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Life Science Ecosystem Formation in Singapore
— The Process of Focusing on ‘Translation’ —

Tatsufumi Aoyama
(Research Institute of Capital Formation, Development Bank of Japan)

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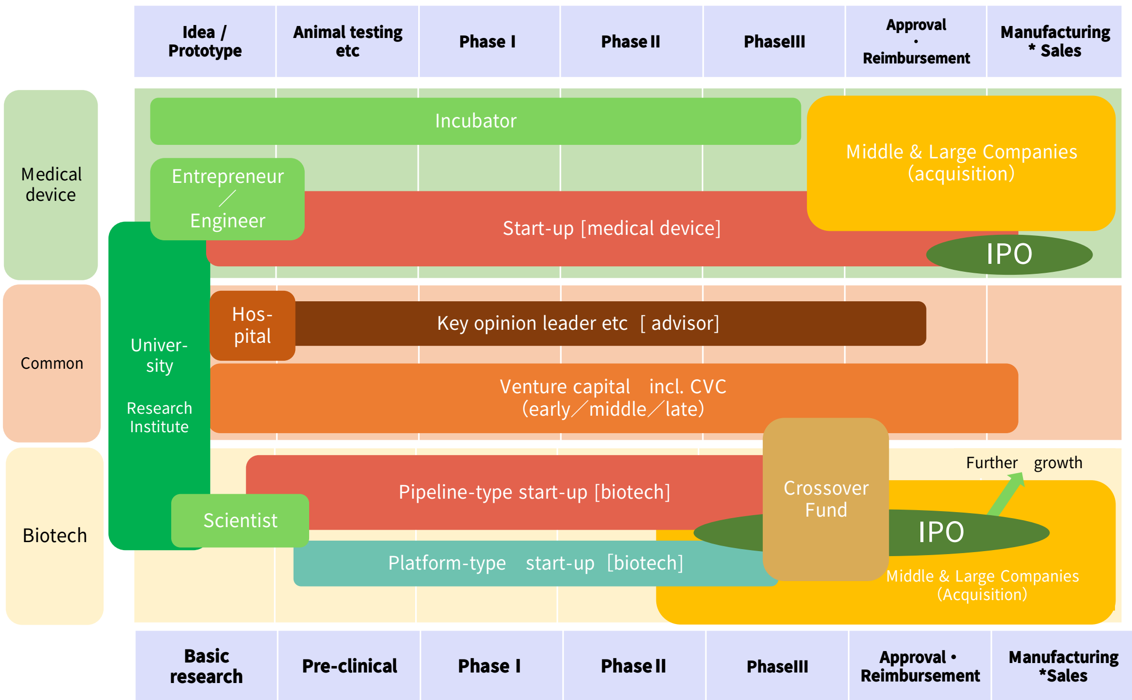
Introduction

This discussion paper examines issues discussed in ‘Structure and Ingenuity of Ecosystem Formation in Life Science: System Formation in Belgium and Challenges in Japan’ (Economics Today, Vol. 44, No. 1, ‘the previous report’) published in April 2023, based on a new case study.

As shown in Figure 1 at the beginning of the previous report and reproduced here, the global life science ecosystem is structured in a way that each country adapts to.

Figure 1 Overview of the life science ecosystem



Created by the author.

This paper qualitatively examines the direction of the transition and how to deal with it through the challenges and responses in the life science ecosystem formation that Singapore has been rapidly implementing. It highlights the issues in the ecosystem formation that are occurring in various regions, contrasting them with those of Belgium, the case in the previous report, and attempts to lay the groundwork for considering practical responses.

Translation, which is the main theme of this paper, means the social implementation of science, and it should be understood as the process depicted in Figure 1.

Chapter 1 History of Science and Technology Policy in Singapore

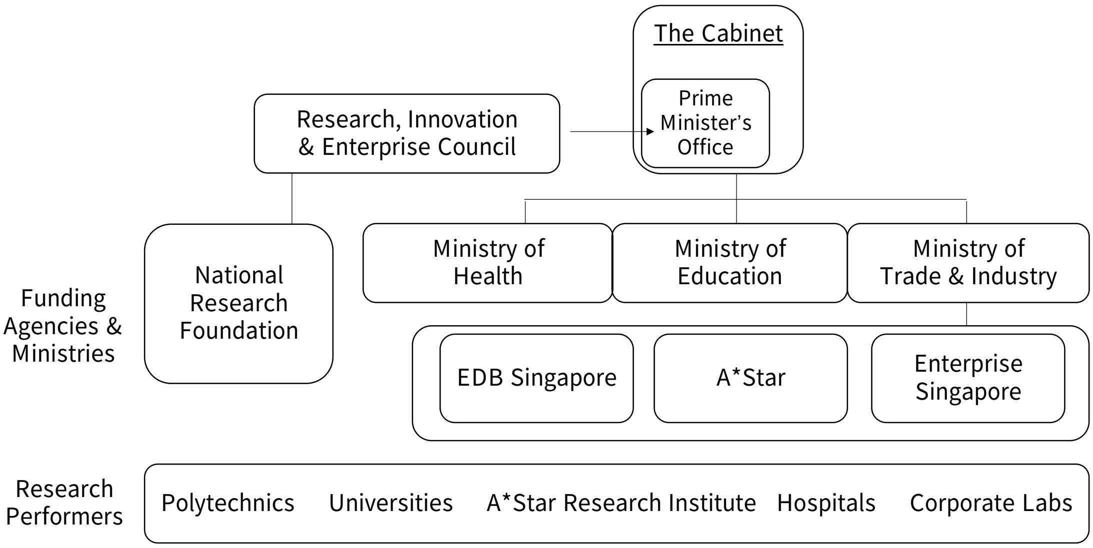
In this chapter, I would first like to briefly summarise the history of life science ecosystem formation in Singapore.

1.1 R&D promotion policy

In Singapore, the National Science and Technology Board (NSTB) was established in 1991 to focus R&D investments to support knowledge-intensive and innovative economic development. The first National Technology Plan (1991–1995), formulated in 1991, was budgeted at S$2 billion and expanded to S$4 billion in the second plan five years later, targeting IT, electrical equipment, water, and the environment.

Biomedical and engineering fields emerged from the third plan in 2001, which was reviewed after the Asian financial crisis, following the initial development of the electronics industry. As part of this, the Singapore Agency for Science, Technology and Research, commonly known as A*STAR, was established under the Ministry of Trade and Industry in 2002. The current national R&D framework is shown in Figure 2.

Figure 2 National R&D framework

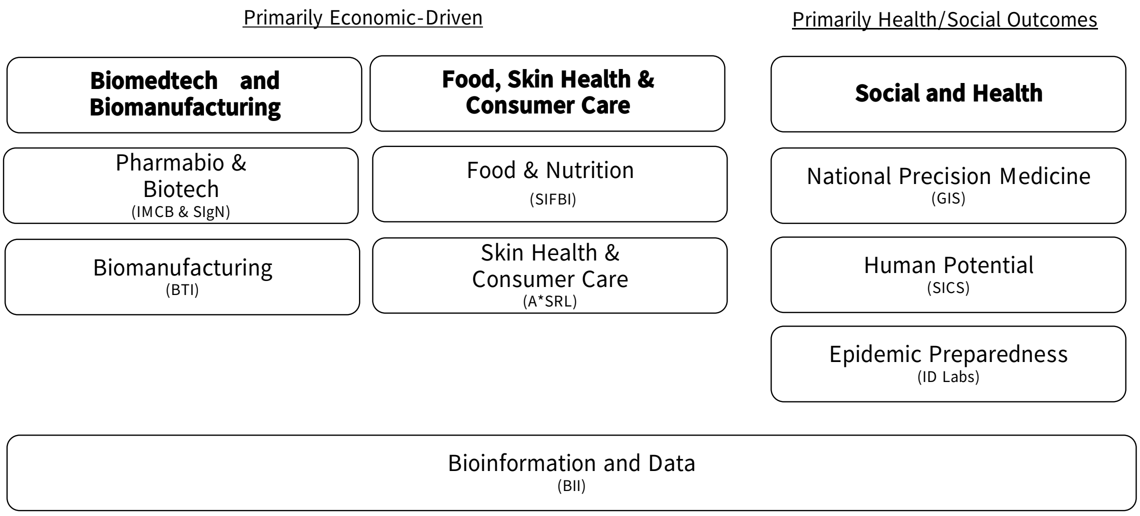


Source: Created by the author from the National Research Foundation website, etc.

A*STAR is a research and development organisation that now has a staff of more than 6,000, including more than 4,700 researchers. The organisation includes The Biomedical Research Council (BMRC), The Science and Engineering Research Council (SERC), and A*STAR Graduate Academy, which provides scholarships and runs various human resource development programmes.

The BMRC is an important organisation for life science research. There are nine research institutes under the BMRC[1], and their research missions are shown in Figure 3. How A*STAR changed its approach will be discussed in Chapter 3.

Figure 3 BMRC research areas



Source: A*STAR material.

1.2 Industrial promotion policy

In parallel with this R&D framework, an industrial cluster of seven buildings called Biopolis was established in 2003 by JTC Corporation, an industrial park development company under the Singapore government.

Tax breaks and subsidies have been provided to biotech companies to encourage their entry into the area and development of the cluster. It is already 20 years old, and after six establishment phases, it is now the core of Singapore's biotech industry.

Biopolis mainly focuses on headquarters and R&D functions, but manufacturing bases have been consolidated in the western area. In the pharmaceutical industry, the specialised industrial park Tuas Biomedical Park was established in 2009, and companies such as Merck, Novartis, and Pfizer have expanded into the area. For example, in 2021, Sanofi announced that it would invest €400 million to set up a state-of-the-art vaccine manufacturing facility over the next five years.

In terms of medical devices, an area called Medtech Hub was completed in 2014 at the Tucan Innovation Park, a medical industrial park in Jurong, also in the west of the country, and a

[1] A*STAR Infectious Disease Labs (ID Labs), A*STAR Skin Research Labs (A*SRL), Bioinformatics Institute (BII), Bioprocessing Technology Institute (BTI), Genome Institute of Singapore (GIS), Institute of Molecular & Cell Biology (IMCB), Singapore Immunology Network (SIgN), Singapore Institute for Clinical Sciences (SICS), Singapore Institute of Food and Biotechnology Innovation (SIFBI).

manufacturing base has been established along with pharmaceutical facilities.

Through these efforts, many companies have established Asian headquarters in Singapore, along with 60 other factories and 30 R&D centres.

Figure 4　Accumulation areas, such as major clusters

Created by the author based on information in the public domain.

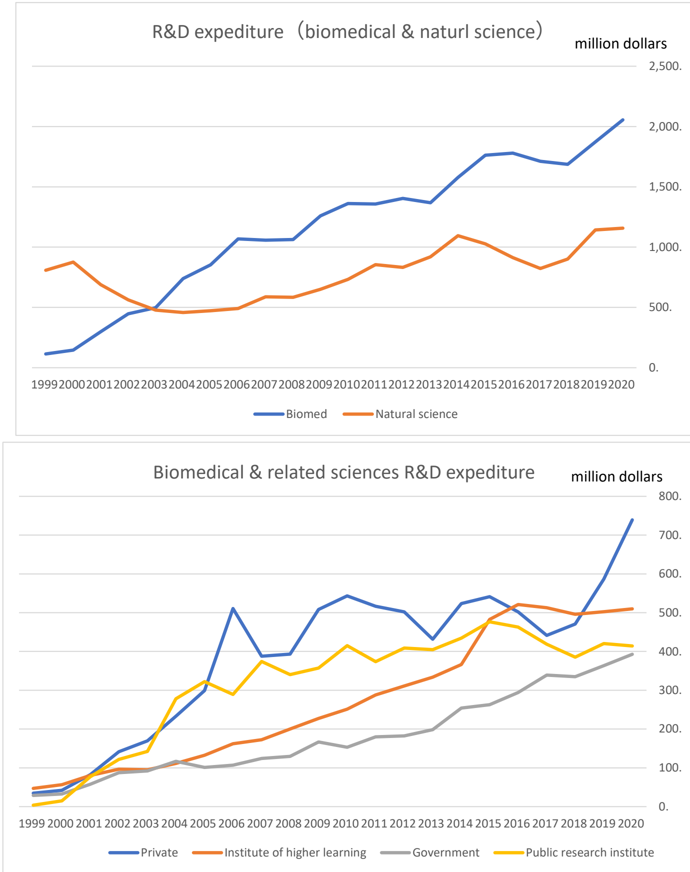
Chapter 2　Trends in Research-related Data

Now, I would like to use objective data to see how the numbers have actually changed. In this chapter, I would like to collect the main data from the Singapore government's SingStat and the OECD.

2.1　Research environment

First, I look at R&D spending over the past 20 years. As can be seen in Figure 5, in the biomed domain, the growth has increased to the right. However, if I look at the figures by sector, the growth of universities and public institutions has been somewhat flat since the mid-2010s, which may be due to the fact that the methodologies that these institutions focus on have changed. On the other hand, this does not mean that the overall growth is stagnant. Growth in the private and government sectors is supporting the biomed upswing. This is particularly healthy in the sense that private sector growth is supporting R&D cost growth.

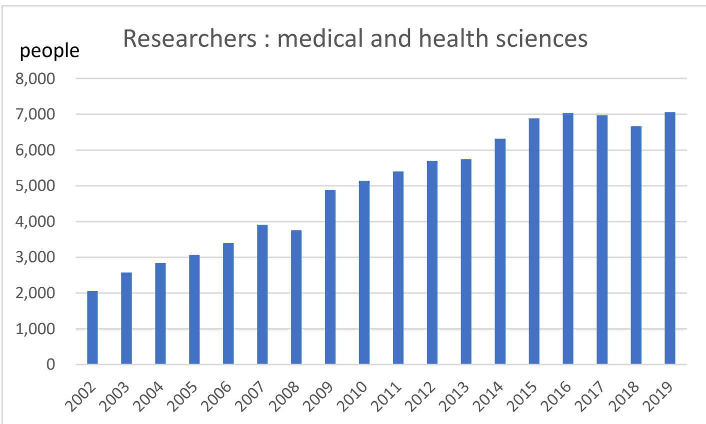
Figure 5 Life science–related R&D costs in Singapore, by sector



Source: SingStat.

The development costs are also allocated to hiring researchers, whose growth can be summarised as follows: Company's efforts to strengthen human resources, including the invitation of overseas personnel, were resulting in upward growth as of around 2015.

Figure 6 Trends in the number of researchers in the medical and health sciences fields



Source: OECD data, 'R&D personnel by sector and major field of R&D'.

This figure, like R&D spending, has been flat since the mid-2010s, but it is assumed that it is largely due to a change in the direction of life science sector support, which will be discussed later.

However, it is important to point out the scale of R&D costs. Singapore's population was projected to be 5.64 million in 2022. Meanwhile, in the context of strengthening the life sciences industry since 2000, the country has implemented very intensive spending in terms of R&D per capita. I would like to compare this situation with that in Belgium, which was mainly discussed in the previous report, as well with those in Japan and the United States (however, they are not included in the OECD data for the last 20 years) on a 10-year basis.

As can be seen in the figures in Table 1, a very large amount of money has been spent by higher education institutions relative to the population, which shows their outstanding focus.

Table 1 R&D expenditure—medical & health sciences—higher education in Belgium, Japan and Singapore (unit: US dollar, 2015)

R&D expenditure on medical and health sciences (higher education)

	1999		2009		2019	
	Population	R&D expenditure per capita	Population	R&D expenditure per capita	Population	R&D expenditure per capita
Belgium	10,226,419	40.6	10,796,498	62.1	11,462,023	74.6
Japan	126,686,000	37.2	128,031,514	46.2	126,555,078	51.6
United States	279,040,168	39.3				
Singapore	3,958,723	17.5	4,987,573	140.0	5,703,569	172.7

Source: Compiled by the author from OECD data, 'Gross domestic expenditure on R&D by sector of performance and field of R&D'.

2.2 Outcome trends

Of course, the outcomes generated by these human resources are important. Let us look at this in terms of the number of papers and patents.

First, in terms of journals, I look at the situation in clinical medicine and basic life sciences in this field. In terms of clinical medicine, the average number of top 10% cited papers and the number of top 1% cited papers from 2019 to 2021 ranked in the top 25 in the world (see Table 2). This is remarkable considering the population of Singapore, and the progress can be seen considering that the average number from 2009 to 2011 did not rank in the top 25. Also, the global share (in whole numbers) of the top 10% papers was below 1.0% from 2009 to 2011, but reached 1.8% from 2019 to 2021. Basic life sciences has not yet reached the top 25, and the global share (in whole numbers) of the top 10% papers was below 1.0% from 2009 to 11, but more recently this has been slightly above 1.0%, showing moderate growth.

Table 2 Comparison of the number of papers in clinical medicine

[Clinical medicine]

	PY2019-2021 (average) Number of papers			PY2019-2021 (average) Number of top 10% cited papers			PY2019-2021 (average) Number of top 1% cited papers		
	Country	Papers	Per Capita	Country	Papers	Per Capita	Country	Papers	Per Capita
1	U.S.	116309	349.9	U.S.	16907	50.9	U.S.	2191	6.6
2	China	64693	44.9	China	6550	4.5	U.K.	1000	14.7
3	U.K.	33597	493.7	U.K.	6318	92.8	China	631	0.4
4	Germany	26344	315.4	Italy	4472	73.9	Italy	621	10.3
5	Italy	22864	377.6	Germany	4147	49.7	Germany	610	7.3
6	Japan	22423	176.8	Canada	3440	92.0	Canada	563	15.0
7	Canada	20138	538.3	France	3002	44.2	France	518	7.6
8	Australia	18658	740.3	Australia	2888	114.6	Netherlands	442	25.4
9	France	16296	239.7	Netherlands	2862	164.2	Australia	442	17.5
10	Netherlands	14361	823.7	Spain	2404	51.4	Spain	412	8.8
11	Spain	14182	303.4	Japan	1989	15.7	Switzerland	304	35.4
12	South Korea	14150	276.2	Switzerland	1868	217.4	Belgium	268	23.2
13	Brazil	10618	50.3	Belgium	1490	129.1	Japan	251	2.0
14	Turkey	10427	125.0	Sweden	1462	145.7	Sweden	226	22.5
15	Switzerland	9769	1,137.1	South Korea	1219	23.8	Denmark	200	34.0
16	Sweden	8385	835.5	Denmark	1183	201.3	South Korea	173	3.4
17	India	8294	6.1	Brazil	1021	4.8	Brazil	169	0.8
18	Belgium	6699	580.5	Austria	887	99.0	Austria	141	15.7
19	Taiwan	6445	273.1	India	871	0.6	Israel	127	14.9
20	Denmark	6392	1,087.6	Poland	730	19.3	Poland	126	3.3
21	Poland	5713	150.8	Israel	685	80.4	India	124	0.1
22	Austria	4772	532.9	Norway	672	124.9	Greece	115	11.0
23	Iran	4635	55.9	Greece	657	62.7	Norway	108	20.1
24	Israel	4327	507.9	Singapore	619	106.6	Singapore	98	16.9
25	Norway	3941	732.7	Taiwan	590	25.0	Ireland	97	19.9

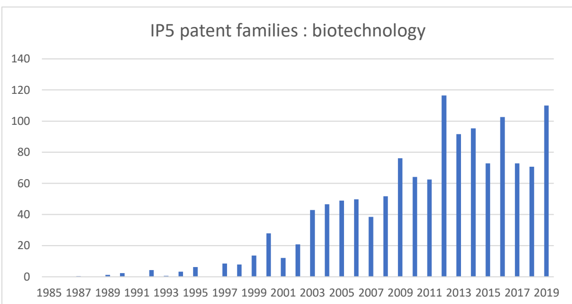
Source: Processed and created by the author based on 'Science and Technology Indicators 2023', National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology (Data Source: Web of Science XML by Clarivate).

Shaded countries are those with relatively high numbers per capita.

A major feature of Singapore is the high number of internationally co-authored papers. The ratio of internationally co-authored papers in all fields (3-year moving average) exceeded 70% as of 2020, and a similar ratio was found in individual fields such as clinical medicine and basic biomedical science. As mentioned above, the invitation of overseas human resources has also had a significant impact.

Next, I would like to look at patents in chronological order. Figure 7 shows the patent transition in the field of biotechnology up to the pre–COVID-19 period.

Figure 7 Patent transition in the field of biotechnology



Source: OECD data, 'Patents by technology'.

Similar to the trend of increasing the number of researchers, the patent-producing trend continued to rise to the right until the mid-2010s, and even after that showed were at a significant level. Of course, there is debate about when to register a patent, and this data does not represent all of the research results, and even though the annual level is more uneven, it is certain that the status of the publication of articles is at global levels.

Table 3 shows the trends per population in the same four countries. As with the R&D expenditure, the figures are outstanding per population.

Table 3 Number of patents in biotechnology (per 1 million population)

	1999	2009	2019
Belgium	13.4	11.2	15.5
Japan	7.9	9.1	11.1
United States	13.4	10.5	15.9
Singapore	3.5	15.3	19.3

Source: Compiled by the author from OECD data, 'Patents by technology'.

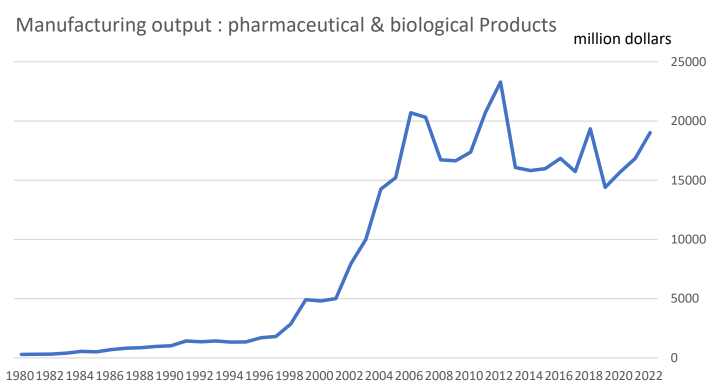
Chapter 3 Trends in Data on the Life Science Industry

In this section, I look at trends in the pharmaceutical and medical device industry as a whole. Singapore has a strong sense of being a hub in Asia for companies expanding globally in production; so, the link between production trends and the country's overall research is not necessarily strong. It can, however, be seen as contributing to the improvement of the industrial base inseparably.

3.1 Trends in production and labour

First, Figure 8 shows the transition of the production value of the pharmaceutical industry. When Biopolis was built, it already showed a great rise, and its peak occurred in the middle of the first decade of the millenium.

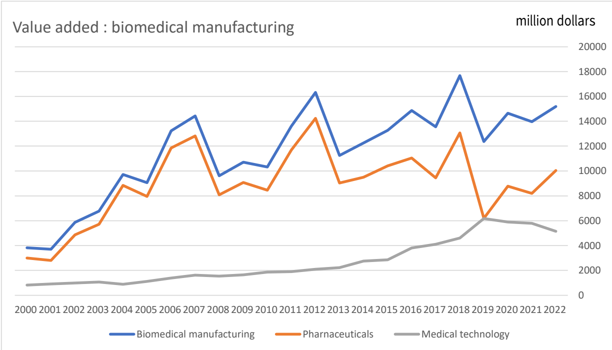
Figure 8 Trends in production



Source: SingStat.

Similarly, looking at the trend of value added[2], including both pharmaceuticals and medical devices (Figure 9), it is apparent that the value added has been rising mainly in pharmaceuticals due to the COVID-19 pandemic, although the peak was around 2006.

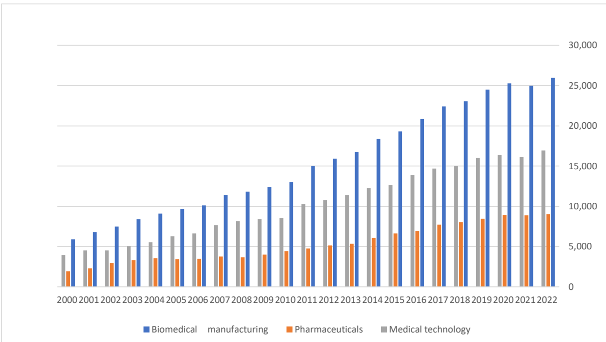
Figure 9　Trend of value added



Source: SingStat.

Importantly, there has been a cumulative increase in employment in this industry. Whereas researchers have come and gone, globally as well as locally, the number of employees in the industry as a whole inevitably shows more local talent, and their careers will add up. The ability to create growth in the industry to match this accumulation will be a major key, but the depth of the talent pool will be an important factor when new companies enter the industry in the future.

Figure 10　Changes in the number of employees



Source: SingStat.

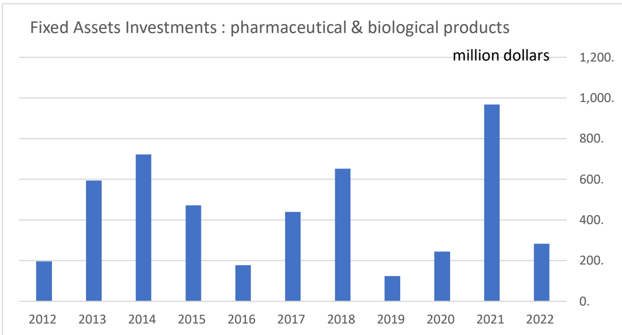
3.2　Capital investment

Compared with the increase in the number of employees, the growth in fixed asset investment itself has been limited in recent years. Figure 11 shows the figures since the 2010s, and although

[2] Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources.

large investments probably occurred due to the COVID-19 pandemic, such as the expansion of vaccine facilities, the trend is basically cyclical, and it is assumed that the fluctuations are large due to large-scale advances and investments.

Figure 11 Trends in capital expenditure



Source: SingStat.

At present, it is unclear whether the investment recovered in Singapore by Western countries expanding into Singapore is being used to form local capital. However, it is natural to assume that the recovered investment is being used mainly in the formation of human capital. In the future, how to utilise the human capital formed here is an important aspect, and the approach will be described in Chapter 6 and later.

3.3 Chugai Pharmaceutical's initiatives in Singapore

In this section, I would like to look at the development of this Singaporean environment in which many global companies are operating. Chugai Pharmaceutical, one of the leading companies, established Chugai Pharmabody Research Pte. Ltd. (hereinafter referred to as our company) in Biopolis in 2012, and has since played a role in potential antibody drug projects. I conducted on-site interviews and heard the following stories.

Our company started with fewer than 50 people in 2012, but now (2023) it has 148 people, and the general ratio of Japanese to local talent has been approximately less than 20%. In recent years, we have been searching for clinical candidates for not only antibody drugs but also medium molecules (cyclic peptides).

In terms of the flow of technology transfer, this was carried out in the beginning with people seconded from Chugai Pharmaceutical, and since then, the seconded people have been rotated in for several-year stints to carry out technology transfer locally. There are some managers under the CEO/research head, but now some of them have been filled by local-hire promotions, including people who have been with our company for eight to nine years.

To date, we have already contributed nine projects to the drug development portfolio of Chugai Pharmaceutical. For these projects, the technology platform transferred from Japan is used, and seconded employees and local personnel work together to lead the projects.

The fact that we have returned nine projects in 11 years means that we have turned it around quite quickly, and this productivity is high. The most advanced is SKY59/Crovalimab for the treatment of PNH (paroxysmal nocturnal hemoglobinuria), a rare disease. Up for approval in China next year, it would be a globally approved drug created by a target originated in Singapore.

One of the reasons for its high efficiency is its scale as a one-floor operation in which managers and researchers are physically close. In the future, it is highly likely that local talent in Singapore will take the lead and develop platform technologies from a perspective that Japan does not have.

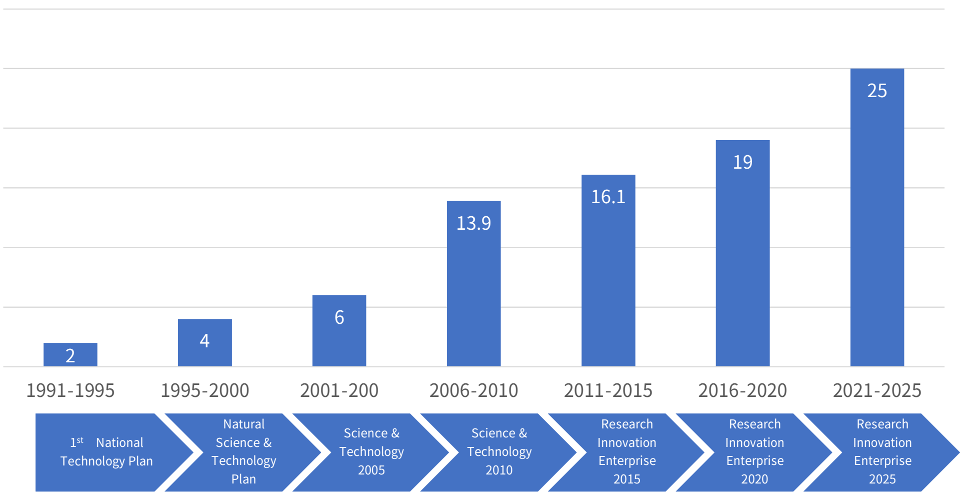
In this process, our company has received support from Singapore's Economic Development Board (EDB) for hiring local human resources and purchasing laboratory equipment. This kind of support from the government is a great asset to our company, and it is important that it continues.

In addition to the government's R&D expenditures, Singapore also offers easy access to networking in environments such as Biopolis. This case clearly shows that Singapore provides a desirable environment for R&D of companies entering the market.

Chapter 4　A* STAR's New Initiatives

As the ecosystem formation matures to a certain extent, I will examine the changes and responses to issues along the dimensions of science, finance, and human resources. First, let us look at the progress of A*STAR from a science perspective.

Figure 12　Trends in science and technology promotion policies (unit: billion S$)



Source: A*STAR Material and National Research Foundation RIE2025 Materials.

Figure 12 shows the transition of the budget for the promotion of science and technology in the national budget and shows very large growth. However, there has also been a change in the direction since the mid-2010s, and I would like to summarise the efforts, based on an interview with Professor Tan Sze Wee, assistant chief executive of The Biomedical Research Council.

4.1 Responses to issues

At first, A*STAR focused on the recruitment of researchers, including those from overseas, but it moved to the next stage amid the results in terms of published papers. In fact, since A*STAR originally pursued academic excellence, the publication of the papers was the main KPI, but in terms of social implementation, for example, the spin-off itself was low in the period from 2000 to 2010.

Specific issues included (1) the intention of the principal investigator (PI) for translation itself, (2) issues in terms of funding for commercialisation/translation, and (3) whether there was any interest after publication.

In light of these circumstances, there was a sense that it would be better to leave the development of commercialisation to those who know how to do it rather than leaving it to researchers. Also, in terms of spin-out, it was decided to create an incubation hub and drive it through that platform. All the leading public sector hospitals are also involved here.

In the past, researchers discussed the subject of the grant from the bottom up, but now it is decided from the top down based on strategic direction, scientific focus and international competitive market conditions. Topics to be researched are discussed by the government and related organisations (A*STAR, EDB, Enterprise Singapore (ESG)[3], etc.) and decided by the government as a whole. These are all for the purpose of 'how to bring it into a translational form'.

As a result of these developments, many of the leading spin-outs in the biotech area are coming from A*STAR (see Table 4). There have been 200 spin-outs, recently at a rate of 15 per year, and given that there were initially fewer than 10 in the first 10 years, the results have been steadily growing.

In addition, a number of public structures such as SEEDS Capital have been put in place to support these developments, and there are several domestic VCs and overseas funds on a private basis; so, the environment is fairly well set.

[Intentionally Blank]

[3] Enterprise Singapore was formed by the merger of International Enterprise Singapore and SPRING Singapore.

Table 4 A*STAR spin-out startups

Company name	Founding year	Major disease areas/modalities
MiRXES Pte. Ltd.	2014	miRNA diagnostic kit
ImmunoScape PTE. Ltd.	2016	TCR (tumor-specific T cell receptor) identification technology/Deep Immunomics platform
CytoMed Therapeutics Limited	2018	Hematological malignancies, etc./CAR-T cell therapy
Lucence Life Sciences Pte. Ltd.	2018	Blood-based tests for cancer screening and treatment selection
Nuevocor Ptd. Ltd	2020	Developing new treatments that target genetic causes of heart disease

Compiled by the author from various sources.

4.2 Focus on human resources

Even in Singapore, however, there is a shortage of people with venture experience. To address this, many entrepreneurship programmes have been created, including A*STAR's Technology for Enterprise Capability Upgrading (T-Up) programme. However, entrepreneurs also have a high probability of failure. That is why A*STAR allows researchers to return after being seconded to a venture.

There are many biotech and medtech companies in Biopolis right now, and they need much talent. Additionally, the startups that came out of this are starting to create local talent circulation, and that is creating sustainable surroundings in which the talent is secured through a talent supply created from startups as well as the government and public sectors.

4.3 Policy directions

RIE2025 is currently running as a science and technology policy, and it has four major pillars: (1) Manufacturing, Trade and Connectivity; (2) Human Health and Potential (including Life Science); (3) Smart Nation and Digital Economy; and (4) Urban Solutions and Sustainability.

As shown in Figure 12, the overall budget is S$25 billion, and when private funds are counted, 2.5% of Singapore's GDP is allocated to R&D for chemicals. Below are striking comments from Professor Tan Sze Wee.

'These developments since 2000 have been largely helped by the prime minister and the biomedical industry. It can be clearly said that it was necessary for the country to improve its momentum by pointing a cross line between ministries and agencies on the axes of academic research, manpower, innovation and enterprise'.

The fact that they were able to make a kind of change in direction across ministries and agencies is very significant.

Chapter 5 Financing Startups

As mentioned in part in the previous chapter, financing startups is still necessary to strengthen science and ensure it flows seamlessly into industry. So how has that investment actually fared?

5.1 Public institutions

First of all, from an institutional perspective, the seed stage is in a very satisfactory situation. Let us list the main programmes. A*STAR grants include the Industry Alignment Fund–Pre-positioning Programme (IAF–PP) and the Singapore Therapeutics Development Review (STDR). Enterprise Singapore (ESG) grants include the Startup SG Tech grant and Enterprise Development Grant (EDG). The National Health Innovation Centre Singapore (NHIC), a nationally appointed programme secretariat for the identification and social implementation of clinical innovations in collaboration with public health agencies across Singapore, also has an Innovation to Develop (I2D) grant for use in medical innovation.

In addition to these grants, ESG offers a programme called SEEDS Capital as a fund manager designated under the Startup SG Equity scheme to co-fund private VC funds.

5.2 The state of startups

In Table 5, I selected several representative startups in this field.

Table 5 Representative startups in this field (one example each)

Company name	Founding year	Major disease areas/modalities	Remarks
TauRx Pharmaceuticals Ltd.	2008	Alzheimer's disease/Tau aggregation inhibitor (TAI)	The main research facility is Aberdeen, Scotland.
Wave Life Sciences Ltd	2012	Genetic diseases/nucleic acid therapy technology	Listed in November 2015 (NASDAQ) /Japanese company SHIN NIPPON BIOMEDICAL LABORATORIES, LTD. was involved in the establishment/ British company GSK introduced the company's products in 2022
MiRXES Pte. Ltd.	2014	miRNA diagnostic kit	Spin-out companies from A*STAR
Lion TCR Pte. Ltd.	2015	Hepatocellular carcinoma/TCR-T cell therapy	Based on A*STAR research/FDA fast track designation
Hummingbrid Bioscience Pte. Ltd.	2015	Multiple Solid Tumors/Rational Antibody Discovery Platform	Signed a partnership with A*Star (EDDC) to jointly develop new antibodies (2021/5)
Biofourmis Holdings Pte. Ltd.	2016	Health condition analysis platform using personalized AI	Headquartered in Boston, USA/Concluded partnership regarding endometriosis-related pain with Chugai Pharmaceutical (2023/3)
MedISix Therapeutics Pte. Ltd.	2016	T cell malignancy/gene editing technology	Founded by Lightstone Ventures Singapore
ImmunoScape Pte. Ltd.	2016	TCR (tumor-specific T cell receptor) identification technology/Deep Immunomics platform	Spin-out companies from A*STAR
Enleofen Bio Pte. Ltd.	2017	Fibrosis including non-alcoholic steatohepatitis (NASH) and interstitial lung disease (ILD)/antibody therapeutics	Established based on research from National Heart Center of Singapore, SingHealth and Duke-NUS Medical School
SCG Cell Therapy Ptd. Ltd.	2017	Helicobacter pylori, HPV, HBV, EBV, etc./T cell therapy, antibodies, therapeutic vaccines, etc.	Signed a cooperation agreement with A*STAR
CytoMed Therapeutics Ltd	2018	Hematological malignancies, etc./CAR-T cell therapy	Listed 2023/04 (NASDAQ) / Spin-out company from A*STAR
Lucence Life Sciences Pte. Ltd.	2018	Blood-based tests for cancer screening and treatment selection	Spin-out companies from A*STAR
Nuevocor Ptd. Ltd	2020	Developing new treatments that target genetic causes of heart disease	Spin-out companies from A*STAR
Paratus Sciences Singapore Pte.Ltd.	2021	Research based on bat immunology/anti-inflammatory drugs	Duke-NUS and the company jointly develop anti-inflammatory drug for humans

Compiled by the author from various sources.

Although the amount of venture investment is a little stagnant on the basis of the number of cases, it is still industry-specific. In the RIE2025 category, it is in the second position after the Smart Nation and Digital Economy category, and it can be said that the fund is coming in sufficiently.

LION TCR, Miraxes, ImmunoScape and others have recently achieved a large Series A round, and the fund's funding performance since the latter half of the 2010s has been accumulating despite ups and downs. However, when going to Series B, it seems that more international funding will be preferred.

On the other hand, the accumulation of exit cases is still to come and there is little precedent for IPOs. Also, since the Singapore Stock Exchange is small, the companies tend to choose NASDAQ or Hong Kong. At the same time, IPO and licensing activity is vigorous, but exit as M&A is still not widely expected.

5.3 VC trends

Not only public grants but also local and US venture capital support the market in Singapore, with the invitation of overseas VCs being a unique feature in the creation of this market. This development was not seen in Japan.

In 2016, Lightstone Ventures established Lightstone Singapore with Temasek to start working together, saying that the early stage could be completed only in Singapore, but after entering the Clinical Stage, the company had to have an overseas orientation. Several projects have emerged from these efforts, and ClavystBio has been established under Temasek as a life science fund contributing to a trend toward localisation.

Additionally, Lightstone Ventures, Evotec SE, Leaps by Bayer, Polaris Partners, and the Polaris Innovation Fund launched a new collaborative initiative, the 65Lab[4], in October 2023.

Singapore is also an Asian hub for VCs. But even if life science funds establish Singapore as their base in Asia, whether or not they will invest in Singapore will depend on how many attractive startups there are.

Conversely, there are cases in which even if the technology originated in Singapore, the company chooses to deploy it more globally in places such as the United States. Connecting to the global ecosystem is a big theme for both startups and VCs, but the foundation for going from local to global is gradually being laid.

Chapter 6 Human Resource Development

As I mentioned in Chapters 4 and 5, human resource development is big in Singapore. Of course, programmes related to human resource development and recruitment are not necessarily

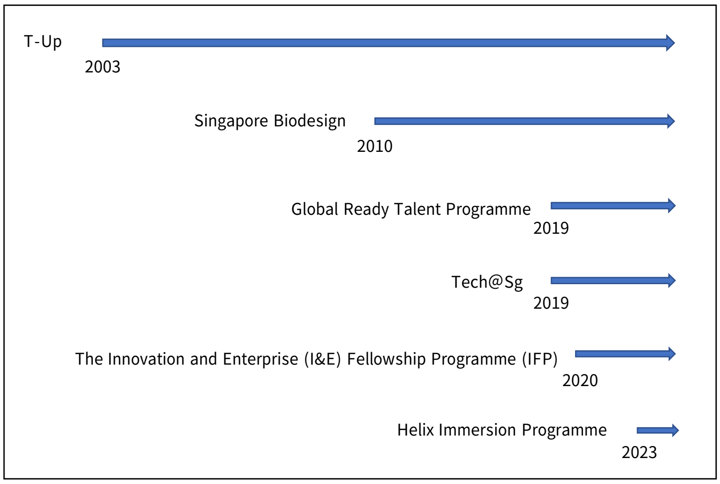
[4] It is a kind of consortium that aims to connect ideas from academia (A*STAR, NUS, DukeNUS) to global syndicates by providing capital and networks to local and international VCs, and enlists the help of German company Evotec for actual drug discovery.

specific to the life sciences, and each industry has its own area of coverage, but I want to see how these programmes have been launched with some concentration.

6.1 Development of programmes related to human resource development and recruitment

First, regardless of industry to some extent, Figure 13 shows the start of various human resource recruitment and development programmes related to entrepreneurial development support.

Figure 13 Start of programmes



Created by the author.

Technology for Enterprise Capability Upgrading (T-Up), operated by A*STAR, sends researchers to member companies for up to two years to serve as technical advisors. The technical advisors will advise on technology upgrade strategies and implement the transfer of technical know-how and skills, which will also provide valuable field experience for the seconded researchers.

The Singapore Biodesign programme from Stanford is representative in terms of more direct training of entrepreneurs for the life sciences. A joint partnership between Stanford University, A*STAR and EDB Singapore was formed in 2010, followed by a fellowship in 2011 and a shift to Singapore Biodesign in 2018. Gradually, companies are born from this programme, and 5–10 fellows are produced every year, and this talent is said to be the result of the programme.

Enterprise Singapore, too, has various programmes. The Global Ready Talent Programme, launched in 2019, offers interns and jobs abroad, while the Tech@Sg programme, run in collaboration with EDB, offers up to 10 new employment passes over two years to foreign employees who are hired as part of the core team of a Singapore company. As for direct talent development, they launched the Innovation and Enterprise (I&E) Fellowship Programme (IFP) in 2020 with the intention of expanding its deep technology talent pool. Over a 12–18 month period, professionals are trained to develop technology commercialisation skills through on-the-job training at designated IFP partners.

6.2 Helix Immersion Programme

With the exception of T-Up and Singapore Biodesign, these human resource development programs cover a wide range of industries, but I would like to focus on SGInnovate's life sciences program.

Established in 2016, SGInnovate is a Singapore government–owned investor and ecosystem builder that supports *deep tech* entrepreneurs. To drive talent development in the various deep tech sectors, SGInnovate runs programmes in collaboration with different partner companies, including programmes for students and graduates (Summation Programme) and working professionals (PowerX).

One of its latest initiatives—the Helix Immersion Programme—aims to build Singapore's talent pipeline for the biomedical sector. Dr Vanessa Ding, Deputy Director (Human Health & Potential), Talent, SGInnovate, shares her comments below.

The Helix Immersion Programme is designed to bridge talent gaps in Singapore's biomedical sector. The immersive learning opportunity provides a platform for talent to gain relevant industry experience, while also creating an avenue for companies to develop their talent pipeline.

*This programme offers individuals a valuable platform to experience the progression of technology across various stages of commercialisation, including fundraising, clinical development, etc. We find that it is crucial to provide education about the intricacies of these processes at the early-career stage for talent, and this sentiment is growing in recognition within the broader ecosystem. Various community stakeholders such as A*STAR, our universities, and other government agencies are working together to create suitable programmes to plug these gaps, and the Helix Immersion Programme is the latest addition to the landscape.*

The outcomes of these ecosystem efforts may take time to materialise, but their potential impact will strengthen our ecosystem for the long run.

In listening to Dr. Ding, it is clear that the focus is on the development of human resources for the unique research environment of the life sciences and that the development of such human resources is a pressing issue in the formation of the ecosystem. Japan faces a very similar issue.

Chapter 7 The Meaning of Concentrating on Translation

To some extent, there is a common need for ecosystem formation in the life sciences: 'strengthen science', 'introduce translational processes' and 'develop and circulate human resources to support this'. Moreover, not all of these factors are 'aligned' at the same time, except in the United States; so, the timing and focus of efforts varies from country to country. In this chapter, I examine the process and how to respond as translation becomes the main theme, focusing on Singapore, Belgium (using examples from the previous report) and Japan.

7.1 Comparison of Singapore, Belgium, and Japan

Figure 14 juxtaposes changes in Singapore's research investment, VC funding, and industry size with those of Belgium and Japan, and illustrates how each has risen[5]. The reader's tolerance is requested regarding various limitations, such as the fact that the absolute value of each data point is different—in particular, it is difficult to trace the exact amount of VC investment from the past in some countries.

Dimensions in Figure 14

[R&D expenditure per capita]

OECD Data 'Gross domestic expenditure on R&D by sector of performance and field of R&D'

Compiled by the author based on country population

[VC investment]

For Japan and Belgium, see the previous report (Belgium is described as a comparison of the EU as a whole).

For Singapore, based on *Singapore Venture Funding Landscape* and various articles

[Production per capita]

Singapore: Manufacturing output for pharmaceutical and biological products was adopted from SingStat.

Belgium: Output (at basic prices) for basic pharmaceutical products and pharmaceutical preparations was adopted from NBB.Stat (National Bank of Belgium).

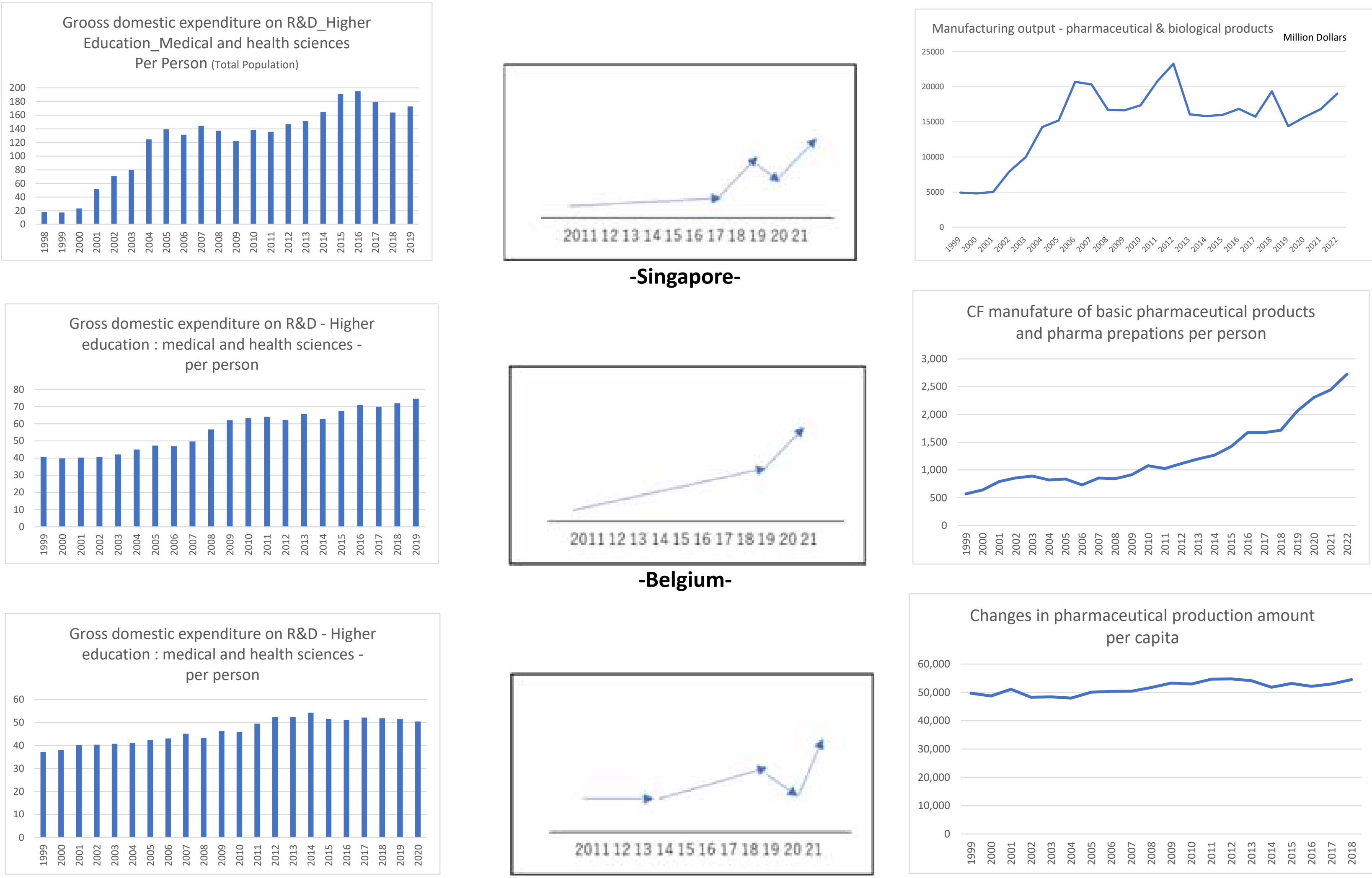
Japan: The amount of drug production was adopted from the annual report of Pharmaceutical Industry Production Dynamics Statistics (however, since the statistical method has changed since 2020, the information is limited to that up to the previous year).

Figure 14 shows that Singapore and Belgium place importance on investing capital in research capabilities. Singapore has done this all at once, and Belgium has done it continuously. Both have achieved some results, as can be seen by looking at the number of articles per population in Table 2, 'Comparison of the number of papers in clinical medicine'.

In addition, the rise of industry in Singapore was intensively conducted at one time because of the strong aspect of attracting foreign capital. It can be seen that Belgium gradually strengthened its position as a hub in the EU because a certain number of companies already existed.

[5] Normally, considering the circulation domestically, it would be desirable to integrate the sales or investment performance of domestic companies as an exit of the ecosystem, or to compare the integration of the value of IPOs and M&As when they are realised, if they are positioned as a part of the global ecosystem. However, due to the limited data available, the output of each country is substituted in its stead.

Figure 14 R&D expenditure (left), VC investment (centre), and production (right), by country



-Singapore-

-Belgium-

-Japan-

Source: Described in the main text.

On the other hand, the population of Japan is about 30 times larger than that of Singapore and about 10 times larger than that of Belgium, and the domestic market is maturing, making it difficult to make a simple comparison. However, the industry itself has been on a fairly long and steady trend (however, sales overseas have increased significantly), and the amount of capital invested in science has increased only moderately.

In this sense, the three countries have been developing in three distinct ways. But in the sense of translation, in all three countries it has been delayed until recently, with the amount of investment starting to rise significantly since the mid-2010s.

Figure 15 briefly summarises this comparison, but it is clear that in each channel, smooth establishment of a system for 'translation', whether through strengthening research capabilities or through strengthening industrial scale, has taken time and not occurred spontaneously, as highlighted in the area surrounded by the blue line in Figure 15. Paradoxically, however, it is necessary for each country to establish a foundation that both enables science to occupy a certain position on the global stage and, at the same time, provides human resources from industry.

Figure 15 Rise in each country, by phase

	Research (R&D expenditure)	Translation (VC investment)	Production scale
Singapore	Rapid implementation	Increased since around 2017	Intensive reinforcement for a period of time
Belgium	Gradually increasing	Increased trend through the 2010s, especially increasing in the second half	Expansion continues over the long term
Japan	Flat over the long term (slight increase between 2000 and 2005)	Increased since around 2014	Remains flat in the long term (but companies are moving forward with overseas production)

Source: Author.

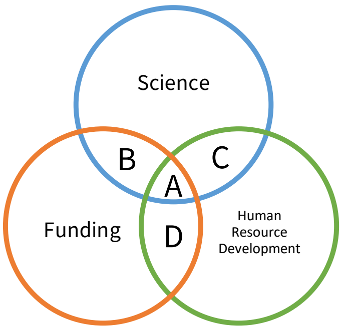
In the previous report, I tried to make a broad comparison among the growth pace of global companies, the rise of the VC market and the degree of strengthening of science. Even in the US, the expansion of the VC market followed the expansion of global companies, and it is considered that the market was improved as the exit points were clarified and the division of roles progressed. To some extent, it is inevitable that there will be a delay in translation in countries where such approaches to global companies tend to lag behind those in the US.

7.2 Characteristics of Singapore's initiatives

On the other hand, if a country tries to build a focused translational process, I feel that what is happening in Singapore is very reasonable. This is probably because in Singapore's case the aims of policy, funding, and human resource development are all heading in the same direction, and there are many areas where they overlap with each other, and localisation is progressing in each field.

Figure 16 illustrates the overlaps, and at the centre of the illustration is the phrase 'The mid-2010s transformation as a symbol = Focus on translation'.

Figure 16 Characteristics of the Singapore ecosystem



A：The mid-2010s transformation as a symbol
= Focus on translation

B：Science /Funding
= Seed money development and connection to global networks

C：Science/Human Resource
= T-up program and other human resources circulation

D：Human Resource/Funding
= Supply of human resources who understand translation process

Source: Author.

At the same time, some of the events that are happening in Singapore have elements in common with Belgium, although they have different time horizons.

Listed below are the elements in common.

1) The clarity of the message: 'Strengthen science and subsequent translation'
2) The point of trying to form an ecosystem by skewing it among universities and ministries
3) The effective use of human resources arising from the strengthening of industry
4) The goal of connecting to the global ecosystem while assessing the scope of what they can do

I can easily see how these elements are being incorporated into practical programmes in both countries. In Japan, on the other hand, although these points are focused on as well, a certain environment had been established before the current events of division of roles and formation of the global ecosystem occurred; so, transitioning to the current trend is more difficult.

7.3 Process of realising translation

In the life sciences, the goal should be to improve medicines, medical devices, and the provision of medical services appropriately to patients or prospective patients. It is my understanding that the division of roles in the name of ecosystem has been developed to more efficiently deliver discoveries at the science level. Needless to say, this includes economic needs.

It can be said that the ecosystem formed in the US, especially in Boston and on the West Coast, quickly took shape, with the inclusion of some kind of implicit rule-making, but it is not easy to find out the factors of success empirically because the methods of division of roles are various and change over the years. Of course, individual parts of this process have also been tested empirically—for example, in industry–academia collaborations[6].

This discussion paper relies on the case studies following the previous report, but what emerges in each interview are some successful examples and 'future issues' ahead. This paper is a continuation of efforts to find practical ideas while examining these issues.

As for Belgium, in the previous report I focused on a case in which the development of science represented by Vlaams Instituut voor Biotechnologie (VIB) and other organisations and the expansion of industry over the medium term have been balanced, and human resource development is flourishing to make this more effective. In addition, the circulation of human resources within the industry has been directed to function complementarily.

In Singapore today, recognition of the need for translation has been reached in a cross-ministerial manner, and while venture funding is utilising connections with global networks, it is also strengthening human resource development locally. Again, increased employment in industry appears to support the development of this initiative in a complementary manner.

Although Singapore differs from Belgium in terms of time horizons, they seem to have taken essential steps in ecosystem formation.

However, even at this point, it is still uncertain what form human resource development can take and how it will contribute to translation. Specifically, in translation it is necessary for each stakeholder to share a certain level of awareness and practice: (1) determining the timing of switching from research to development, (2) setting the appropriate exit at that time, and (3) designing patent strategies and grants accordingly. At present, however, there does not seem to be a clear answer as to whether such matters are truly educable, whether they are more OJT-related, whether the intelligence is broadly held by the various parties, including advisors, and whether there is a need for IT to be used more effectively. Part of the overall issue is that the correct answer keeps changing as the modality changes.

Programmes such as T-Up, Singapore Biodesign, and the Helix Immersion Programme seem to be trying to address these issues in Singapore, as was the case driving the establishment of Solvay

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[6] Michele O'Dwyer, Raffaele Filieri & Lisa O'Malley, 2022, 'Establishing successful university–industry collaborations: barriers and enablers deconstructed', The Journal of Technology Transfer

Brussels School (SBS) in Belgium. In the future, I would like to create a new research paper and examine Japanese development along these themes, based on the case studies presented here.

Finally, the greatest motivation for finishing this paper is the sense of ‘anticipation for the future’ that I felt at each interview I conducted in Singapore. It is not a sense of lofty expectations subject to gradual dissipation, but rather a sense that ‘there are problems, but a positive future can be anticipated’, which seems to overlap with the ‘shared sense of a certain direction’ mentioned in this paper.

I would like to thank the many people I spoke with during my research, including those not mentioned directly in this paper. I sincerely appreciate the experience.

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