

**INFECTIOUS
DISEASE
TASKFORCE
REPORT**

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INFECTIOUS DISEASES TASKFORCE REPORT: RECOMMENDATIONS FOR A NATIONAL ID RESEARCH STRATEGY

AIM

1. This report details the analysis and recommendations of the Infectious Diseases Taskforce (IDTF) (**Annex** – Composition of the IDTF). It reviews both global and local ID research landscapes and identifies Singapore's current strengths, challenges and potential areas of growth. The report recommends a single unifying theme in ID research for the Open Fund – Large Collaborative Grant (OF-LCG). Lastly, the report proposes a five-year research roadmap and articulates the resources required to achieve the desired outcomes of ID research in Singapore.

BACKGROUND

2. Emerging and re-emerging IDs continue to pose a substantial threat worldwide, due to their health, social and economic impact. With improved global connectivity, Singapore as a travel and trade hub is increasingly exposed and vulnerable to threats posed by emerging IDs (EIDs) around the world. Recent EIDs such as the Middle East Respiratory Syndrome (MERS) coronavirus, novel influenza viruses and epidemic antimicrobial-resistant (AMR) pathogens continue to threaten us because of their potential to cause severe epidemics. In addition, Singapore continues to face challenges posed by endemic IDs such as dengue fever, tuberculosis (TB), AMR pathogens and the human immunodeficiency virus (HIV).

3. Efforts to fight IDs are ongoing, as these diseases cannot be eliminated locally or internationally in the short to medium term. In addition, our healthcare system has been increasingly threatened by outbreaks of healthcare-associated infections (HAIs). Going forward, Singapore will need a swift, effective and targeted response to effectively curb the spread of IDs.

CURRENT ID RESEARCH LANDSCAPE

4. The public sector has invested heavily in a diverse range of research and core capabilities in ID, with an increasing focus on the capture of health and wealth outcomes from such research investments. MOH has funded several programmes for ID research, such as the Singapore Infectious Diseases Initiative (SIDI) and efforts in the Saw Swee Hock School of Public Health (SSHSPH). A*STAR has also established platforms such as the A*STAR Programme in Translational Research on ID and the Collaborative Research Programme in Extensively Drug Resistant Enterobacteriaceae (XDR-E). Two projects on locally prevalent ID, which focused on Dengue and TB respectively, were also supported under the Research, Innovation and Enterprise (RIE) 2015 tranche (FY2011–2015). In addition, Singapore has attracted world-class researchers in ID, through the Singapore Translational Research Investigator Award (STaR)¹.

¹ The STaR Investigator Award is a prestigious award offered by the MOH National Medical Research Council (NMRC) to attract and nurture established world-class clinician investigators to undertake cutting-edge translational clinical research (TCR) in Singapore.

5. On the wealth capture end, A*STAR has been successful in forging industry partnerships and collaborations. Among the many A*STAR's commercial achievements is a research collaboration agreement with AstraZeneca to develop new antimicrobial drugs to combat Gram-negative bacterial infections.

6. Although there have been many individual success stories in the ID research landscape, one major issue that remains is the large number of diseases that are being researched, leading to fragmentation of efforts and resources. As such, there is a need to focus research efforts on key IDs to answer questions that are relevant for clinical and public health practice. This does not mean that the scope of research should be limited. The IDTF recognises that diversity is important and researchers with specific interest areas can continue to pursue them through the many open competitive funding schemes available.

SELECTION OF RESEARCH FOCUS AREAS

7. The IDTF ranked a list of major ID research areas during an ID workshop in Nov 2015, according to the criteria below:

- a. Local disease burden;
- b. Overall impact on Singapore (including social and economic impact);
- c. Impact of research on disease control programmes and policy;
- d. Impact of research on scientific excellence;
- e. Current talent and future development;
- f. Potential for Singapore to be an international leader; and
- g. Attractiveness to industry.

8. Together with the ID research community, the IDTF identified the top three priority areas in ID research with the highest potential for impact: (i) RTIs (respiratory tract infections) and pandemic threats²; (ii) dengue and vector control; and (iii) AMR/HAIs.

RECOMMENDED ID RESEARCH PRIORITY AREAS FOR THE OPEN FUND – LARGE COLLABORATIVE GRANT (OF-LCG)

9. All of the three research priority areas for the OF-LCG, as stated in para. 8, have been identified as areas that will generate substantial impact on ID control, improved health outcomes, high potential research prominence and industrial interests for Singapore. **Cross-disciplinary** and **cross-institutional** collaborations that include **cost-effectiveness evaluations** and **social science approaches** will be required to address the challenge statements issued for each priority area that aim to target the key issues within each disease area.

10. RTIs and pandemic threats. The IDTF is of the view that research in this area should focus on **determining and breaking the transmission chain** to prevent the spread of respiratory infections, as this is the main factor that will enable the reduction of health and socio-economic impact of RTIs and pandemic threats. This is also the

² The IDTF decided to merge RTIs and pandemic threats into one focus area, as the capabilities built in these two areas are mutually applicable. Most of the credible pandemic threats are respiratory in nature (e.g. novel influenza viruses and coronaviruses), while endemic RTIs such as influenza can be and often are used as proxies in research on pandemic threats.

area where there are many gaps in international research, especially in tropical regions, and where Singapore's contribution can yield direct policy benefits and international recognition. This includes the design and performance of better **surveillance systems** for early detection of novel diseases; understanding the complex **disease transmission mechanisms, especially in the tropics**, and the settings where diseases are amplified and can therefore be targeted with control measures; **socio-behavioural factors** and influences of the spread of diseases and the acceptance of interventions; as well as the **effectiveness of interventions** (e.g. clinical trials and studies that model the effectiveness and cost-effectiveness of potential interventions). To strengthen our borders against EIDs, it is also important to build global and regional collaborative networks to enable to collective detection of novel diseases and develop strategies to manage them.

Challenge Statement for RTI and Pandemic Threats

To utilise basic, clinical, public health and translational research to build capabilities to understand the factors influencing the transmission of pathogens, and to develop novel pharmacological and public health approaches for disease control. These capabilities will be used to build a system³ that could provide early detection of RTIs/EIDs and aid in prevention of tertiary transmission of these diseases in Singapore's densely urban context, contributing to the reduction of case counts and socio-economic costs.

11. AMR and HAIs. The IDTF recommends focusing on understanding the **impact of AMR and HAIs** in Singapore, as this is a poorly understood area, so as to build baseline information for further research and measure the future impact of interventions. This will also help to determine the specific diseases and drug-resistant pathogens on which research should be focused, and to strengthen Singapore's national AMR strategy. Subsequently, research could focus on **detecting and preventing transmission of drug-resistant pathogens**, which could include the design and performance of **surveillance systems** to identify the emergence of these pathogens in different settings, understanding the **transmission mechanisms** to enable targeted intervention and develop optimal **infection control policies**, determining the **socio-behavioural factors** and influences that affect the **emergence and transmission** of AMR as well as the acceptability of various interventions; and the **effectiveness of interventions** (e.g. engineering, infection control, clinical studies and modelling).

Challenge Statement for AMR and HAIs

To utilise basic, clinical, public health and translational research to understand the characteristics and development of antimicrobial resistance, to develop better infection prevention measures, and to reduce inappropriate prescription of antimicrobial agents. This will contribute to a significant and sustained reduction in the burden of HAIs and AMR in Singapore hospitals, particularly with regard to carbapenem-resistant Enterobacteriaceae (CRE) and/or methicillin-resistant *Staphylococcus aureus* (MRSA).

³ The actual implementation of the system should not be funded from the OF-LCG.

12. Dengue and vector control. There is a need for an integrated national plan to eradicate dengue in Singapore, and Singapore has the possibility to be the first country in the world to eradicate endemic dengue. Building on past successes in this area, research should focus on evaluating the **effectiveness of novel vector control measures**, such as sterile mosquito techniques (e.g. NEA is currently exploring the use of Wolbachia-infected mosquitoes as a vector reduction method, and the effectiveness of this and other methods require evaluation), and the **effectiveness of therapeutics and vaccines** (e.g. the new dengue vaccine by Sanofi and other candidate vaccines will require an evaluation of their cost-effectiveness in the local context), as well as strengthening the **clinical management of dengue** in both primary care and hospital settings.

Challenge Statement for Dengue and Vector Control

To utilise basic, clinical, public health and translational research to understand the virus, host and entomological factors influencing dengue spread, to develop new dengue prevention and vector control methods, and to determine the effectiveness of these methods in the Singapore context. This will support the national goal to reduce the overall burden and impact of adult dengue, and other IDs transmitted by the same vectors.

FIVE-YEAR ROADMAP AND GAPS IN THE RESEARCH LANDSCAPE

Research Focus Areas

13. While the IDTF has recommended three priority areas of research for the OF-LCG, the IDTF also emphasised that not all available research funding for ID should be allocated to these three areas. As ID is a broad research area where there are many opportunities for research and collaboration to benefit Singapore, other diseases (e.g. HIV/AIDS and TB) should also be considered for funding through other schemes. In addition, there are many niche areas of ID research that will benefit local disease control or address a national need [e.g. the role of the social science in furthering local prevention programmes on sexually transmitted diseases (STDs)]. Research in all of these diseases should be given ample opportunities to flourish either through dedicated funding (e.g. commissioned studies to address specific policy questions) or various competitive grant mechanisms. In consultation with MOH, the IDTF recommends that Singapore invest in the following research priority areas in the next 5–10 years:

14. Pandemic threats. With the rise of pandemic threats around the world, Singapore needs to be better prepared for national security threats and public health emergencies. While there is a comprehensive operations plan to respond to pandemics, the IDTF is of the view that research can play an important role in this area in terms of enabling better early warning and detection systems both locally and regionally, and developing new measures that can be used to control the spread and impact of the pandemic's spread to Singapore and within Singapore. The IDTF recommends to focus on the following fields of research activity:

- (a) **Evaluation** of existing pandemic preparedness plans and strengthening

these plans with new measures that are available, including surveillance programmes and interventions to prevent and control the spread of a pandemic;

(b) **Exploratory “blue-sky” research** to develop silver bullets against pandemic threats. As funds in Singapore are limited compared to other large global players, researchers should aim to collaborate with other stakeholders to bring such technologies to the market. Singapore can either be involved in the early-stage development of novel technologies or in trial technologies that have already been developed; and

(c) **Pandemic research during the actual outbreaks** to respond and understand the response. There are two aspects of research during a pandemic that need to be strengthened. First is the availability of existing capabilities that can be mobilised at short notice as part of a surge capacity response, as new programmes cannot be expected to materialise without preparation time. Second, rapid disbursement of new funds for pandemic research is also needed as several promising research proposals during previous epidemics were delayed due to the lack of available funds. There should also be a well-designed assessment tool to review the criteria for outbreaks to warrant activation of this fund, and to trigger this mechanism when necessary.

15. RTIs. The spread and impact of RTIs are poorly understood, especially in the tropics, which is thought to be the region where different RTIs mix and spread to other regions. There is potential to improve the understanding of, and to subsequently intervene in, the regional and global transmission of disease. The IDTF is of the view that Singapore is well placed to conduct research in:

(a) Understanding **RTIs in the tropical setting**, e.g. disease **transmission, socio-behavioural factors** influencing transmission and effectiveness of public health and pharmaceutical **interventions**; and

(b) Designing an improved **surveillance system**, both within Singapore and regional/international systems, for the early detection of outbreaks.

As there is already substantial research in the development of pharmaceuticals including vaccines and drugs against RTIs, the IDTF proposes that this should not be a major focus area.

16. AMR and HAIs. AMR and HAIs remain a major issue for the local healthcare system, and research is needed to find solutions in the Singapore context. Research in this area should be in line with the national plan for AMR, which is currently being developed by MOH based on a “One Health” approach, together with stakeholders from the agricultural and environmental sectors. With this approach, research should focus on:

(a) Better **surveillance** of AMR (including genomics) and overall antibiotic use, both in the hospital, community and food sources;

(b) **Socio-behavioural** research to study antibiotic prescription patterns and the link to transmission of drug-resistant pathogens, and also to determine what are the most effective method of reducing the misuse and overuse of antibiotics;

(c) Modelling and testing of hospital-based and community-based **interventions** in the above areas;

(d) Basic science research to understand the **factors affecting** the rising

rates of local drug-resistant pathogens, e.g. in CRE; and

(e) Applied research into **infection control** in both acute care and intermediate long-term care (ILTC) settings, including health services research (HSR) and operations research to redesign processes and protocols, and trial of novel human-use and surface/material technologies to reduce AMR.

Similarly, research should not focus primarily on the development of novel therapeutics as this is a globally competitive area where other countries and organisations are pouring significant resources into, and where Singapore comparatively may not be competitive.

17. Vector-borne diseases. For vector-borne diseases such as dengue, Zika, chikungunya and malaria, the IDTF recommends placing the priority of research on vector control. The suggested research themes include:

(a) Basic and applied research in **novel vector control technologies** such as gene editing (CRISPR-Cas9), and **engineering solutions** to reduce the breeding of mosquitoes in our urban environment;

(b) Evaluating the **effectiveness of the Wolbachia method** which is currently deployed in Singapore (a deeper dive into this area that is currently primarily performed by the Government institutions);

(c) Phase III **clinical trials** for new dengue vaccines in adults and Phase I to II trials for Zika vaccines. This should ride on the existing vaccines being developed and ensure that they are relevant in the Singapore context, and not develop new vaccine candidates locally; and

(d) Basic research to **understand the viruses and immune response** of the virus specifically as it relates to understanding the effectiveness of our current vector control methods, and developing new ways of controlling the spread of the virus.

18. AIDS/HIV. The epidemiology of AIDS/HIV in Singapore reflects regional trends, with a high male-to-female ratio. The IDTF suggests focusing HIV research on social science and community interventions, such as early diagnosis, which are the weakest link in HIV management in Singapore, as they will have more impact on health outcomes. The recommended research priorities are:

(a) **Social science research** in community interventions targeted at (i) improving outcomes in the prevention of infection and (ii) improving diagnosis of unknown-infected and linking them to care; and

(b) **HSR** to evaluate the implementation of interventions such as promoting the use of self-testing kits.

19. TB. TB is more prevalent in Asia than in Western countries, and Singapore still has an intermediate prevalence of TB that is higher than most other high-income countries. The IDTF recommends the following research priority themes for TB:

(a) **HSR** to improve TB control in Singapore. In particular, there is a need to study ways to better manage imported cases and cases in specific settings, such as institutional (e.g. school, prison, dormitory and healthcare) settings. Research in this area should aim to understand the impact of spread of TB from foreigners, and to improve the implementation and effectiveness of latent TB testing. The IDTF also observed that there could be a potential rise in rates of multidrug-resistant (MDR) and extensively drug-resistant (XDR) TB, and recommends that Singapore should improve TB operations through HSR to

cope with the rise, as well as evaluate the use of new technologies for TB control; and

(b) **Social science research** to improve behavioural interventions. This includes studying more effective contact tracing methods, and improving early diagnosis of TB potentially by changing health-seeking behaviour.

20. Build up capabilities in HSR and socio-behavioural sciences. As there is a clear need for HSR and socio-behavioural research methods for all of the above-mentioned disease areas, there is thus a need to build up HSR and socio-behavioural sciences in Singapore as a cross-cutting horizontal capability to ensure the effective translation of research findings into clinical application and system implementation.

21. For HSR in ID, the IDTF notes that the expertise is currently concentrated in the SSHSPH and Duke-NUS, but there is a need to expand the capabilities to cope with the increased demand for HSR activities, and to improve coordination across all the relevant research groups so that these capabilities are available to all ID researchers in times of need.

22. For socio-behavioural sciences, there are generic capabilities in the NUS Faculty for Arts and Social Science, the SMU Behavioural Sciences Institute and the NTU Wee Kim Wee School of Communication and Information, but capabilities specific to socio-behavioural sciences in health are lacking, while the behavioural sciences group in SSHSPH is small and research efforts are spread across many disease areas.

23. For HSR and socio-behavioural sciences research in other disease areas apart from those previously mentioned, the IDTF recommends to prioritise the following research themes:

(a) Ways to improve the screening and detection of hepatitis in the local setting;

(b) Ways to improve the surveillance of disease outbreaks, including diarrhoeal diseases;

(c) Ways to improve the prevention of transmission of sexually transmitted infections (STIs) among at-risk individuals, and to improve detection through screening and the use of different STD diagnostic kits;

(d) Research on behavioural interventions such as condom use to reduce STD transmissions;

(e) Research to improve hand, foot and mouth disease (HFMD) control policies, beyond school closure and isolation of infected children; and

(f) Ways to monitor the effectiveness and increase the uptake of recommended vaccines for both childhood and adult vaccines.

24. The IDTF has tried to conduct a holistic review to the best of its ability in recommending the research areas above. However, we acknowledge that the commercialisation potential of a research area was not given as much weightage as compared to clinical outcomes. The IDTF thus proposes to focus on public health goals and outcomes for ID research in Singapore for now, but leave open the opportunity to pursue diagnostics and therapeutics research should a more suitable programme arise.

Roadblocks and Gaps

25. To assist in the development of the roadmap, the IDTF has identified gaps in the current ecosystem that impede ID research in Singapore, and that need to be addressed as soon as possible. Previous gaps have been identified by earlier reviews and many have been addressed by the various initiatives as discussed in the section on 'Current ID Research Landscape' above (paras. 4–6). The gaps and initiatives to address them are summarised below.

26. The ID research community is often criticised as being disparate and disorganised, as there were occasions where multiple research teams have worked on the same disease topic without communication and collaboration. While such competition is sometimes unavoidable and may often deliver good results, in priority research areas or critical situations (i.e. outbreaks) this may dilute efforts or compromise research outcomes.

27. To address the lack of manpower, the SSHSPH was established in 2011 and has the potential to strengthen capabilities for outbreak prevention and management. However, these capabilities are spread across different health areas (including cancer, diabetes, physical activity, healthcare financing, smoking, environmental health and eye disease) and relatively few faculty focus exclusively on ID.

28. MOH has received feedback on the difficulties in accessing data due to legislation such as the Personal Data Protection Act (PDPA) and is currently conducting a review on the related regulations.

29. To address the long wait time for approval by Institutional Review Boards (IRBs), the SingHealth Centralised Institutional Review Board (CIRB) and NHG Domain Specific Review Board (DSRB) have signed a memorandum of understanding (MOU) to provide a process for establishing single IRB review of cross-cluster studies. The mutual recognition of research ethics review took effect from Jul 2014.

30. Notwithstanding, some of these gaps still persist, and will require support from various agencies to address them and to enable ID research to meet the short- and longer-term objectives. The gaps for ID research that are currently relevant include:

ID-Specific Issues

31. **Cyclicality of IDs.** There are periodic surges in the incidence of IDs corresponding to cycles due to various factors such as global seasonal trends, emergence of new strains from mutations or environmental issues. As such, funding and ramping up of capacity is needed during the surges, but some of the research work may seem irrelevant after an epidemic is over, only to be relevant again during the next epidemic.

32. **Lack of mechanism to disburse funds rapidly during outbreaks.** In the event of a pandemic, resources are needed to support research to better understand the disease and develop ways to diagnose, contain and cure the disease. The routine grant calls usually take up to 5–6 months from application to award, and hence are unable to meet the rapid funding requirements of research during outbreaks.

33. **Delays in local transfer of materials and difficulties in obtaining clinical samples from public institutions.** Delays in the research process and extension of timelines for grants occur frequently. This is due to the long lead time required to obtain ethics approval, recruit participants, hire staff and negotiate cross-institutional research agreements. Further, the IDTF notes that although prior research agreements were signed, it will still take a long time to complete specific material transfer agreements. The wait for clinical samples is usually longer due to patient confidentiality issues, and it is a main cause of delay in research.

General Issues

34. **Lack of mechanisms to translate research outcomes into clinical practice and policy.** There is a need for better translation of research outcomes into policies and measures to improve public health. Policy makers generally focus on developing policies to improve health outcomes, while researchers place their emphasis on publications and academic output, and there have been no strong links between the two.

35. **Lack of mechanisms to review desired research outcomes, especially to sustain capabilities/platforms developed with grants.** Currently, the majority of the ID research funding is awarded through a competitive process. There are concerns that this will result in high turnover and difficulties in building and maintaining core capabilities.

Recommendations to Address These Gaps

36. To address the gaps highlighted above, the IDTF recommends the following five-year roadmap, which is broadly categorised into three areas: (i) governance and structure; (ii) research capabilities and funding; and (iii) talent and others.

Governance and Structure

Recommendation 1: Establish leadership and mechanisms to address ID research needs, translate research into health and economic outcomes, and improve coordination.

37. The IDTF recommends the establishment of a neutral body (i.e. one that is not partisan and is able to independently work with all stakeholders) with dedicated staff to play an executive and coordinating role for the ID research landscape. The IDTF suggests that such a neutral body could be positioned within the National Centre for Infectious Diseases (NCID). In particular, this body will (i) study (through continuous mapping of the ID research institutions, individuals and projects) and determine the needs of the ID research landscape across the entire research spectrum (i.e. from basic science to TCR, HSR and public health research); (ii) work with researchers to channel research efforts into the priority areas, and assist them in securing the funding to do so; (iii) engage researchers to facilitate partnerships and collaborations; (iv) organise informal, regular engagements for the research community to align their interests and missions; (v) communicate with regulators and policy makers to address the research roadblocks; and (vi) review research findings and facilitate their

translation into clinical applications and health policy.

38. Regardless of where the body is placed, it is essential that the body is suitably staffed with individuals familiar with ID research, the researchers and research institutions, and is well resourced to perform the tasks. The cost of sustaining such a body is small compared to the amount of funding that had been provided to ID research, and it is small price to pay to ensure that research is translated into outcomes, especially in a diverse field such as ID where research is essential to policy making, national response and operations.

39. The IDTF is aware of concerns that NCID may be viewed as a clinical and public health research entity, and that it will be biased against the basic science research community. To address this issue, the IDTF suggests reconstituting the current IDTF into a standing advisory committee, and revising its TORs and composition, so that it can provide guidance to the neutral executive body (e.g. NCID). The advisory committee should comprise experts from different areas of ID research who are familiar with the local system. The advisory committee can be reviewed and reconstituted every three years to ensure fair and relevant representation.

Research Capabilities and Funding

Recommendation 2: Build research capabilities in social science in ID.

40. In an era where transnational mobility is a norm, the containment of IDs must involve co-opting the community. We have to shift from traditional top-down initiatives that serve to police the community to measures that *involve* the community and seek buy-in from community members. In short, we have to grow a culture where good health is a commodity that is valued by all, and every member is an active stakeholder in this endeavour. Social science — defined here more broadly to include social, behavioural, organisational, communications and similar areas of research — plays an important role in this.

41. To nurture active stakeholders within the community, two main factors need to be in place. First, to raise awareness and disseminate information, there is a need to **identify effective networks within the various segments of the community**. While mass broadcasts remain important for the dissemination of top-line information, these need to be deconstructed at the community level to ensure that prescriptive public health messages are aligned with cultural codes. To do so, the IDTF recommends attracting social scientists with both quantitative as well as qualitative research skills to invest their careers in health research.

42. Second, for the management of IDs to be effective and sustainable, there is a need to **build a framework which facilitates two-way communication between formal health agencies and the community**. Through this, mutual trust can be established over time, and health promotion becomes a sustained conversation among the various stakeholders.

Recommendation 3: Build and participate in regional and global ID research networks.

43. With globalisation, border control for ID is increasingly difficult. The IDTF recommends working closely with our neighbouring countries and beyond to strengthen our defence for ID. This could be done by organising international workshops, roundtables and conferences with neighbouring countries to network and facilitate collaborations. In addition, we should build core capabilities in unique disease areas where others have not yet fully developed, so that we can become a research centre where regional and global partners will approach us for collaborations. These areas could potentially be in the priority areas mentioned above, such as in tropical RTIs and pandemic control, vector-borne disease control, and AMR surveillance and management.

44. In addition, the IDTF observes that not everyone in the ID local research community is aware of international funding opportunities which Singapore has access to, such as the research grants provided by the Human Frontier Science Programme and Excellence in the Life Sciences (EMBO) supported by the European Molecular Biology Conference (EMBC). There may be a need for a body to educate and provide guidance to the researchers to apply for such international R&D funding, including other established research funding agencies such as the Wellcome Trust, Gates Foundation and NIH grants where monies can be used internationally, instead of solely relying on local funds, most of which cannot be used overseas.

Talent and Others

Recommendation 4: Building a talent pool (especially PhDs) in (i) microbiology and bacteriology; (ii) socio-behavioural sciences; (iii) health economics and HSR; and (iv) applied biostatistics, computational biology, bioinformatics and big data analysis.

45. Talent development is an important pillar in building research capabilities. Currently, there is a lack of the following expertise in the ID research landscape:

- (a) Microbiology and bacteriology – lack of researchers for wet lab basic research;
- (b) Socio-behavioural sciences – see Recommendation 2 above;
- (c) Health economics and HSR – MOH has set up the Agency for Care Effectiveness (ACE) in Aug 2015 to promote appropriate care for Singaporeans through objective and credible recommendations developed through health technology assessments (HTAs). There is a need to build capabilities in both HTAs and health economics, so that cost-effectiveness analyses can be incorporated in the early stages of research. HSR is one of the currently missing steps in translating both local and international research findings into the local healthcare system.
- (d) Applied biostatistics, computational biology, bioinformatics and big data analysis – A*STAR's Bioinformatics Institute (BII) has played a significant role

in ID research. There is a need to expand the talent pool to conduct such research. For biostatistics and data analytics, there are several programmes in NUS (i.e. in the Faculty of Science, SSHSPH and Duke-NUS), but the number of graduates coming through these in medical/public health areas is small, and the number in ID even smaller. Furthermore, these graduates attract high salaries in industry and face unclear career progression in research. In computational biology and bioinformatics, the situation is similar. There is a need to expand the talent pool to conduct such research, including dedicated courses in the universities.

46. The IDTF notes that NMRC talent development programmes support clinicians in furthering their studies in some of these areas, such as HSR and bioinformatics. There is a need to create and increase awareness of these schemes among clinicians and researchers, as well as expand the funding pool to allow for more beneficiaries.

47. There are some concerns that currently, most research staff in non-traditional areas (such as biostatistics or behavioural sciences) do not have career stability and development opportunities. The IDTF recommends developing a clear career path for such non-traditional areas, such as by establishing a central hiring and deployment model. A model that might be explored is that of Biomathematics and Statistics Scotland (BioSS) in the United Kingdom, in which statisticians working in different biological research institutes simultaneously work for a secondary organisation (BioSS) that provides clear career progression and a network of experienced colleagues to provide domain-level support. Competitive remuneration packages can also be explored to retain these highly trained individuals.

48. Lastly, there is a lack of ground-up research leadership within the ID research community. As such, the IDTF recommends the need to strengthen the structure to groom young research leaders. There should be an active search for succession, together with the identification of local talent from the early stages of their career and institution of mentorship to provide guidance. Various institutions currently have systems to identify and groom researchers in specific fields. The best practices can be tapped on to ensure that young leaders are identified, groomed and monitored throughout the span of their career.

CONCLUSION

49. Singapore has invested significantly in ID research, and we have built substantial capabilities, attracted industry engagement and improved clinical outcomes. However, more can be done to improve the landscape, maximise resources and better translate research findings into health and wealth outcomes. The IDTF has reviewed the landscape and recommended research priority areas for the next five years, especially in pandemic research, RTIs, AMR, vector-borne diseases, TB and AIDS/HIV. There is also a need to focus on cross-cutting themes such as HSR and socio-behavioural research. The IDTF has also made several recommendations aimed at addressing the gaps in the research landscape, but a deeper analysis is needed to determine the approach of implementing the recommendations, as well as analysing the returns on investment for ID research.

50. To bring Singapore ID research one step further, we aspire to set up a world-

leading research centre in one of the recommended ID focus areas, so that Singapore can build a track record, have a competitive advantage over others and bring together multiple disciplines across ID research.

Prepared by: Infectious Disease Taskforce

Composition of the HBMS Infectious Disease Taskforce

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2	A/Prof Hsu Li Yang (Co-Chair)	Director, Singapore Infectious Disease Initiative (SIDI)
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4	A/Prof Raymond Lin	Head & Senior Consultant (National Public Health Laboratory), Public Health Group, Communicable Diseases Division, MOH; Head & Senior Consultant, Division of Microbiology; <i>and</i> Clinical Director, Division of Molecular Diagnostic Centre, NUHS
5	A/Prof Paulin Straughan	Associate Professor, Vice Dean of International Relations and Special Duties, Faculty of Arts and Social science, NUS
6	Dr Mark Chen	Assistant Professor, Saw Swee Hock School of Public Health, NUS <i>and</i> Head of Research at the Institute of Infectious Diseases and Epidemiology, TTSH
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