Supporting early career health and biomedical sciences investigators in Singapore

1. Research, Innovation and Enterprise Ecosystem in Singapore

Overview

The Research, Innovation and Enterprise (RIE) ecosystem in Singapore comprises various government ministries, funding organisations and R&D performers. Please see Figure 1 below.

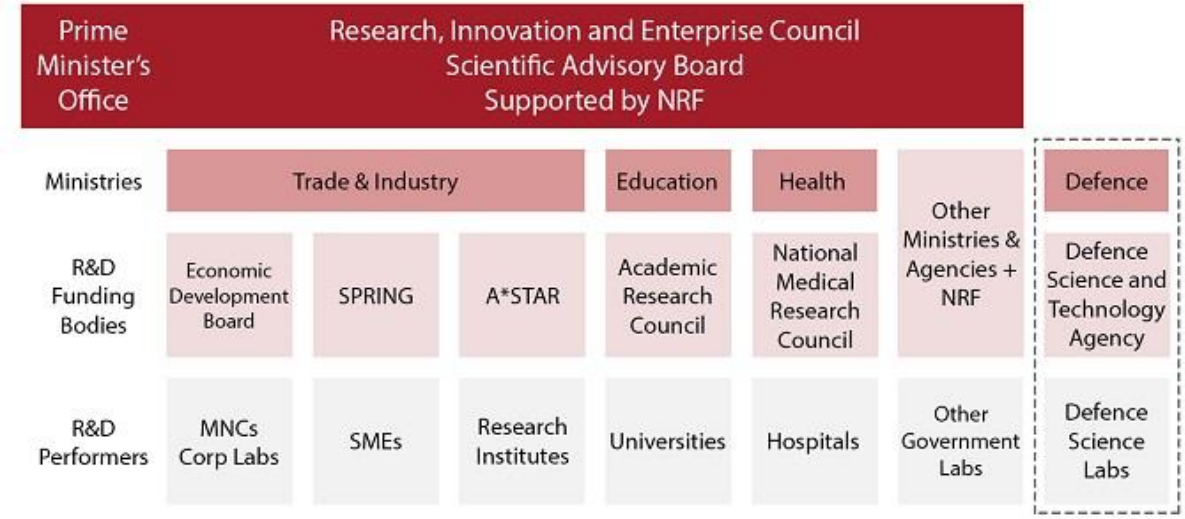

Figure 1. Singapore's RIE ecosystem[1]

Our Prime Minister chairs the Research, Innovation and Enterprise Council (RIEC) which oversees Singapore's long term strategy to transform itself into a knowledge-based economy with strong research and technological capabilities. The RIEC is supported by the National Research Foundation (NRF) Board, which is responsible for the formulation of our 5-year plans and policies to grow Singapore's research capabilities, support economic growth and meet future national challenges.

[1] https://www.nrf.gov.sg/about-nrf/rie-ecosystem

Singapore's government has progressively invested in research and innovation over the last 25 years in 5-year tranches. S$19 billion will be invested in the current tranche (2016 – 2020) called the RIE2020 plan. More details are provided in Table 1 below.

Table 1. Singapore's public sector RIE investments[2]

Plan	National Technology Plan 1995	National Science & Technology Plan 2000	Science & Technology 2005 Plan	Science & Technology 2010 Plan	Research, Innovation and Enterprise 2015 Plan	Research, Innovation and Enterprise 2020 Plan
Budget	$2 billion	$4 billion	$6 billion	$13.5 billion	$16 billion	$19 billion

Besides the government, industry plays a significant role in fostering industry-science linkages such as public-private research partnerships (e.g. corporate laboratories hosted in universities) and industry research consortia. Our R&D investments are also catalysing new economic activities and enhancing the local start-up ecosystem which is increasingly vibrant. In 2015, for every $1 spent in research from public sources, $1.57 was spent by businesses. For the Biomedical Sciences sector, the Business Expenditure on R&D (BERD) was $727 million, while the Public Expenditure on R&D (PUBERD) was $1,311million[3].

Unlike other countries where philanthropic foundations (e.g. Bill & Melinda Gates Foundation, Wellcome Trust, Howard Hughes Medical Institute) play a major role in funding research, their role here in Singapore is not as significant as compared to the government and industry.

Peer review system

The peer review framework in Singapore is similar to other countries where selection of research proposals for funding is based on competitive peer review.

2. Background on Singapore's Biomedical Sciences (BMS) initiative

The BMS initiative was launched in 2000 to develop the BMS sector as one of the key pillars of Singapore's economy.

[2] https://www.nrf.gov.sg/rie2020
[3] National Survey of R&D in Singapore 2015

BMS Phase I (2000 – 2005) established strong basic biomedical research foundations, and included extensive development of research capabilities and infrastructure. This was continued in BMS Phase II (2006 – 2010) which also placed a particular focus on building up strengths and supporting infrastructure in translational and clinical research (TCR), to facilitate bench-to-bedside translation. BMS Phase III (2011 – 2015) focused on greater integration of activities across the entire HBMS community, including public and private sector performers, hospitals and government agencies, with a greater emphasis on the application or commercialisation of research that would lead to health and economic outcomes. This has continued in the current funding cycle.

Development of research institutes

In the early 2000s, the Agency for Science, Technology & Research (A*STAR) spearheaded the BMS effort through the establishment of a range of Research Institutes (RIs), the construction of Biopolis, and recruitment of international talent and development of a robust local talent pipeline. There are currently more than 10 A*STAR biomedical RIs and consortia that straddle the spectrum from fundamental to applied research.

Building up research in universities

Over the last decade, Singapore's universities have grown into world-class research institutions. This was driven by the autonomy granted to the universities, increase in research funding and the launch of Research Centres of Excellence (RCEs). The autonomous universities (AUs) recruited top faculty while building a strong local core of leading faculty.

Singapore has also become a nexus for international R&D collaborations. For example, the Campus for Research Excellence and Technological Enterprise (CREATE) established joint research programmes between our local universities and top overseas institutions (including Massachusetts Institute of Technology, Swiss Federal Institute of Technology in Zurich, and University of Cambridge).

Building up new medical schools and academic medical centres

To address the need for more doctors, two new medical schools, namely Duke-NUS Medical School and Lee Kong Chian School of Medicine (partnership between Nanyang Technological University (NTU) and Imperial College), were set up in 2005 and 2013 respectively. Given the critical role academic medical centres (AMCs) play in world-class biotechnology hubs, two AMCs, namely National University Health System (NUHS) and SingHealth/Duke-NUS were established to create synergies between clinical care, medical education and research.

Supporting translation

Besides establishing a good science base, investments were made in a number of initiatives to translate scientific discoveries into novel therapies or diagnostics. The Experimental Therapeutics Centre (ETC)/ Drug Discovery & Development (D3) was set up to translate discoveries into medicines. The Diagnostics Development (DxD) Hub does the same for *in vitro* diagnostics and research reagents, and a new Experimental Biotherapeutics Centre is being set up for biologic-based drugs. Singapore also has two Investigational Medicine Units (IMUs) for experimental studies and early phase trials. The Singapore Clinical Research Institute serves as an academic CRO to support investigators who are conducting clinical trials locally, and also has strong networks with hospitals in Asia for access to patients.

Focus on diseases with an Asian phenotype

To differentiate Singapore from research efforts in the west, there is a strong focus on basic, translational and clinical research on diseases which have an Asian phenotype. Large collaborative programs have been formed across the universities, A*STAR research institutes and hospitals to tackle diseases such as liver cancer, gastric cancer, as well as certain eye disorders such as glaucoma and age-related macular degeneration, which have a distinct Asian prevalence and phenotype and pose significant burden to the local health system and population.

Overview on Industry Alignment Fund

To encourage public researchers and institutes to work with industry, the Industry Alignment Fund (IAF) was established to foster industry-relevant public sector R&D. It supports projects which connect public and private-sector researchers and in turn facilitate R&D investments in Singapore, or seed capabilities in emerging technologies which would strengthen Singapore's position for future economic opportunities.

3. HBMS Trainees and Workforce

Singapore's Health and Biomedical Sciences (HBMS) ecosystem has developed significantly over the past 15 years, and has grown to include an increasing number of public and private R&D players. This has in turn resulted in a growing number of BMS PhD research scientists and engineers (RSEs) as shown in the chart below (Figure 2). Compared to 2002, the number of BMS PhD RSEs had quadrupled by 2015.

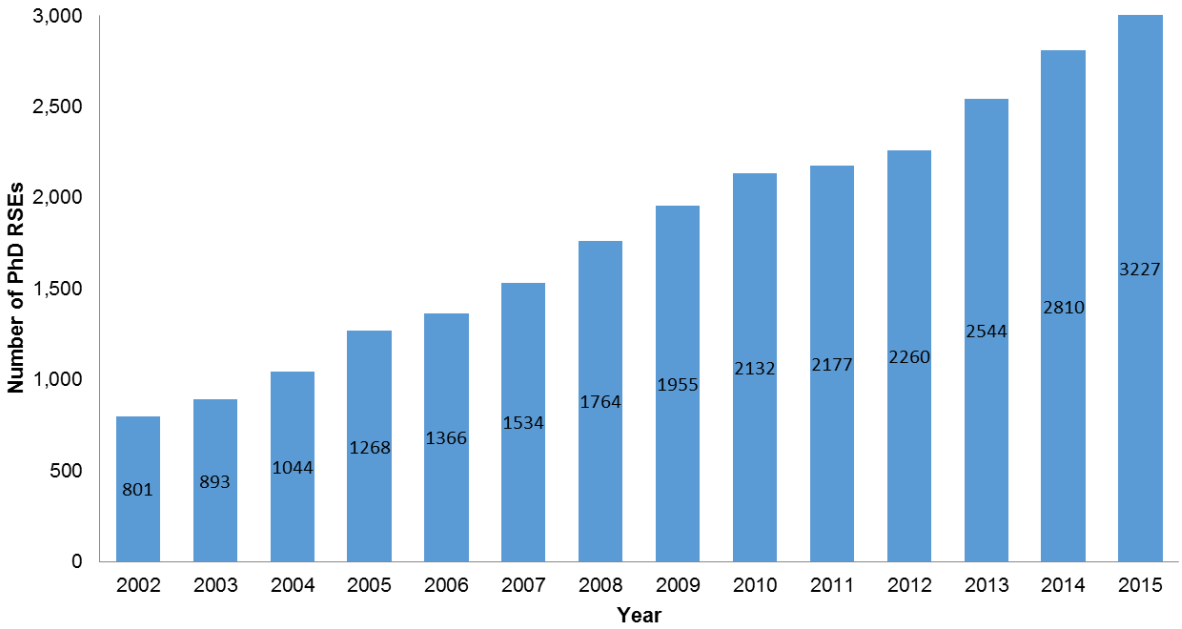

Figure 2. Number of BMS PhD RSEs (2002 – 2015)[4]

[4] National Survey of R&D in Singapore 2002 – 2015

Talent development strategy

To jump start the BMS initiative, a two-pronged strategy was adopted. To build a core of Singaporean researchers, the A*STAR scholarship scheme was established. More accomplished overseas scientists were recruited to kick-start BMS research and help mentor these young local researchers.

The A*STAR Graduate Academy was established to provide and manage the A*STAR scholarships and fellowships to enable young aspiring scientific talent to pursue their passion in science, and prepare them for a R&D career. Key schemes include the National Science Scholarship (NSS) and NSS (MBBS-PhD).

Our local universities train the majority of PhDs for our research workforce. They are mainly supported through Research Scholarships provided by the Ministry of Education (MOE). This scholarship supports stipends and tuition fees of PhDs and Master's students enrolled in AUs. In August 2015, the stipends for Singaporean students were increased to lower the opportunity cost for those who choose to pursue postgraduate research and better support local aspiring researchers. These enhancements were made to help grow the local core in Singapore's research institutions[5].

For more sustainable development of BMS RSEs in Singapore, MOE also made some adjustments to its Research Scholarship scheme in RIE2020. Besides funding PhD/Masters scholarships, AUs will be able to use the funding to support postdoctoral and staff scientist positions. This will provide better support for local PhD graduates who are transiting to the postdoctoral training phase and would help address concerns on oversupply of BMS PhDs which could become a future problem if no adjustment is made. MOE also offers the MOE-AU Scholarship[6] to better support young Singaporeans who have an interest in an academic career.

Each university has its differentiated scholarship schemes to attract outstanding PhD students. These include setting up graduate school for interdisciplinary PhD research in science and

[5] https://www.moe.gov.sg/news/press-releases/first-scholarships-awarded-under-new-singapore-teaching-and-academic-research-talent-scheme-start---giving-singaporeans-a-career-jumpstart-in-academia
[6] https://www.moe.gov.sg/moe-au

engineering. An example is the National University of Singapore (NUS) Graduate School for Integrative Sciences and Engineering (NGS) which was set up in 2003. The NGS coursework curriculum provides extensive training in research ethics, soft skills and interdisciplinary exposure to research frontiers. Other coursework is tailor-made to help students cross disciplinary boundaries. NUS also provides opportunities to outstanding individuals for international doctoral studies under its NUS-Overseas Graduate Scholarship scheme.

NTU offers the Nanyang President's Graduate Scholarship, a competitive and prestigious scholarship scheme, designed to encourage outstanding graduates or final-year students to take their first step towards a leading research career by studying for a PhD at NTU.

The Ministry of Health/National Medical Research Council (NMRC) in Singapore recognises the need to train and develop clinician scientists who are able to play a critical role in TCR. Their close interactions with patients enable them to identify gaps related to causes, diagnosis and treatment of diseases, while their experience and expertise as scientists allow them to frame these clinical insights as relevant research questions.

For aspiring clinician scientists, the Ministry of Health provides training through the NMRC Research Training Fellowship and Master of Clinical Investigation programme. It aims to train clinicians to acquire the knowledge and skills to become clinician scientists and equip health science professionals with the qualifications and skills to become principal investigators.

4. Early Career Investigators

In HBMS research, it has become necessary to undergo postdoctoral training in order to be considered for an independent position. Around the world, this stint could last from two to even 10 years. Postdoctoral researchers in Singapore are funded through various schemes. Many of them are supported on competitive grants while others are through assured funding allocated to research centres or institutes.

It is recognised that early career scientists could take different routes in their transition to independence. To support them, the following categories of funding schemes were developed:

Grants: to support individuals seeking to transition to independence through their first grant as a Principal Investigator and with host institution support.

Fellowships/Investigatorships: to support individuals seeking to transition to independence through protected research time and embarking on independent research.

Grants

HBMS Open Fund Young Individual Research Grant (YIRG)

YIRG is a step for the new investigator to a first independent national level grant. YIRG applicants are strongly encouraged to work with a mentor for guidance in their research. This mentoring will provide support for a period of supervised research leading eventually to the investigators conducting larger scale research projects independently.

Upon the award of the YIRG, the host institution will be required to provide written confirmation from either the applicant's Head of Institution or supervisor to describe the steps the institution will take to demonstrate its commitment to his/her career development. This must include provision of appropriate space to carry out the work proposed, but may also include investment in the equipment necessary to establish the laboratory, access to shared institutional resource, provision of mentorship and career development support etc.

The average YIRG application success rate is 21% and a total of 46 awards has been made so far. This is a new scheme established in RIE2020. It is hoped that successful applicants could achieve research excellence in their projects so that they are able to go on to apply for independent positions or win their first independent national level grant.

Fellowships/Investigatorships

Fellowship and investigatorship schemes were established to support early career investigators' careers as they progress in seniority and work towards independence (see Figure 3 below).

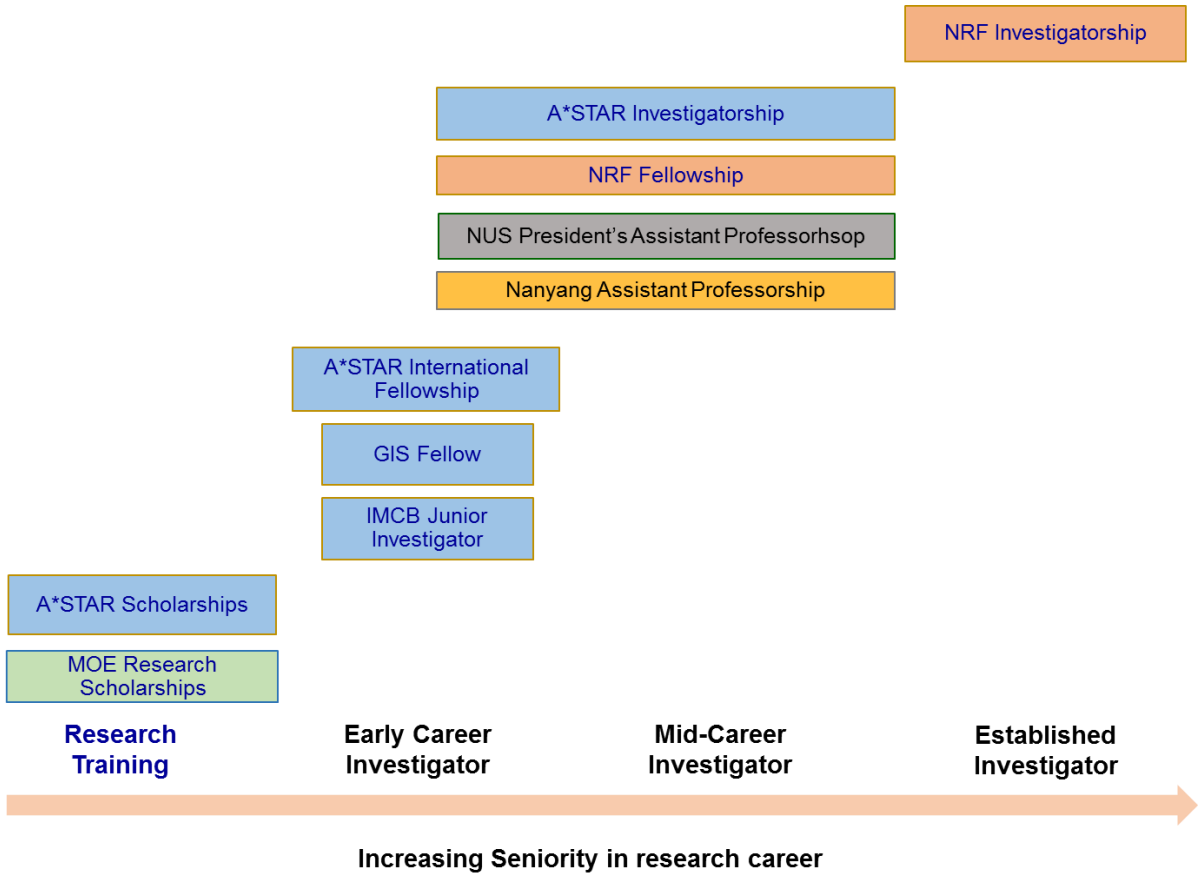

Figure 3. Fellowships/ Investigatorships to support early career investigators

A*STAR International Fellowship funds local PhD graduates for post-doctoral training at leading overseas laboratories. At the A*STAR research institute-level, some institutes such as Genome Institute of Singapore (GIS) and Institute of Molecular and Cell Biology (IMCB) have also set up their own schemes to support early career scientists' transition to independence.

The GIS Fellow programme aims to support accomplished PhD graduates so that they could bypass the traditional academic postdoctoral training phase and have intellectual and funding independence. The eventual goal is for GIS Fellows to develop and run research programmes that could propel them over the course of 3-6 years into full-fledged investigators.

The IMCB Junior Investigator (IJI) programme provides opportunities for young scientists with exceptional ability and drive to pursue their own research programme. IJIs should have promising capacity for independent research and scientific excellence, and an exceptional high potential to develop and lead an internationally competitive programme in the near future.

Outstanding postdoctoral investigators can apply for two local premier schemes which support independent research. The A*STAR Investigatorship aims to attract and nurture the most promising young researchers from around the world to conduct independent research at A*STAR RIs. Successful applicants will receive research funding of up to S$6 million dollars over six years. Applicants should ideally be 35 years of age or younger. The Singapore NRF Fellowship provides opportunities for early career researchers to carry out independent research in Singapore, over a five-year period. Each Fellow is provided with a research grant to support projects that exhibit high likelihood of a research breakthrough.

The local universities also offer prestigious schemes similar to A*STAR Investigatorship and NRF Fellowship. They are the President's Assistant Professorship award by NUS and the Nanyang Assistant Professorship (NAP) by NTU. Successful NAP candidates will receive start-up research grants of up to S$ 1 million, enjoy attractive remuneration package and other benefits and hold tenure-track appointments and play lead roles in the university's multi-disciplinary, integrative research.

Clinician scientist-specific schemes

NMRC administers a range of human capital awards and talent development programmes aimed at supporting individuals in their research and career progression. These are illustrated in Figure 4 below. Since the start of the Human Capital Awards program in 2006, NMRC has now built up a good base of 106 clinician scientists (CSs) in Singapore, or 66% of our long-term goal of 160 CSs.

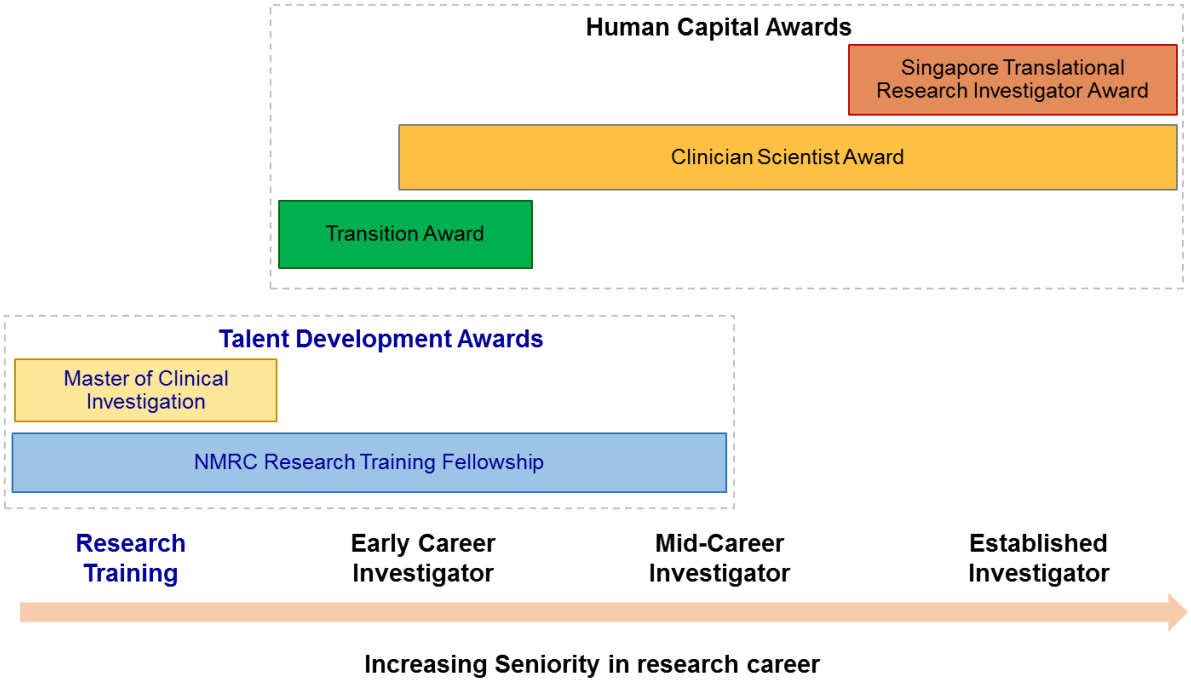

Figure 4. NMRC Human Capital and Talent Development schemes

The Clinician Scientist-Individual Research Grant-New Investigator Grant (CS-IRG-NIG) is a sub category of the CS-IRG to cater for new clinical investigators. The CS-IRG-NIG is a step for the new investigator to a first independent national level grant. Applicants with substantial research experience will not be accepted under this category. The average CS-IRG-NIG application success rate is 24% and a total of 19 awards has been made so far in RIE2020.

The NMRC Transition Award (TA) provides mentored research funding support for aspiring CSs who have just completed their formal research training, with the aim of helping budding CSs transition to an independent research position or research funding to build up their research capabilities. The long-term goal of the award is to increase the cohort of new and talented, NMRC-supported independent CSs. The award is non-renewable as the award recipients are expected to apply for national-level independent research grant support after this career transition period.

The average TA application success rate is 36% and a total of 54 awards has been made to-date. Three TA awardees have since progressed and won the Clinician Scientist Award which provides funding support to CSs with a consistent record of research excellence.

5. Outcomes

Singapore's HBMS research community has grown significantly in the last decade with a rich mix of local and international scientists from both the public and private sectors. This includes both PhD and CSs. A key factor for the future of Singapore's BMS initiative is the pipeline of many young Singaporean basic, translational and clinical researchers nurtured through various scholarship schemes.

A*STAR has built up a critical mass of over 1,400 Singaporean PhD and postdoctoral talents through its scholarships and fellowships. More than half are in BMS. Many have completed their training and have returned to Singapore to further their research careers.

Some of these A*STAR scholars are already beginning to make their own mark. A number of them have gone on to win awards in A*STAR Investigatorship or NRF Fellowship. They and some other scholars have obtained junior PI or even PI positions within the A*STAR research institutes or moved on to faculty positions in the AUs. Some have chosen to join the industry, or even take on research support roles such as patenting and commercialisation. More entrepreneurial scholars have also gone on to start companies. We are beginning to see A*STAR scholars being deployed across the RIE value chain and not just focusing on basic research.

Two out of three A*STAR researchers who received Howard Hughes Medical Institute (HHMI) scholarships in 2017[7] were A*STAR scholars. These HHMI scholarships are awarded to exceptional early-career scientists poised to advance biomedical research across the globe. This year, 41 scientists from 16 countries have been chosen from more than 1,400 candidates as HHMI International Research Scholars. HHMI has teamed up with the Bill & Melinda Gates

[7] https://www.a-star.edu.sg/News-and-Events/News/Other-Highlights/ID/5459/ASTAR-researchers-first-in-Singapore-to-receive-Howard-Hughes-Medical-Institute-scholarships.aspx

Foundation, the Wellcome Trust, and the Calouste Gulbenkian Foundation to develop scientific talent around the world, and will award a total of nearly $26.7 million to this group of scholars.

Some A*STAR scholars have also gone on to win the Young Scientist Award (YSA) for their research achievements. The YSA recognises "*highly innovative and productive Singapore-based scientists and engineers who are at the age of 35 or under who have shown great potential to be world-class researchers in their fields of expertise*[8]". Even with a longer training runway, some of the A*STAR MBBS-PhD scholars have completed their training and are embarking on careers as CSs.

To understand the factors that influence career progression for young CSs, a study was commissioned and it also sought to identify ways to mitigate these factors. Not unlike in other countries, an overarching concern reported by many was the challenge in delineating responsibilities between clinical care and research. Where institutional-level support for research was perceived to be lacking, there were concerns that this would adversely influence career progression. Mentorship was limited not only in terms of scientific guidance but also long-term commitments to the mentor-mentee relationship. Other challenges include career direction. Study participants recognised family support as important for their careers. However, work-life balance was not generally perceived as a 'barrier' to pursuit of research career.

The findings showed that for better retention of CSs, additional measures such as improving institutional research culture, building mentoring networks, adopting effective career tracking and providing clear and viable career progression path for CSs are required.

6. Conclusion

Since the launch of the BMS initiative in 2000, Singapore has come a long way in building up her basic science and TCR capabilities. These are underpinned by a growing RSE workforce.

[8] https://snas.org.sg/young-scientist-award/

Sustainable growth and development of this workforce is essential to building our intellectual capital and developing peaks of excellence in HBMS research.

As Singapore continues her HBMS journey in the coming years, we will continue the focus to build a strong local core through increasing the pipeline of Singaporeans entering research careers and developing early career investigators who can become scientific leaders. We will also continue to attract world-class scientists from around the world to undertake research in our universities, research institutes and industry, and entrepreneurial researchers who can translate research into commercial products.

List of abbreviations

A*STAR	Agency for Science, Technology and Research
AMC	Academic Medical Centre
AU	Autonomous University
BERD	Business Expenditure on R&D
BMS	Biomedical Sciences
CREATE	Campus for Research Excellence and Technological Enterprise
CS	Clinician Scientist
CS-IRG-NIG	Clinician Scientist-Individual Research Grant-New Investigator Grant
D3	Drug Discovery & Development
DxD	Diagnostics Development
ETC	Experimental Therapeutics Centre
HBMS	Health and Biomedical Sciences
GIS	Genome Institute of Singapore
HHMI	Howard Hughes Medical Institute
IAF	Industry Alignment Fund
IJI	IMCB Junior Investigator
IMCB	Institute of Molecular and Cell Biology
IMU	Investigational Medicine Unit
MOE	Ministry of Education
NAP	Nanyang Assistant Professorship
NGS	NUS Graduate School for Integrative Sciences and Engineering
NMRC	National Medical Research Council
NRF	National Research Foundation
NSS	National Science Scholarship
NTU	Nanyang Technological University
NUHS	National University Health System
NUS	National University of Singapore
PUBERD	Public Expenditure on R&D
RCE	Research Centre of Excellence
RI	Research Institute
RIE	Research, Innovation and Enterprise
RIEC	Research, Innovation and Enterprise Council

RSE	Research Scientist and Engineer
TA	Transition Award
TCR	Translational and Clinical Research
YIRG	Young Individual Research Grant
YSA	Young Scientist Award