to move into biotechnology was made, as Tan puts it in his 1983 budget speech, "the spectre of protectionism continue[d] to loom large". His recommendation is clear:

> [O]ur best defence against trade protectionism is to increase our productivity so that our goods will still be competitive in price and quality despite protectionist barriers.… In the longer term, we can become less vulnerable to protectionism only by restructuring

[4] For the cases of Canada and Australia, see "The poll will bring 'high tech' closer", *The Sydney Morning Herald*, 9/2/1983, p. 23, and "'Local boy' developing plans", *The Citizen* (Ottawa), 22/3/1983, p. 53 – the "local boy" in question being Donald Johnston, Canada's Minister of State for Economic Development.
[5] For a discussion, see (Ho 1993).

> our economy and producing products and services of increased value-added content. (Tan 1983: 7-8)

Biotechnology is mentioned only once in Tan's speech, but in a strategic place. Having listed areas in which research and development are already being undertaken – which "include work in robotics, micro-processor technology, civil engineering and medical research" (Tan 1983: 5) – he goes on to define potential areas of future investment, "such as computer software, engineering design and technical services, medical testing and laboratory services" (Tan 1983: 7). Biotechnology brings together several of these areas, which is why the speech includes a recommendation to amend the Economic Expansion Incentives Act, originally devised in the the 1960s to promote manufacturing industries, "to encourage the development of knowledge-based services and activities involving biotechnology, microbiological production, and other new technologies" (ibid.). It is this almost offhand remark that contains, as it were, the seed of Singapore's future biotechnology policy.

Interestingly, the argument for the adoption of new emerging technologies is, at least implicitly, supported by a rhetoric of global competition. This corresponds to subsequent portrayals of the global biotechnology discourse as a technological race, not least between countries in the West (who "have not taken advantage of fast changes in technology", instead resorting to protectionism; Tan 1983: 19) and the emerging economies in Asia and beyond. The *Straits Times*'s leading article following Tan's budget speech ("Technology is the answer"), contains a nice illustration of this, when it refers to US-Japanese technological rivalry, which was to become a familiar theme in 1980s technology policy discourse:

> Not surprisingly even the Americans are finding that they would have to do something to catch up with the Japanese.… We can do no worse than to take advantage of the current adversity to lay our own foundation. (*ST*, 5/3/1983)

Since early on, the mantra of Singapore's industrial and economic policy has been to "move up the value chain" and attract "high value-added" industries and technologies. This is clearly reflected in the early biotechnology discourse in Singapore. Once the initial reluctance towards giving special treatment to biotechnology (see Section 2) had been overcome, biotechnology in the first half of the 1980s comes to be described as "a priority industry". In an article on a proposed joint venture between a US firm and local investors – a "Biotech 'first' for Singapore" (*ST*, 12/9/1984) – the *Straits Times* quotes an EDB official who described such international cooperation as "the kind of activity the government was looking for to push Singapore into the forefront of biotechnology". Reflecting on these developments, another article, published in July 1988, makes the link between biotech efforts and Singapore's overall industrial policy even more explicit:

> Singapore's involvement in this new field about three years ago came about partly because the sudden surge in biotechnology worldwide coincided with the Republic's

> decision to move into high-technology industries. It has been identified as a growth industry of the future by the Government because biotechnology is a high value-added industry. (*ST*, 9/7/1988)

What was described as "the new science of biotechnology" by the *Straits Times* in one of its earliest references in early 1983 (*ST*, 11/1/1983), by 1988 has – at least in the perception of the relevant parties to the discourse on biotechnology policy – matured into a "billion-dollar industry worldwide" that "has great potential in many fields, especially agriculture and medicine" (*ST*, 6/9/1988). It is precisely this motivation for biotechnology that is invoked when, following the announcement of the NBP in 1988, a national committee – composed of policymakers (representatives of the EDB and Primary Production Department), scientists (the director of the IMCB), and academics (the vice-chancellor of NUS) – is formed "to draw up a development plan for the biotechnology industry" in Singapore: "Singapore's move into biotechnology is in line with its thrust into brain-intensive, high value-added industries." (*ST*, 6/9/1988)

From a policy perspective, biotechnology in the 1980s presented a challenge to an institutional environment and business culture that had become accustomed to dealing with manufacturing and industry. A good indicator of this need to become acculturated to the new demands of biotechnology enterprises is the EDB's initial position, quoted earlier, to treat biotechnology "the same way as it does other industries". The view that establishing a biotech presence would require considerable effort, was widely shared at the time. Thus, Daniel Wang, an MIT expert questioned by the *Straits Times* about Singapore's prospects, is quoted as saying

> You can attract the companies who come here because it's cheaper to conduct their field trails here, or those whose markets are in this region. But it will be difficult to attract the really sophisticated companies, for example those who are playing with changing the molecular genetics of a palm oil tree. (*ST*, 16/3/1983)

While an extension of the established strategies for investment promotion – attracting companies by offering tax credits and cheaper labour costs – may have seemed like the safest bet in 1983, it quickly became apparent that this would neither facilitate Singapore's move towards "high-value added" activities, such as cutting-edge R&D, nor be an adequate response to the specific requirements of biotechnology. Thus, in the run-up to Biotech Asia '85, Singapore's "first major international biotechnology conference" (*ST*, 25/11/1985) and "the last in a series of three biotechnology conferences held worlwide" (*ST*, 12/9/1985) that year, Vincent Yip, the executive director of the Science Council, argued that "a different set of promotional strategies may have to be introduced just to cater to these people [in biotechnology]", since, as the *Straits Times* paraphrases, unlike in other industries, "the investment promoters from the Economic Development Board would not be talking to businessmen; they would be talking to scientists turned investors who would want to know very different things, such as the availability of research facilities and top calibre scientists" (*ST*, 25/11/985).

What began in the early 1980s as an attempt at diversifying Singapore's industrial base, with efforts to establish biotechnology (then primarily understood as "the industrial processing of materials by micro-organisms and other biological agents"; *ST*, 16/3/1983) by attracting "plant and food biotechnology companies", in the mid-1980s took on a new dynamic. The realization that establishing a biotechnological base would be a long-term project, as early as 1985 led to calls on Singapore "to further refine its niches in biotechnology" as well as warnings, for example by Yip, to "take care that the large sums of money we spend are not thinly divided over several fronts" (*ST*, 25/11/1985). As the *Straits Times* noted, these new priorities – along with new groups of actors such as "scientists turned investors" – were poised to "create a whole new scenario for Singapore's investment promoters" (*ST*, 25/11/1985). Equally evident is a keen interest on the part of policymakers to promote the metamorphosis of an initially loose collection of actors into a community of "biotechnologists" working together as a team. The idea of a marriage between science and industry also infuses the rhetoric that accompanied the refocusing of the Science Council's role in 1986, which Yip described as that of a "matchmaker", "looking at joint ventures [and] introduc[ing] possible partners" (*ST*, 8/5/1986).

4. Biotechnology as science and higher education policy

Biotechnology *as industrial policy* is but one aspect of Singapore's biotech efforts since the early 1980s. As the discussion towards the end of the previous section indicates, investment promoters were only one group of stakeholders that participated – initially with some reluctance, as noted earlier – in the drive towards biotechnology. Of equal importance were the interests of scientists themselves – not merely the (initially elusive) "scientists-turned-investors", but especially those scientists who were already represented in local universities and research institutes. In this section, I wish to analyze the response of local scientists, universities (including other institutions of higher learning), and their representatives to the biotechnology efforts that grew out of the government's overall industrial policy. As I hope to show, the scientific community – at the institutional level as well as via individual scientists, both local and from overseas – gradually became an important factor in reshaping Singapore's biotechnology agenda. More specifically, in a reversal of the usual roles, scientists were able to co-opt the government's more instrumentalist outlook – a move that was, in turn, if not encouraged then at least tolerated by policymakers; it is this constellation of what one might call a "managed détente" between the two groups of stakeholders which contributed to the sustained establishment of biotechnology in Singapore.

Interestingly, it was the educational sector – polytechnics and universities – that was the main driver in this process: Biotechnology was construed as another piece of the

puzzle of developing "strategies to develop the population and transform it into a qualified and disciplined citizenry employable by multinational companies" (Reubi 2010: 147) – and, by extension, *deployable* to newly emerging technologies. Thus, following the March 1983 budget speech and the subsequent floating of the idea of Singapore as a future "biotech centre", a demand was issued in the *Straits Times* that

> [m]uch of the infrastructural support has to come from the National University of Singapore. Not only has the university to train enough scientists to man the industry, it has to make changes to its science curriculum to prepare its graduates for a career in biotechnology. (*ST*, 16/3/1983)

The University, however, seems to have anticipated such demands – or perhaps, in an instance of fortuitous timing, had enacted independent changes to the curriculum – since the same article reports that NUS is "changing the teaching programme, although slowly":

> For example, students at the Science Faculty will, from July [1983], be able to study microbiology as a single subject. Previously, they did it as part of biology. As a result, the teaching hours on microbiology for second and third year students will be more than doubled. (*ST*, 16/3/1983)

Changes to the undergraduate curriculum, however, only partially addressed the needs arising from biotechnology as an emergent, research-intensive technology. Hence, a year later, a government representative (Chua Sia Eng, the Commissioner of the Parks and Recreation Department), in an address directed at science and pharmacy graduands, demanded that "graduates must join the research and development programme in biotechnology so that a strong base can be formed from which Singapore can tap the vast potential of this science" ("Do research in biotechnology, grads urged", *ST*, 15/11/1984). There is clearly an element of "quid pro quo" in the commissioner's advice, paraphrased by the *Straits Times*, that graduates "will need further training in postgraduate and advanced courses if they are to contribute to" – and, presumably, *profit from* – "the rapid developments in this field":

> "If sufficient numbers of you join postgraduate courses, the university can then set up multi-disciplinary project teams to conduct basic and applied research in biotechnology and other related fields." (Chua Sian Eng quoted in *ST*, 15/11/1984)

Remarkably – perhaps in order to drive home the urgency of the need for qualified biotechnology experts – the call on science and pharmacy graduates to join postgraduate courses, seems to have preceded the expansion of genuine biotech-centred postgraduate opportunities.[6] This was one of the motivations given for the setting up of the Institute of Molecular and Cell Biology in early 1985, which, according to NUS's vice-chancellor,

[6] Indeed, it was not until 1999/2000 that PhD scholarships were made widely available to postgraduates in Singapore; as Philip Yeo recalls in an interview, this was one of his primary concerns when he took over

> would not only create a pool of competent manpower to service the biotechnology industry but also offer a research career to NUS graduates in chemistry and microbiology. (*ST*, 24/1/1985)

Polytechnics, too, joined the biotech bandwagon, with Singapore Polytechnic having tweaked its chemical process technology courses in 1986 to include "new biotechnology-related topics" and adding new laboratories, operational by 1988, for both biotechnology and medical technology (*ST*, 30/7/1988). From June 1989, both Singapore and Ngee Ann polytechnics started offering "three-year full-time diploma course[s]", with Singapore Polytechnic basing its biotech offerings on a "common first-year course in chemical process engineering" and Ngee Ann offering a designated biotechnology course from year one. (*ST*, 1/2/1989)

Scientists and researchers themselves became a more and more vocal group of stakeholders as the build-up of biotechnology capacities progressed in the 1980s. However, it was not only the extant community of local researchers that contributed to the biotechnology discourse in Singapore. Individual scientists, too, especially high-profile foreign visitors, some of whom were brought in via the Lee Kuan Yew Distinguished Visitors Programme or in various advisory capacities, played an important part in highlighting the needs of scientists involved in biotechnological research.

One of the most prominent and influential overseas figures was Sydney Brenner (Nobel Prize 2002) who, from 1983 onwards, played a crucial role as recurring visitor (and first guest as part of the LKY Distinguished Visitors Programme in 1985), public proponent of biotechnology, "biotechnology advisor to the government" (*ST*, 20/1/1985), and, from 1985, as chairman of the advisory board of the IMCB. Brenner's pronouncements on the future of biotechnology, and what it would take for Singapore to succeed, were widely publicised and often pithy. On the occasion of his first publicized visit, for an Asean-EEC conference on biotechnology, Brenner urged Singaporean policymakers that

> "Biotechnology is not a spectator sport. One must participate to gain knowledge or else you may be left behind." (*ST*, 15/11/1983)

This attitude – including its emphasis on knowledge-generation – directly contradicted the earlier, more reserved attitude of the EDB, which explicitly aimed "to attract companies which are working in areas where the technology is proven" (*ST*, 16/3/1983). Far from merely lobbying for more funding for basic research, however, Brenner displayed a keen awareness of the need to "focus on selected areas instead of trying to develop in all areas of biotechnology" (*ST*, 22/1/1985). During his 1985 visit, he

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the NSTB in 2000, having previously, in 1999, shifted funds – "illegally", as Yeo said tongue-in-cheek in an interview – from the Glaxo/EDB scholarship fund, initially established in 1990 for BS/MSc scholars, to PhD studentships, in order to address the shortage of post-Master's level biotechnology specialists. (See Yeo 2008.)

specifically mentioned three areas – medicine ("the production of diagnostic kits for certain diseases"), health care ("the production of vaccines for infectious diseases common to the tropical areas") and agricultural biotechnology (work "to improve plant strains") – which "should form the major thrust of Singapore's move into biotechnology": "These are areas where Singapore has a natural advantage and they should be exploited" (*ST*, 22/1/1985).

In a second lecture on the same 1985 visit, Brenner argued that "scientific research must be aimed at delivering effective health care to the majority of people" and that, if necessary, "[s]ociety should make judgments which are different from those made by a doctor" (*ST*, 25/1/1985). By acknowledging the primacy of broader societal and economic interests, while at the same time insisting that "biotechnology is not a spectator sport", that "one must participate to gain knowledge", and that "[t]he laboratories here are to make discoveries" (*ST*, 2/10/1987), Brenner was thus able to mediate between policymakers" (implicit) demands for tangible social and economic benefits and the scientists" emphasis on basic research, aimed at making discoveries and contributing to the growth of scientific knowledge. It was this ability to bridge what Chris Tan (in a short piece on the occasion of Brenner's 75th birthday) called "a mismatch of expectations between the civil servants and the scientists", that made Brenner an instrumental figure in convincing policymakers that the setting up of the IMCB was "the entrance fee for Singapore into the world of biotech" (Tan 2002: 20).

The story of biotechnology in Singapore in the 1980s is one of the gradual realization of the necessity of fundamental research. The setting up of the IMCB in 1985, and its formal opening in 1987, mark the institutionalization of this move towards basic research in the service of long-term innovation and future economic returns. Scientists themselves pushed for the inclusion of basic research in government funding for biotechnology, while at the same time assuring themselves, the public, and policymakers of the applied nature and practical goals of their basic research.[7] Two comments, published side by side in the *Straits Times* in January 1987, convey a clear sense of the scientists' desire to prove the practical relevance of their research and to broaden traditional categories of science and technology policy to make room for fundamental research.

The first article, by the executive director of the Science Council of Singapore, Vincent Yip, was originally written for an internal publication of the Ministry of Communications and Informations and was excerpted in the *Straits Times* expressly "at the request of Dr Yip". In it, he outlines how the Science Council "has restructured its priorities and affirmed its primary mission", namely "to promote the growth of the

[7] A later echo of this tendency to creatively elide the distinction between "basic" and "applied" research can be found in Jackie Ying's reply when A*STAR invited her to move from MIT to Singapore as head of the planned "Institute of Bioengineering". Reportedly, her only request was: "Can we make it 'Institute of Bioengineering & Nanotechnology?'" (See Gelfert 2012: 154.)

technology-based innovation process in Singapore, from basic and applied research to product process development and industrial applications". In particular, he assures his (civil servant) readers that, while the Council "will continue to promote awareness of emerging technologies", it will "concentrate [its] resources more on the practical aspects" (*ST*, "We"ll focus on practical aspects", 19/1/1987).[8]

The second article, by Nga Been Hen, an associate professor of microbiology, in addition to describing the plethora of actively pursued research projects and noting the restructuring of undergraduate curricula at NUS "to include fundamental basics in course topics in biotechnology", also describes as a "most helpful component in an R&D programme" the "participation of post-doctoral research workers with relevant research experience in current techniques" (*ST* 19/1/1987). Postdoctoral researchers, while no doubt valuable assets in fundamental science, are not typically associated with long-term applied R&D – at least if the latter is understood in Yip's sense, as being directed as "product/process development", preferably "at small and medium-sized enterprises" (*ST* 19/1/1987). Over time scientists became noticeably more adept at presenting their basic research, and preferred institutional arrangements, as in line with the "official" roadmap towards a biotechnological future. One might even go so far as to say that scientists, as one group of stakeholders among others, were keen to exploit a strategic ambiguity in the official biotechnology discourse, which arose from the fact that, although Brenner's advice to focus on "selected areas" of biotechnology had been taken on board, it had never been made sufficiently explicit which areas of specialization were to be considered appropriate for Singapore.[9] At the same time, the presence of this unresolved ambiguity forced both policymakers and scientists to remain alert and responsive to changes in external circumstances as well as to shifts in mutual expectations.

Clearly, one cannot expect a complete alignment between perspectives of policymakers and scientists – not least since scientists, too, differed in their views on what constitutes fruitful lines of research. An interesting illustration of this point is the fate of agricultural biotechnology in Singapore, and of the Institute of Molecular Agrobiology (IMA) in particular. Agricultural applications had been part and parcel of the global biotechnology discourse from the late 1970s onwards, and it is not by chance that "improving plant strains" was one of the three areas of research that were singled out as well-suited to Singapore by Brenner during his 1985 visit as Lee Kuan Yew Distinguished Visitor. However, as molecular methods moved to the forefront across much of biological science, agricultural biotechnology – insofar as it concerned areas such as bioprocessing, food technologies, and applied microbiology (what in 1983 was

[8] It is worth noting that when Yip was installed as the Science Council's first executive director in June 1984, this was partly because of "government dissatisfaction over the council's performance", since the Council, although "charged with advising the government on scientific and technological R&D, … did little more than organise seminars and exhibitions" (*ST* 20/6/1984).

[9] On the notion of "strategic ambiguity", see Eisenberg (1984).

described as "proven technology", as opposed to "unrealistic" science "in the frontiers of biotechnology such as gene splicing"; *ST* 16/3/1983) – lost its cutting-edge status to "red" (biomedical) biotechnology. This process was well underway in 1995, when the IMA was set up.[10] Indeed, even the EDB, which on the cover of its 1992 promotional brochure "Biotechnology: A Growing Industry – Focus for Tomorrow" had featured three images, representing the perceived major industries – food, agriculture/plant science, and biomedicine, respectively – in its revised 1995 edition had replaced the images of foodstuffs and plants with white-coated scientists in biomedical labs (see fig. 1).

This move away from its past agricultural ambitions may be interpreted both as a dissociation from Singapore's developing (rural) neighbouring countries and as an indicator of Singapore's aspiration to being a fully developed modern city. As has been noted by other authors, the "will to modernize" – often expressed explicitly in terms of a contrast between urban industrialized economies (such as Japan) and rural developing countries – has been at the centre of nation-building efforts ever since Singapore gained independence, and also infuses "Singapore's efforts to transform the island into a 'world-class hub for the life sciences'" (Reubi 2010: 143). Among the technologies that most directly signified the self-consciously modernizing system of governance were biotechnology and artificial intelligence (often mentioned in tandem, e.g. *ST* 8/5/1986). Indeed, as Greg Clancey has argued, the "intelligent island" campaign of the 1980s – which aimed at creating a hybrid between videotext and what was later to become the internet, in order to allow for "disembodied" communication between citizens and access to government services – may be seen as "the inheritor of Singapore's fabled cleanliness" campaigns of the 1960s and 1970s, when cleanliness itself was regarded as a measure of technological and societal progress. (See Clancey 2012: 30.) Perhaps it is not surprising, then, that agricultural research topics, with their messy connotations of livestock production, breeding, and soil science, were increasingly being crowded out by their "clean" and hygienic biomedical counterparts.

[10] An anonymous referee suggested that worries about genetically modified food might have contributed to the relative decline of agricultural biotechnology in Singapore; however, such worries were more pronounced in Europe – as discussed by Cantley (1995: 669-671), who attributes this to Europe's "strategic blunder" of an "uncritical and inappropriate transfer of the culture of chemicals control" to biotechnology regulation, and contrasts the European case with "less constrained environments (such as the USA)" and "those where long-term strategic vision was taken seriously", as in Japan (and, I would argue, Singapore).

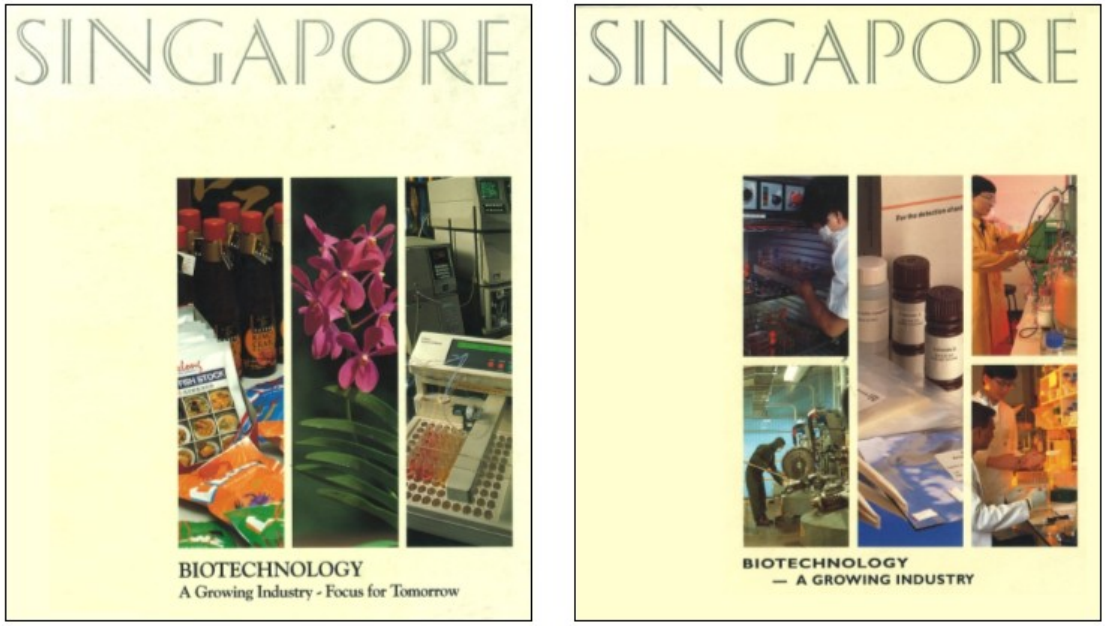

Fig. 1 Cover images of "Singapore Biotechnology - A Growing Industry - Focus for Tomorrow" (left, 1992) and "Singapore: Biotechnology - A Growing Industry" (right, 1995) courtesy of the Singapore Economic Development Board (EDB)

The initial rationale behind establishing the IMA was that, by focusing on crops such as rice and cotton and developing new strains, which would then be patented, it would be possible to profit from much of the region's reliance on agriculture. While its scientific output was by all accounts solid, the IMA remained something of an anatopism. Rumours of its imminent shut-down were reported in the *Straits Times* in December 2000, but were quelled by the (retroactive?) appointment of Ho Ching to the position of chairman from 1 November 2000. Things boiled over again in late July 2001, however, when the international science journal *Nature*, in an article that first floated Singapore's self-description as a "biopolis" to the wider scientific public ("Building a biopolis", *Nature*, 26/7/2001), quoted Philip Yeo, who five months earlier had taken over as chairman of the National Science and Technology Board, as saying that the IMA was "a criminal waste of tax-payer's money" and that, if he could, he "would close it down tomorrow". In order to illustrate his point, Yeo suggested "a trip to the supermarket": "Everything there is imported. We have no agriculture." (Quoted after Cyranoski 2001: 371.) In what was widely regarded as, to some extent, a face-saving operation, parts of the IMA were finally, in October 2002, merged with the IMCB, while the remaining research groups were absorbed by the newly-founded Temasek Life Science Laboratory (TLL) Ltd., by its own description a "non-profit organization" affiliated with NUS and NTU and partly funded by Temasek Holdings (see Temasek Holdings 2009). Individual scientists also joined the various new institutes that were founded from 2000 onwards, or

were relocated to Biopolis – the 2003 opening of which marks the completion of a gradual move towards the integration of basic and applied research under the paradigm of biomedical and molecular biotechnology.

5. Putting biotechnology to work

Official technology discourse in Singapore has tended to blend in with, and lend support to, Singapore's self-image as a pragmatic nation which could rely on nothing but the tenacity and ingenuity of its own people, and whose economic successes were hard-won in the face of adversity. A good example of this is Tan's 1983 budget speech, which contends that "it is when the going gets rough that the importance of cooperation, of working as a team, of discipline and cohesiveness can be brought home to Singaporeans" (Tan 1983: 30). A potent psychopolitical factor has been the pervasive emphasis on "human capital" and "upgrading of skills" – expressions that, along with their cognates, have proven to be rhetorically effective vehicles of communicating both a sense of individual responsibility and an awareness of the vulnerability of Singapore in the race for global competitiveness. This is nicely captured by a passage from Prime Minister Lee Hsien Loong's 2005 National Day speech celebrating forty years of independent statehood:

> What will Singapore be like 40 years from now? I can't tell you. Nobody can. But I can tell you it must be a totally different Singapore because if it is the same Singapore as it is today, we're dead. We will be irrelevant, marginalised, the world will be different. You may want to be the same, but you can't be the same. Therefore, we have to remake Singapore – our economy, our education system, our mindsets, our city. (Lee 2005)

Earlier, the Ministry of Trade and Industry's Economic Review Committee had concluded its 2003 report "New Challenges, Fresh Goals: Towards a Dynamic Global City" on a similar note:

> We envisage each Singaporean being imbued with the necessary mindset, skills and competencies to excel in the new environment, with resilient and entrepreneurial individuals creating wealth and ensuring the continued prosperity for our country. (ERC 2003: 177)

Aihwa Ong (2008: 122) in this context speaks aptly of "a milieu of intellectual upgrading, accumulation, and production". Government programmes were enacted in order to facilitate this process, for example through the Skills Development Fund (1984), which would reimburse employers for part of the expenses incurred from retraining workers in selected activities (see Kuruvilla and Chua 2000). Such programmes served the goal of creating a critical mass of manpower and expertise necessary for Singapore to function as a hub in the relevant industries. Rather than merely "be just a node on a

network", the goal, especially in the new knowledge industries of biotechnology and artificial intelligence, was to become "a hub on a wheel, a center of something, a place that could think originally and creatively in its own right and not just learn" (Clancey 2012: 26).

A similar sentiment also pervades much of the country's biotechnology discourse. A clear example of this is the case, discussed earlier, of a government commissioner addressing science and pharmacy graduands in 1984 – well before the wheeling out of postgraduate opportunities and scholarships in biotechnology – insisting that they "must join the research and development programme in biotechnology" since its "vast potential" could "only be realised if academic institutions, research bodies, and the industry set up the necessary R and D facilities in the country" (*ST*, 15/11/1984). Similarly, in 1989, the National Biotechnology Committee recommended that a Training in Biotechnology Scheme (TIBS) be created, in order "to promote and speed up the transfer of knowledge, technology, and skills in biotechnology" (*ST*, 1/11/1989). In the remainder of this section, however, I shall not rehearse how the publicization of Singapore's biotechnology efforts contributes to the mobilization of the general population for the next stage in the country's move "up the value chain" (for an analysis, see Holden and Demeritt 2008 and Pereira 2006). Instead, I wish to focus on an analogous rhetoric of upgrading and "pulling on the same rope" in the discourse between scientists, policymakers, and their advisors.

From early on, the biotechnology discourse is marked by an emphasis on collaboration – between different departments and disciplines, between science and industry, and between local and overseas institutions. In its first main article, which picks up on Tony Tan's reference to biotechnology in his 1983 budget speech, the *Straits Times*, commenting on the preparedness of the National University, notes that not only is it "increasing contacts with overseas universities", for example through hosting "visits from other prominent scientific universities", but that, in addition, "[f]aculty members also report greater cooperation between the various departments". A member of the Department of Pathology is cited as saying "that faculties are now encouraged to collaborate, and to keep each other informed of research projects and what each department is doing" (*ST*, 16/3/1983). The rationale for collaboration in the pursuit of scientific knowledge is, of course, well-established; its contribution to the creation of a viable biotechnology industry is less clear. If one thinks of collaboration in terms of the formation of alliances, it is clear that, while they offer potential benefits – for example, through the sharing of expertise – they also carry the risk of intra-alliance rivalry. Empirical studies of alliance formation by (and between) commercial biotechnology firms confirm that a variety of processes need to be considered. Thus, alliances with downstream partners (e.g., the pharmaceutical and chemical industry) can "provide access to complementary assets critical to successful development and commercialization"; in turn, alliances with upstream partners (e.g., "universities, research

institutes, and government labs") can "provide timely access to new ideas and concepts, … emerging knowledge … and technological knowhow" (Baum, Calabrese and Silverman 2000: 273). By contrast, alliances between potential rivals were found to be "particularly susceptible to the deleterious effects of intra-alliance competition" (ibid.: 288). As Celia Umali (2010: 96) notes, "in Singapore where segments of the biotechnology sector are still in its nascent stage, the government leads the initiative to develop" various areas of biotechnology through the creation of a joint infrastructure for research and via designated research institutes, some of which – like the Novartis Institute for Tropical Diseases, set up in 2002 – take the form of public-private partnerships (in this case between Novartis and the EDB) and combine fundamental with applied research. Much of the relevant expertise, of course, had to be imported from abroad; indeed it has been argued that, within the Asian biotech-pharma sector, "Singapore appears to be the only case where biotech development goes beyond indigenous incubation and where foreign know-how, entrepreneurship and capital is encouraged as part of a fast development strategy" (Umali 2010: 94).

As in the case of "upgrading of skills", the move towards greater cooperation among scientists was presented as a matter of necessity, an individual responsibility, and a break with old habits. In the same article that quoted Brenner's slogan "Biotechnology is not a spectator sport", the *Straits Times* ("Scientists advised to work as one team", *ST*, 15/11/1983) summarizes the prevailing view as follows:

> Scientific researchers should pool their skills and work as a team instead of competing against one another. They should put aside individual considerations and work as a group, for only then can they tap each other's talents. (*ST*, 15/11/1983)

As chief witnesses, the *Straits Times* cites three scientists – one local (Tan It Koon), one locally born but working overseas (Chua Nam Hei), and one from abroad (Sydney Brenner) – who take turns to reiterate that no individual alone "can keep up with what is happening elsewhere" (Brenner). Division of labour is important, since "the scientist who obtains the approval and gets the funds for the project may not have all the necessary skills" (Chua); hence, "[r]ather than working separately and sometimes even competing with one another for limited funds and resources for similar projects, they should complement and cooperate with one another" (Tan).

While scientists were happy to publicly acknowledge the need for cooperation with other scientists, and with international research groups in particular, this did not always extend to cooperation with industry, nor did cooperation between academic and research institutes always go as smoothly as the public pronouncements might suggest. That cooperation, and calibration of mutual expectations, were not always easy and would remain a challenge, is illustrated by interviews with the various stakeholders, conducted by Phillips and Yeung in 2000. These bring out "a stark difference" between research institutes and university researchers, regarding "their understanding of their

respective roles and functions" (Phillips and Yeung 2003: 723). Thus, one marketing director representing a research institute is quoted as complaining that they

> had university staff come in here... They used our facilities freely and expected us to wait for them... What they didn't understand is that we are not here to serve them. We were set up for the industry. (Quoted after Phillips and Yeung 2003: 723)

Some of the difficulty stems from differences in outlook on how knowledge should be treated – as a goal in itself and a public good, or as an intermediate step in the development of patentable innovations. As another interviewee from an R&D-oriented research institute puts it, contrasting the research culture at his institute with that of the public universities: "We can do research projects, but they cannot do development projects"; furthermore, no one at his institute "would pass around such knowledge to universities because one never knows where it will end up" (quoted after Phillips and Yeung 2003: 726).[11] Cooperation between academic researchers and R&D-oriented scientists thus often tends to be "more a discursive ideal than a practical reality" (Phillips and Yeung 2003: 725).

Similar observations at an earlier stage in the process seem to have been a cause of concern for parts of the government. As mentioned earlier (see fn. 8), the revamping of the Singapore Science Council was partly the result of the government's perception that the Council was neglecting its role as an advisor on R&D matters, preferring instead to do "little more than organise seminars" (*ST*, 20/6/1984). Similar worries extended to government-funded research institutions, which in 1986 prompted a Minister of State, Yeo Cheow Tong, to call "for more joint research between government departments and industry" ("'Co-operate in research' call from Cheow Tong", *ST*, 5/8/1986). This would not only "allow local scientists to interact closely with foreign experts", but "would also help scientists in Singapore to update their knowledge and skills faster" (ibid.). Referring back to a visit by Robert Gallo, the co-discoverer of HIV, a year earlier, Yeo suggests that researchers as well as medical practitioners have much to gain from personal interaction with leading scientists: "Singapore doctors who had a chance to speak to Dr Robert Gallo would have learnt much more than reading Dr Gallo's papers in scientific journals." (*ST*, 5/8/1986) Gallo's visit in 1985 was highly publicised at the time, as was the Biotech Asia '85 conference it was part of, which was even accompanied by a specially produced Singapore Broadcasting Corporation (SBC) documentary on "Biotechnology", which was broadcast, on the Chinese-language television channel, four days before the opening of the conference.

The involvement and role of foreign researchers – some of whom, like Brenner, in an advisory capacity over a period of almost three decades, others as principal

[11] How persistent such mutual suspicions are is nicely illustrated by the headline for a full-page *Straits Times* article on the state of biotechnology in Singapore in 2011: "Researchers uneasy about 'going to bed with industry'" (*ST*, 9/9/2011).

investigators or heads of major research institutes – has always been a complex affair. More recently, this was brought into sharp focus when, in August 2011, several senior foreign scientists (among them Edison Liu, who had worked in Singapore for ten years, setting up the Genome Institute of Singapore, as well as cancer researchers and wife-and-husband team Nancy Jenkins and Neal Copeland), announced – independently of one another, and ostensibly for different reasons – that they would leave Singapore. This led to considerable public soulsearching, with the media referring to the departure of star scientists as "the 'whale' migration" and speculating "that other scientists might follow, due to unhappiness over issues like red tape, the introduction of KPIs perceived to be unrealistic, and a new Industry Alignment Fund introduced this year, which ties the granting of biomedical research funds to industry partnerships" ("Shedding Light on 'Whale' Migration", *ST*, 1/10/2011). This came on the heels of what was perceived to be a sudden policy shift when, in late 2010, it was announced that, from the following financial year onwards (which was due to start in April), about one third of the budget of the Biomedical Research Council (BMRC) would be set aside for direct industry collaboration, work with clinical researchers, and the creation of technology platforms, and would be made subject to reapplication by senior researchers. Much of the money was eventually released ("$180m doled out from stalled biomed fund", the front page of the *Straits Times* screamed on 9/9/2011), but the abruptness and top-down nature of the policy change, which was reportedly made by the relevant ministries without prior consultation with the BMRC, left the impression that, as one anonymous scientist told a reporter, "essentially the bean counters have taken over" (*ST*, 9/9/2011). Interestingly, once again foreign scientists were called upon, this time by the media, to assess the impact of such policy changes on Singapore's biotech future and to allay fears of wider repercussions: All three experts whose comments were specially featured in the *Straits Times* – Sydney Brenner, Morris Birnbaum, and Richard Sykes – were foreigners in an advisory capacity, with Brenner striking the most critical note ("I do not know whether you can measure the performance of scientists by KPIs") and the other two noting that "pressure to cooperate with industry is not necessarily a bad thing" (Birnbaum) and characterizing the changes as "a process or transition", rather than as a sign of things going wrong (Sykes).[12]

From early on, the prospect of technological innovation and economically viable applications of biotechnology, has clearly been a driving motivation behind calls for more cooperation, especially between scientists and industry. In his opening remarks for the Biotech Asia '85 conference, Richard Hu, the Minister for Finance and Health, stated with some boldness:

> The emphasis in biotechnology is no longer on purely academic research and questions of technological feasibility. Attention has now moved to the translation of technical

[12] Quotations from "Experts on pressure to deliver the goods", *ST*, 9/9/2011, page A10.

> discoveries into viable commercial activity. Concerns in production efficiency will undoubtedly soon assume increasing importance as the race to get affordable products into the market ahead of the competition intensifies. (Hu 1985)

What might have seemed a premature shift in outlook to those scientists engaged in fundamental research, clearly indicates a desire on the part of the government to generate social and economic returns from its heavy investment in biotechnological research. A perhaps more realistic assessment was given in the corresponding leading article of the *Straits Times* (29/11/1985) which argued that, while the conference marked "the laying of the foundation of what can possibly be a promising industry for Singapore", the country was in for "a long haul ahead". As Tsui-Auch notes, since 1991 "the Economic Development Board has gradually shifted its focus from building infrastructure for research to strengthening the biotechnology industry and the commercialization of R&D" (Tsui-Auch 2000: 258). In spite of this, the translational capability of Singapore – that is, its ability to turn fundamental research into commercially viable applications – continues, on occasion, to be called into question by biotech analysts. Thus, Gurinder Shahi, a biotech consultant, notes as a "comparative weakness" of Singapore as bioeconomy its "[l]ack of translational biotechnology capabilities" (Shahi 2004: 160). The developments in 2010/11, as outlined above, can thus be seen as simply the latest in a series of attempts to recalibrate Singapore's sustained investment in biotechnology research against its expected economic payoff.

Given that biotechnology in Singapore, conceived of as a national project, had its historical roots in a response to an economic crisis, it may seem only natural to assess its overall success in terms of its contribution to the economy. At the same time, such a narrow focus on commercial applications has, on occasion, obscured other criteria of success – such as the sustained establishment of a novel technoscientific complex which encompasses different groups of actors and, though not financially or institutionally self-sufficient, displays considerable resilience and adaptability. Partly, I have argued, this was the result of the peculiar dynamic between (academic) scientists and policymakers, which has been marked by the presence of strategic ambiguities, which forced a continuous reshaping of mutual expectations, but also enabled a shared acknowledgment of open-endedness that too often tends to be absent from government-led innovation policies. Thus, as biotechnology developed in Singapore, its function evolved. What was initially perceived as merely another emergent technology that would lend itself, in a top-down way, to product/process development, has gradually come to be seen as a more complex, exploratory endeavour, whose social and economic payoff also consists in its contribution to a future knowledge society, helping to turn Singapore into a nation – to use the official slogan of the "one-north" development that comprises Biopolis – "where ideas grow".

Acknowledgments

I am grateful to Greg Clancey, Catelijne Coopmans, Connor Graham, Erik Holmberg, and two anonymous referees for helpful comments on an earlier version of this paper. The research for this article was conducted as part of the "Asian Biopoleis: Biotechnology and Biomedicine as Emergent Forms of Life and Practice" Project, funded by the Ministry of Education, Singapore, and the Humanities and Social Sciences (HSS) Division in the Office of the Deputy President (Research and Technology) at the National University of Singapore (NUS).

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