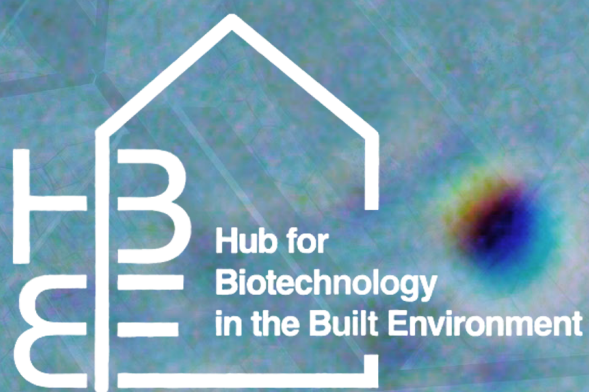
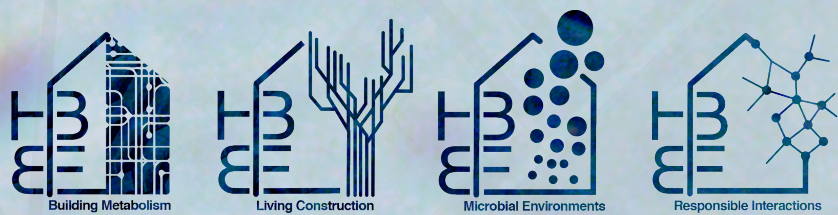


Hub for Biotechnology
in the Built Environment (HBBE)

ANNUAL REPORT 2022





The Hub for Biotechnology in the Built Environment

Table of Contents

Directors Forward	5
Establishment of HBBE Facilities	7
The OME	8
Networks of Collaboration	10
External Networks	12
Emergence of New Research Themes	14
Key Data	16
Appendix of Data	18
HBBE Staff List	24

***"Creating a new generation
of 'Living Buildings'
which are responsive
to their natural
environment"***

***"We look towards the
future of the HBBE with
real optimism, pride and a
renewed sense of mission in
a post-Covid world"***

Directors Forward

This annual report is themed on delivery and renewal. As of writing we now have access to all four of our facilities. From the Omics lab through to the OME we now have the capability of working at all scales from nano to buildings. Most of the (close to 70) staff are now able to work in the Hub for Biotechnology in the Built Environment (HBBE) together 'on site' and meet with each other; this is forging deep collaborations and has already given us significant grant successes. Our access to the OME building, which is a unique research infrastructure, gives us even more reasons to come together and the first building prototypes will be installed in early 2022. With over £33M of research grants submitted in the last year we expect to be able to hit (and hopefully exceed) our funding targets next year, and with over 44 national and international presentations by our HBBE members our international profile is growing.

We also recognise the need to renew our vision. The research landscape and our capacities have changed over the past two years. It has become clear that key to our

sustainability will be our adaptability. The old framework which governed our original grant application for the HBBE is still relevant, but we have also seen the emergence of new ideas.

These developments are reflected in our work sequencing the COVID-19 causing virus as one of the 16 academic partners in the COVID-19 Genomics UK Consortium (COG-UK) initiative to the development of new Special Interest Groups (SIGs) in Bio-futures for Interplanetary Habitats and Mycology for Architecture. These SIGs go beyond our original thematic structure and pose cross thematical questions and new areas of application.

As we are now in the third year of the hub's existence, we look towards the future of the HBBE with real optimism, pride and a renewed sense of mission in a post-Covid world.

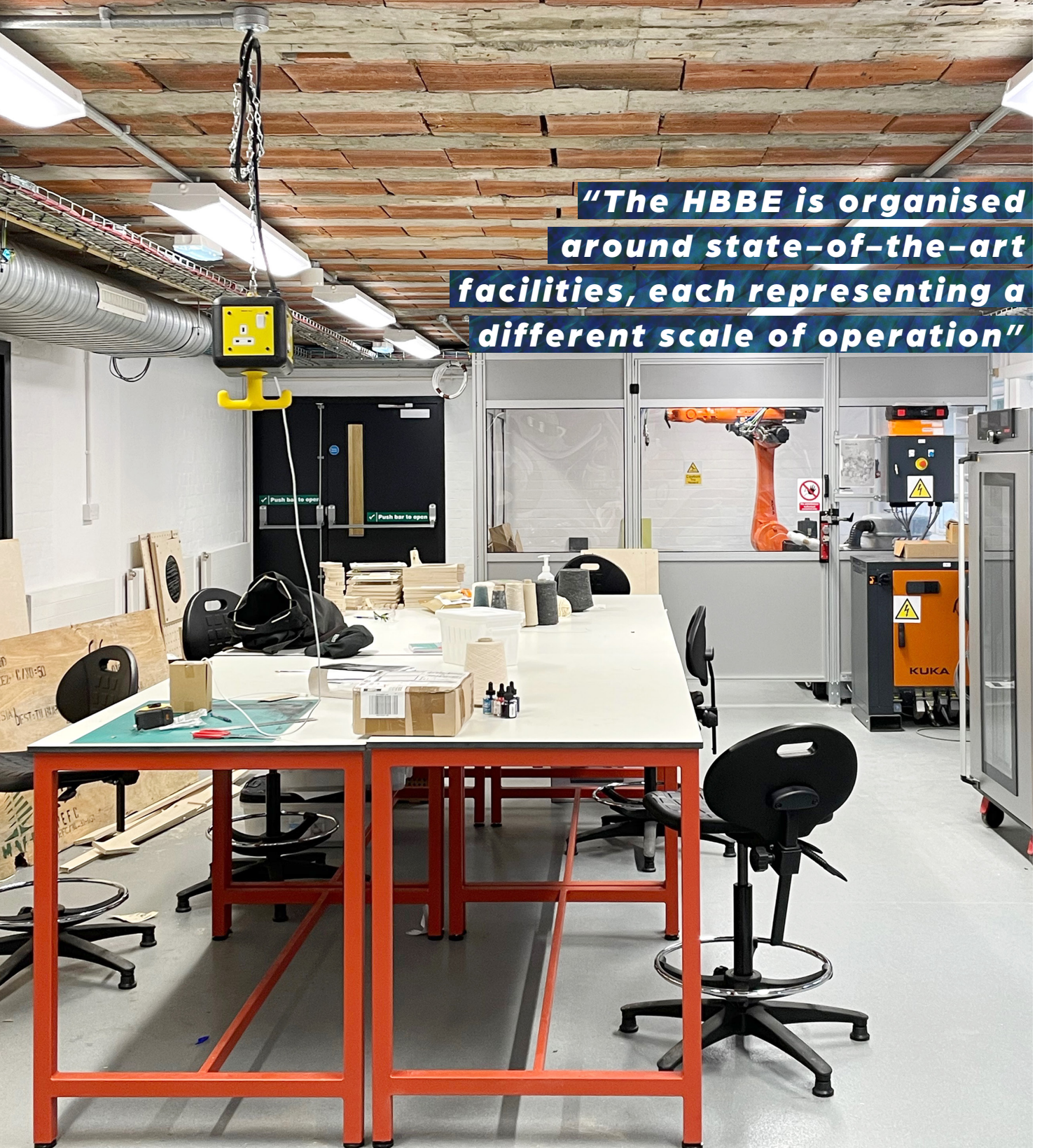


Gary Black
(Northumbria University)



Martyn Dade-Robertson
(Newcastle University)

"The HBBE is organised around state-of-the-art facilities, each representing a different scale of operation"





HBBE Facilities

NEWCASTLE UNIVERSITY

The HBBE is organised around state-of-the-art facilities, each representing a different scale of operation to the analysis and biological engineering conducted at the nano-scale in the Multi-Omics laboratory through to prototyping at building scale with the OME.

OME Workshop

This facility is designed as a bridge between our wet labs and dry construction. It contains both a wet fabrication space with a growing room and a suite of fabrication and material testing equipment including a Kuka robot arm, waterjet cutter, knitting machine and Instron as well as environment and weathering chambers.

Macro Bio-Design Lab

Designed as a flexible lab facility, the macro bio-design lab bridges between the micro bio-design lab and the OME workshop providing a fully functional microbiology facility to enable us to develop benchtop demonstrators and materials. The lab includes imaging facilities and incubation as well as basic fabrication capabilities with 3D printers.

NORTHUMBRIA UNIVERSITY

Multi-Omics Laboratory

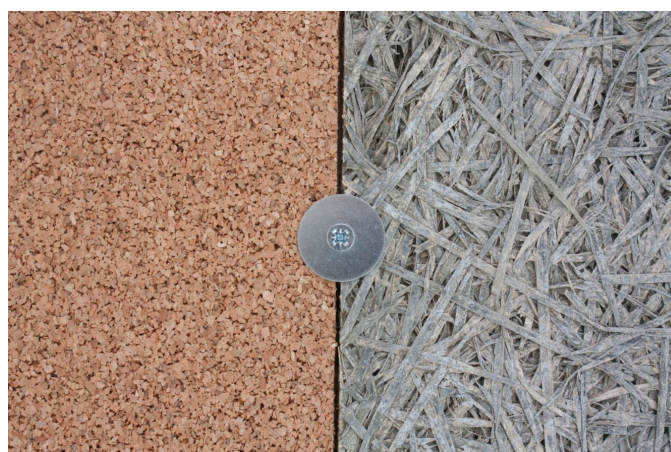
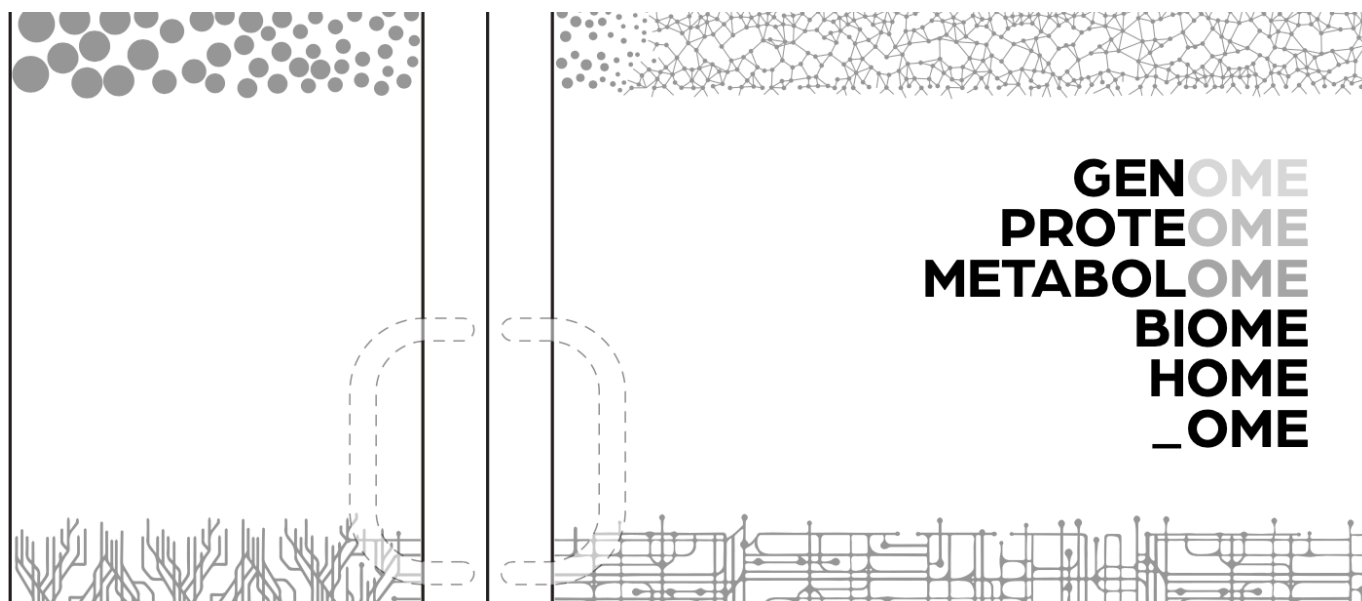
This flagship facility has state-of-the-art instrumentation to study biological systems at the molecular level. The laboratory contains genomics technologies from Illumina (MiSeq x2, NextSeq x3), Pacific BioSciences (Sequel) and Oxford Nanopore (GridION), supported by Hamilton and Tecan liquid handling, and proteomics and metabolomics instruments from Thermo Scientific (QExactive Plus and ID-X Tribrid Orbitrap Mass Spectrometers).

Micro Bio-Design Lab

This multi-user biosciences laboratory can accommodate up to twenty-four researchers, with connected offices for three associated principal investigators. It is supported by dedicated equipment for microbial propagation, DNA amplification and analysis, centrifugation, spectrophotometry, freeze-drying, water purification, electroporation, ultra-sonication and safe sample storage and handling.

Fermentation Facility

This gas fermentation facility is multi-functional, enabling us to produce both aerobic gas fermentation - utilising carbon dioxide, hydrogen, oxygen and methane, and anaerobic gas fermentation - utilising carbon monoxide, carbon dioxide and hydrogen. All of the functions are supported by robust analytical equipment. This facility has enabled us to focus our research on engineering microbiology for sustainable chemical production.



The OME is an experimental building in the heart of the Newcastle University campus. The OME provides the space where HBBE researchers will come together to test and demonstrate their technologies in the building and at scale. The OME also provides a space where we can engage with external partners and the public to shape and co-produce our future research.

The construction of the OME is now complete and we are looking forward to bringing the building to life with a diverse range of large-scale experimental prototypes which address the key areas of HBBE research:

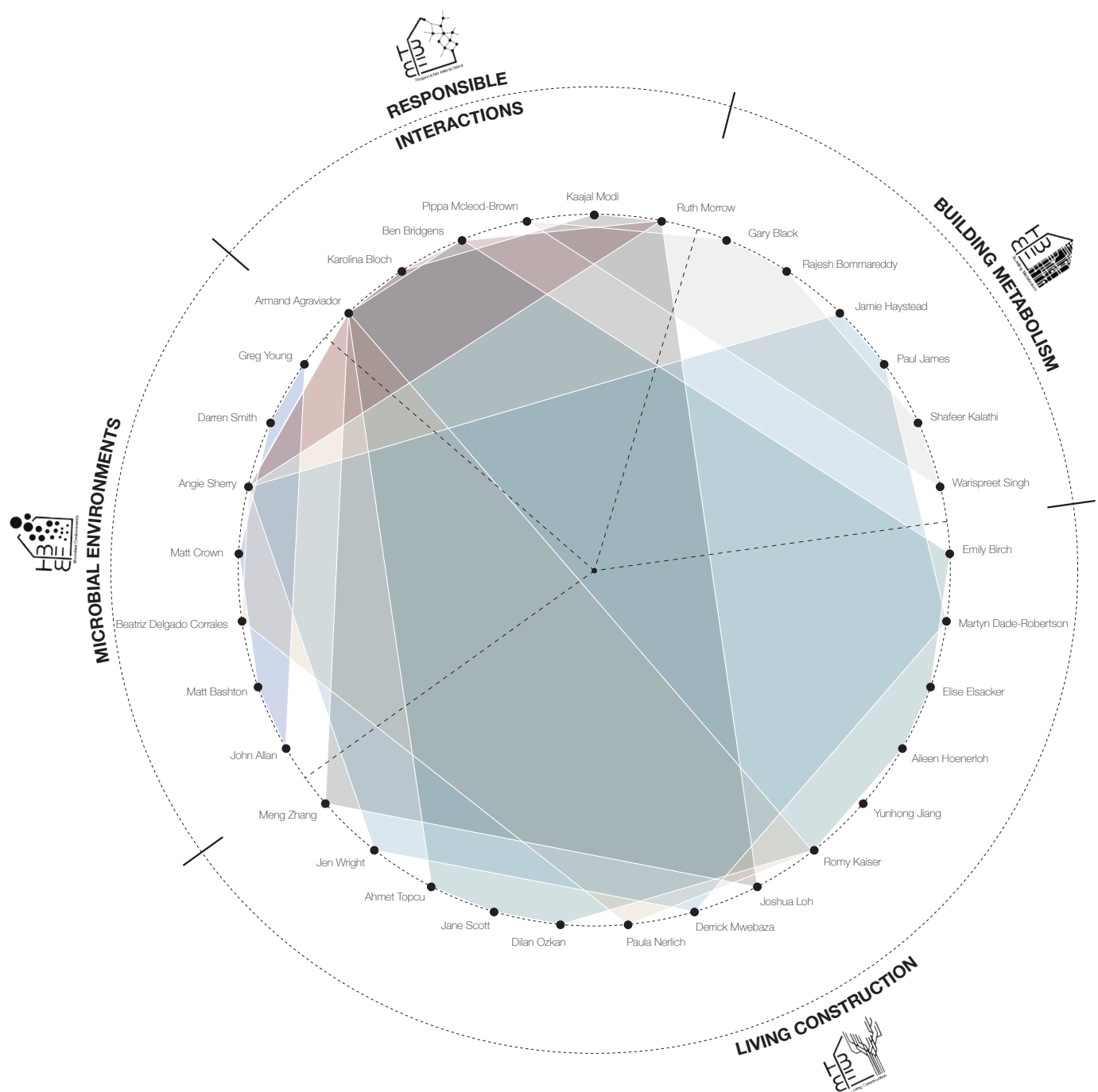
- Biomaterials for living construction;
- Understanding & modulating the internal microbiome;
- Processing domestic waste to create valuable products.

We will explore the interactions between these technologies to begin to understand how to create self-sustaining, regenerative, living buildings which benefit human and ecological health and wellbeing.



"HBBE researchers will come together to test and demonstrate their technologies in the building and at scale."

10 | NETWORKS OF COLLABORATION



Prototypes

While the HBBE is structured around four research themes the real potential of biotechnology for the built environment will involve the integration of approaches and expertise across the themes. To this end we have coordinated a series of prototype projects. Many of these prototypes will be installed in or on the OME in 2022. The diagram above shows the network of relationships built by members of the HBBE from different themes.

With special thanks to: Nathan Hudson supporting Healing Masonry, Janet Simkin supporting Biocellular Concrete and Oliver Perry, the Workshop Technician, involved in the support and development of all prototypes

Bacterial Cellulose

This project explores the evolution and testing of Bacterial Cellulose as a façade material for the built environment, based on the challenges and opportunities of its highly hydrophilic and absorbing material properties.

BioKnit

The project is focused on the biocompatibility of knitted fabrics as scaffolds for mycelium growth, creating complex forms using knitted textiles for hierarchical structuring systems. This highlights the potential to tune material properties to for material growth and environmental bioremediation.

BioMateriOME

The project aims to shed light on the invisible microbial world inhabiting common indoor surface materials through a public-facing material library. In addition, we will test new innovative materials of the future, in order to explore and nurture microbial awareness.

Bio-Cellular Prototype

This project develops and tests bio-receptive concrete panels for the façade. The use of waste materials and an increased surface area create a viable environment for plant life as well as facilitating diverse microbial life.

Healing Masonry

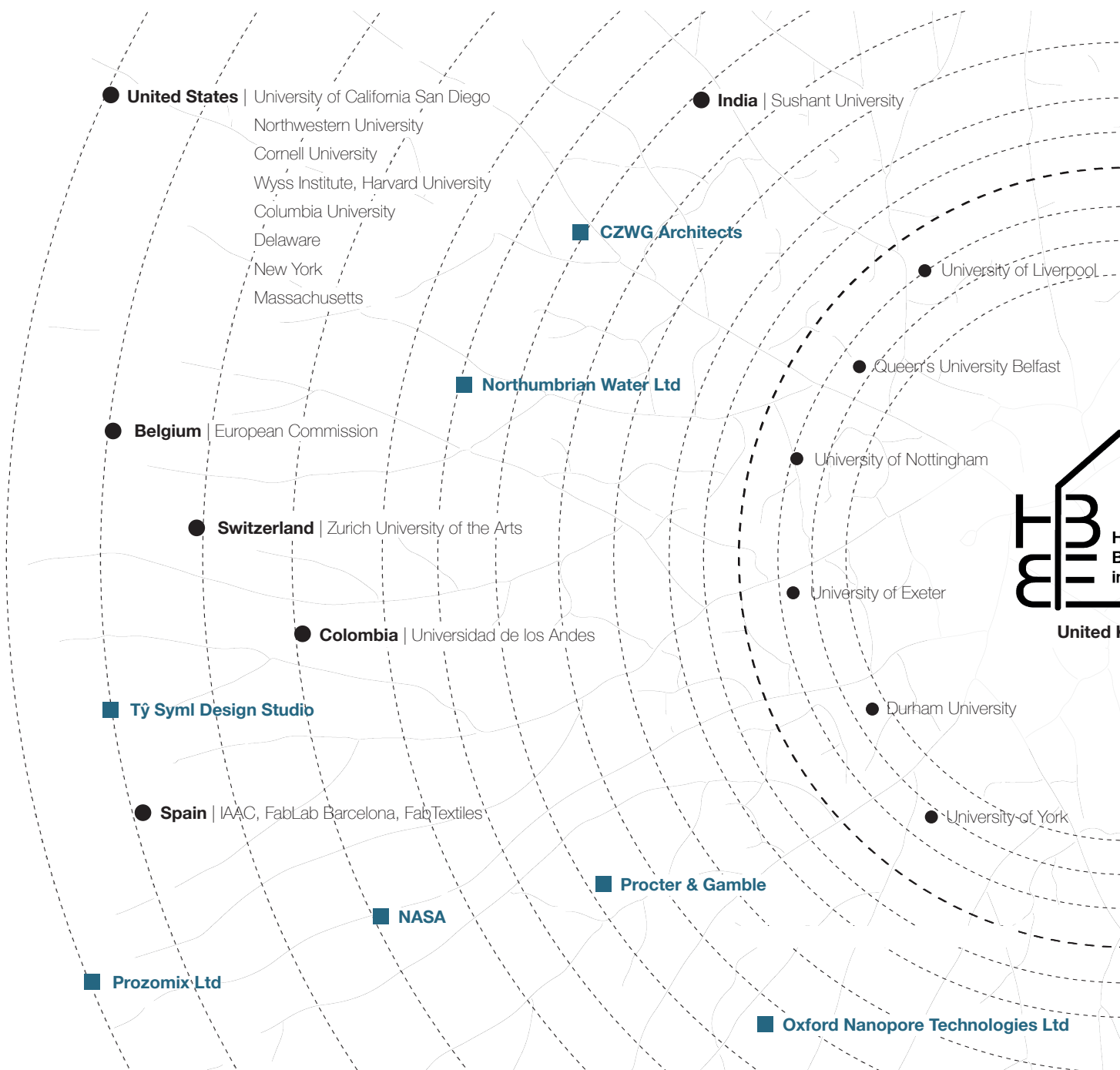
This project develops and tests bio-receptive concrete panels for the façade. The use of waste materials and an increased surface area create a viable environment for plant life as well as facilitating diverse microbial life.

Energising Waste

This project proposes two methodologies for on-demand electricity generation, an anaerobic digester to produce gas from home waste, and a microbial fuel cell to produce energy, creating a circular system that manages organic waste at the domestic scale.

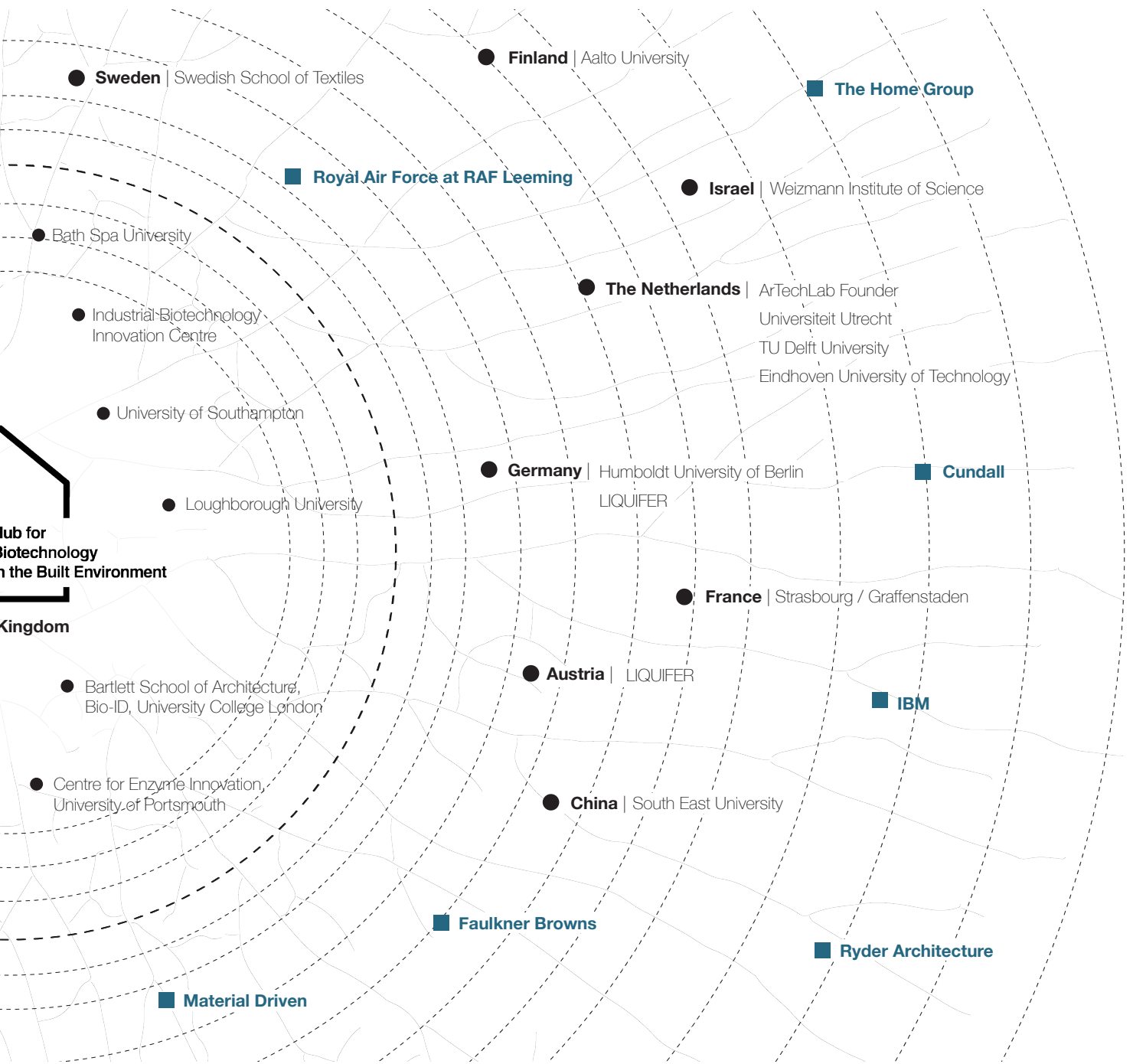
OME Pod

The OME Pod is a connected living biosensor monitoring microbial health in the built environment. By using phage based biosensors, real-time imaging with florescence based read out, we aim to automatically and continually monitor microbial health, as well as detecting pathogens and pollution.



National and International Networks

The HBBE emphasises the word 'Hub' in its title. To grow a new field of research can't be the task of two institutions alone. To this end, through our advisory board and initiatives such as the BBE 2021 Conference and the Bio Design Challenge Europe event we have built a network of national and international universities and industrial collaborators.



The diagram above captures some of the organisations we have had contact with over the past two years.

14 | EMERGENCE OF NEW RESEARCH THEMES

HBBE Research Groups and Special Interest Groups

In addition to our four core themes (Building Metabolism, Living Construction, Microbial Environments, Responsible Interactions) there have been two SIGs and a new research group established within the HBBE. These groups provide a platform to develop new opportunities for exchange and collaboration, working across more than one theme and represent emerging areas of interest within the HBBE.

**A platform to develop
a common ground for
exchange and collaboration**



The Living Textiles Research Group positions textiles as a critical biofabrication strategy for the development of new materials and construction methods.



**Mycelium
3D Printing**

29 July 2021
4pm (UK)-11am (NY)



**Mycelium
Structures**

19 August 2021
4pm (UK)-11am (NY)



**Big Scale Applications of
Mycelium Composites**

2 September 2021
4pm (UK)-11am (NY)

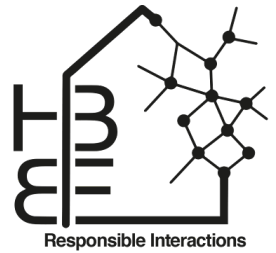
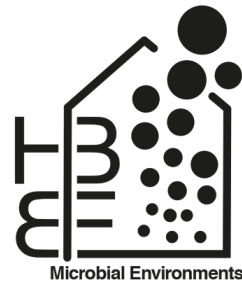
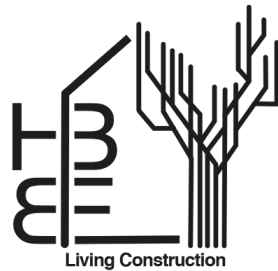
Mycology for Architecture is a collaborative to share knowledge and ideas about fungi and their role in the architectural field.

April 7th - 8th 2022
Newcastle-Upon-Tyne, United Kingdom

SYMPOSIUM

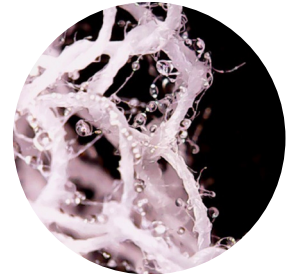
First onsite and remote networking symposium on bio-futures for transplanetary habitats
hosted by BFfTH and the Hub for Biotechnology in the Built Environment

BFfTH will grow its network and presence by hosting a two-day symposium in April 2022.



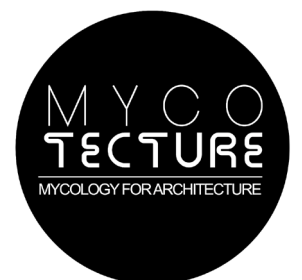
Living Textiles Research Group

The group looks at how to transform biomaterials and biosynthesised polymers into environmentally responsive, and programmable systems that operate at the scale of the built environment. Our research examines the potential to design with biology using textile materials, textiles thinking and advanced textiles technology. We enable multidisciplinary research collaborations with experts from across design and science communities leading to innovation across scales and applications.



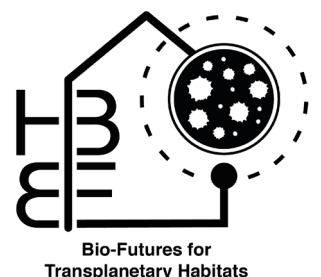
Mycology for Architecture

The aim is to allow those working with fungi as a biomaterial to help each other, find individual collaborators, and create a resource for the field. Each month we focus on a different method and purpose of producing/using fungal materials and invite a variety of people and groups who are leading scholars in this field to present their ideas and work. The talks are then shared via the HBBE YouTube channel.



Bio-Futures for Transplanetary Habitats

Bio-Futures for Transplanetary Habitats (BFfTH) is an interdisciplinary research group exploring biotechnology and bio-design applications that are being developed to support safety, sustainability, habitability, reliability, and crew efficiency and comfort in extreme environments both on Earth and in the wider universe. The work of the BFfTH is carried out with an emphasis on bio-social and biotechnological relations.



Successful Funding Applications

Key to the sustainability and future of the HBBE is our ability to attract external funding. The last year has shown our capability for cutting-edge projects across a range of funders, both private and public and across scales from molecular design to full building prototypes.

BBSRC/IBioIC ————— **£ 181,837**

An omics-based approach to identifying novel biocatalysts and metabolites: This project will use high-resolution mass-spectrometry to identify metabolites in *Escherichia coli* clones expressing recombinant enzymes. Synthetic biology approaches will then be used to engineer these clones to over-produce any novel metabolites.

Procter and Gamble ————— **£ 396,798**

Demand-led Enzyme Development for Consumer Products: This project will identify and produce novel enzymes for detergent formulations to improve cleaning by targeting a variety of polysaccharide-based soil components on clothing and dishware for improved detergent sustainability.

EPSRC ————— **£ 243,395**

Principles for Microbial 3D Printer: This project proposes the first steps to develop a 3D printing process which involves the synthesis and modification of materials from live microbes to make 3D functionally graded materials and objects. We will integrate genetically engineered microbes and the design and building a novel bioreactor as a new type of 3D printer.

Leverhulme Trust ————— **£ 328,800**

RESPIRE: Passive, Responsive, Variable Porosity Building Skins: The three year project led by Ben Bridgens, Helen Mitrani and Jane Scott aims to create a new generation of low-cost, low-environmental impact, responsive building skins that moderate internal temperature and humidity by varying their porosity. This transformative approach would improve internal air quality and eliminate the need for energy-intensive, high-maintenance mechanical ventilation systems, enabling fully passive, zero-energy buildings.

HBBE Publications

Technology Architecture + Design

Architectural Laboratory Practice for the Development of Clay and Ceramic-Based Photosynthetic Biocomposites

This article describes the development of clay and ceramic-based living biocomposite materials which support living, metabolically active photosynthetic microorganisms (microalgae) in minimal moisture environments, with potential applications for removing carbon dioxide and improving air quality in buildings. The paper was awarded the 2022 Research Contribution Award by the US Association of Collegiate Schools of Architecture.

Routledge (Taylor & Francis)

Living Construction (1st book in the Bio Design series)

This book, the first in the Bio Design series, acts as a bridge between design speculation and scientific reality and between contemporary design thinking, in areas such as architecture, product design and fashion design, and the traditional engineering approaches which currently dominate biotechnologies.

International Journal of Biological Macromolecules

Co-immobilization multienzyme nanoreactor with co-factor regeneration for conversion of CO₂

The conversion of the greenhouse gas, carbon-dioxide, for chemical synthesis has attracted attention. Multi-enzymatic conversion of carbon-dioxide is possible, but the regeneration of enzymes for continued conversion is problematic. This paper describes an enzyme co-immobilization strategy for continued carbon-dioxide conversion.

COG-UK

COVID-19 Genomics UK Consortium

Using state-of-the-art DNA sequencing equipment procured as through the HBBE's E3 Funding, Northumbria University continues to be a resilience site for UKHSA assisting in rapidly sequencing whole SARS-CoV-2 genomes. It also continues to be a core academic partner of the COG-UK consortium. In the early part of the pandemic the team worked in partnership with 7 different Northern England NHS Foundations Trusts, generating data which has fed into over 100 publications. A list of all publications can be found in the Research section of the COG-UK website.

HBBE Publications

Article Title	Publication / Journal
A facile and regioselective multicomponent synthesis of chiral aryl-1,2-mercaptoamines in water followed by monoamine oxidase (MAO-N) enzymatic resolution.	Organic and Biomolecular Chemistry
Acquisition and Development of the Extremely Preterm Infant Microbiota Across Multiple Anatomical Sites	Journal of Pediatric Gastroenterology and Nutrition
Sediment cooling triggers germination and sulfate reduction by heat-resistant thermophilic spore-forming bacteria	Society for Applied Microbiology
Liquid Life: On Non-Linear Materiality	Punctum Books
Concordance of copy number abnormality detection using SNP arrays and Multiplex Ligation-dependent Probe Amplification (MLPA) in acute lymphoblastic leukaemia	Scientific Reports
How biotechnology can transform delivery and operation of the built environment.	Proceedings of the Institution of Civil Engineers
Setting the agenda for social science research on the human microbiome	Palgrave Communications
Changes in the gut microbiota of mice orally exposed to methylimidazolium ionic liquids	PLOS ONE
Anaerobic microbial communities and their potential for bioenergy production in heavily biodegraded petroleum reservoirs	Society for Applied Microbiology
Agarose Gel as a Soil Analogue for the Development of Novel Bio-mediated Ground Improvement Applications. Compositions of lopinavir	Canadian Geotechnical Journal
Compositions of lopinavir	US Patent
Monsterring: A transdisciplinary method for an unstable world	Palgrave Communications
Soul Chasers: The Decomposition Comedy	NewCon Press
Monoamine Oxidase (MAO-N) Biocatalyzed Synthesis of Indoles from Indolines Prepared via Photocatalytic Cyclization/Arylative Dearomatization	ACS Catalysis
Moisture buffer, fire resistance and insulation potential of novel vio-clay plaster. Construction and Building Materials	Construction and Building Materials

An integrated national scale SARS-CoV-2 genomic surveillance network COGUK Consortium	Microbe
YerA41, a Yersinia ruckeri Bacteriophage: Determination of a Non-Sequencable DNA Bacteriophage Genome via RNA-Sequencing	Viruses
Architectural Laboratory Practice for the Development of Clay and Ceramic-Based Photosynthetic Biocomposites	Technology Architecture + Design
Self-assembly of activated lipase hybrid nanoflowers with superior activity and enhanced stability	Biochemical Engineering Journal
Bimetal based inorganic-carbonic anhydrase hybrid hydrogel membrane for CO ₂ capture	Journal of CO ₂ Utilization
Colour Trans:Form:Ation the Application of Knit as Knowledge	Journal of Textile Design Research and Practice
Co-immobilization multienzyme nanoreactor with co-factor regeneration for conversion of CO ₂ , International Journal of Biological Macromolecules	International Journal of Biological Macromolecules
Erosion-initiated stromatolite and thrombolite formation in a present-day coastal sabkha setting	Sedimentology
Spaces of rehearsal: theorising socio-spatial practices in a postconflict context	Architectural Research Quarterly - Cambridge University Press
Regio- and Stereoselectivity of CYP450 - BM3 Catalyzed Hydroxylation of Complex Terpenoids: A QM/MM Study	Physical Chemistry Chemical Physics
Cytochromes P450 (P450s): A review of the class system with a focus on prokaryotic P450s	Advances in Protein Chemistry and Structural Biology
The Art of Experiment: Post-pandemic Knowledge Practices for 21st Century Architecture and Design	Book: Routledge (Taylor & Francis)
Objective Ageing	Beauty Demands
Rhythmic Buildings: a framework for sustainable adaptable architecture, Building and Environment	Building and Environment
Proceedings of the Global Community Bio Summit 2020	Global Community Bio Summit
Turbulent Casting Bacterial Expression in Mineralized Structures.	ACADIA 2020 Distributed Proximities:
Architectural Laboratory Practice for the Development of Clay and Ceramic-Based Photosynthetic Biocomposites	Technology Architecture + Design
Living Construction (1st book in the Bio Design series)	Routledge (Taylor & Francis)
A 'Split-Gene' Transketolase From the Hyper-Thermophilic Bacterium Carboxydotherrmus hydrogenofomans: Structure and Biochemical Characterization	Frontiers in Microbiology

Bacterial Choreography: Designing Interactions through Biological Induced Mineralisation.	MBCMGE
Soft Robotics and Posthuman Entities	Journal for Artistic Research (JAR)
The clinical and microbiological utility of inhaled aztreonam lysine for the treatment of acute pulmonary exacerbations of cystic fibrosis: An open-label randomised crossover study (AZTEC-CF)	Journal of Cystic Fibrosis
Chapter: Engaged Practices: Learning from Improvisation	Book: All-Inclusive Engagement in Architecture: Towards the Future of Social Change
Chapter: The use of by-products in new materials	Book: The Routledge Handbook of Waste, Resources and the Circular Economy
The Effect of Miss and Tuck Stitches on a Weft Knit Strain Sensor	Sensors
Reconciling the Sustainable Manufacturing of Commodity Chemicals with Feasible Technoeconomic Outcomes	Johnson Matthey Technology Review
SARS-CoV-2 evolution during treatment of chronic infection	Nature
Grasp Classification With Weft Knit Data Glove Using a Convolutional Neural Network	IEEE Sensors Journal
Sensitivity of SARS-CoV-2 B.1.1.7 to mRNA vaccine-elicited antibodies	Nature
A Weft Knit Data Glove	IEEE Transactions on Instrumentation and Measurement
Bacterial Spore-Based Hygromorphs: A Novel Active Material with Potential for Architectural Applications	Sustainability
Managing Air in the Built Environment: Creating Benefits for Human Health and Wellbeing	National Biofilms Innovation Centre
Initiate: This could wean humanity off fossil fuels	Enlit Europe
The Impact of NOD2 Genetic Variants on the Gut Mycobiota in Crohn's Disease Patients in Remission and in Individuals Without Gastrointestinal Inflammation	Journal of Crohn's and Colitis
Photosynthetic Textile Biocomposites: Using Laboratory Testing and Digital Fabrication to Develop Flexible Living Building Materials,	Science and Engineering of Composite Materials (De Gruyter)
Science and Engineering of Composite Materials Expanding the Upcycling Paradigm: A case study in the creative use of waste streams and waste plastic in interlocking blocks	PLATE (Product Lifetimes and the Environment) Conference
The Sustainable Path to a Circular Bioeconomy	Trends in Biotechnology

Lecture Notes: Introduction: State-of-the-Art Upcycling Research and Practice	State-of-the-Art Upcycling Research and Practice: Proceedings of the International Upcycling Symposium 2020
State-of-the-Art Upcycling Research and Practice: Proceedings of the International Upcycling Symposium 2020	International Upcycling Symposium
Thebaine is Selectively Demethylated by Thebaine 6-O-Demethylase and Codeine-3-O-demethylase at Distinct Binding Sites: A Computational Study	ACS Catalysis
Thebaine is Selectively Demethylated by Thebaine 6-O-Demethylase and Codeine-3-O-demethylase at Distinct Binding Sites: A Computational Study	ACS Publications
Structural basis of the membrane intramolecular transacylase reaction responsible for lyso-form lipoprotein synthesis	Nature Communications
Emergence and maintenance of actionable genetic drivers at medulloblastoma relapse	Neuro-Oncology

HBBE Researcher Presentations

Presentation / Poster Title	Conference Name
Bacterial Sculpting: Process oriented approach to biologically induced materials and advanced fabrication practices.	Designer Biology 2019
Application of bacterial cellulose for architectural material systems and design.	Designer Biology 2019
Synthetic Biology for the Built Environment: A Pressure Sensing and Responsive Bacillus subtilis	Designer Biology 2019
Bacterial Choreography: Designing interactions through biological induced mineralisation	International Symposium on Biomineralization (Biomin) 2019
Living Experimental Setups Exhibitors	OPEN CELL. Biodesign Here Now
Biotechnology in the Built Environment	Newcastle University Public Lecture
Future Cities: Panel Discussion	Dezeen Day 2019 International Architecture and Design Conference

Scaling up research with Living Systems (Panel Member)	The Design Museum's – Design with the Living Symposium at the Design Museum
Soft Matter(s): Sciences-Design junctions & frictions	ENSAD ArcInTex 2019
Making the Circular Bioeconomy Sustainable	The Carbon Recycling Network Conference 2020
Thinking Soils: Micro Scale	Materials Research Exchange 2020
Living Construction: Travels in Topology from Information Architecture to Synthetic Biology	Technical University of Liberec
Our Vision: The Hub for Biotechnology in the Built Environment	Bio-based Industries Joint Undertaking: (BBI JU)
Ecologies of Knitting: Programmable Responsive and Adaptive Textiles	Arkintects Conference 2020
Living Construction: Biotechnology for the Built Environment	Knowledge Transfer Network: Nature Inspired Construction SIG Webinar Series
Wicked Home: Sacred Spaces	Digital Futures World
A 'Split-gene' transketolase from the hyper-thermophilic bacterium <i>Carboxydotherrmus hydrogenoformans</i> : structure and biochemical characterisation	South West Structural Biology Conference 2020
Conversation in Future Art Ecosystems (Future Art Ecosystems)	Future Art Ecosystems Live
Navigating an Age of Uncertainty through Architectural Research: Rethinking value in our learning cultures and research environments	EAAE General Assembly (European Association for Architectural Education)
Facing 21st Century Nature: Configuring Fresh Approaches Through Biodesign	ESDRI 2020
Panel Discussion: Voices from the Future on Women in STEM	EICFTW2020
Microbes and Urban Sustainability: "Living" Architecture	FETFX Ted Talk
Biological self-healing for masonry materials	APTNT2020 International & National Trust for Canada 2020
Part of the Session: In the Limelight: Examining the Spectrum of Lime and Cement Binders in Heritage Conservation	ACADIA2020 (Association for Computer Aided Design in Architecture)
In Silico, In Vitro, In Vivo: Programming in Processing and in Life	ACADIA2020 (Association for Computer Aided Design in Architecture)
Turbulent Casting: Bacterial Expression in Mineralized Structures	Design with the Living 2020
Principles From Plant Biology to Responsive Textile Systems Keynote Speaker: Martyn Dade-Robertson	MBCMG2020

Thinking Soils: engineered bacteria as computation agents in the design and manufacturing of new materials and structures.	MBCMG2020
Bacterial Choreography: Designing Interactions through Biological Induced Mineralisation.	1st International Conference on Microbial Biotechnology in Construction Materials and Geotechnical Engineering, China
PhD Guest Speakers at Award Ceremony	Mars City Design 5th Annual Challenge Gala Award Ceremony 2020
Bio Materials in Buildings	Design Network North: Rise and Design 'Smart Materials and their Applications'
The Future of Cities: Green Buildings and Sustainable Infrastructure	AAAS Meeting 2021
Inclusiveness and diversity in the academic workplace culture	Marie Curie Alumni Association Annual Conference 2021 Research in times of crisis
Current Challenges of monitoring the microbial quality of air in the built environment	Studying and Controlling the Microbiome of the Air Webinar
Living Construction	North of England Institute of Mining and Mechanical Engineers
Microbial induced carbonate healing and self-healing for repairing and preventing damage in stone structural elements	ASCE Engineering Mechanics Institute International Conference 2021
Soft Materials: Working with materials that bend, stretch, conform, and respond.	DigitalFUTURES (Tongji University)
The Art of Experiment: Post-pandemic Knowledge Practices for 21st Century Architecture and Design (Podcast)	New Books Network
Expanding the Upcycling Paradigm: A case study in the creative use of waste streams and waste plastic in interlocking blocks	PLATE (Product Lifetimes and the Environment) Conference
RIBA Gulf Chapter: Architecture in Extreme Environments Workshop	Architecture in Extreme Environments (RIBA Gulf Chapter)
Senses as Drivers for Space Habitats Design in Microgravity	50th International Conference on Environmental Systems
Leaders Perspectives: Rachel Armstrong (Podcast)	MIPIM Leaders' Perspectives
Can we grow a city? (Video)	CITYX VENICE (Venice Architecture Biennale Italian Virtual Pavilion Sezione del Padiglione Italia)

Academic Leads

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Derrick Mwebaza
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Ahmet Topcu
Mandy Yau

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