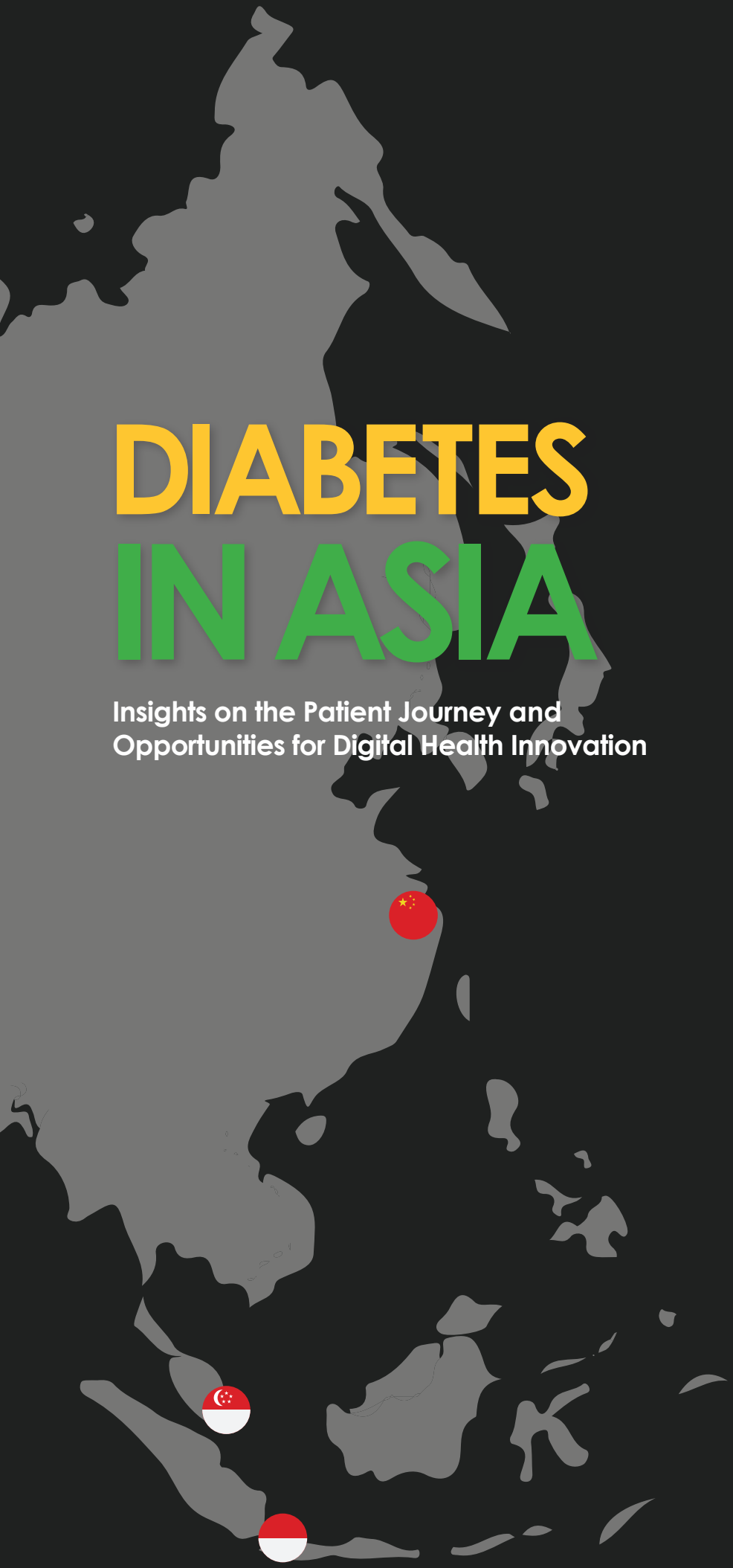
SINGAPORE BIODESIGN

DIABETES IN ASIA

Insights on the Patient Journey and Opportunities for Digital Health Innovation



Andrew Chou
Shanaz Rauff
Scott Wong
Hanzhong Zhang
Will Greene

DIABETES IN ASIA

Insights on the Patient Journey and Opportunities for Digital Health Innovation

SINGAPORE BIODESIGN

Foreword from the Programme Director

DR DANNY SOON

Programme Director,
Singapore Biodesign, A*STAR
Senior Director,
Health & Biomedical Cluster,
Biomedical Research Council, A*STAR

To address Asia's growing diabetes epidemic, many healthcare stakeholders are exploring novel approaches to care delivery and public health management. Some see particularly exciting potential in digital health technologies that leverage mobile apps, connected devices, and other hardware and software tools to improve health and wellbeing. Yet the ultimate utility and value proposition of these new technologies for diabetes prevention and disease management is often elusive.

Part of the challenge is that diabetes is a complex condition that has an array of causes and arises in a wide variety of social, cultural, and economic contexts. This limits scalability and suggests there is no one-size-fits-all approach to diabetes care. Effective digital health technologies must therefore be tailored to local circumstances and designed for the unique needs of patients in a given country or demographic group.

The Biodesign innovation process developed by the Stanford Byers Center for Biodesign at Stanford University and later adapted by its joint programme partner, Singapore Biodesign, a division of the Agency for Science, Technology and Research (A*STAR) in Singapore, provides a time-tested framework for uncovering those local and regional needs. This process is built on the premise that the best solutions are often the product of observation and research in real-life healthcare settings. This supports the identification of unmet opportunities and the development of novel technologies to address them.

In 2018, Singapore Biodesign made diabetes the central focus in its flagship Biodesign Fellowship Programme, which recruits a multidisciplinary team of Fellows every year to apply the Biodesign innovation process to a specific disease category or therapeutic area in an Asian context. The 2018 Fellows—Andrew Chou, Shanaz Rauff, Scott Wong, and Hanzhong Zhang—conducted observations, research, and clinical immersion in Shanghai, Jakarta, Singapore, and Stanford to understand and prototype how healthcare and technology innovation can improve diabetes care in Asia.

Their work yielded detailed insights into the complex dimensions of diabetes in the region, and specific areas of opportunity where digital health solutions can make a difference. Some of these insights were presented at Singapore Biodesign's annual Thought Leaders Series event in December 2018, which brought together local and international experts from across the healthcare ecosystem for productive discussions on the role of technology in addressing Asia's growing diabetes epidemic.

With this white paper, we also aim to share these insights in greater detail with the broader Asian healthcare community. This includes our colleagues at the Diabetes Clinic of the Future (DCOF), a new initiative between A*STAR and SingHealth, Singapore's largest healthcare system, to develop a sandbox for tech developers and industry partners to build solutions in a regulated, real-world clinical setting. The main findings of this study can assist in the selection and integration of technologies into a healthcare setting.

We hope this white paper provides useful insights for those working to forge solutions for diabetes care in the region and look forward to deepening our impact in other therapeutic areas as well in the coming years.

About the Authors

SINGAPORE–STANFORD BIODESIGN 2018 FELLOWS

DR CHOU CHIA CHEN ANDREW

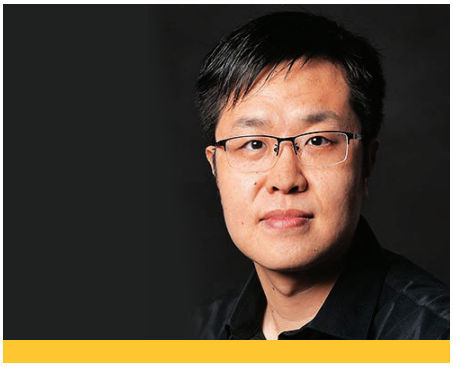
ANDREW is a surgeon-engineer with broad experience in medicine, biodesign, and research. He is currently an orthopaedic surgery resident at SingHealth with a special interest in sports medicine and children's orthopaedics and the course director for Innovation & Design Thinking at the Duke-National University of Singapore Medical School. He earned his B.S. in Biochemical Engineering from Stanford University, where he was awarded the Dean of Students Outstanding Achievement Award and the Pitch Johnson Bio-X Fellowship to pursue his research in protein engineering. He later moved to Singapore to earn his M.D. from the Duke-National University of Singapore Medical School and his membership with the Royal College of Surgeons of Edinburgh, where he was awarded the Seah Cheng Siang Gold Medal in Medicine and the ESCEO-Eli Lilly Healthcare Provider Scholarship. He has published extensively in clinical orthopaedic research journals and has presented his research at meetings for the American Association of Orthopaedic Surgery, Paediatric Orthopaedic Society of North America, and the World Congress of Osteoporosis.

MS SHANAZ RAUFF

SHANAZ is an investment professional with a global background in healthcare, strategy, and private equity. Prior to the SSB Fellowship, she was a principal at LCP Partners, where she focused on venture and growth-stage healthcare direct investments in Asia. She has been in private equity for over a decade, previously in London with RHJ International and in New York with Ripplewood Holdings. She began her career in the Corporate Finance and Strategy practice with McKinsey & Company's pharmaceutical and medical products sector team in New York. She graduated from the Jerome Fisher Program at the University of Pennsylvania, with dual degrees in Finance and Biomedical Science.

DR WONG WEI GEN SCOTT

SCOTT is a medical doctor with experience in entrepreneurship, clinical practice, and regulatory affairs. He graduated from the University of Manchester with an MBChB. He previously worked as a regulator at the Singapore Ministry of Health, focusing on digital health and telemedicine regulations, and has experience creating health IT software and apps with a special interest in diagnosis/predictions using machine learning. His previous projects include an eye screening platform for babies (retinopathy of prematurity) and a cloud-based electronic medical records system that predicts injuries in athletes. He is currently working in the diabetic foot and digital telepathology space. He has also won 2nd place at the Blueprint Datathon, and was a finalist in the Business Association of Stanford Entrepreneurial Students Challenge at Stanford University.



MR HANZHONG ZHANG

HANZHONG is a clinical and biomedical engineer. After receiving a B.Eng degree in Electrical Engineering and an M.S. degree in Biomedical Engineering, he started his career as a biomedical engineer in the medtech industry. After 3 years of service, Hanzhong joined Singapore's healthcare industry, taking charge to evaluate and apply novel technologies in clinical settings, develop technical solutions, and lead R&D projects for medical device and healthcare robotics initiatives. Hanzhong also serves as an advisor and vice chair in Biomedical Engineering Society (BES) Singapore Industry Chapter, and a collaborator of the International Federation of Medical and Biological Engineering (IFMBE) Clinical Engineering Division, supporting the BME community as well as promoting the clinical engineering profession.

SINGAPORE BIODESIGN – WRITER IN RESIDENCE

MR WILL GREENE

WILL is a writer and marketing consultant with ten years of experience in Asia, where he has worked with many of the region's top medtech, pharma, and biotech firms, as well as innovative startups, trade associations, NGOs, universities, and research institutes. He currently serves as Writer in Residence at Singapore Biodesign, where he supports research and writing projects related to biomedical innovation. He also writes and speaks regularly on healthcare innovation, with bylines in Forbes, TechCrunch, Techonomy, The Diplomat, and other leading media outlets. Based in Singapore, he has on-the-ground project experience across the region. He earned a B.A. in Political Science from Amherst College.

DIABETES IN ASIA:

A Regional Overview

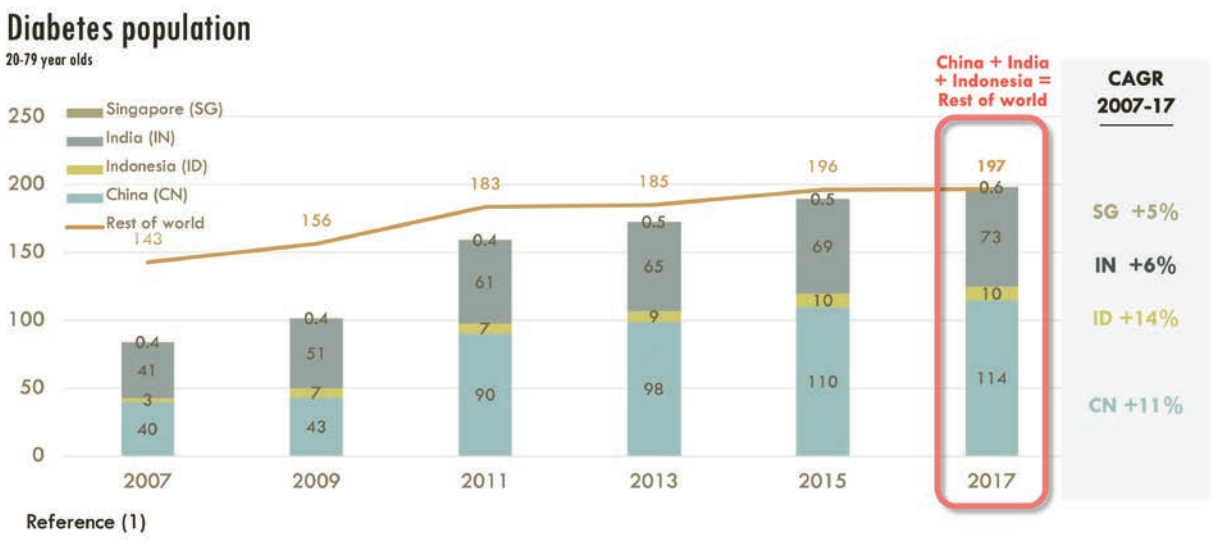
Diabetes is a metabolic disease affecting over 450 million people globally. A chronic disorder that interferes with the body's ability to manage blood glucose, it can lead to a number of serious or even life-threatening health problems, such as depression, neuropathy, or heart and kidney failure. Treatment may involve lifestyle adjustments, medications, regular blood glucose monitoring, daily insulin injections, and other procedures that can be burdensome for patients and their caregivers. Many patients have difficulty with management and adherence to such protocols in their daily lives, experiencing lapses in self-management that often result in treatment failure.

Diabetes is a particularly serious problem in the Asia Pacific region. Over 240 million diabetes patients live in the region—almost 1 in 10 of the population, one of the highest rates of prevalence worldwide.[1] Incidence of the disease has grown rapidly in the past decade (FIGURE 1), and more than half of diabetes patients in the region today are undiagnosed. Without further intervention, many will seek treatment when the disease is at a relatively advanced stage, with higher risk of complications and higher expected costs of treatment.

Many factors contribute to the rapid growth in diabetes incidence and high prevalence in Asia. One major cause is urbanisation. As millions of people across the region move to congested megacities in the region, they are eating more processed, energy-dense foods and adopting sedentary lifestyles. Health education has failed to keep pace, and

FIGURE 1

10-Year Population Growth of Diabetes Patients in Four Asian Countries



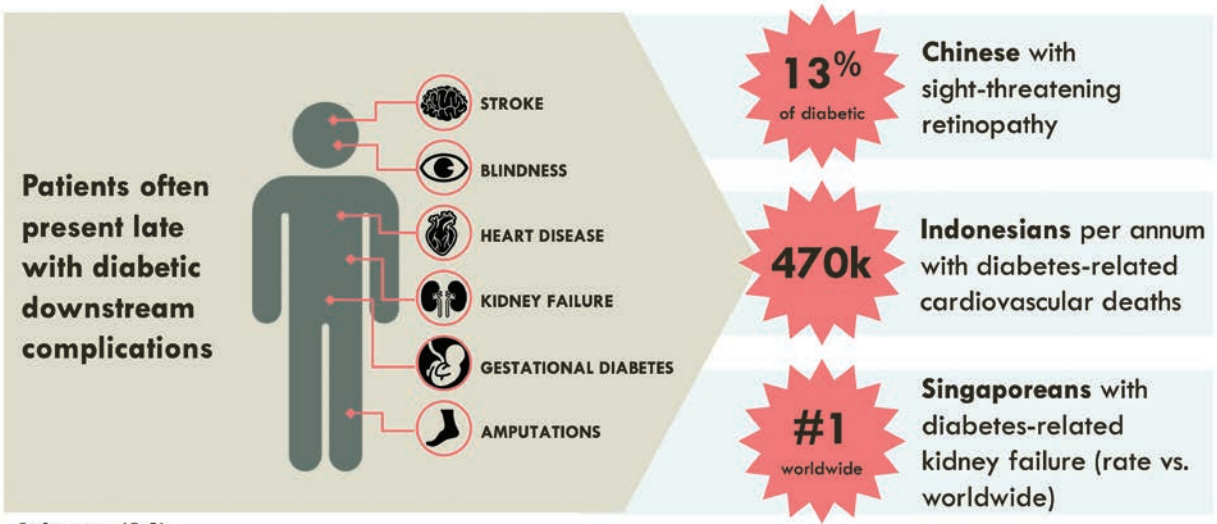
populations across Asia are experiencing a rise in average body mass index (BMI) and obesity.

Asians also tend to be more predisposed to diabetes, showing an increased incidence at a younger age and a lower average BMI than peers in the US and Europe.[2] At the same BMI, Asians tend to have 3-5% more body fat than Caucasians, and accumulate this fat around and inside the abdomen, resulting in a different metabolic profile that increases the risk of developing diabetes. Furthermore, diabetes in Asia often occurs due to impaired insulin secretion and glucose tolerance as opposed to the insulin resistance typical of European and North American populations.[3] This has significant implications for diabetes management—screening may occur at lower or ethnicity-specific BMI thresholds;[4] diagnosis may be more accurately performed through the more time-consuming oral glucose tolerance test; and treatment of diabetes may require different medications and protocols.

These factors help explain why Asians experience particularly high rates of complications from the disease, and inadequate public health infrastructure, health literacy, and access to care often compound the issue. For example, an estimated 470,000 Indonesians die of diabetes-related cardiovascular deaths each year.[5] 13% of diabetics in China have sight-threatening retinopathy,[6] compared to 4.4% in the United States.[7] Singapore has the world's highest rate of kidney failure secondary to diabetes, despite also having one of the world's most developed and efficient healthcare systems (FIGURE 2).[8]

FIGURE 2

Asians Face High Rates of Diabetes-Related Complications



References (5-8)

The result of these trends is a significant strain on healthcare systems across Asia. Since 2007, total diabetes expenditure per capita increased by double-digit rates across much of the region (FIGURE 3). In addition to direct costs, the disease also imposes significant indirect costs in terms of the patient quality of life and lost productivity for the broader economy.

Many Asian countries lack sufficient resources to address this issue effectively. While well-resourced countries like Singapore have comparable ratios of physicians per capita to the United States, systemic strain on poorly-resourced countries means the average consultation duration with a diabetes patient is relatively brief and may not provide sufficient care (FIGURE 4).

It is clear that solutions deployed effectively in more developed healthcare settings will face significant challenges to adoption in the Asian context. Furthermore, patient care norms in Asia differ as well. In Asia, specialist care has been highly overburdened, leading to slower adoption of gold-standard integrated and multidisciplinary care protocols. Trust and uptake of allied and primary health tend to be poorer in Asia, where patients may be less willing to involve primary care physicians, nurses, dietitians and other key providers needed to provide appropriate care. At the same time, in-home caregivers, such as family members, domestic helpers, and home nurses tend to be far more prevalent and critical in managing chronic disease in Asia (FIGURE 5). Lastly, outside the healthcare system, technology use is also currently limited due to cost: most patients in Asia cannot afford a simple blood glucometer or test strips and may only check random blood glucose monthly in primary care settings. For solutions to be effective in Asia, they would need to target such norms.

So, while many innovative diabetes solutions are already being developed or deployed in the West, some may not be applicable to patients in Asia due to significant differences in epidemiology, biology, healthcare systems design, and culture. The following section explores some of the unique aspects of healthcare systems in three Asian countries.

FIGURE 3

Diabetes Expenditure per Capita in Four Asian Countries (2007-2017)

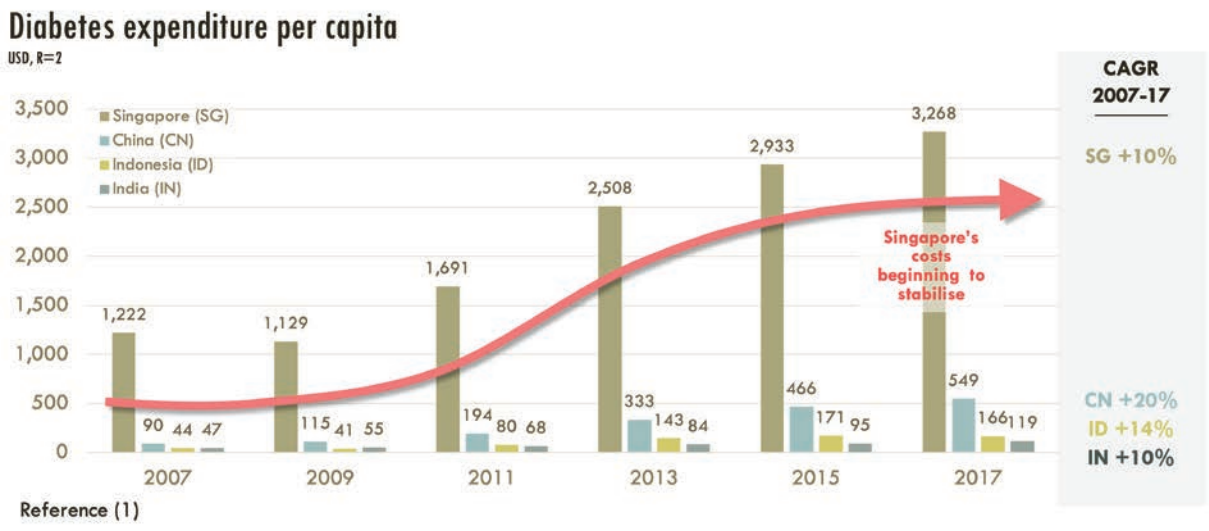


FIGURE 4

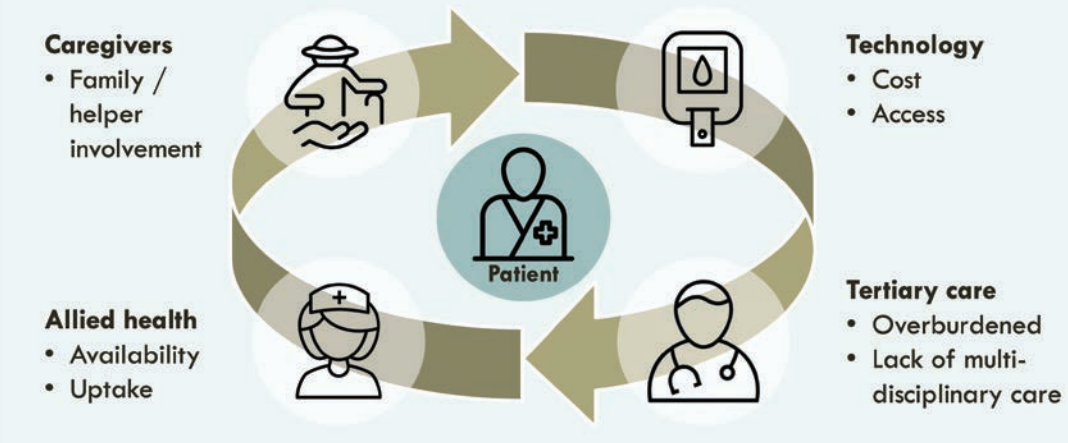
Systemic Strain for Three Urban Asian Hospitals Compared with the United States

	US	SG	CN	ID
Diabetic population	30M (9%)	0.6M (13%)	114M (11%)	10M (4%)
Physicians /1,000	2.6	2.3	1.8	0.2
Minutes /consult	15-45	10-15	1-5	2-10
Public cost /person	$9,500	$2,300	$425	$111

Reference (1). Minutes/consult figure based on observations by Singapore-Stanford Biodesign Fellows.

FIGURE 5

Key Factors Influencing Care Delivery in Asia



Insights into the Diabetes Patient Journey in Asia

To better understand the nuances of diabetes management in Asia, the Singapore-Stanford Biodesign Fellows spent an initial period of research and training in the US healthcare system at Stanford, California, followed by several months conducting clinic-based immersive research in Shanghai, Jakarta, and Singapore. As the goal was to obtain on-the-ground insights to inform solutions for unmet medical needs, this research is based primarily on a limited set of site visits and expert interviews over the course of several months, and is not meant as a systematic overview of diabetes care in each country. We hope instead to provide a snapshot of care processes in each hospital system that can provide local context and a starting point for wider local research efforts.

The following sections explore these insights and their implications for potential areas of opportunity in detail on a city-by-city basis for Shanghai, Jakarta, and Singapore.

SHANGHAI, CHINA:
REDUCING THE URBAN HOSPITAL BURDEN

JAKARTA, INDONESIA:
BOLSTERING ACCESS TO BASIC HEALTHCARE SERVICES AND EDUCATION

SINGAPORE:
IMPROVING INTEGRATED AND COMMUNITY CARE

SHANGHAI, CHINA:
REDUCING THE URBAN HOSPITAL BURDEN

Clinical observation and research were conducted at a large public hospital in Shanghai, China with over four thousand staff and nearly two thousand regular hospital beds. A Class 3A teaching hospital, it attracts a relatively high share of clinician trainees and patients. Observation was conducted in the outpatient clinics, surgical theatres, and inpatient wards of the Endocrinology, Vascular Surgery, and Ophthalmology departments.

As previously noted, China's diabetes patient population nearly tripled between 2007 and 2017 to 140 million (11% prevalence).[9] By some estimates, China's middle class (defined as those with a household income of between USD $16,000-$34,000) will grow from 14% of households in 2012 to 54% in 2022.[10] While the expansion of the middle class corresponds with expectations of greater access to healthcare and health education, it also corresponds with ageing populations, sedentary lifestyles, dietary changes, and behavioural stresses that increase the risk of diabetes. Indeed, the prevalence of diabetes remains highest among Chinese seniors, urban residents, and individuals living in economically-developed areas.[11]

Diabetes patients often travel many hours or upwards of a day from other provinces just to receive care in Class 3A hospitals in Tier 1 cities, rather than visiting local facilities. This is partly due to a shortage of primary care physicians — China is estimated to have less than 1 primary care physician per 10,000 citizens.[12] Other factors also drive this behaviour, including poor health literacy, lack of public health screening competency, minimal confidence in rural or secondary hospitals, and a healthcare infrastructure that fails to discourage patients from seeking unnecessary care. Another major issue is that Chinese patients often self-triage, choosing a specialist doctor depending on their interpretation of their symptoms, which may be incorrect and require a second specialist appointment. This increases the burden on specialists and reduces time for cases truly requiring the care only the specialist can provide.

Like many large urban tertiary hospitals in China, the hospital where the research was conducted faced serious overcrowding issues. This is true across most specialties, including Endocrinology, with busy specialists sometimes having only a few minutes for each consultation. Patients often queued for hours during registration, in the waiting room, and later for payment and discharge.

This hectic backdrop is where diabetic patients are likely to get their first diagnosis of diabetes, with little time for explanation or education. It is little surprise then that achieving diabetes self-management is a major challenge. For example, research shows that up to 81% of diabetic patients do not manage their blood sugar with the recommended frequency, and 35% reported not monitoring their blood sugar at all.[13]

Patients at this particular hospital are sometimes given a choice to come for an inpatient admission for 5-7 days if a bed is available. The admission allows for clinicians to titrate appropriate diabetic medications, arrange for specialist doctors, and provide access to diabetes education. It also allows for patients to form informal support networks. Many clinicians said that inpatient admissions offered the best opportunity for diabetes patients to learn self-management skills. While this approach is more costly and less efficient than providing diabetes education in the outpatient setting, it remains an option for patients who may otherwise lack access to such comprehensive support.

In order to cope with its growing diabetic population, China will need to shift care delivery away from overcrowded urban hospitals and still improve disease awareness, promote adherence to treatment regimes, and avert treatment failure.

JAKARTA, INDONESIA:
BOLSTERING ACCESS TO BASIC HEALTHCARE SERVICES AND EDUCATION

In Indonesia, observation and primary research were conducted at a private tertiary hospital in Jakarta; a private hospital in Karawang (a city outside of Jakarta); and at a Puskesmas, a public community health centre, in the Karawang vicinity.

As in China, urbanisation and socioeconomic changes in Indonesia are leading to more sedentary lifestyles and increasing rates of obesity, with great impact on working-age Indonesians,[14] resulting in 10 million diabetes patients (6% prevalence) in 2017.[15] These trends are exacerbated by the Indonesian diet—roughly 75% of the typical Indonesia meal consists of carbohydrates, with a relatively small share of meat and vegetables.[16] Access to nutrition education is also poor, as material is not widely available and dietitians are scarce, and visits are not reimbursed by Badan Penyelenggara Jaminan Sosial Kesehatan (BPJS Kesehatan), the public insurance system.

Another challenge is the low absolute number of physicians, at 2 physicians per 10,000 population, as well as the concentration of specialists in Jakarta and urban areas. Given the basic rural transport networks, patients outside of cities tend to be managed through the local Puskesmas system. While BPJS covers 80% of Indonesians[17] and reimburses walk-in visits to the Puskesmas to improve patient access to healthcare, the centres themselves vary significantly in staffing, screening, diagnostic services,[18] and patient outreach (Posyandu) and education (Prolanis) programmes.

The Prolanis programme was introduced by the public health system to manage chronic diabetes and consists of regular health consultations, diagnostics, educational events, and home visits for patients and their family members. The programme provides a coordinated effort to improve health knowledge for self-care and to motivate participants to have regular engagement with healthcare personnel. Recent research indicates that it is effective in controlling levels of fasting blood sugar and total cholesterol in type 2 diabetic patients.[19]

Despite these efforts, diabetes self-management remains a challenge in Indonesia. Part of the problem is that many patients have only a high school or primary school education,[20] which limits their ability to understand the nature of the disease and strategies for self-management. This is especially true for the elderly patients that are more likely to suffer from diabetes-related complications. Overall literacy is around 70% for Indonesians over 65 years old, compared to 92% for those aged 15-55.[21]

Religious culture may also impact attitudes and habits of diabetes self-management in Indonesia. For example, 79% of Muslims with Type 2 diabetes fast for the month of Ramadan, abstaining from eating, drinking, and use of oral diabetic medications from predawn to after sunset. While patients are specifically exempt from fasting, during Ramadan there is still a threefold increase in rates of severe hypoglycaemia requiring hospitalisation, and fivefold increase in rates of severe hyperglycaemia.[22] Hence, innovations have to be contextualised to these cultural and religious elements to achieve acceptance.

While the overall incidence of diabetes in Indonesia is still low, improving access to locally-relevant, culturally-specific healthcare and health education will be key to ensuring the growing urban, middle-class Indonesian population avoids the diabetes burden faced by its neighbours.

SINGAPORE:
IMPROVING INTEGRATED AND COMMUNITY CARE

In Singapore, the Fellows conducted their clinical immersion and observations at an integrated care facility in a large public tertiary teaching hospital. The facility offered integrated multi-disciplinary services in general diabetes medicine, endocrinology, renal care, ophthalmology, podiatry, post-operative care, dietetics, and nurse education, in order to improve patient convenience and drive care coordination efforts. Recent research indicates that interdisciplinary team care can improve outcomes for diabetic patients.[23]

Like Indonesia and China, Singapore faces a growing diabetes burden, with 600,000 patients (11% prevalence) in 2017.[24] With diabetes on the rise, the Singapore public health system launched a variety of community-focused programmes to help prevent diabetes, such as encouraging local eateries to make their menus healthier. All patients above the age of 40 are also automatically offered diabetes screening tests in the primary care setting via the Singapore Health Promotion Board's Screen for Life programme, which subsidises a fasting blood glucose test and one subsequent consultation.[25]

After a diagnosis is made, patients are mainly cared for in primary care settings, such as neighbourhood polyclinics, where they are regularly offered screenings for any diabetic complications, such as annual eye and foot checks or blood tests to detect kidney disease. Patients are also given necessary lifestyle advice and access to medical management services. If diabetes control is difficult or if associated complications require specialist input, patients can be referred to specialists or tertiary hospitals. In this regard, Singapore benefits from the use of a regular appointment system and a National Electronic Health Records (NEHR) system that was deployed in 2011. Through NEHR, clinicians are better able to coordinate primary care and specialist care in a public setting. Medication and laboratory testing records are also available for review on the medical system, and patients can schedule their appointments without needing to queue for long hours.

One challenge to diabetes care provision in Singapore is the cultural tendency for patients to defer to physicians for guidance. In one study, 52% of a cohort of chronic disease patients said they did not want to learn more about their condition; among those that did express interest, 42% said they would just want to follow their doctor's advice, as opposed to doing their own research.[26]

Furthermore, diabetes disproportionately impacts older and less-educated Singaporeans. In 2013, a majority of self-reported diabetics were men over the age of 60.[27] Of that group, 81.2% did not have a university education, and many do not speak English, which impacts their ability to seek and receive institutional care. Elderly patients often have other age-related conditions such as dementia and difficulty in ambulation, which makes self-management and lifestyle changes difficult to implement.

To overcome these challenges, physicians need to engage family members and domestic helpers during the consultation, providing information on topics such as keeping a glucose log or administering insulin injections. Dietary advice should also be given to caregivers, who often prepare meals for the whole family or coordinate the purchase of food outside of the home. For the 9% of Singaporean citizens above the age of 65 who live alone,[28] however, this is not always an option. Providing care to the elderly also presents other challenges, such as watching out for symptoms of depression or other incapacities.

For Singapore to effectively manage its older diabetic population, solutions must address or even leverage prevailing patient behaviour and care patterns. Improving streamlined access through integrated care facilities and assisting caregivers in managing the burden may be key drivers of improved outcomes.

Digital Health Innovation for Diabetes Care in Asia

Given the scale and complexity of these challenges, many healthcare stakeholders are looking at novel approaches to care delivery. A growing number are exploring digital health solutions, which leverage connected devices, software applications, and other digital tools to provide scalable healthcare services. Since the clinical and socioeconomic realities related to diabetes care vary considerably between countries in Asia, the areas of opportunity for innovation differ as well.

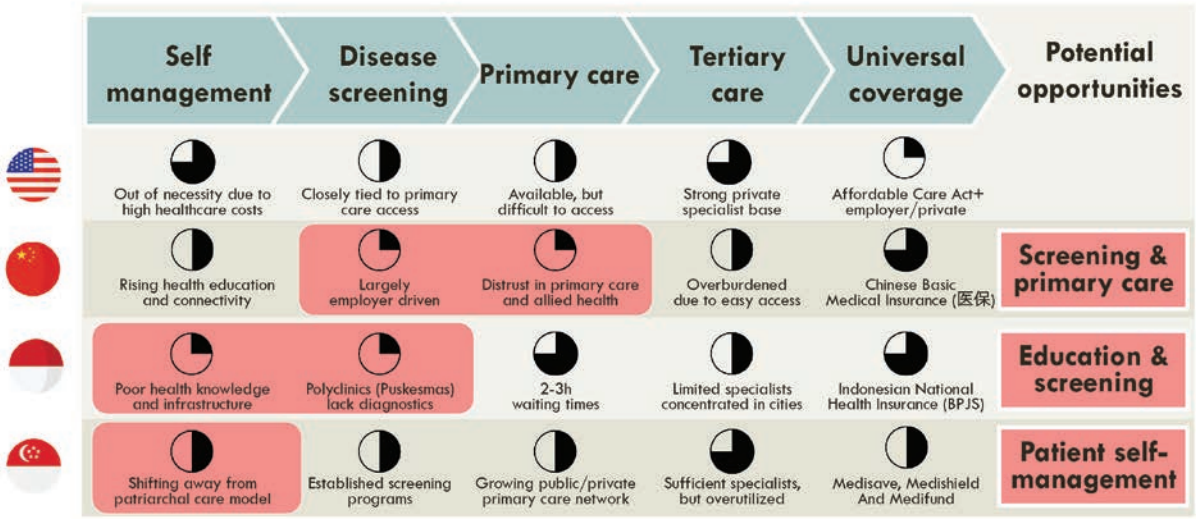
Advanced countries like Singapore tend to have accessible and high-quality screening programmes, primary care facilities, and specialist services. Most patients have the means to afford consultations and treatments. Singapore's major challenge, however, is encouraging diabetics to be more engaged in self-management of their condition. This is particularly difficult among the older and less-educated segments of their population.

In countries like China and Indonesia, workforce and infrastructure gaps pose some of the biggest challenges. Both countries have overburdened tertiary care centres that are concentrated in urban areas. Primary care facilities remain underutilised and underdeveloped, and healthcare facilities of any sort are limited in rural and remote settings. Many patients lack the education and personal resources to effectively treat or sometimes even understand their conditions (FIGURE 6).

In all these countries, digital healthcare entrepreneurs and innovators are working on solutions to local challenges. In China,

FIGURE 6

Areas of Opportunity for Innovation Depend on Location-Specific Gaps in the Diabetes Patient Journey



for example, Ping An Good Doctor and WeDoctor are building large-scale online healthcare platforms that facilitate access to primary care and redirect patients away from the overcrowded tertiary care facilities that remain the biggest bottlenecks to effective treatment. These platforms enable online consultations with primary care physicians, as well as a range of ancillary services such as drug delivery. They both claim millions of monthly active users and are backed by leading Chinese corporations.[29,30]

In Indonesia, where poor transit infrastructure remains a major pain point and barrier to healthcare access in the cities, online healthcare platforms are also garnering interest. One example is Halodoc, an Indonesian firm that facilitates online consultations, medicine delivery, and access to laboratory services. As of March 2019, the company claims that it has over 20,000 registered doctors on its platform and 1,300 pharmacies that provide medicine delivery services through its mobile app.[31]

In Singapore, where rising chronic disease burden is a key driver of increasing healthcare costs, digital health companies are working to address the issues of patient and caregiver-assisted management of chronic health. For example, Holmusk focuses on digital behaviour change programmes and predictive algorithms through a patient self-management tool called Glycoleap; Homage offers a caregiver marketplace; and Doctor Anywhere provides telehealth services.

Conclusion

Across Asia, healthcare systems and professionals are buckling under the cost and labour burdens of the mounting diabetes epidemic. Innovation in these healthcare systems will be critical to addressing the rising costs, and digital health solutions provide a significant new opportunity to provide diabetes care at unprecedented scale and personalisation.

This report provides a glimpse into the local context of hospital systems in three major Asian cities in order to offer insights for innovation and entrepreneurial opportunities in the region. With any entrepreneurial effort, scalability is critical, and wider research will be needed to fully validate the applicability of innovative ideas across a market. The key in the effective management of the diabetes epidemic will be to balance the twin goals of scale and individual relevance. We hope this paper increases awareness of the key factors required to solve the diabetes epidemic in Asia, and look forward to seeing a leap in innovation driving better patient and systemic outcomes.

Acknowledgements

The authors owe a debt of gratitude to many people who made this research and publication possible.

First, we offer thanks to the team at Singapore Biodesign (SB) for their hard work in coordinating the Biodesign Fellowship and working with partners to facilitate access to the hospitals in the different countries. We are particularly grateful to Dr Mary Kan, SB's deputy programme director, and Ms Fiona Loke, SB's curriculum co-head, for their active role in editing and supporting production of this report.

Second, we are grateful to the National Research Foundation Singapore and the Agency for Science, Technology and Research, both of which fund and support the Singapore Biodesign Programme. We are also grateful to our joint programme partner, Stanford Byers Center for Biodesign, the original visionaries behind the Biodesign innovation process, for providing support in our efforts to apply Biodesign here in Asia.

Finally, we wish to thank our clinical immersion partners (the organisations that allowed us to observe diabetes care in a real-life clinical setting) across the region. This includes Hermina Hospital and RS Lira Medika, as well as the Indonesia International Institute for Life Sciences (i3L) in Jakarta, Indonesia; Zhongshan Hospital Fudan University and Gateway Medical in Shanghai, China; and the Diabetes and Metabolism Centre at the Singapore General Hospital in Singapore.

References

1 IDF Diabetes Atlas, 8th edition (2017). Brussels, Belgium: International Diabetes Federation.

2 Ma, R. C. and Chan, J. C. (2013), Type 2 diabetes in East Asians: similarities and differences with populations in Europe and the United States. *Annals of the New York Academy of Sciences*, 1281: 64-91.

3 Tan VM, Lee YS, Venkataraman K, et al. (2015). Ethnic differences in insulin sensitivity and beta-cell function among Asian men. *Nutr Diabetes*; 5(7):e173. Jul 20.

4 Hsu WC, Araneta MR, Kanaya AM, Chiang JL, Fujimoto W (2015). BMI Cut Points to Identify At-Risk Asian Americans for Type 2 Diabetes Screening. *Diabetes Care*; 38 (1) 150-158.

5 Hussain MA, Al Mamun A, Peters SA, Woodward M, Huxley RR (2016). The Burden of Cardiovascular Disease Attributable to Major Modifiable Risk Factors in Indonesia. *J Epidemiol*; 26(10):515–521.

6 Liu Y, Song Y, Tao L, et al. (2017). Prevalence of diabetic retinopathy among 13473 patients with diabetes mellitus in China: a cross-sectional epidemiological survey in six provinces. *BMJ Open*; 7:e013199.

7 Zhang X, Saaddine JB, Chou C, et al. (2010). Prevalence of Diabetic Retinopathy in the United States, 2005-2008. *JAMA*; 304(6):649–656.

8 Woo, Keng-Thye et al. (2011). The contribution of chronic kidney disease to the global burden of major noncommunicable diseases. *Kidney International.* Volume 81, Issue 10, 1044-1045

9 IDF, 2017

10 Barton D, Chen Y, Jin A (2013) Mapping China's Middle Class. *McKinsey Quarterly*; June 2013 edition.

11 Wang L, Gao P, Zhang M, et al. (2017). Prevalence and Ethnic Pattern of Diabetes and Prediabetes in China in 2013. *JAMA*; 317(24):2515–2523.

12 Center for Strategic & International Studies (2018). "Is China's health care meeting the needs of its people?" China Power; https://chinapower.csis.org/china-health-care-quality (accessed 27 Jul 2019)

13 Yuan L, Guo X, Zhenzhen, et al. (2014). Self-monitoring of blood glucose in type 2 diabetic patients in China: current status and influential factors. *Chinese Medical Journal*; 127(2):201–207.

14 Rachmi CN, Li M, Baur LA (2017). Overweight and obesity in Indonesia: prevalence and risk factors—a literature review. *Public Health*; Vol. 147, 20-29.

15 IDF, 2017

16 Food and Agriculture Organisation of the United Nations Rome (2012). The State of Food and Agriculture 2012; http://www.fao.org/3/a-i3028e.pdf (accessed 29 Jul 2019)

17 BPJS Kesehatan homepage; https://bpjs-kesehatan.go.id/bpjs/home (accessed 29 Jul 2019)

18 Kosen S, Tarigan I, Usman Y, et al. (2014). Supply-side readiness for universal health coverage: Assessing the depth of coverage for non-communicable diseases in Indonesia; Washington, DC: World Bank Group.

19 Ahmad M, Rachmawaty R, Sjattar E, Yusuf S (2017). Prolanis implementation effective to control fasting blood sugar, HBA1c and total cholesterol levels in patients with type 2 diabetes. *Ners*; 12. 88-98.

20 Organisation for Economic Co-operation and Development (2018). "Education at a Glance: OECD Indicators, Indonesia," *Country Note*; http://gpseducation.oecd.org/Content/EAGCountryNotes/IDN.pdf (accessed 29 Jul 2019)

21 United Nations Educational, Scientific and Cultural Organization (2019). "Indonesia: Education and Literacy." UNESCO Institute for Statistics; http://uis.unesco.org/en/country/id (accessed 29 Jul 2019)

22 Salti I, Benard E, Detournay B, et al. (2014). A population-based study of diabetes and its characteristics during the fasting month of ramadan in 13 Countries. *Diabetes Care*; 27 (10) 2306-2311.

23 McGill M, Blonde L, Chan JCN, et al. (2016). The interdisciplinary team in type 2 diabetes management: Challenges and best practice solutions from real-world scenarios. *J Clin Transl Endocrinol*; 2016;7:21–27.

24 IDF, 2017

25 Goh SY, Ang SB, Bee YM, et al. (2014). Ministry of Health clinical practice guidelines: diabetes mellitus. *Singapore Med J*; 55(6): 334-347.

26 Zheng KS, Heng KY, Seng B, et al. (2011). Assessing Attitudes of Patients towards Chronic Disease Self-management in Singapore. *Archives of Pharmacy Practice*; 2.

27 Chua L, Soh I. (2016). Health status and health-related behaviours in adults with self-reported diabetes. Singapore Statistics Newsletter (September edition)

28 Linton E, Gubhaju B, Chan A (2018). Home alone: older adults in Singapore. Center for Ageing Research and Education, Duke NUS; Research Brief Series 4.

29 "Ping An Good Doctor expands reach to 265 million registered users in 2018," MobiHealthNews. https://www.mobihealthnews.com/content/ping-good-doctor-expands-reach-265-million-registered-users-2018 (published 28 Feb 2019; accessed 29 Jul 2019)

30 "WeDoctor's Jerry Liao: Medicine For The Masses," Asian Scientist. https://www.asianscientist.com/2018/12/features/wedoctor-jerry-liao-ai-healthcare (published 28 Dec 2018; accessed 29 Jul 2019)

31 "Indonesia's Halodoc raises $65m to expand hi-tech healthcare app," Nikkei Asian Review. https://asia.nikkei.com/Business/Startups/Indonesia-s-Halodoc-raises-65m-to-expand-hi-tech-healthcare-app (published 4 Mar 2019; accessed 29 Jul 2019)

Empowering Asia's Healthtech Innovators of Tomorrow

Modelled after the established Biodesign Programme at Stanford University, Singapore Biodesign is a capability development initiative that aims to train and nurture the next generation of healthtech innovators for Asia.

We are a dedicated talent development and knowledge resource for health technology innovation, riding on the robust biodesign methodology and our wide-ranging international network to place and equip talent for critical startup and innovation roles so as to accelerate projects towards commercialization and startup creation.

MISSION

High-touch development of healthtech talent centered on needs-based approach and quality industry mentoring to accelerate health technology innovation and adoption for Asia's* unmet healthcare needs.

VISION

To be Asia's* leading healthtech talent development and knowledge partner for accelerating health technologies innovation towards commercialization and adoption.

*Asia refers to SG, China and ASEAN

SINGAPORE BIODESIGN

sbenquiry@hq.a-star.edu.sg f sgbiodesign in sgbiodesign

HOST INSTITUTION:

Agency for Science, Technology and Research
SINGAPORE

JOINT PROGRAMME PARTNER:

STANFORD BYERS CENTER FOR BIODESIGN