

# THE HERSTON BIOFABRICATION INSTITUTE

Metro North Hospital and Health Service  
*Putting people first*





## SETTING THE SCENE

The Herston Precinct Strategic and Integrated Framework for Renewal identified a range of strategic service opportunities for the Herston Precinct (and specifically the Royal Brisbane and Women's Hospital).

One of these, the Herston Biofabrication Institute, will bring together clinicians, scientists, researchers and engineers on one of the largest integrated health, teaching and research precincts in Australia to focus on developing next generation fabrication technologies combined with biological systems in three key areas:

- medical data acquisition and 3D clinical imaging
- computational medicine, 3D modelling and visualisation
- 3D cell culture and advanced manufacturing to create engineered tissue platforms/constructs.

Metro North Hospital and Health Service and QUT, in collaboration with academics and researchers, industry partners and government are pursuing the development of the Herston Biofabrication Institute to realise the transformational opportunities presented by the emerging and dynamic field of biofabrication.



“This world-leading institute will accelerate the convergence of biofabrication technology innovation and biological systems knowledge leading to novel medical solutions. This provides a unique opportunity to transform current thinking and pursue collaborative innovation within the world-class health, scientific, research and industry corridor of Brisbane.”

# WHAT IS BIOFABRICATION?

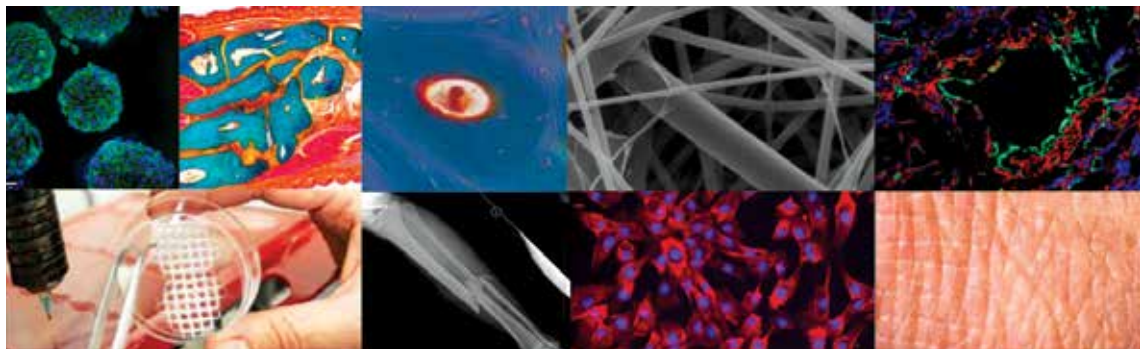
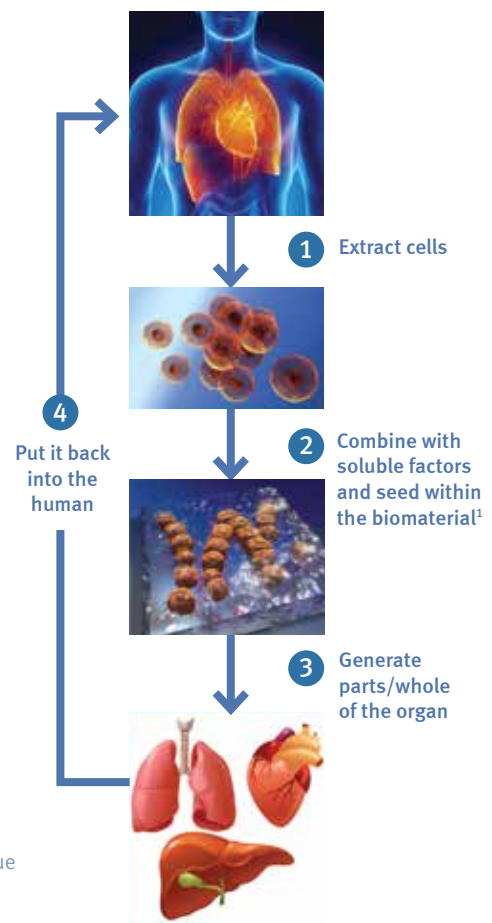
The hospital of the future will incorporate revolutionary technologies that will transform healthcare, delivering highly automated, personalised and customised patient solutions using advanced manufacturing.

These advances will lead to lower health costs, improved access to the best treatments and better health outcomes and quality of life for individuals and society.

Biofabrication sits at the convergence of biology and engineering, applying 3D technologies to medicine. It involves strong collaboration across the fundamental sciences of chemistry, biology, physics, technology disciplines, engineering and applied clinical practices.

Biofabrication research aims to apply engineering principles to regenerative medicine, to find better ways to solve complex medical problems through the novel use of platform technologies, and understanding of cell and tissue function and behaviour.

**Image credit:** Bajaj, Piyush et al. "3D Biofabrication Strategies for Tissue Engineering and Regenerative Medicine." *Annual review of biomedical engineering* 16 (2014): 247–276. PMC. Web. 16 Nov. 2016. Image courtesy of PMC. Reproduced with permission.



Advances in biofabrication technologies are driven by fundamental research investigating the nature of tissue and cell behaviour, biomaterials, and the interaction between natural and engineered structures.

It involves the development of new biomaterials, novel ways to interface these with natural tissue, and techniques to understand and create new ways to grow 3D tissue structures using

advanced imaging, cell and tissue analysis, microscopy, micro-computed tomography, magnetic resonance imaging, and pre-clinical models and scaffold/tissue histological analyses.

This will ultimately lead to the development of newly generated tissue constructs and implants that will undergo clinical trials and be commercialised in partnership with industry.

# BIOFABRICATION PLATFORM TECHNOLOGIES

Biofabrication related technologies can be broadly grouped into three areas:

- Clinical 3D imaging
- Computational medicine and 3D computer modelling
- 3D printing/bio-printing and advanced manufacturing.

**Clinical 3D imaging** involves patient scanning techniques from advanced magnetic resonance micro-imaging, computed tomography techniques, 3D laser scanning, low-cost 3D photogrammetry, and motion capture for patient movement analysis. These technologies are key to acquiring the highly accurate 3D patient information required for high levels of healthcare personalisation.

**Computational medicine and 3D computer modelling** are vital for developing solutions to treat individual patient needs. Visualisation technologies have potential to improve clinical capabilities through personalised surgical analysis and planning. This includes the use of novel customisable computer models of relevant patient anatomy for patient specific tissue repair. Future medicine will also be enhanced through the use of machine learning to assist with clinical analysis and diagnostics, enhanced surgical/robotic vision, and the emerging technologies of virtual and augmented reality. Computational medicine also includes the development of software, electronics and robotics hardware for next generation robotic surgery and bionics.

**3D printing/bio-printing and advanced manufacturing** are key future technologies that will revolutionise healthcare. Research in this area aims to produce biologically-relevant, anatomically-precise 3D printed constructs for the repair of damaged or lost patient tissue. This includes the use of customised permanent metallic implants, biodegradable scaffold-based tissue regeneration, and 3D printed personalised prosthetics and bionics. This technology also has numerous other applications such as the development of customised radiation treatment devices, personalised splints to improve tissue repair, temporary patient specific ear and nose prosthetics and design and print of anatomically precise surgical drill-and-saw guides for spinal and orthopaedic procedures.

## CLINICAL 3D IMAGING



- 3D Laser/Structured-light Scanning
- 3D Photogrammetry Scanning (SfM)
- Clinical Scanning (MRI/CT/PET)
- 3D Motion Capture for Diagnostics
- 3D Ultrasound CT
- Advanced Clinical Imaging



## COMPUTATIONAL MEDICINE



- 3D Anatomical Modelling
- Customised Implant Designs
- Virtual and Augmented Reality
- Machine Learning for Diagnostics
- Medical Robotics/Bionics
- Surgical Visualisation
- Virtual and Augmented Reality



## 3D PRINTING TECHNOLOGIES



- Biofabrication and Cell Printing
- Tissue and Organ Printing
- 3D Printing Polymer Scaffolds
- 3D Printing Metallic Implants
- 3D Plastic Printing Splints
- 3D Printing Prosthetics
- 3D Printing Semiconductors
- 3D Printing Radiotherapy Shields
- 3D Printing for Surgical Planning

# WHAT WILL THE HERSTON BIOFABRICATION INSTITUTE DO?

The concept of biofabrication is simple: capture detailed 3D information about the patient's condition, process that information on a computer to enable personalised treatment, then use 3D printing technologies to automatically produce a biologically, mechanically and anatomically customised solution.

## TRANSFORM HEALTHCARE

The Herston Biofabrication Institute will develop bioengineered constructs/tissues which are harmonised with the body's own regenerative capacity and will transform how we provide healthcare in the future.

The Institute will draw on the expertise of multi-disciplinary teams, collaborating with patients, clinicians, academic, research, and industry partners to pursue innovative approaches to complex clinical issues/problems which disrupt traditional thinking and approaches to healthcare.



## CENTRE FOR ADVANCED MANUFACTURING

The Herston Biofabrication Institute will represent a new era for advanced manufacturing in Queensland and Australia, combining biology, medicine, chemistry, engineering, bionics, robotics, and computing to create new bioengineered constructs and medical devices. The Institute will fill a void left by the recent contraction of advanced manufacturing disciplines in Australia, and represents a new era in the Advance Queensland agenda to transition the economy towards the jobs of the future.

## GROW QUEENSLAND'S SCIENTIFIC FOOTPRINT

The Herston Biofabrication Institute will contribute to the Queensland Government's objective to grow and advance Queensland's global scientific footprint. It provides a catalyst for renewed industry engagement to bring biotechnology, robotics, advanced manufacturing, mechatronics (a unified engineering platform), advanced manufacturing, and other 'smart' industries to Queensland.

## A CATALYST FOR ECONOMIC GROWTH

The Herston Biofabrication Institute will be a catalyst for economic growth in Queensland and Australia through the development of new bioengineered constructs/products and new medical devices, attracting pre-industry and industry partners to Queensland, and developing and commercialising its intellectual property.

## TRANSFORM EDUCATION AND TRAINING

The Herston Biofabrication Institute will change how we educate and train people, offering new inter-disciplinary training pathway for our future clinicians, scientists, engineers, mathematicians, and entrepreneurs which are not currently available in Australia.

This includes providing:

- a training pathway for high school students interested in combining their skills across Science, Technology, Engineering and Maths (STEM) disciplines
- new vocational pathways for under-graduate and post-graduate trainees to equip them with the complex skills required for the future
- new development pathways to continue to evolve the skills of the existing workforce around the changing fields in medicine.

# THE HERSTON BIOFABRICATION INSTITUTE

The Herston Biofabrication Institute offers a breadth of application and depth of possibility which cuts across a diverse range of service partners and sectors. There are five pillars to the Institute, illustrated below.

**Clinical:** The Herston Biofabrication Institute will play a critical role in the discovery, translation, and delivery of new and innovative clinical services as part of an integrated and multidisciplinary team. It will represent an extension of the clinical model of service programs at the Royal Brisbane and Women's Hospital and on the Herston Precinct.

**Education and Training:** The Herston Biofabrication Institute will employ a highly skilled and multi-disciplinary team, and have capacity to accommodate a dynamic team structure which is responsive to new opportunities and the changing dynamics within the field of biofabrication.

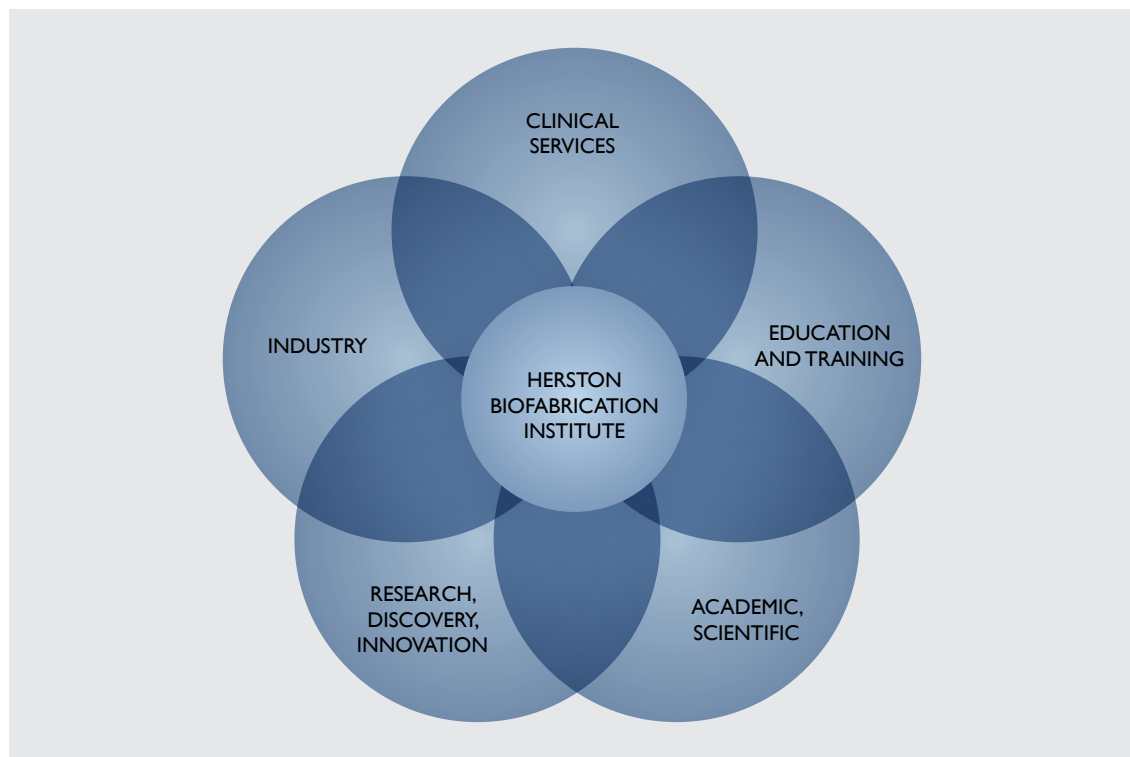
It will serve as an education and training pathway for a comprehensive and diverse range of vocations based around the future paradigm of service delivery, training our next generation workforce to develop, adopt and commercialise new technologies to enhance patient and community health outcomes and quality of life.

**Academic, Scientific:** The Herston Biofabrication Institute will provide a hub for a world-leading academic and scientific collaboration of people, expertise, ideas, applied research, and partnership, which is at the forefront of the advancement of biofabrication technologies.

**Research, Discovery, Innovation:** The Herston Biofabrication Institute will be at the cutting edge of research, discovery and innovation through its linkages with the clinical environment, academic, research and industry partners.

It will pursue an 'accelerated model' which brings together the people, sciences and processes to support translation into new therapies, devices and applications.

**Industry:** The Herston Biofabrication Institute will form foundational relationships with industry partners to develop and realise its discoveries, deliver the broadest social and economic benefit, and capture the commercial value of its intellectual property.



# WHAT WILL BE PROVIDED IN THE HERSTON BIOFABRICATION INSTITUTE?

The Herston Biofabrication Institute will provide a diverse range of spaces which enable collaboration between patients, clinicians, multi-specialty teams, and a range of services partners in the pursuit of the Institute's ambitions and functions. These spaces may include, but are not limited to, the following:

## PATIENT INTERFACE ZONE

The interface between patients and the Institute is critical. A diverse range of patient interface areas will be provided to support patients coming into the Institute for consultation, counselling, diagnostics, care planning, and treatment evaluation.

Metro North Hospital and Health Service is the largest public provider of health services in Australia. The Herston Precinct is one of the largest integrated health, research and education Precincts in Australia, and the Royal Brisbane and Women's Hospital is the largest referral hospital in Queensland.

This scale will provide the Herston Biofabrication Institute access to large patient volumes and a depth of clinical content which is an essential part of establishing, developing, evaluating, and advancing the services it offers.

## DISCOVERY, INNOVATION, AND INDUSTRY HUB

The discovery, innovation and industry hub will provide a central, flexible, and transformable zone which encourages collaboration between clinical staff, broad multi-specialty teams, researchers, industry partners, and other external partners around clinical issues, and seed the next innovative research idea and clinical application. The hub will include a virtual network allowing people to engage anywhere in the world.

## EDUCATION HUB

The education hub will provide a focal point for the education activities and ambitions of the Institute. It will include a range of flexible work spaces for students and meeting and education spaces which will support the Institute to engage with schools and stimulate interest in the STEM disciplines, and to have ongoing engagement and connection with the public.

## BIOFABRICATION AND ADVANCED MANUFACTURING LABORATORY

Developing the latest 3D bioprinting platforms and advanced manufacturing is a major focus of the Institute's research. This includes developing proprietary hardware and software for the precise control of the entire fabrication process, for example, technologically advanced 3D printers capable of creating the most clinically relevant implants at cellular resolutions.

These technologies are key to enabling personalised biofabrication solutions to complex medical conditions, from permanent implants to biodegradable tissue replacement constructs and cell printing.

Researchers, working alongside clinical teams, will come together to better understand the major challenges in tissue engineering with the aim of achieving routine fabrication of personalised living replacement tissue constructs.

This laboratory will also develop 3D printing approaches for use by clinicians such as low-cost prosthetics and orthotics, surgical guides, surgical models for treatment planning and patient communication and the application of advanced manufacturing in areas such as radiation therapy.



## TISSUE ENGINEERING LABORATORY

A state-of-the-art environment will be available for the in-depth study of 3D tissue scaffold performance and tissue growth. Scaffold and cell/tissue analysis laboratories will contain the relevant equipment for routine cell culture and analysis and storage of cells and tissue constructs including microscopy and cell assay equipment.

Another focus of the tissue engineering research laboratory is the development of biocompatible and bioactive materials, new cell and tissue integration techniques, and the development of efficient bioreactors for tissue growth in scaffolds. This research forms an integral part of the Institute's research to harmonise the degradation rates of biofabricated tissue constructs with the healing rate of different tissue within the patient.

Implants that are developed may be pre-clinically tested and implanted via close links with the Medical Engineering Research Facility at The Prince Charles Hospital campus. The histological analysis of cell and tissue constructs and implanted scaffolds will also be enabled via collaboration with QUT's Institute of Health and Biomedical Innovation in Kelvin Grove.

## CLINICAL SCANNING AND VISUALISATION LABORATORY

Critical to enabling personalised biofabrication-based medical treatment is the accurate measurement of 3D patient information. The clinical scanning research laboratory will develop novel 3D image and motion capture technologies to rapidly and non-invasively acquire high fidelity 3D patient information.

This includes portable and rapid 3D surface scanning techniques for clinical and surgical applications and 3D motion capture technologies to enable dynamic analysis of human movement for diagnostics and research.

Also within this space will be a 3D virtual reality area which will form part of one of the most advanced surgical training pathways in Australia by creating a more immersive visual and haptic environment which mirrors the operative experience.

## 3D MODELLING AND COMPUTATIONAL MEDICINE LABORATORY

3D modelling and computational medicine technology enables the critical link between patients, their condition, and the ability to provide customised clinical treatments. This technology will give healthcare professionals powerful tools to analyse 3D patient data and produce dynamic 3D models for use in custom implants and tissue engineering fabrication, 3D printing of surgical models, custom splints, prosthetics and orthotics, and virtual and augmented reality environments for surgical planning and patient consultation.

Within this laboratory, space for developing the next-generation of clinical computational tools such as artificial intelligence and machine learning will be available with applications in diagnostics, robotics and bionics.

The collection, management, and analysis of mass data is also critical to the Herston Biofabrication Institute. A central analytics and coding centre will form part of the Institute, employing a highly skilled computing scientist workforce which provides a pivotal interface between the different technology platforms of the Institute. The computational medicine laboratory will be supported by an electrical and mechanical engineering facility for hardware innovation in computation, robotics, and sensing.

## HEALTH ECONOMICS NODE

The Herston Biofabrication Institute will have a health economics node to evaluate and measure the economic impact of the Institute's products, and bring this together with Australia's regulatory framework.

Key partnerships which will be pivotal to this node, and define the potential application of the Institute's products within the population, including the Australian Centre For Health Services Innovation at the QUT Institute for Health and Biomedical Innovation, and the Clive Berghofer Queensland Institute of Medical Research epidemiology team.

# CLINICAL APPLICATIONS OF BIOFABRICATION

## 3D RADIO THERAPY TREATMENTS

The application of biofabrication to radiotherapy will improve outcomes and reduce patient discomfort through the development of 3D patient scanning and 3D printing technology to non-invasively fabricate personalised radiotherapy bolus and shielding options.

The radiotherapy bolus is used to help attenuate the beam so the dose is delivered in a controlled manner. It is important that the bolus conforms to the personal geometry of each patient and the treatment plan to shield healthy tissue and optimise treatment.

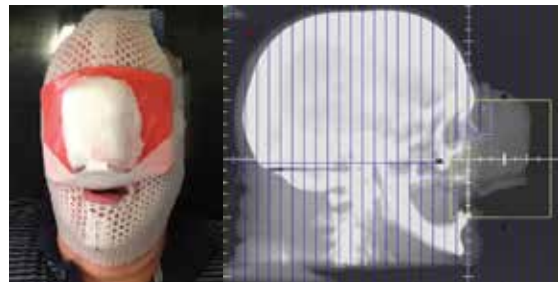


Image credit: Rhonda Baer.

3D scanning, modelling and printing technologies are an important innovation to replace the highly invasive manual moulding methods employed now.

### The situation today – traditional, hand-crafted radiation therapy bolus

- imprinting and moulding creates significant discomfort for the patient (the mould is applied to the patient's face at temperatures of around 60-70 degrees)
- requires casting various moulds
- expensive, labour-intensive and time-consuming.



### The future – 3D printed radiation therapy bolus

- 3D image scanning enables non-invasive modelling of the patient
- 3D model is ready for analysis to compute radiation profile
- 3D printed bolus improve the patient's care experience.

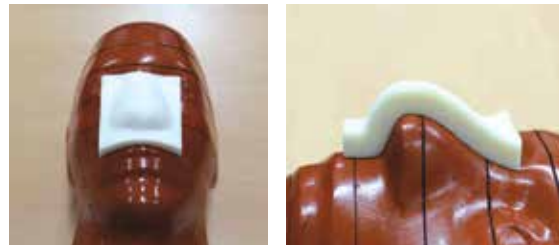
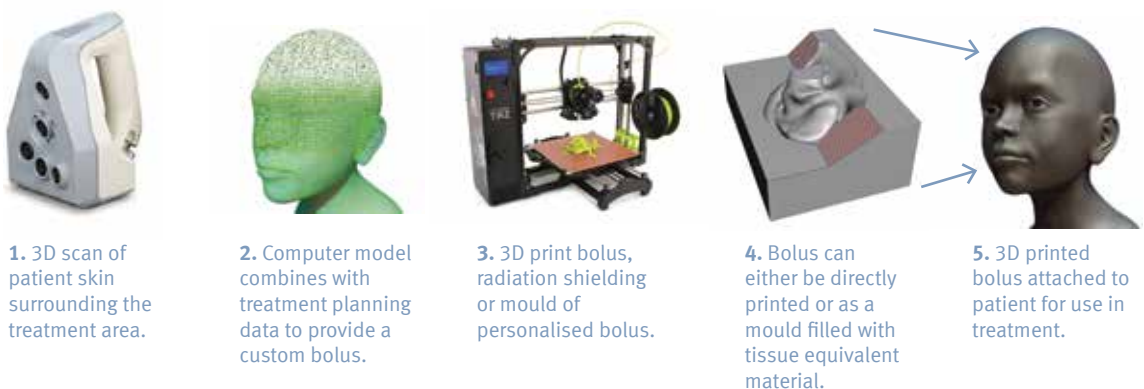


Image credit: Kim SW, Shin HJ, Kay CS, Son SH (2014) A Customized Bolus Produced Using a 3-Dimensional Printer for Radiotherapy. PLOS ONE 9(10): e110746. doi: 10.1371/journal.pone.0110746. Reproduced with permission.

## PERSONALISED MEDICINE EXAMPLE: 3D PRINTED RADIO THERAPY BOLUS



## CLINICAL APPLICATIONS OF BIOFABRICATION (CONTINUED)

### 3D PRINTED PROSTHETICS, ORTHOTICS AND BIONICS

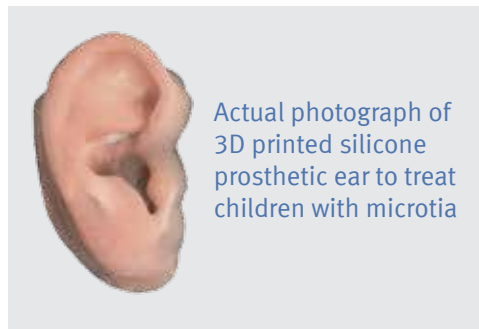
Biofabrication technology has significant potential to improve the production of prosthetics offering highly personalised solutions, life-like outcomes, and lower costs compared with manual techniques. This is particularly important in the case of prosthetics for craniofacial deformities such as ear prosthetics for children with microtia (a congenital condition affecting the development of the outer ear). Prosthetics are also used in cases where large regions of the face, nose and eye are missing as a result of tumour resections.

Today, prosthetics are largely hand-made requiring a highly skilled prostheticist who takes a physical mould of the patient's anatomy.

The biofabrication approach non-invasively takes 3D scans of the patient which are then used to produce a computer model of the personalised prosthetic. The model is used to drive a 3D printer which can automatically produce the prosthetic. Another significant advantage of the use of 3D printers for prosthetics is the ability to make complex multi-layer multi-material prosthetics.



Two year old Maia was born with microtia.



Actual photograph of 3D printed silicone prosthetic ear to treat children with microtia



## CLINICAL APPLICATIONS OF BIOFABRICATION (CONTINUED)

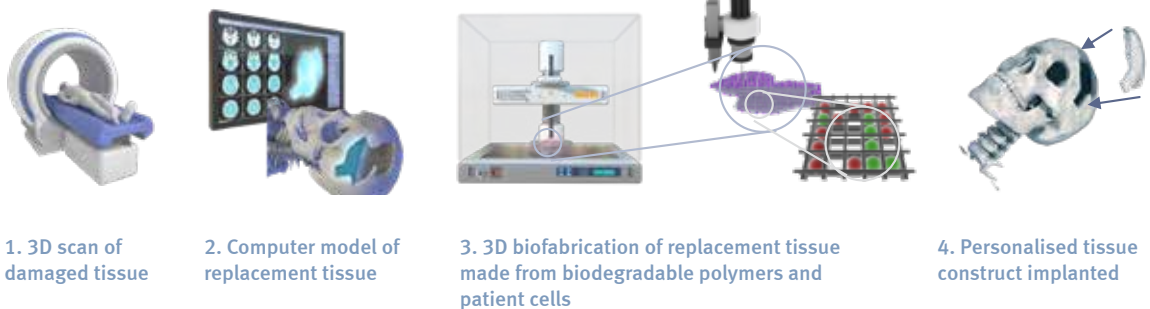
### BIOFABRICATION IN ORTHOPAEDICS

3D printing and biofabrication has direct application in treating many orthopaedic conditions. It is already used in many surgeries worldwide, enabling customised permanent metallic and ceramic implants improving patient outcomes and lowering costs.

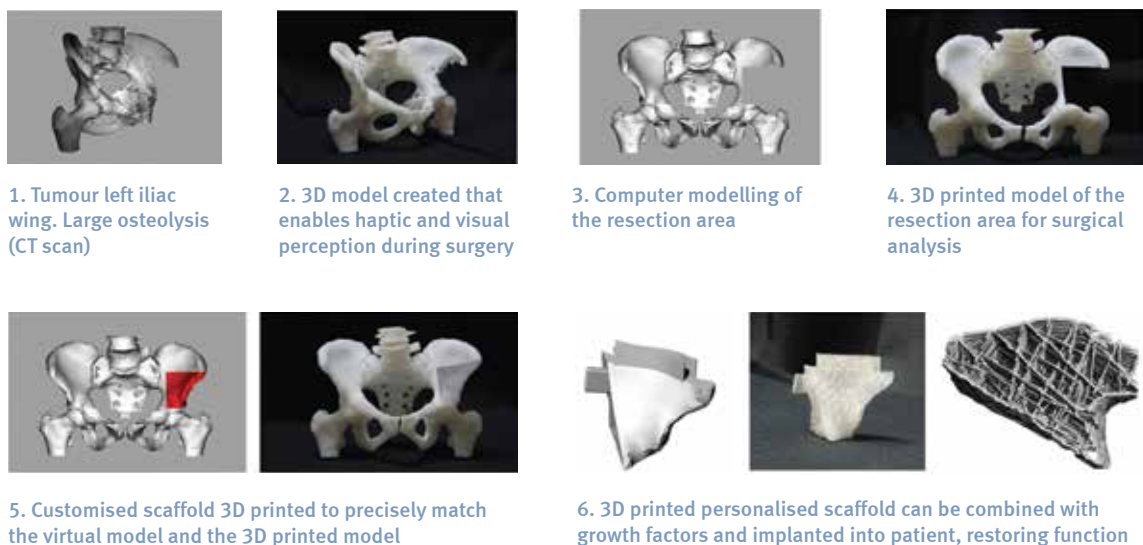
An exciting area of clinical application is in the use of 3D printed biodegradable polymers with cellular resolutions customised to the patient's anatomy. The patient's own cells and growth factors can be selectively printed into the polymer scaffold which is then placed in a bioreactor to establish tissue growth. The replacement tissue construct can then be surgically implanted into the patient where the biodegradable polymer slowly degrades as new tissue forms completely restoring the patient's damaged or missing tissue. 3D printing also has important application in surgical planning and patient communication; particularly important for complex surgeries.



### TISSUE REPLACEMENT



### SURGICAL PLANNING, ANALYSIS AND TISSUE ENGINEERING



**Image credit:** Boris Michael Holzapfel, et al., Sarcoma, 2013, 153640. Reproduced with permission.

# OTHER CLINICAL APPLICATIONS OF THE HERSTON BIOFABRICATION INSTITUTE



## 3D tissue surface scanning

- craniofacial deformities
- physiological analysis
- soft tissue damage
- burns



## Medical robotics and bionics

- robotic assisted surgery
- bionic limbs
- robotic endoscopies
- tissue engineering support



## 3D printing in orthopaedics

- surgical models
- surgical guides
- personalised splints
- orthotics and prosthetics



## 3D computer modelling

- personalised scaffolds
- prosthetic design
- radiation therapy models
- physiological analysis



## Computation and machine learning

- image analysis
- bionic limbs
- robotic endoscopies
- tissue engineering support



## 3D printing tissues

- tissue engineering
- personalised implants
- bone, skin, cartilage, blood vessels, cell printing and organs



## Advanced technology platforms

- new software development
- new hardware
- advanced engineering



## Augmented/virtual reality

- surgical consultations
- surgical training
- immersive patient experiences
- facial recognition and reconstructive surgery planning



## 3D printing temporary wearables

- personalised ear prosthetics
- personalised bolus, shielding and phantoms for radiation therapy treatment

# THE HERSTON BIOFABRICATION INSTITUTE AND THE HERSTON PRECINCT

The Herston Precinct is one of the largest integrated health, research, education, and skills development precincts in Australia. The Precinct provides quaternary and tertiary clinical services for Queensland and Australia, is a critical anchor in educating, training and skills development for the current and future workforces, and undertakes world-leading research and innovation programs.

The co-location of the Herston Biofabrication Institute on the Herston Precinct provides the venue to bring together the critical mass of patients, clinicians, scientists, researchers, engineers, and industry partners into a truly integrated and translational environment.

## HERSTON PRECINCT VISION AND ASPIRATIONS

### The vision for the Herston Precinct is:

A globally eminent health, research, education, training, scientific, and community precinct.

### The aspirations for the Herston Precinct are:

<b>Service Transformation</b>	Transform services around future delivery models which best meet the needs of the community, and which harness opportunities to extend the breadth of service capability and how it is delivered to the community
<b>Integration</b>	Deliver world-class integrated clinical services which drive new ways of working, link to advanced education, training, and research programs and resonate with the community
<b>Innovation</b>	Be recognised as a global leader for its imagination and pursuit of innovation across the domains of health, research, education and training, technology, manufacturing, and capture the value of its collective intellect, capacity, and expertise
<b>Knowledge, Research, Skills</b>	Harness the knowledge, research, and skills of service partners to transform the depth of clinical service delivery, drive broad innovation across industry, and leverage social and economic benefits
<b>Collaborate, Share, Learn, Discover</b>	Promote collaboration, sharing, learning and discovery, harness the expertise, skills, knowledge and commitment of national and international partners, and change the education and training paradigm through an immersive and expansive program which is integrated into clinical care
<b>High Quality Environment</b>	Be fundamentally integrated with its surroundings, provide a connected and highly mobile stimulating environment which supports the pursuit of collaboration, sharing, learning, and discovery

## CRITICAL MASS

The Herston Precinct is one of the largest integrated health, research, and education and skills development precincts in Australia, and home to 13,000 clinical and non-clinical staff, students, scientists and researchers.

There are an expansive range of local, state, national and international partnerships which emanate from the Precinct, and which will be critical to supporting future potential of the Herston Biofabrication Institute.

The Herston Precinct is also a strategic priority for Government, and will be intensified through the Herston Quarter Redevelopment which comprises mixed uses in areas such as health-related activities, bio-medical research, residential and retail spaces.

The Precinct will be one of the most innovative and vibrant places in the world to receive care, work, and live, which will also further the international attraction of the Herston Biofabrication Institute to leaders in the biofabrication field.

## STRATEGIC LOCATION

The Herston Precinct is strategically located within a knowledge, research and innovation corridor in Queensland and is close to the Brisbane CBD. It is a major transport hub and is well-connected by road, rail and tunnel infrastructure to Brisbane's suburbs, the north and south of Brisbane, and Brisbane international and domestic airports.

This will facilitate ease of access to the Herston Precinct, the Herston Biofabrication Institute, and the surrounding amenities for patients, community, staff, and local, state, national and international collaborators.

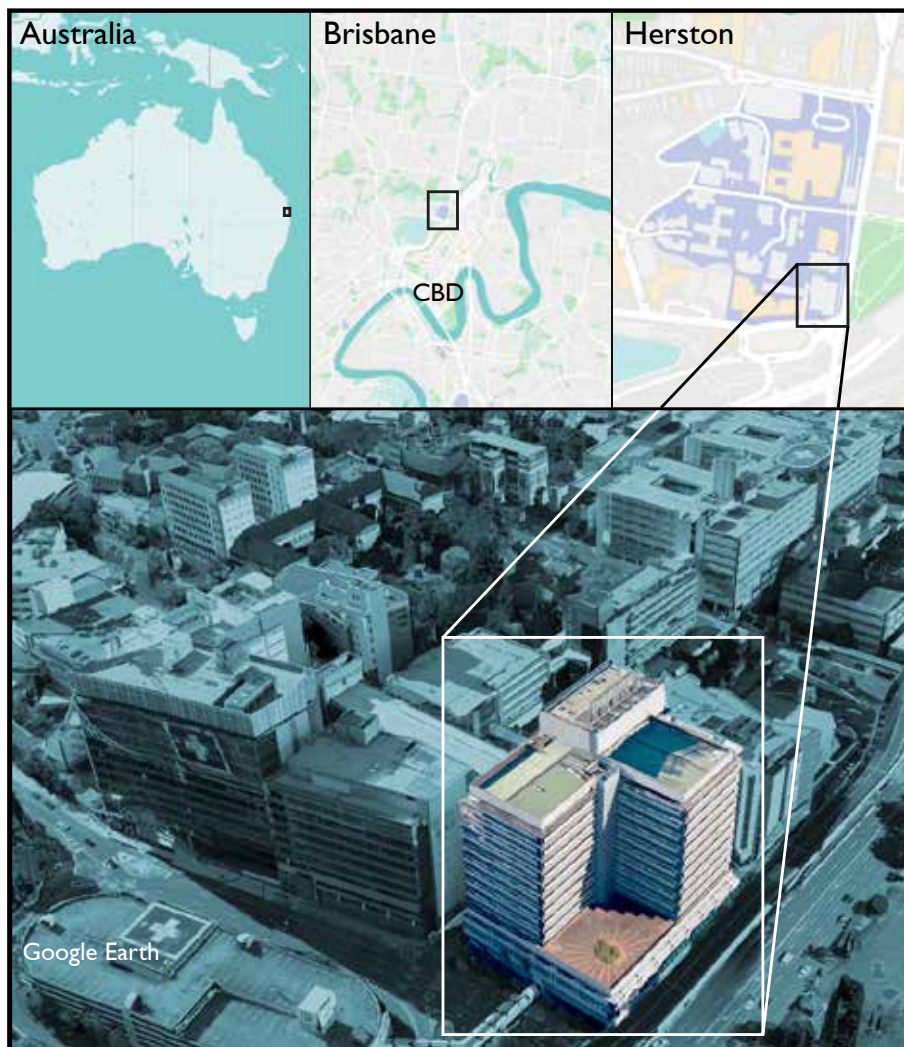


Image credit: Google map data. Reproduced with permission.

## PATIENTS

The footprint of the Herston Precinct, and in particular the Royal Brisbane and Women's Hospital, provides extensive opportunities to partner with patients to support the research mission of the Herston Biofabrication Institute.

### THE ROYAL BRISBANE AND WOMEN'S HOSPITAL

The Royal Brisbane and Women's Hospital provides quaternary and tertiary clinical services for Queensland and Australia, and is the largest referral hospital and public provider for Queensland.

The collocation of the Herston Biofabrication Institute with the Royal Brisbane and Women's Hospital provides an unparalleled depth of integration into the clinical programs of the Royal Brisbane and Women's Hospital in areas such as (but not limited to) burns, cancer, maxillofacial, neurosciences, and orthopaedics.



Image: 3D modelling in the Royal Brisbane and Women's Hospital orthopaedics department, provided by Nic Green and Kevin Tetsworth.

### METRO NORTH HOSPITAL AND HEALTH SERVICE SUPPORT

Metro North Hospital and Health Service is the largest public provider of health services in Australia. Metro North will play a pivotal role in supporting the Institute in relation to:

- forming partnerships, particularly with clinical programs
- committing funding for clinician/scientists to spend time in each of the prioritised clinical programs of the Institute
- appointing skilled workforce positions into each of the prioritised clinical programs including a clinical nurse consultant and Fellowship positions
- contributing recurrent funding to the utility costs of the Institute.



## THE VENUE

The Herston Biofabrication Institute will be located in building 7 on the Herston Precinct. This is located at the junction between the clinical and research zones of the Precinct, and has strong physical connectivity via high, level enclosed links across the Herston Precinct (and with the Herston Quarter Redevelopment).

The location will support collaboration, clinical and research integration, and the movement of a dynamic workforce to and from the Institute.

## WORLD-LEADING RESEARCH

The Herston Precinct is home to world-leading research Institutes including The Clive Berghofer Queensland Institute of Medical Research, The University of Queensland Centre for Clinical Research, and the Herston Imaging Research Facility.

These research institutes also have highly specialised and critical infrastructure which will be vital to supporting translational medicine and the clinical trials required prior to integrating new therapies and treatments into the clinical environment.



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THE HERSTON  
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