Submission
2016 National Research Infrastructure Roadmap
Capability Issues Paper

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Question 1:   Are there other capability areas that should be considered?

This list is adequate from the perspective of QIMR Berghofer

Question 2:   Are these governance characteristics appropriate and are there other factors that should be considered for optimal governance for national research infrastructure.

The governance characteristics appear appropriate.

Question 3:   Should national research infrastructure investment assist with access to international facilities?

Transnational collaborations are common in medical research. Access to facilities is usually negotiated between collaborating institutions. However, assistance with access to international facilities could be beneficial in some circumstances. From our perspective there are two relevant examples. The first of these is related to storage, access and analysis of large data sets arising from genomics. The future work that will bring benefit to Australians requires access to international data and we should and can contribute and benefit from that. The recently announced 'Cancer Moonshot' proposal from the USA or the International Cancer Genomics Consortium and its successor (ICGC-MED) are examples of the global nature of clinically relevant databases to which access is required. The second example comes from the established link between Australia and the European Molecular Biology Laboratory (EMBL). The EMBL headquarters and the specialist out-stations have assembled and renew a very extensive collection of leading-edge research infrastructure of relevance to all cell, molecular and structural biology research. The associate membership of Australia with the intergovernmental EMBL should be maintained and used to facilitate ease of access to this rich collection of laboratory equipment.

Question 4:   What are the conditions or scenarios where access to international facilities should be prioritised over developing national facilities?

Access to international facilities should be prioritised over development of national ones in circumstances where it is not feasible to develop national facilities (due to cost, usage demand etc). National facilities should be prioritised where there is sufficient demand or a strategic reason for developing such facilities.

Question 5:   Should research workforce skills be considered a research infrastructure issue?

We are of the opinion that infrastructure can be 'soft' in nature as well as instrument-based, meaning that a facility may comprise a specialised work group rather than a piece of equipment. It follows that a subset of workforce skills are needed by many endusers and if they are not available

research and other outputs suffer. Examples of workforce skills that could be considered 'research infrastructure' include bioinformatics, statistics and health economics. Some of the discussions surrounding possible changes to the National Health and Medical Research Council (NHMRC) funding models are particularly relevant as they might preclude the extensive involvement of these experts (due to proposed restrictions capping the number of grants in which they could be named as investigators); these new restrictions should be anticipated in this analysis of future needs. The ability to obtain maximum benefit from complex instruments is also a skill that should be included.

Question 6: How can national research infrastructure assist in training and skills development?

Each site that is dedicated to a special methodology (e.g. proteomics) should be viewed as a training site for researchers who are not working in that location.

Question 7: What responsibility should research institutions have in supporting the development of infrastructure ready researchers and technical specialists?

Training for these individuals is best (and perhaps only possible) when there is access to the advanced equipment or specialised workforce skills. It follows that the primary responsibility resides with the institute that has been awarded funds for the establishment of the infrastructure (both instrument-based and 'soft') with the external users having a secondary support role.

Question 8: What principles should be applied for access to national research infrastructure, and are there situations when these should not apply?

With an award to provide infrastructure comes the absolute responsibility to being available for 'all' applicants who have a reasonable justification for use of the infrastructure. When demand outstrips supply, an expert group, dominated by people external to the facility, should derive policies for rationing access. This group should have a role also in ensuring that internal clients do not have a priority right to use of the national facility. The private sector should make full cost payments as they will have sole financial benefits from the work that is performed. Other federal programs should provide support for earlier stage or incubating companies.

Question 9: What should the criteria and funding arrangements for defunding or decommissioning look like?

There are two distinct questions here. When defunding occurs, it is not simply a matter of the end of a grant. Personnel are involved and face redundancy. It follows that there must be adequate advance notice provided; the recent example of rolling one-year extensions was very destabilising and does not give an institute adequate opportunity to plan for a transition. Equipment in a facility also has maintenance contracts and these can be extended after the defunding. Therefore, financial provision should be made for that transition. Funding should be for the whole of the lifecycle of physical infrastructure. Therefore, it should allow for the option of full decommissioning of some or all equipment. It should include provision for the removal and disposal of equipment and write off of any residual value.

Decommissioning may overlap with maintenance costs but is best considered for equipment that is particularly large. Consider PET- or MR-based facilities. When that equipment is obsolete there is a

significant cost associated with its disposal and that should be included in any Infrastructure award.

Another point to consider is depreciation of equipment purchased with infrastructure funding. Some equipment, such as compute infrastructure, may depreciate rapidly and this is a further complication which needs to be considered.

Question 10:   What financing models should the Government consider to support investment in national research infrastructure?

It is a core basis of this consultation that Australia, like all countries, needs to invest in research infrastructure. The test for the inclusion of a facility in the ultimate list of infrastructure is that (a) it would put Australian research – including private research –at a disadvantage if there was not access to that piece of infrastructure, (b) the cost of the infrastructure, which often requires a combination of related equipment and/or personnel, would be greater than an individual institute or research grant could reasonably afford and (c) unnecessary duplication can be avoided by having a coordinated approach to the provision of infrastructure. Clearly, the value of the infrastructure in relation to its cost will need to be factored into decision-making.

Government should be open to considering the full range of financing models, provided appropriate controls and access agreements are in place and national security issues are addressed. The current model is generally by grant, with the host institution owning the asset and the associated liabilities. Two other models that should be explored are (1) that the funder maintains ownership and risk (not likely to be acceptable to the funder) or (2) commercial lease for the period of investment. The second option has some particular advantages in the case of managing risk for both the funder and host, and makes defunding arrangements simpler. Consideration would need to be given for the options at the end of funding period, e.g. renew funding and rollover lease, host to buy out equipment by capital purchase or roll over lease, funder to buy out equipment and sell asset (not likely to be viable).

What is not realistic is that the government has a position that reneges on its responsibility to provide the required infrastructure. As stated, this is a time of fiscal constraints, but that is true for all and it is not limited to government.

Question 11:   When should capabilities be expected to address standard and accreditation requirements?

With the current emphasis and efforts being made to bridge the gap between 'academic' research and the translation of the research to industry or the clinic, it is necessary to ensure that work carried out in funded infrastructure units meets high formal standards. This will vary from case to case and one could envisage that e.g. generating structural data in a synchrotron would not require accreditation (other than for safety aspects). For other activities it will be essential and the related costs should be included in any award. For example, the initiatives occurring to implement **genomics** into the clinic through the Australian Genomics Health Alliance (AGHA) or similar state level work in Victoria and Queensland (MGHA and QGHA) requires the implementation of accredited testing in sequence and analysis labs.

Additionally from our perspective we propose that there is a national need for the manufacture of **cellular therapeutics** (adoptive immunotherapy of various immune cells) and **therapeutic antibodies or novel hybrid biological response modifiers** (eg. of antibodies, lipids, small molecules, immune-editing molecules). These are required for human clinical trials and such infrastructure must have TGA GMP certification. Equally in the area of imaging (PET, MR etc), the facilities should fully conform with standard hospital-level patient-related requirements, even when healthy volunteers are involved.

An issue that needs to be addressed is whether Commonwealth-funded infrastructure should meet GLP, GCP or ISO17025 standards. Funders will inevitably require some form of quality accreditation for centrally-funded infrastructure.

Question 12: Are there international or global models that represent best practice for national research infrastructure that could be considered?

Each country and continent has addressed this question in a manner that best suits the nature, cost and demand for the infrastructure. Although some of these are spectacularly successful, they cannot be replicated in Australia for reasons of geography and population size. For example, CERN is unique and depends on international support. Similarly, other European inter-governmental (e.g. ESO, ESA, EMBL etc) or EU developments are beyond the scale of what Australia can consider. These tend to be mega-projects and Australia gains by partnering in these and obtaining access for its researchers in the process. For facilities that are of more modest scale, a key driver of decisions internationally appears to be the focussing of a good level of support in a restricted number of locations (e.g. in the USA at the early high-cost phase of DNA sequencing) and hence the avoidance of random investment by individual institutes with consequential sub-optimal use and wasteful duplication. This would seem the appropriate approach for Australia also. However, care is required that some simplified thinking does not mean that a core activity has other ancillary activities associated with it for 'tidiness' sake. For example, there are many flavours of 'omics'. Each has a different instrument expertise and skill requirement. Using the -omic tag to justify a super concentration of these in one location is not the best model. An example from Europe addresses this point. Structural biology requires different scales of analysis. That could have been an argument for the concentration of NMR, electron microscopy and X ray crystallography in one location. This did not happen; instead a limited number of centres that excel on one such technological approach were developed with success.

Question 13: In considering whole of life investment including decommissioning or defunding for national research infrastructure are there examples domestic or international that should be examined?

QIMR Berghofer has no comment at this time.

Question 14: Are there alternative financing options, including international models that the Government could consider to support investment in national research infrastructure?

See response to question 10. Note also that the burden of costs is often shared by different governments. This is not a realistic option for Australia.

Health and Medical Sciences

Question 15: Are the identified emerging directions and research infrastructure capabilities for Health and Medical Sciences right? Are there any missing or additional needed?

The various subsections of Chapter 5 provide a very good scan of the trends and requirements. A lot of that is lost in the summary table and there is a danger that this will become a shorthand for some of the more nuanced comments made earlier. In addition, the sections in boxes described as 'Now' may give the impression that these are satisfactory when in fact some things listed are inadequate or will be in a few years, so should not be described as an existing capability. As a consequence we make short comments on the various aspects presented in section 5. There are inevitable areas of overlap between 5.1 (Emerging Directions) and 5.2 …. Current Capability and Emerging Capability Needs.

5.1.1 We agree with the focus on Big Health Data but suggest that greater emphasis should be put on integrating and having access to the data. The emerging trend is to fuse analysis of genomic and other –omic data and link them to patient records. Ethics and legal aspects need to progress rapidly if Australia is to participate in this trend and have the health-related outcomes. Section 5.2.5 is relevant here. Big Data is only as useful as its contribution to research or clinical care. Legislative and codes of practice improvements will be required to deliver the potential of big data, including privacy, access to data (especially clinical), incidental findings, insurance etc.

5.1.2 We do not see Structural Biology as an emerging or growth area. The era of obtaining significant insights from Structural Biology is passed. The generation of detailed structures for e.g. drug development is routine.

5.1.3 Translation is of course the end-point (together with pure knowledge) that justifies investment. However it is a very elastic word and care needs to be taken that discovery research (which is an essential pre-requisite) is neither overlooked nor confused with translation which has to be close to the clinic or commercialisation.

5.1.4 Although there is a correction in 5.2.6, it is inadequate to highlight PET (and the related tracer development) only. The exciting brain connectome work is dependent on MRI and Australia has great strength in all of these imaging modalities.

5.1.5 The benefits of rQMS are appreciated. However we do not see this as a fully desirable 'emerging direction'. rQMS may also bring a burden (time and costs) that could stifle some research for which that level of certification is not required. Australia has a propensity to excessively control health-related activities (e.g. see difficulties in getting ethical and governance approval) and a further intrusion at the wrong time would be counterproductive. Research means trying out new things to find novelty. That phase does not benefit by codified procedures. When the discovery phase is complete the rQMS is justified but not for all 'academic' investigator-driven research.

5.2.1/5.2.2 We agree with this assessment, but note that there is an overlap between aspects of Biologics and the next section. Immunotherapy is discussed in 5.2.2 which is confusing. If the two sections are retained in future discussions 5.2.2 might be re-named Cellular Therapeutics and some sections currently in 5.2.2 moved to 5.2.1.

We agree that the impact of **Biologics** is current and growing and it deserves to be highlighted. **Cell-based therapies** (including adoptive immunotherapies, CAR-T and transformed or pluripotent stem cells and other approaches) are an emerging area that needs to be very high on the future infrastructure list. Immunotherapy is revolutionising cancer treatment and capabilities around creating and testing novel agents (cellular or molecular) are critical if Australia is to participate. With the great strength in basic immunology in Australia and clinical oncologists of international reputation, this investment would appear very sound for generating better clinical outcomes and commercial investment. The investment would also have other applications in chronic diseases with immune basis. Specialist environments are required and the highest level of certification is a necessity.

The prospects for the use of **exosomes** and other extra-cellular vesicles and also growing and the capabilities for these are lacking. While the text focuses on the **therapeutic** possibilities, there is also a growing need for facilities where **diagnostic** analyses can be developed. Methods for the isolation of exosomes, or circulating tumour cells, need to advance and rapid diagnostic analyses of these components by genomics, transcriptomics, proteomics or flow cytometry are needed.

5.2.3. The importance of omics is obvious. The trend will be to integrate different omic data sets (e.g. genomics, proteomics and transcriptomics) and the bioinformatics support workforce to address that need should be highlighted. Section 5.2.3 entitled 'omics' is currently lacking in content as it focusses only on DNA-based data. Another oversight in this section is the fact that **epigenetics** are not included. This is a major emerging trend, as the onset of disease is not restricted to the DNA sequence, but also crucially to the way in which life style and other factors modulate which genetic information is expressed and that is the essence of epigenetic analysis

5.2.4. Fully agree. Attention should be paid to ensure that the **Biobank** is not simply a stored repository. It has to be accessible and enriched for all of the other clinical and phenotypic data associated with the sample. It is suggested that an integration of existing biobanks into collaborative networks should occur. We agree, but also recommend that prior to integration the existing biobanks are accessed for quality of banked material and data. **Population genomics** is an agreed area of national importance, and would be further enhanced by enabling provision of linked clinical data, including outcomes, pharmacy and pathology records.

5.2.5 Fully agree.

5.2.6 See comments above (5.1.4). One aspect that needs to be addressed is the fact that the imaging facilities are frequently based in a clinical setting. This can mean that priority is given to patients' needs (not surprisingly), therefore access to facilities that are established for human research should be recognised as an infrastructure need.

5.3.1 Agree but note that this is the third reference to **PET-related infrastructure** (5.1.4 and 5.2.6). This could be translated into a special role in future ranking. We recognise its importance; we propose that other imaging modalities such as MRI and PET/MR etc. are equally important. We also point to the crossover that is desirable between immunotherapies and labelled molecules for analysis, research and also for the emerging field of Theranostics.

5.3.2 Agree.

5.3.3 Agree with the need for bioengineering to be integrated into the development of clinical solutions but we think the term precision medicine is misplaced in this restrictive context.

5.3.4 Agree.

5.3.5 Agree. This section has overlap and represents the integration between serval previous sections (5.1.1., 5.2.3., 5.2.4, 5.2.5.). New facilities for approaches like whole genome sequencing should be considered only when there is a need to scale up existing national capacity or when complimentary technologies will add to Australia's existing national infrastructure capability.

Question 15: Are the identified emerging directions and research infrastructure capabilities for Health and Medical Sciences right? Are there any missing or additional needed?

The identified emerging directions of big health data, large bio models, translation, imaging and research quality management are appropriate, as are the emerging capabilities of biologics, novel therapies, 'omics, biobanking, data and imaging (not restricted to PET). The desired new capabilities relating to PET tracers and cyclotrons, Indigenous research, precision medicine, stem cells and data are all supported.

Other emerging directions and research infrastructure capabilities that should be considered include:

- **Medicinal Chemistry**

Obtaining molecules that impact some process under study is almost inevitable in any screen of any collection of molecules. The gap towards utility from the screen is the availability of Medicinal Chemists.

- **Epigenetics**

See above. Sequencing the epigenome is a start point but this overlooks histone modifications and these are equally important. A complex set of skills are required to deliver on this emerging need (including proteomics, genomics and bioinformatics working in an integrated manner).

- **Insect Containment Facilities**

These are required to sustain long term programs on the various malaria or virus transmission models that exploit model pathogens and mosquitoes and that support research into diagnostics, vaccines and therapeutants. An equally important function of these facilities is to facilitate rapid responses to new threats. Zika, Dengue and Chikungunya, for example, are rapidly emerging mosquito-borne diseases that are a global threat and that have a real impact on Australian health and the economy. In the context of these viruses, exotic mosquito invasions also present new complications for pathogen transmission, surveillance and control. The public health threat posed by imported viruses and invading mosquitoes is a major pre-occupation of local, state and federal governments.

Special containment facilities that enable studies on mosquito-borne diseases should have a very high priority. These premises must have the capacity to facilitate work on basic biology and ecology, as well as insect-pathogen interactions. They must prioritise access to those mosquitoes and virus strains that represent the greatest current and future risks. In this context, the streamlining of the

permissions process (granted by the Animal and Biological Imports Assessment Branch, DAWR) should also be a priority. In response to the Zika threat, for example, obtaining an import permit for QIMR Berghofer took 9 months, and the In Vivo Approval to work on mosquitoes and quarantine strains of Zika has not yet been approved despite the involvement of an experienced and dedicated administrative team at the Institute. These delays can put Australia at a considerable competitive disadvantage.

Drivers of mosquito invasion and disease transmission are regional and international. Containment facilities should be used to understand those drivers. We are continually approached by partners in the Asia-Pacific region to work with them on understanding transmission threats. The process of gaining permits is so unwieldy that we have so far been unable to capitalise on these collaborations.

- **Others**

Other emerging directions and research infrastructure capabilities that should be considered include:

- Shifting the focus from disease to health: Prevention is better than cure. Chronic diseases account for the bulk of health expenditure in Australia, and most are preventable with current knowledge. We need to find better ways to ensure more Australians have access to effective prevention strategies.
- Development of advanced heath research and translation centres (AHRTCs) to integrate research into clinical practice.
- The need to develop research career structures that are internationally competitive and maximise the return on investment in training researchers.

Question 16: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

In the case of genomic data a collaborative project which Australia should engage with is the Global Alliance for Genomics and Health (GA4GH). The NHMRC and several Australian institutes (including QIMR Berghofer) are already members of the GA4GH which is building a framework to enable effective and responsible sharing of genomic and clinical data.

Further examples of international infrastructure collaborations include the US National Cancer Institute 'Cancer Moonshot' Program, the International Cancer Genome Consortium, The Cancer Genome Atlas, The Malaria Vaccine Initiative, among many others. These are all areas in which Australian scientists and institutions have internationally-recognised reputations for excellence, and for which our global contribution in terms of volume of output far outstrips our relative population size.

Question 17: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Health and Medical Sciences capability area?

Ideally, Australia would build 'soft infrastructure' into the health care system so that every patient admission was viewed as a 'research event'. All data from every patient admission should be available (de-identified) for research and evaluation. By standardising consent forms, ethics and governance processes into a single 'standard operating procedure', Australia should be aim to

engage the public in medical research. Similarly, the Medicare and Pharmaceutical Benefits Schemes (PBS) datasets are vast repositories of information that should be made available routinely for research and analysis.

Environment and Natural Resource Management

Question 18: Are the identified emerging directions and research infrastructure capabilities for Environment and Natural Resource Management right? Are there any missing or additional needed?

QIMR Berghofer believes capability in researching the health impacts of climate change could be further developed.

Question 19: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

QIMR Berghofer has no comment at this time.

Question 20: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Environment and Natural Resource Management capability area?

QIMR Berghofer has no comment at this time.

Advanced Physics, Chemistry, Mathematics and Materials

Question 21: Are the identified emerging directions and research infrastructure capabilities for Advanced Physics, Chemistry, Mathematics and Materials right? Are there any missing or additional needed?

QIMR Berghofer has no comment at this time.

Question 22: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

QIMR Berghofer has no comment at this time.

Question 23: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Advanced Physics, Chemistry, Mathematics and Materials capability area?

QIMR Berghofer has no comment at this time.

Understanding Cultures and Communities

Question 24: Are the identified emerging directions and research infrastructure capabilities for Understanding Cultures and Communities right? Are there any missing or additional needed?

The emerging directions and capabilities are all supported, especially innovation and translation; and greater access to data through cultural, national and state institutions. QIMR Berghofer has established programs in Indigenous Health Research and has world-class expertise in genetics and genomics. We strongly support the proposals to development agreement and harmonisation of policies and procedures to gather, link and share data.

Question 25: **Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?**

QIMR Berghofer has no comment at this time.

Question 26: **Is there anything else that needs to be included or considered in the 2016 Roadmap for the Understanding Cultures and Communities capability area?**

QIMR Berghofer has no comment at this time.

National Security

Question 27: **Are the identified emerging directions and research infrastructure capabilities for National Security right? Are there any missing or additional needed?**

QIMR Berghofer supports the comments relating to national security, noting that biosecurity has particular relevance for health and disease control, while cyber security has particular relevance to clinical big data and how/where we store the patient derived data. In the case of cyber security, capabilities and security within cloud services (within and outside of Australia) need to be understood as it is likely that patient derived big data, for example genomic data, will continue to increase. A significant increase in the data will mean that the computational resources required for analysis may be provided more cost-effectively in a cloud environment than in dedicated computing centres within Australia.

We note that the Defence Trade Controls Amendment Act imposes some limits on the transfer of materials or information to external parties. The implications of this Act must be considered when formulating research infrastructure policy.

Question 28: **Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?**

QIMR Berghofer has no comment at this time.

Question 29: **Is there anything else that needs to be included or considered in the 2016 Roadmap for the National Security capability area?**

Biosecurity and cyber security are important issues that have to be considered.

Underpinning Research Infrastructure

Question 30: **Are the identified emerging directions and research infrastructure capabilities for Underpinning Research Infrastructure right? Are there any missing or additional needed?**

QIMR Berghofer supports the comments relating to high performance computing (HPC), high capacity networks, eResearch infrastructure and digitisation. In addition to the physical computer infrastructure located at the existing HPC sites increased capacity through access to cloud-based compute providers should also be considered.

The connectivity within Australia and from Australia to overseas should be improved, as the speed at which large data can be moved between institutes and centres within Australia, and between Australia and the rest of the world, is frequently inadequate.

Question 31: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

QIMR Berghofer has no comment at this time.

Question 32: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Underpinning Research Infrastructure capability area?

QIMR Berghofer has no comment at this time.

Data for Research and Discoverability

Question 33 Are the identified emerging directions and research infrastructure capabilities for Data for Research and Discoverability right? Are there any missing or additional needed?

QIMR Berghofer supports the comments relating to data.

In the case of medical data, there are vast tracts of health data held in archived storage which could be harnessed for public-good research. Access to those datasets has been virtually impossible for health researchers, yet the potential for benefit is very high. Similarly, existing clinical and population health studies would benefit from linkage to those datasets, yet the barriers to access are very great.

Enabling access to those datasets in such a way as to preserve individual privacy but allow legitimate research conducted in an ethical manner would place Australian research at a competitive advantage. Very recently, Medicare Australia has made available a tranche of de-identified health-related data for 10% of the Australian population. This is an extremely promising step in making big data available for unspecified research purposes. The full benefits of releasing these data have yet to be realised, but it is hoped that more datasets of similar scale will be made available in the future.

Question 34: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

In the case of human genomic data a collaborative project which Australia should engage with is the Global Alliance for Genomics and Health (GA4GH), which is building a framework to enable effective and responsible sharing of genomic and clinical data.

Question 35: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Data for Research and Discoverability capability area?

QIMR Berghofer has no comment at this time.**Other comments**

QIMR Berghofer believes an expansive view of what constitutes 'infrastructure' is necessary for a comprehensive roadmap. The points below set out QIMR Berghofer's thinking on the need for hard and soft infrastructure, as well as small- and large-scale infrastructure.

In the area of biomedical research, we feel that national infrastructure could be strengthened in the following areas:

1. Small-scale infrastructure
2. Soft infrastructure
3. National-scale infrastructure

Small-scale infrastructure

Despite having world-class research institutions, Australia lacks high-tech industry clusters found in other parts of the world, e.g. around Cambridge or Harvard. There is an opportunity to capitalise on the small-scale infrastructure owned by individual research institutions and used almost exclusively by internal clients. By using a voucher scheme to confer 'preferred provider' status on institutions with suitable infrastructure, government could facilitate the development of industry clusters. This could be outside, but coordinated with, the current formally designated and funded NCRIIS centres and would expand access and solve some geographical constraints.

For example, QIMR Berghofer either owns or is a partner in a range of small-scale infrastructure that could be opened to commercial users, potentially through such a government-supported voucher scheme. This could facilitate the development of industry clusters around the Herston health precinct.

QIMR Berghofer-related small-scale infrastructure includes:

Q-Gen Cell Therapeutics, a TGA-licensed GMP manufacturing facility. This is particularly important for the development of novel Immunotherapies and Cell Therapies. An expansion of this type of facility to the national level will likely be required in the future (see below) to match growing demands.

QIMR Berghofer insectary, a high-security quarantine facility that is/will be essential in research to protect Australia from emerging mosquito-borne diseases.

Herston Imaging Research Facility (HIRF), a $24 million state-of-the-art imaging centre backed by QIMR Berghofer, The University of Queensland, QUT, the Royal Brisbane and Women's Hospital and Siemens.

Soft infrastructure

There are significant gains to be made through improvements to 'soft infrastructure', such as capitalising on data, knowledge and networks; standardising policies, procedures and processes; and reducing the administrative burden. Examples include:

- Viewing every patient admission as a 'research event'. Ideally, all patient data from every admission would be available (de-identified) for research and evaluation (for accredited

researchers with all the usual safeguards). Billions are spent on delivering healthcare and recording data, yet there is almost no evaluation or meta-analysis of that data to improve health outcomes.

- Similarly, the Medicare and Pharmaceutical Benefits Schemes (PBS) datasets are vast repositories of information that should be mined – undoubtedly there would be major discoveries awaiting the aware researcher. With suitably designed research infrastructure, e.g. a national health data linkage clearing house, these datasets could be exploited to permit their interrogation, while safeguarding patient confidentiality. As noted above, the first release of such data has been announced.

- Standardising consent forms, ethics and governance processes into a single 'standard operating procedure' for engaging the public in medical research. The Australian Health Ethics Committee (NHMRC) could take leadership in this area. A national statement on ethics and the NEAF have been developed previously by NHMRC, so a single SOP to enable this is the next logical step. This would yield huge improvements to competitiveness in the translational sciences.

- Linking established biobanks into a national network with standard governance procedures to establish central tissue repositories and thereby turning an expensive under-utilised product into a valuable resource. Under such a national system for collecting and biobanking human tissue samples, researchers would still collect their own samples, but a standard for data gathering and sample curation would assist in the sharing of materials and would help expand collaborations. The regulatory framework would need to be more efficient to enable this.

- Academic health centres (e.g. the Advanced Health Research and Translation Centres) in which clinicians and researchers work side-by-side are being certified by the NHMRC and require funding as they would also constitute vital infrastructure investments.

- Australia could establish a 'virtual national library subscription' to facilitate cheaper access to journals. Currently, publishers negotiate separately with each institution, at immense cost to Australia's institutions collectively.

National-scale infrastructure

Frequently-used facilities are usually best located locally. However, some facilities are so expensive or so specialised that they are best housed in central locations. Suggestions for facilities best located centrally and best delivered nationally include:

- National sequencing infrastructure – with an expected increase in genomic testing, national sequencing infrastructure may be best supported by strengthening facilities that are already strong in this area.

- National computational infrastructure – to enable access to computational capability, software tools and data. A wealth of data will be generated over the next 10 years and this will create enormous data storage and computational issues. It is essential to have very large scale data storage and handling capacity to handle future needs at a reasonable cost. The last decade has seen a growth in data that is far greater than what was anticipated, so future plans need to be ambitious.

- National (clinical) genomic data warehouse – to house genomic information with patient clinical data to allow genotype to phenotype correlations to occur. Australia should also take advantage of international efforts in this area.

- Clinical bioinformatics network – to train and educate researchers and the clinical workforce in the use of large-scale data.
- Functional genomics facility – to validate the functional consequence of genomic variants i.e. preclinical mutant models, CRISPR.
- Cellular Therapy Manufacturing Facilities. There is rapid growth occurring in the use of Cell Therapies for a range of clinical conditions. Some of these are based on adoptive immunotherapy where T Cell populations are stimulated *ex vivo*. Others (in a rapidly advancing area of research) are developing CAR-T cells that increase the linkage between the tumour target and the T Cells. A third development of this kind is the modification of bone marrow stem cells to provide greater safety for the patient in transfusions. In every case a GMP level facility is required to safely manufacture the cellular therapeutics. The Q-Gen Cell Therapeutics suite (see above) is such a unit and could be expanded to meet national needs

National-scale facilities should be adequately resourced, focussed on the needs of users, genuinely open to external users and properly promoted so that potential users are aware of the service.