Singapore's Success Story in Research and Development and a Decade of the Biomedical Sciences

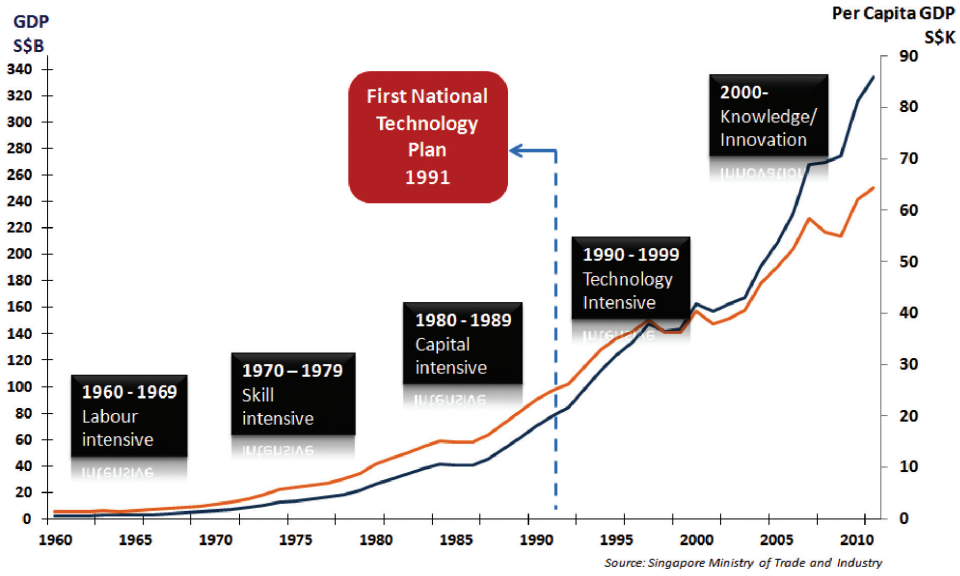
George K Radda

Lee Kuan Yew, the Founding Father and first Prime Minister of Singapore, said a few years before the independence of the country in 1965:

"I believe our future depends upon our ability to mobilise the qualities in our population to maximum advantage. It is the one thing we have which makes up for our lack of size and numbers, and it is of the utmost importance that, in the field of science and technology, we should lead the field in this part of the world."

Since that time, Singapore has evolved from a labour-intensive economy to a booming knowledge and innovation-based economy. The first National Technology Plan in 1991 focused on promoting R&D in the private sector and resulted in a dramatic increase in R&D expenditure.

TRANSFORMATION OF SINGAPORE'S ECONOMY

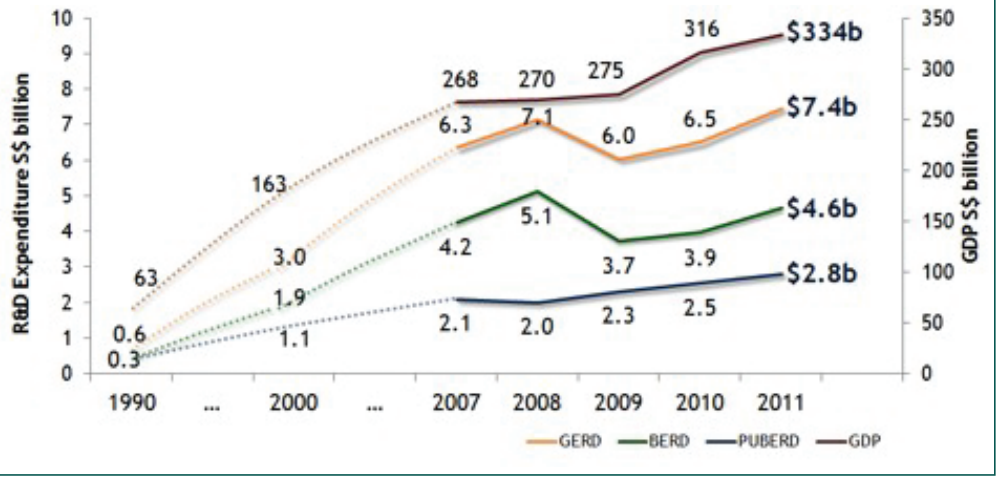


Following Lee Kuan Yew's visionary statement, another bold step was taken in 2000 to establish the **Biomedical Sciences (BMS)** as a key pillar of Singapore's economy. **"Biopolis"** was established in 2003 as the key location with state-of-the-art infrastructure for biomedical research among public and private players. In just one decade, a small country of 5.3 million people achieved in BMS what others have taken generations to accomplish.

What had made this possible? I regard four aspects of the programme as key.

(I) The firm commitment of Government to R&D and its ability to provide the appropriate Research Governance. (II) The ability to take bold new initiatives that are implemented with speed. (III) The recognition for the need and mechanisms for building up talent at all levels

R&D EXPENDITURE IN SINGAPORE (2011)



to support the research enterprise. (IV) The ability to integrate capabilities across different scientific disciplines, and between clinicians and scientists.

I Research Governance and Structure

Research funding comes from a variety of sources and agencies under the umbrella of a National Organisation.

The **Research, Innovation and Enterprise Council (RIEC)** is helmed by Prime Minister Lee Hsien Loong and is responsible for setting the broad research, innovation and enterprise strategies and directions for Singapore. The **National Research Foundation (NRF)** was set up in 2006 under the Prime Minister's Office to coordinate the research of different agencies, within a larger national framework, in order to provide a coherent strategic overview and to help advance Singapore's national R&D Agenda.

The **Ministry of Education (MOE)** oversees and funds academic research at the tertiary institutions as well as investigator-led research through the Academic Research Fund. Its focus is on research with longer time frames and driven by knowledge creation. The **Institutes of Higher Learning** comprise the Autonomous Universities (NUS, NTU, SMU and SUTD) and the polytechnics. MOE has also established five Research Centres of Excellence (RCE) in NUS and NTU since 2007, to drive globally competitive peaks of excellence within the universities.

The **Ministry of Health**, through the **National Medical Research Council (NMRC)**, focuses on scientific and health research, driving the translation of basic research to advance human healthcare. There are also **hospitals and academic medical centres** under the Ministry of Health, which engage in translational clinical research.

The **Ministry of Trade & Industry** is responsible for mission-oriented research through the close integration of the efforts of its research and economic agencies A*STAR, EDB and SPRING.

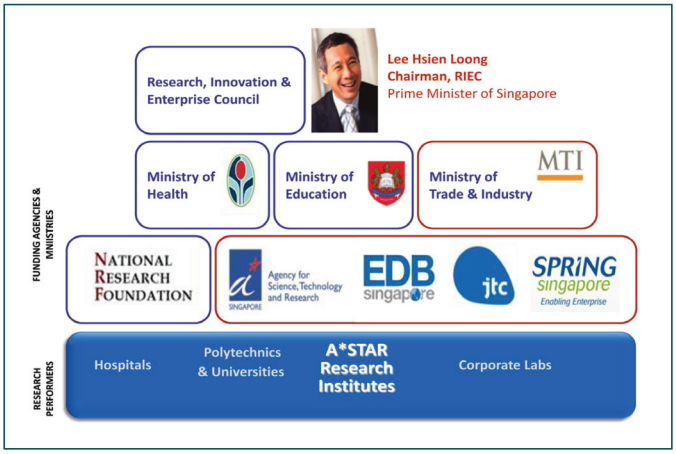
A*STAR is the lead mission-oriented R&D agency responsible for supporting Singapore's key economic clusters and developing industry-relevant talent. Under 18 research institutes, A*STAR nurtures public sector R&D across biomedical sciences and physical sciences and engineering. A*STAR works with the **Economic Development Board (EDB)** to attract multinational corporations and corporate R&D laboratories to Singapore. **SPRING**, another close partner of A*STAR, is the enterprise development agency for growing innovative companies and fostering a competitive small and medium enterprise sector.

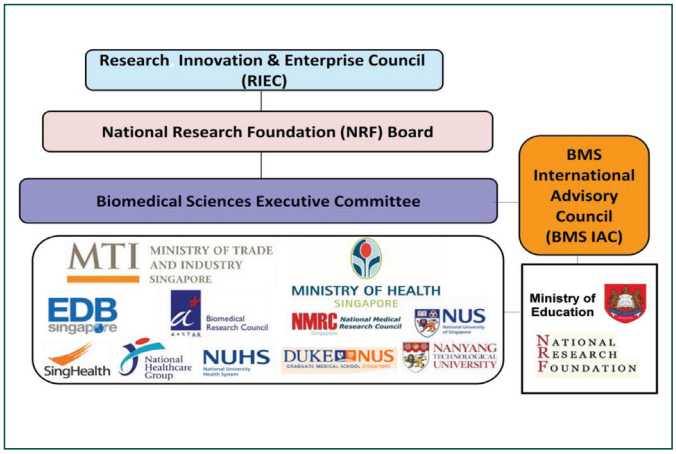
The R&D planning cycle is over 5 year periods. The first was conceived in 1991 where S$2 billion was allocated for public research between 1991 and 1995. This was really the turning point where Singapore's R&D investments began rising significantly. In the latest 5th S&T plan, S$16.1 billion has been allocated for public R&D, over 8 times the budget of the first S&T plan. The focus is on fostering R&D which encourages greater public-private sector partnerships, as well as technology translation and commercialisation that bring along positive economic and societal impact.

II Singapore's Biomedical Sciences Initiative: a Bold New Venture

The Biomedical Sciences Initiative has been carried out within a well-coordinated governance framework.

The **BMS Executive Committee** functions as a





coordinating body for the overall planning of research as funded by the different Agencies and Ministries, and reports directly to the NRF Board. The Executive Committee draws on the combined experience of the **BMS International Advisory Council**, comprising renowned scientists for strategic advice and guidance.

The three phases of the BMS Initiative were centred around the concept of a "bio-city." One-north, a 200 hectare R&D and business park, was identified to be the home for **Biopolis**, a term coined by Nobel Laureate Sydney Brenner. "What I wanted is to have public-private research taking place at the same place." Mr Philip Yeo, Biopolis Tenth Anniversary publication. Today, as Chairman of A*STAR Mr Lim Chuan Poh said, "Biopolis is a thriving eco-system of public research institutions and corporate labs, and a vibrant community of local and international biomedical scientists carrying out world-class R&D."

Phase 1 (2000-2005): Building the Foundation. The first phase focused on establishing a firm foundation of basic biomedical research in Singapore. Five of BMRC's research institutes developed research in the areas of bioprocessing, genomics, molecular and cell biology, bioengineering and nanotechnology, and computational biology. Seven research buildings were completed in Biopolis, linked by sky bridges to encourage collaborations. The concept of co-location of public-private research institutes was also promoted.

Phase 2 (2006-2010): Strengthening Translational and Clinical Research. The second phase focused on strengthening translational and clinical research. BMRC launched consortia in key areas, such as the Singapore Bioimaging Consortium, Singapore Stem Cell Consortium and Singapore Immunology Network. On the manufacturing side, the biologics cluster was developed, with the spin-off of A-BIO from A*STAR's Bioprocessing Technology Institute in 2004.

In parallel with the activities of BMRC, the two main Universities NUS and NTU built up their strengths in the Biomedical Sciences, with major new efforts in Clinical Research at NUS. The Duke-NUS Graduate Medical School and 2 RCEs in the Biomedical Field were established.

... globally competitive peaks of excellence ...

Phase 3 (2011-2015): Capturing Opportunities for Greater Economic and Health Impact. The next phase focused on bringing economic, health and social impact for Singapore. Enhanced industry engagements were sought, with the establishment of BMS Industry Partnership Office as the one-stop coordinating office for multinational companies. Greater integration of research players was fostered. New opportunities in biomedical research were seized, such as in food and nutrition, and skin research.

Further advances in clinical research were made, for example through attracting clinician/scientists to the Medical Schools with generous grants. Several joint funding schemes between the Universities, Hospitals and A*STAR have been developed. At NTU, in partnership with Imperial College London, a third Medical School has been set up.

The results were good. R&D expenditure in BMS grew six-fold over the past decade, while BMS manufacturing output has increased nearly five-fold. Singapore has attracted investments from leading biopharmaceutical companies, such as Chugai, Novartis, Arkray, Fluidigm and P&G. Singapore has also become a leading location for commercial operations in BMS, with seven of the top ten pharmaceutical companies and all top ten medical technology companies having regional or global commercial operations based in SG.

One significant public-private alliance Singapore established in January 2010 is the Roche Hub for Translational Medicine, which focuses on expanding knowledge of disease biology to develop new personalised treatment approaches. With an investment of SFr100 million, the Hub is an example of how companies can leverage on Singapore's integrated network of biomedical sciences research institutes and academic medical centres. Another pioneering partnership is the collaboration between A*STAR's Experimental Therapeutics Centre (ETC) and Switzerland's Cytos Biotechnology to develop the H1N1 vaccine, which has already entered into Phase 1 clinical trials. The success of this research will have the potential to provide Singapore and the region with an independent supply of vaccine, which is especially crucial in times of outbreaks.

... greater public-private sector partnerships ...

III Building Talent for Rapid Action and Sustainability

The speed at which the BMS effort has been achieved relied on an open talent strategy in recruiting established Senior Scientists to set up and lead the Research Institutes in 2001.

Singapore has always been able to call on the best advice and support from the international scientific community and UK scientists have played major roles. The International Scientific Council, chaired from the very beginning of the BMS effort by Sir Richard Sykes, still plays an important role in giving advice to government. Its members include or have included Sydney Brenner and four previous or current Chief Executives of the UK MRC. Sydney Brenner, George Radda and Sir David Lane are still actively involved in making scientific contributions as well as having leading roles in the organisation of the BMS research developments.

At the same time, a long-term plan for training the best Singaporean students at major universities in the US, Europe and Asia was put into action. Since 2001 A*STAR has nurtured more than 1,100 Singaporeans through its range of scholarships and fellowships and by providing opportunities to "returning scholars". Today young PhDs work side-by-side with top scientists in a diverse research community.

In the past five years the Universities have also been actively recruiting faculty at all levels and training many PhD students. Singapore as a whole has a thriving BMS community and its challenge is to organise this in a strategic way. The BMS

research community has grown by 2.5 times, from 2150 in 2002 to over 5400 in 2011. Biopolis itself holds over 2500 public and private sector researchers of over 70 nationalities.

... unprecedented opportunities for collaborations...

IV Integration for the Future

Integrating Biomedical and Physical & Engineering Sciences

It is recognised world-wide that the integration and convergence of different scientific disciplines is key to future major progress in biomedicine, which will create innovations and products of value to companies. In A*STAR the biomedical and physical sciences and engineering capabilities are under a single agency and located within the compact one-north area. This gives unprecedented opportunities for collaborations and has proved to be attractive to companies in locating their R&D in Singapore.

Through A*STAR's Joint Council Office, many initiatives have been started to connect biologists with chemists, physicists and engineers. One example is the Silicon Biophotonics programme for cancer biomarker discovery. The team leverages on the Institute of Microelectronics' advanced silicon nano-fabrication technologies and molecular diagnostic device capability, and the Institute of Molecular and Cellular Biology's expertise in cancer research.

One strategic area with large growth potential is Medical Technology. The MedTech programme leverages on the interdisciplinary capabilities of A*STAR Institutes, spanning electronics, precision engineering and biomedical sciences, and also links to the strong network of clinical researchers and companies. Thus, Singapore is positioned as the Asia MedTech Hub. By 2015, MedTech is expected to contribute $5 billion to manufacturing output.

Integrating with the Clinical Research Community

To bring scientific discoveries from bench to bedside and to make greater impact for human healthcare, Singapore fosters close collaboration between research institutions and the clinical community. The Translational and Clinical Research (TCR) Flagship Programmes, administered by NMRC under MOH, were started to bring clinicians and scientists to work together in specific disease areas.

... scientific discoveries from bench to bedside ...

The joint NUS/A*STAR Clinical Imaging Research Centre was one of the first cases of a major collaborative programme. Other examples include: the concerted programme in stratified medicine, a partnership between the Genome Institute of Singapore, and several public Healthcare Institutions; a comprehensive birth cohort study towards healthy outcomes, focusing on epigenetics, involving A*STAR's Singapore Institute for Clinical Sciences with NUH and KK Women's and Children's Hospital.

Conclusion

Singapore's R&D achievements were rooted in firm and dedicated government support, well-coordinated research governance, a daringness to implement bold new initiatives with speed, an open talent strategy, and efficient frameworks for the integration of scientific disciplines and research performers. All these factors can be encapsulated in Singapore's BMS Initiative.

As President Tony Tan stated in a dinner celebrating Biopolis' 10th Anniversary, *"The success of Biopolis and the BMS sector is symbolic of Singapore's commitment to anchor BMS as the fourth pillar of Singapore's economic strategy...The fact that this was achieved in 10 years could not have happened without the close cooperation of A*STAR, EDB and JTC, with strong support from MTI, MOH, NRF and many other agencies."*

ROCKETING SKY HIGH: UK & RUSSIA IN SPACE

Dr Julia Knights, First Secretary, Head Science & Innovation Network (SIN) – Russia

The UK's relationship with Russia has never been stronger in science and space. Our nations are ideally matched for collaboration. Russia accounts for 40% of rocket launches globally; the UK is world number one in small satellites, Europe number one in telecomm-unications satellites and has a strong upstream and downstream space industry. Both our nations share a goal to own 10% of the global space market by 2030.

In May 2013, our Science & Innovation Network (SIN) – Russia based at the British Embassy in Moscow provided high level briefing in liaison with the UK Space Agency (UKSA) for a meeting between President Putin and Prime Minister Cameron. They agreed to step up collaboration in science and Space.

SIN Russia put this agreement into practice by organising a UK Russia Ministerial Joint Committee Science & Technology co-chaired by the Secretary of State for BIS, Minister Cable and Minister Dmitry Livanov of Russia's Ministry of Education and Science on 17th October 2013, hosted by the Royal Society. A Statement was signed by both ministers with agreement to