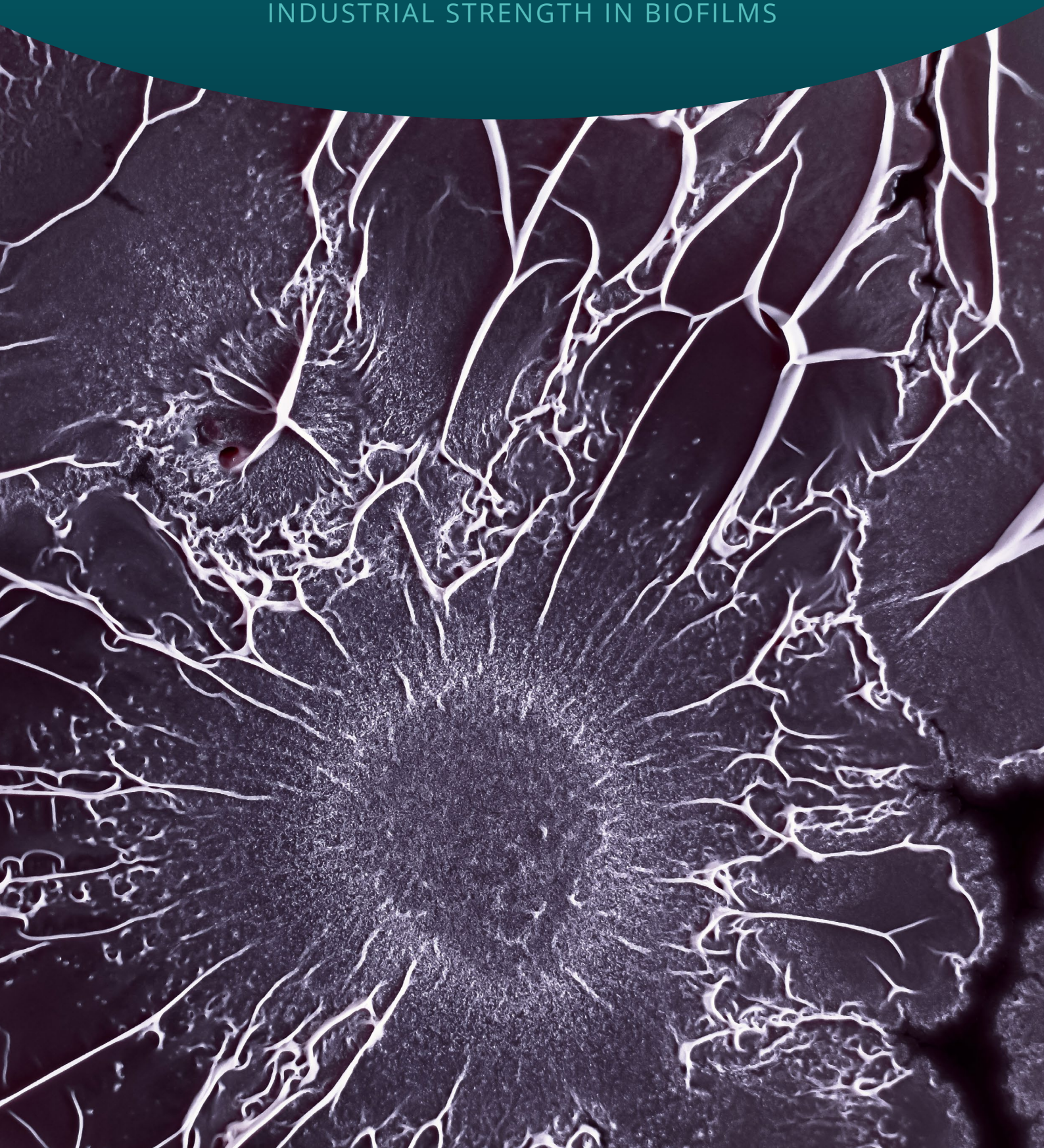
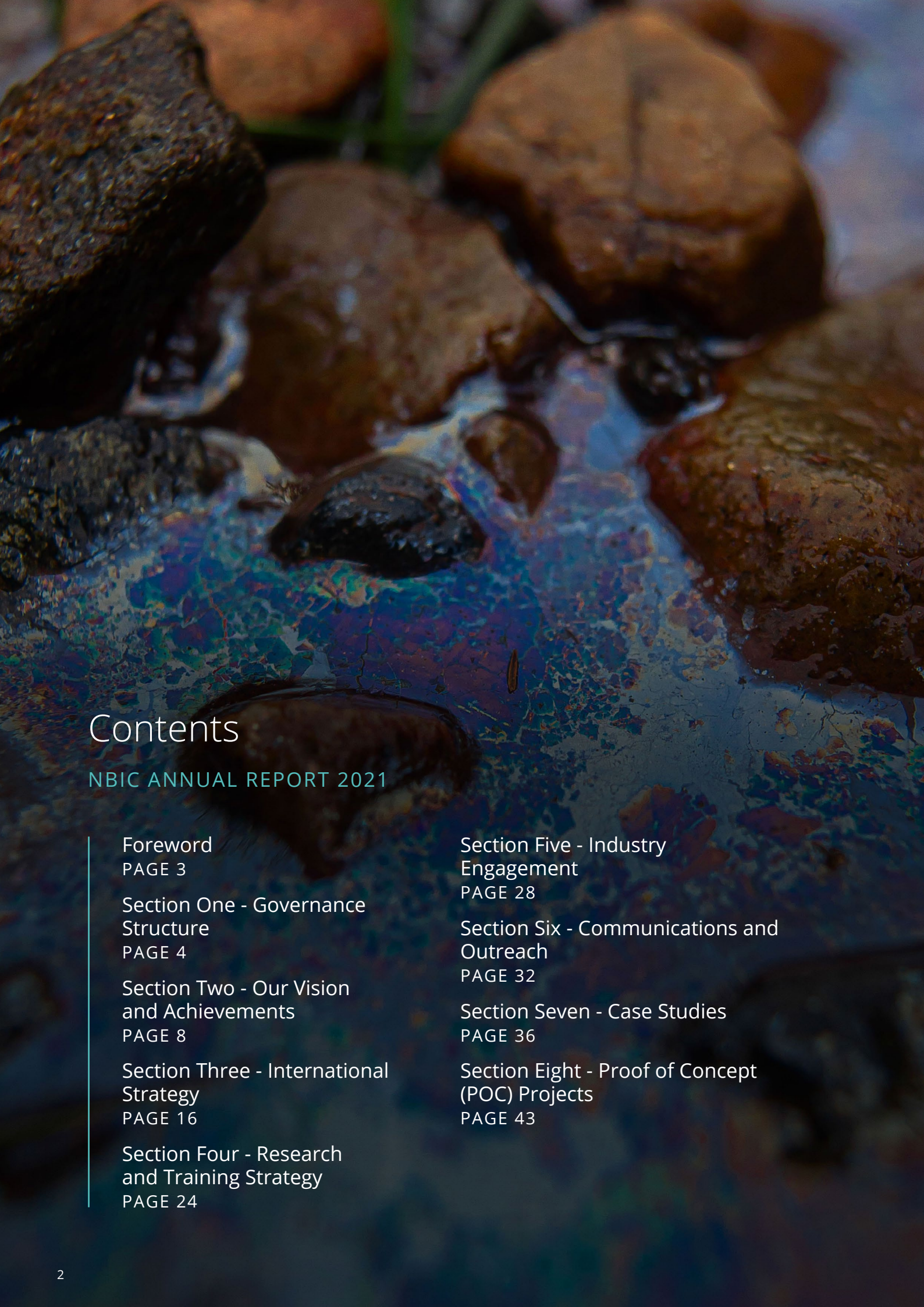
National Biofilms Innovation Centre

Annual Report 2021

HARNESSING THE UK'S ACADEMIC & INDUSTRIAL STRENGTH IN BIOFILMS





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NBIC ANNUAL REPORT 2021

Foreword

A FEW WORDS FROM OUR CEO

The National Biofilms Innovation Centre (NBIC) enters its fourth year still very much focussed on supporting and connecting the industrial and academic biofilm community across the UK and with our international partners in the USA, Singapore, India and Europe. NBIC's intent remains to behave in a national, inclusive and transparent way to benefit our community. We judge ourselves by our ability to harness and translate the capability, knowledge and technology in the prevention, detection, management and engineering of biofilms across the UK. We believe we are having a significant impact across all these dimensions as you will see in this report. We recently updated our market impact report and estimate the value in the UK of addressing biofilm opportunities and challenges is £45bn (and $4tn globally).

I am delighted that our membership has further grown to 63 UK research institutions and that these academic partners share our desire to collaborate and connect with the (approximately) 250 companies we continue to talk to across a range of sectors. The last year has been immensely challenging for everyone. Despite circumstances, we have been able to continue to communicate with companies and academics via web-based tools and we have also held several well attended webinars in conjunction with groups as diverse as the Society for Applied Microbiology (SfAM), the India Biofilms Society, the Singapore National Biofilms Consortium (SNBC) and Cosmetics Cluster UK (CCUK).

At heart we aim to connect unmet industrial and commercial needs and possible scientific or technological solutions that may exist in our partners. We do this both through personal introduction, and by sharing needs and solutions across our network.

We endeavour to build on three key pillars that our funders (BBSRC, Innovate UK and the Hartree Centre) have asked us to establish, namely:

RESEARCH

Our funding has allowed us to continue to support our cohort of Interdisciplinary Research Fellows (IRFs) across our four core universities. They are all actively engaged in a mixture of underpinning research, and projects with industry partners.

INNOVATION

This year we ran our fourth Proof of Concept (POC) call, with a record number of applications from which we awarded 18 new projects. This brings our portfolio to 81 POC projects funded from 207 applications and an NBIC (on behalf of UKRI) investment of £4.4m, with a total of £6.7m value when company contributions are included. As our first projects finish, we are now tracking the impact of these on the translation of technology. In addition, we have run four themed workshops resulting in policy papers and multiple industry and academic collaborations and connections. If circumstances allow, our fifth workshop will run later this year.

All of this innovation activity is supported by a core NBIC team including three field-based sector specialists who visit and connect our partner companies and research institutions.

TRAINING

We continue to build our cohort of PhD students across our four core universities, for whom we are running a core Doctoral Training Programme (BITE).

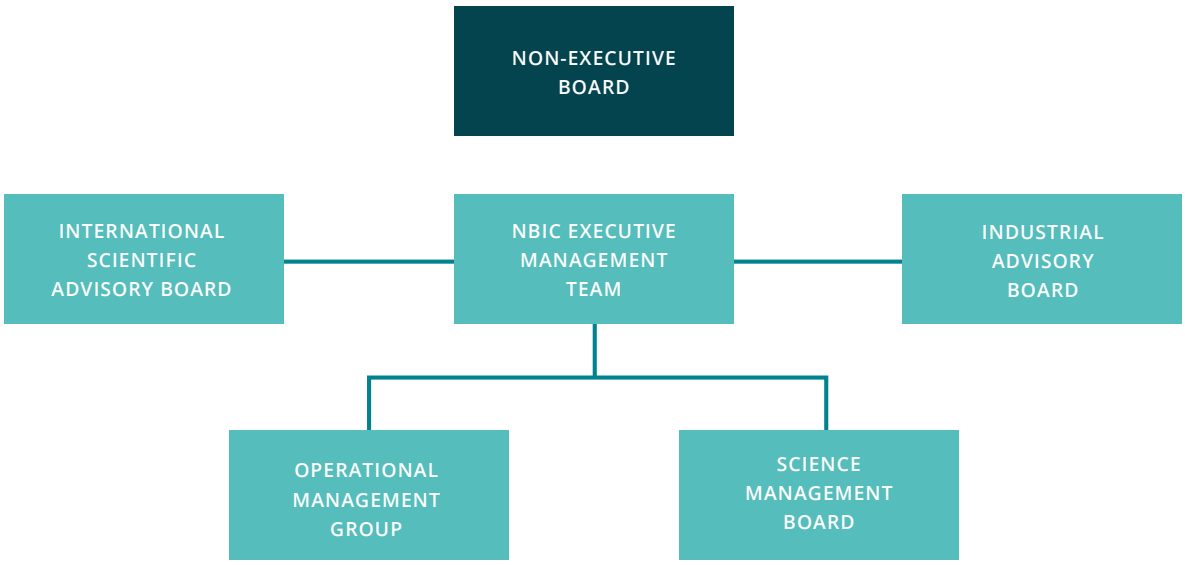
It is very clear that everyone involved in biofilms across the UK remains jointly committed to our vision of delivering both breakthrough science and technologies to control and exploit biofilms, and to inspire the next generation of research leaders and entrepreneurs.

- MARK RICHARDSON, CEO, SEPTEMBER 2021

Governance Structure

GOVERNANCE AND ADVISORY BOARDS

Our advisory bodies aid NBIC in setting the strategic direction of our research, innovation and outreach activities. Our Non-Executive Board regularly review NBIC's progress against our strategic plan.



EXTERNAL GOVERNANCE AND ADVISORY BOARDS

NBIC Non-Executive Board

NBIC has established a Non-Executive Board of external members, which includes representatives from the NBIC's funders, International Science Advisory Board and Industrial Advisory Board. The Non-Executive Board's role is to guide the strategic direction and development of NBIC as well as having oversight of the operation and management of NBIC and the implementation of the Consortium Agreement.

GORDON FORD
Innovation Lead – Biomedical Enabling Technologies, Health & Life Sciences, Innovate UK

HILARY LAPPIN-SCOTT
Honorary Distinguished Professor, Cardiff University

FIONA LETTICE
Pro-Vice-Chancellor (Research & Innovation), University of East Anglia

KATH MACKAY
Director of Life Sciences, Bruntwood SciTech

NEIL PARRY
R&D Programme Director, Biotechnology & Biosourcing, Unilever

VANISREE STANIFORTH
Senior Portfolio Manager, Health Sector, Biotechnology and Biological Sciences Research Council, UKRI

CERI WILLIAMS (CHAIR)
Director of Research and Innovation Development, University of Leeds

NBIC Industrial Advisory Board

Business leaders from multinational companies and SMEs have been recruited to the Industrial Advisory Board (IAB) on the basis of their experience and knowledge of the biofilms industry across the identified strategic sectors. They advise the Executive Management Team (EMT) on the development of NBIC, the industrial engagement strategy for NBIC, NBIC funding calls and the commercial exploitation of the results of the research conducted through NBIC.

IAN ARCHER
Technical Director, IBioIC

DAVID BRADSHAW
Principal Innovation Scientist - Oral Care, GlaxoSmithKline (GSK)

KEN JOHNSTON
Consultant, Chilled Food Association

STEWART MCKINLAY
Vice President of Research & Innovation, Smith+Nephew

NEIL PARRY (CHAIR)
R&D Programme Director, Biotechnology & Biosourcing, Unilever

KEVIN PEEL
Senior Programme Manager - Advanced Development, Kohler Co.

STEVEN PERCIVAL
Chief Executive Officer, 5D Health Protection Group Ltd

KIRSTY SALMON
VP Advanced Bio & Physical Sciences for Low Carbon Energy, BP Plc

NBIC International Scientific Advisory Board

Scientific leaders from international institutions have been brought together to evaluate and challenge the scientific strategy of NBIC and its delivery and implementation in the context of the international development of the field. They advise the Executive Management Team (EMT) on the opportunities for exploitation of the scientific profile and advances made by the centre.

TOM COENYE
Professor, Laboratory of Pharmaceutical Microbiology, Ghent University, Belgium

LARS DIETRICH
Associate Professor, Columbia University, USA

HILARY LAPPIN-SCOTT (CHAIR)
Honorary Distinguished Professor, Cardiff University, UK

IÑIGO LASA
Professor of Microbiology, Navarrabiomed, Universidad Publica de Navarra, Spain

MARK VAN LOOSDRECHT
Chair Professor in Environmental Biotechnology, Delft University of Technology, Netherlands

RIKKE LOUISE MEYER
Associate Professor, Interdisciplinary Nanoscience Center, Aarhus University, Denmark

CLAIRE-MARIE PRADIER
Scientific Advisor, Institute of Chemistry, Centre National de la Recherche Scientifique (CNRS), Netherlands

AGNETA RICHTER-DAHLFORS
Professor in Cellular Microbiology, Karolinska Institutet. Professor in Chemistry and Biotechnology, KTH Royal Institute of Technology. Director of AIMES - Center for the Advancement of Integrated Medical and Engineering Sciences, KI & KTH, Sweden

NBIC Executive Management Team

The Executive Management Team (EMT) have overall executive responsibility. In consultation with the International Scientific Advisory Board (ISAB), the Industrial Advisory Board (IAB) and the Scientific Management Board (SMB), the EMT develop NBIC's strategy and delivery plan.

Professor Miguel Camara, NBIC Nottingham Co-Director

Miguel Cámara is a Professor of Molecular Microbiology in the School of Life Sciences at the University of Nottingham. He sits on the UK Cystic Trust Strategic Implementation Board and the Cystic Fibrosis Syndicate Steering Committee. He has also coordinated several international antimicrobial drug discovery programs. The core of his work has focused on studying quorum sensing (QS)-mediated signaling mechanisms and their control of virulence and biofilm formation. In collaboration with other researchers and industrial partners he is working on new drug delivery systems which can increase the penetration of compounds into biofilms and their uptake by bacteria.

Professor Cait MacPhee, NBIC Edinburgh Co-Director

Cait MacPhee is Professor of Biological Physics at the University of Edinburgh. Her expertise is in the use of experimental and computational methods to understand mechanisms of self-assembly of peptides and proteins and to interrogate microbial biofilm structure and function. She is able to advise on protein aggregation to form gels and particulate aggregates, the self-assembly of polypeptides and proteins at interfaces, analytical methods to assess the degree of polypeptide aggregation in formulations, methods to prevent or promote polypeptide aggregation, and methods to modulate the physical properties of formulations. She has prior experience of working with food-related products and pharmaceutical formulations.

Professor Rasmita Raval, NBIC Liverpool Co-Director

Rasmita Raval is a Professor in the Department of Chemistry, the Director of the Surface Science Research Centre and the Open Innovation Hub for Antimicrobial Surfaces at the University of Liverpool. Her research includes rational design of functional surfaces and bio-interfaces. There is strong emphasis on multi and inter-disciplinarity; research group expertise spans surface science, smart materials design, nanoscience, advanced analytical tools, metrology, imaging (from single atoms to cells), allied with microbiological and 'omic approaches. This experimental effort is combined with modelling to yield detailed insights into molecular and biological responses and behaviour at surfaces and to establish structure-property relationships.

Professor Jeremy Webb, NBIC Southampton Co-Director

Jeremy Webb is Professor of Microbiology at the University of Southampton. His work focuses on the adaptive biology, antimicrobial resistance, evolution, and molecular genetics of biofilms and polymicrobial communities. His work includes discoveries in the regulation and control of biofilm dispersal, which are now being exploited for therapeutic applications in cystic fibrosis, including the first human clinical trial for a biofilm-targeted therapeutic. Current research also seeks to identify genes that undergo adaptive evolution during bacterial biofilm development.

Dr Mark Richardson, NBIC CEO

Mark joined NBIC on its formation in December 2017 having worked for over 30 years in R&D in the medical device industry, leading projects and global teams. He led the Global Innovation Team for Smith+Nephew Wound Management from 2000-2002, and then formed and led their approaches to open innovation, including engaging with Innovation Knowledge Centres in the UK.

Mark gained his degree in microbiology at the University of Leeds followed by an MSc and PhD in biochemistry from the University of Birmingham. He also has an MBA from the Open University.

Dr Jo Slater-Jefferies, NBIC Operations Director

Jo joined NBIC in April 2018 and is also the Associate Dean of Enterprise for the Faculty of Environmental and Life Sciences at the University of Southampton. Jo has been a Director and Trustee of the Asthma, Allergy and Inflammation Research (AAIR) charity since 2011. She started her scientific career as a Senior Scientist and Quality Manager at Sciona Ltd, a spin-out company combining lifestyle data and genetic analysis. Between 2011 and 2018 she held the position of General Manager for EpiGen, a global research consortium.

Jo holds a BSc Honours in molecular biology and an industrial sponsored PhD from the University of Portsmouth. In 2014, Jo received an MBA, and in 2017 became a Chartered Manager at the Chartered Management Institute.

Our Vision

RESEARCH, INNOVATE AND TRAIN

The National Biofilms Innovation Centre exists to create a fusion of world class interdisciplinary research and industry partnerships to deliver breakthrough science and technologies to control and exploit biofilms.

Biofilms are central to our most important global challenges – from antimicrobial resistance and food safety to water security – and exert significant economic, social and environmental impact. NBIC was launched in 2017 to address these challenges and unmet needs and bring together the best of UK research and businesses to drive the translation of biofilm research into innovative solutions.

NBIC's vision is to create a truly pioneering and national centre, by bringing together the original four lead universities (Edinburgh, Liverpool, Nottingham and Southampton) and a partnership that has now expanded to include 59 associate research institutions, support from a growing base of more than 250 companies, and an inclusive strategy to new companies and research institutions. This brings an unprecedented set of capabilities, and a huge potential for innovation and collaboration that will allow us to lead on a global stage with the world's leading biofilm researchers. By combining our collective talent, we will grow the next generation of research leaders and entrepreneurs, delivering growth and wealth creation in the UK and beyond.

Our Achievements

SINCE 2017

START OF THE JOURNEY

FEBRUARY 2018, KNOWLEDGE TRANSFER NETWORK BIOFILM WORKSHOP
NBIC attended and launched at a Knowledge Transfer Network (KTN) workshop on identifying and prioritising industrial challenges and solutions in controlling and exploiting biofilms.

JUNE 2018, FIRST PROOF OF CONCEPT CALL LAUNCHED
Call for projects tackling biofilms launched in the UK - open to all members of the NBIC consortium and industry collaborators.

SEPTEMBER 2018, FIRST NBIC WORKSHOP & THEORY OF CHANGE MODEL ESTABLISHED
First cross-sectorial workshop on one of NBIC's 4 key strategic themes, Detect, was held in Birmingham, with 70 delegates from academia and industry coming together to discuss unmet needs.
Our aims for the next 5 years were established in a comprehensive Theory of Change model, with the ultimate long-term goal of increasing the UK economy.

NOVEMBER 2018, NBIC WON BBSRC FTMA (FLEXIBLE TALENT MOBILITY ACCOUNT) AWARD
Won funding to facilitate PhD and research fellow mobility between academia and industry.

MARCH 2019, MEMORANDUM OF UNDERSTANDING SIGNED WITH SCELSE IN SINGAPORE
We signed a Memorandum of Understanding (MOU) with the Singapore Centre for Environmental Life Sciences Engineering (SCELSE) to address global biofilm challenges through collaborative projects and student and staff exchanges. We also formed a close partnership with the Singapore National Biofilms Consortium (SNBC), led by SCELSE, to further commercial opportunities and drive technological advancements.

MAY 2019, FIRST NBIC ANNUAL RESEARCH SUMMIT & INTERNATIONAL SCIENTIFIC ADVISORY BOARD (ISAB) ENDORSEMENT
The first NBIC Annual Research Summit was held at the Royal Society, where our researchers showcased their work and we received endorsement from ISAB regarding our research strategy.

JULY 2019, SECOND PROOF OF CONCEPT CALL PROJECTS AWARDED
A further 26 projects awarded funding, bringing the total number of projects to 51 and a total investment of £2.79m from NBIC, with an overall project value of £4.05m.

SEPTEMBER 2019, SUCCESSFUL 2 YEAR FUNDING REVIEW
As part of the condition of the NBIC IKC award. An external panel reviewed the progress of NBIC against their vision, mission and key performance indicators (KPIs). The panel deemed that NBIC was making good progress, the highest outcome that could be expected.

2017

DECEMBER 2017, NATIONAL BIOFILMS INNOVATION CENTRE ESTABLISHED
£26m investment from BBSRC, Innovate UK and the Hartree Centre with additional funding from industry and the support of 4 core partner universities: Edinburgh, Liverpool, Nottingham and Southampton.

2018

MAY 2018, PARTNER MEETING & 1ST WAVE ACCESSION
Partner meeting in York brought together representatives from research institutions interested in joining NBIC.
12 new research institutions join the NBIC consortium, bringing us to a total of 16.

AUGUST 2018, 2ND WAVE ACCESSION
Welcomed 15 new research institutions to the NBIC consortium, taking our total to 31 institutions.

OCTOBER 2018, FUNDING OF 25 NEW PROJECTS & GOING INTERNATIONAL
NBIC invested £1.4m, averaging £50k per project, to 25 new projects from the first POC call. The total project value, with company investment, amounting to approximately £2.1m.
NBIC launched at the American Society for Microbiology in Washington, and visited the Center for Biofilm Engineering (CBE) at Montana State University, where a Memorandum of Understanding (MOU) was signed, declaring to work together, partake in student exchanges and knowledge transfer.

DECEMBER 2018, >60 BUSINESSES AND INDUSTRY COLLABORATORS TO DATE
From large multinationals to SMEs, NBIC continues to grow in its mission to control and exploit biofilms by bringing research and industry together.

2019

APRIL 2019, BIOFILM ENGINEERING WORKSHOP HELD, SECOND PROOF OF CONCEPT CALL LAUNCHED & RECEIVED INTERNATIONAL WORKSHOP AWARD
Second cross-sectorial workshop on one of NBIC's 4 key strategic themes, Engineer, was held in Edinburgh, bringing together over 85 delegates from academia and industry to discuss and identify unmet needs and facilitate collaborations.
Our second Proof of Concept call was launched – open to all members of the NBIC consortium and industry collaborators.
We were also awarded £10k by BBSRC to host an international symposium on 'Microbes and Metals'.

JUNE 2019, 3RD WAVE ACCESSION
14 new research instutions joined the NBIC consortium, bringing us to a total of 45.

SEPTEMBER 2019, NBIC ATTEND EUROBIOFILMS
NBIC attended the Eurobiofilms meeting in Glasgow. This was the first meeting we had attended as a full NBIC team with our new brand. It was a great chance for us to meet our partners and make new contacts. We also had the honour to present at the final session.

2020

DECEMBER 2020, SKIN MICROBIOME AND BIOFILMS WEBINAR

Together with Cosmetics Cluster UK (CCUK) NBIC held a joint webinar, 'The science behind the skin microbiome and biofilms – evidence and claims'. Skin microbiome claims are becoming a trend in many categories yet the science is in its relative infancy. This webinar included presentations and discussions covering the market, research and innovation, and addressed questions like, "can pro/prebiotics be used in cosmetics?" and "how can claims be credible and relevant to the consumers?".

OCTOBER 2020, MARINE BIOFOULING WEBINARS

In conjunction with the Plymouth Marine Laboratory and the Singapore National Biofilm Consortium NBIC held a series of webinars on marine biofouling. This webinar series was designed to inform cross sector participants of the current challenges in producing efficacious antifouling coatings under the current regulatory framework, but also to investigate the novel antifouling technology development opportunities this legislative pressure is stimulating.

JUNE 2020, FIRST ONLINE ENTREPRENEURIAL TRAINING COHORT

Run in collaboration with Alderley Park, NBIC members participated in a 2 ½ day pre-accelerator programme to explore how to take their idea or early business forward with the chance to be funded by NBIC in a further mentored 8-week full accelerator programme.

MAY 2020, THIRD PROOF OF CONCEPT CALL PROJECTS AWARDED

A further 14 projects awarded funding, bringing the total number of projects to 65 and a total investment £3.6m from NBIC and £5.4m total value when we also consider funds from companies either in cash or in kind. These awarded projects have involved 28 research institutions, 52 companies and of these companies, 33 are SMEs.

FEBRUARY 2020, FLEXIBLE TALENT MOBILITY AWARD

NBIC awarded a second round of funding from BBSRC to support our current Flexible Talent Mobility Award (FTMA) Account, with a call opening in September 2020 with the aim to fund innovation placements and fellowships, perspectives and knowledge, skills and expertise between the academic and industrial sectors.

FEBRUARY 2020, 4TH WAVE ACCESSION

7 new research institutions joined the NBIC consortium, bringing us to a total of 52.

NOVEMBER 2019, MICROBE-METAL INTERACTIONS WORKSHOP

Our workshop on microbe-metal interactions was held in London. This workshop brought together key complementary academic expertise and thought leadership from industry in biofilms, contamination of metal surfaces and biocorrosion processes across the life and physical sciences and engineering domains within NBIC, CBE and internationally, in order to identify the key knowledge gaps and research challenges for future projects and research collaboration.

DECEMBER 2020, NBIC LAUNCH THEIR RESEARCHFISH PLATFORM

The Researchfish plartform allows NBIC grant holders and funded researchers, to upload outcome data about research to multiple funders easily and quickly, in order to capture the outcomes of NBIC funded research.

DECEMBER 2020, FOURTH PROOF OF CONCEPT CALL LAUNCHED

Fourth call for projects tackling and exploiting biofilms launched in the UK - open to all members of the NBIC consortium and industry collaborators.

AUGUST 2020, LAUNCH OF #BIOFILMAWARE CAMPAIGN

NBIC announced the launch of their biofilm awareness campaign. Through a blend of content, events and outreach activities #BiofilmAware works to raise awareness of NBIC and its research, and the many societal and economic impacts of biofilms. The campaign included the introduction of the first ever #BiofilmWeek.

JUNE 2020, LAUNCH OF BITE DOCTORAL COLLEGE TRAINING

The NBIC Doctoral Training Centre in Biofilms Innovation, Technology and Engineering (BITE) is launched. A world class integrated pipeline of interdisciplinary training, it is the UK's first graduate training centre to address the skills and knowledge gap in the biofilm field.

MARCH 2020, INTERNATIONAL PARTNERING AWARD

NBIC received a funding award 'Singapore: Building a globally leading partnership between the National Biofilms Innovation Centre and SCELSE', which enabled NBIC to facilitate PhD and research fellow mobility between the UK and Singapore.

FEBRUARY 2020, FORMATION OF INTERNATIONAL STANDARDS TASK GROUP

To address the rise in prevalence and popularity of biofilm and microbiome technologies an international task group was formed. The first meeting of the task group was held in Virginia (USA), with delegates from SCELSE, the Center for Biofilm Engineering (CBE; USA) NBIC, and the Singapore National Biofilm Consortium (SNBC), along with representatives from regulatory bodies and agencies from the USA and the European Union.

FEBRUARY 2020, BIOFILM MANAGEMENT WORKSHOP

Third cross-sectorial workshop on one of NBIC's 4 key strategic themes, Manage, was held in Nottingham. This workshop was aimed at exploring unmet industrial needs in the field of biofilm management. NBIC partner organisations shared their unmet needs and the 65 attendees (34 from industry) worked in syndicates to discuss the key challenges and ways to overcome them.

NOVEMBER 2019, SOFTWARE SUSTAINABILITY WORKSHOP

The Software Sustainability Workshop brought together 20 attendees from seven UK universities, plus Unilever, in Birmingham. We ran this event alongside the Software Sustainability Institute in a bid to raise awareness of the need for sustainability in software, particularly when it comes to the potential risks to software reproducibility.

2021

DECEMBER 2020, SOFTWARE SUSTAINABILITY INSTITUTE WORKSHOPS
The Software Carpentry Workshop focused on fundamental data skills needed to conduct research, included writing, managing and automation of code for conducting more robust and reproducible research. The Data Carpentry Workshop was aimed at researchers in the NBIC community who have little to no prior computational experience, and explored best practices for data management and organisation using spreadsheets, data cleaning using OpenRefine, and data analysis skills in R.

FEBRUARY 2021, NBIC CONTRIBUTE TO THE KTN MICROBIOME STRATEGIC ROADMAP
As a member of the KTN Microbiome Innovation Network, NBIC are proud to have contributed to the KTN Microbiome Strategic Roadmap in the personal care and hygiene sector.

FEBRUARY 2021, MICROBES AND BIOFILMS IN THE FOOD INDUSTRY
NBIC's joint webinar with the Society for Applied Microbiology (SfAM) was designed for anyone working in either the production of food or researching/controlling the role microbes and biofilms play in the whole food chain.

MARCH 2021, LAUNCH OF THE PRIORITY QUESTIONS EXERCISE FOR MICROBIAL BIOFILMS
Together with the Center for Biofilm Engineering (CBE), Singapore Centre for Environmental Life Sciences Engineering (SCELSE), COST AMiCI Consortium and the ESCMID Study Group for Biofilms (ESGB) we called on the international biofilms community to help us identify priority questions that, if answered, will make a considerable impact on the fundamentals of the field of microbial biofilms, to innovation in approaches to prevent, detect, manage and engineer biofilms, or which would be expected to have an impact in influencing policy makers and funders.

JUNE 2021, FOURTH POC CALL AWARDED
A fourth portfolio of projects awarded in the UK between universities and industry partners with a focus on controlling and exploiting biofilms. This brings the NBIC portfolio of projects funded since it launched in December 2017 to 81 representing a programme value of £6.7m.

AUGUST 2021, NBIC LAUNCH FIRST #BIOFILMWEEK
The first ever awareness week dedicated to celebrating all things biofilm took place between 16-22 August 2021. #BiofilmWeek promotes the economic and physical impact that biofilms have on our world, and highlights research taking place to prevent, detect, manage and engineer biofilms.

AUGUST 2021, LAUNCH OF OPEN INNOVATION PLATFORM
NBIC's Open Innovation partnering platform, hosted by Innoget provides industry and academic partners exclusive access to directly post technology calls and offers and generate connections and collaboration opportunities online.

JANUARY 2021, NBIC LAUNCH #BIOFILMAWARE PHOTO COMPETITIONS
NBIC launched two national biofilm photo competitions as part of their #BiofilmAware campaign - 'Biofilms in Real Life' and 'Biofilms in the Lab'.

FEBRUARY 2021, NBIC AND INDIA BIOFILMS SOCIETY SYMPOSIUMS
NBIC hosted three open joint online biofilms symposiums between UK biofilm researchers from the NBIC academic community, and from the newly formed India Biofilms Society.

MARCH 2021, 5TH WAVE ACCESSION
11 new research institutions joined the NBIC consortium, bringing us to a total of 63.

MARCH 2021, STUDYING AND CONTROLLING THE MICROBIOME OF THE AIR WEBINAR
Our joint webinar 'Studying and Controlling the Microbiome of the Air' with the Singapore Centre for Environmental Life Sciences Engineering (SCELSE) and Singapore National Biofilm Consortium (SNBC) was designed for anyone in industry and academia with an interest in transmission of bacteria and viruses in both outdoor and built environment and what the evidence is starting to tell us about this field and the future work that is needed.

MAY 2021, INNOVATION IN DEODORANTS WEBINAR
Our joint 'Innovation in Deodorants' webinar with Cosmetics Cluster UK (CCUK) looked at innovation trends and market opportunities in deodorants, translational research in skin microbiome/biofilms, *in vitro* alternatives to animal testing, new technology and small brand perspectives and promoting consumer health and sustainability.

JULY 2021, PRIZES AWARDED TO WINNERS OF THE #BIOFILMAWARE PHOTO COMPETITIONS
Our two national NBIC photo competitions which formed part of our #BiofilmAware campaign ran from January through to 31 May 2021. 'Biofilms in Real Life' received 53 entries and 'Biofilms in the Lab' received 42. A diverse panel of 6 judges took into account creativity, originality, composition, imagination used, scientific value and the overall artistic impression and Amazon gift cards were awarded to first, second and third place in both competitions.

AUGUST 2021, TWO NBIC FUNDED PROJECTS WITH THE QUADRAM INSTITUTE LAUNCHED
The MicroBattle card game, to communicate the importance of bacterial diversity within biofilms, and the 'Biofilm Brainhub' website, built with the support of the wider research community, which aims to be the 'go-to-place' for anyone looking to learn about biofilms.

FUTURE MILESTONES...

NBIC Highlights

81 NBIC Funded

Proof of Concept projects, a total programme value of **£6.7m**

12 Courses Provided

12 Courses attended by masters, post-doc and PhD students across 4 NBIC core institutions

226 Connections

made as a result of responses to our partner searches

309

questions received for our international biofilm priority questions collaborative call

178

peer reviewed publications produced in association with NBIC have been cited by 1024 articles

More than 250 companies engaged

Training Provided

Statistical analysis, data analysis, R programming, Introduction to Entrepreneurship, Introduction to Commercialisation and Public Engagement and Outreach

75% of NBIC Interventional **Theme Workshops**

held, with a total of 198 participants (40% industry, 60% academic)

870

marketing emails sent, with 36% open rate and 24% click-through rate

724 mentions of #BiofilmAware

across all social media channels since the start of the campaign in August 2020.

FOLLOW

4,054 Followers

across NBIC social media channels

420 mentions of #BiofilmWeek

across all social media channels throughout the awareness week in August 2021.

248

publications produced in collaboration with NBIC, from 826 different institutions, with 75 involving 2 or more NBIC research partner institutions and 136 involving 1 or more institution based outside of the UK

63

Acceded Research Institutions

£25,654

awarded across 10 projects from our Public Engagement and Outreach grant scheme

12 Webinars

delivered throughout the pandemic with industry and international partners, with a combined total of over 1,000 attendees

136

Individual Introductions

made linking academic and industry contacts with shared areas of interest or objectives

88

private and third sector organisations involved with NBIC funded projects

95 Submissions

received, from both scientists and the public, for our #BiofilmAware photo competitions

1,435

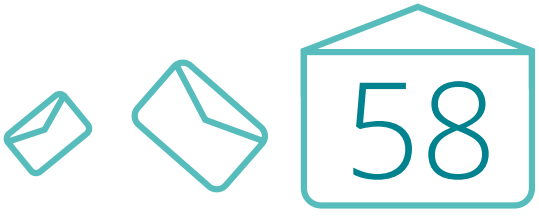
contacts

subscribed to the NBIC newsletter

6

Interdisciplinary Research Fellows

progressed into permanent roles in industry or academia



letters of support generated by NBIC. 36 for grant applications and bids for capital funding

Building an International Community of Biofilm Researchers

OUR KEY OBJECTIVES

NBIC AIMS TO DELIVER:

- World class science
- NBIC sustainability
- Meaningful and productive interactions between academic and industry members
- Economic and societal value to the UK
- The next generation of scientific leaders
- Raised awareness of biofilm issues and opportunities

Theory of Change

NBIC STRATEGY & GOALS

LONG TERM

FINAL GOAL:
MEASURABLE IMPACT ON THE UK ECONOMY

National Biofilms Innovation Centre

THE UK'S RECOGNISED HUB FOR ACCESSING BIOFILM EXPERTISE, CAPABILITY, SCIENCE AND INNOVATION
SCIENTIFIC, COMMERCIAL, ECONOMIC, SOCIETAL AND ENVIRONMENTAL BENEFIT CREATED
INCREASINGLY RESPONSIVE TO SECTORAL CHANGES WITH BREAKTHROUGH INNOVATIONS

MID TERM

IMPACT & BENEFIT
- Strong national infrastructure developed & well-established Innovation Knowledge Centre (IKC)
- Economic and societal value created
- Raised public awareness of biofilms and implications on public health
- Return on investment - created more value

SUSTAINABILITY & LEGACY
- Research and innovation capacity catalysed
- Continued funding (aim to win £40m)
- Brand recognition
- Critical mass developed from collaboration

DIRECT OUTPUTS
- **Science**: Publications, IPs/patents, citations, facilities & services
- **Innovations**: Completed projects to industry products and spin-outs
- Increased academic-industry partnerships through workshops
- NBIC roadmap for biofilms established

INTERMEDIATE OUTCOMES OVER INITIAL 5 YEARS

SHORT TERM

CONCISE OUTPUTS SUCCESSFULLY ACHIEVED OVER INITIAL 3 YEARS
- Award >50 Proof of Concepts (POC) across various sectors, from health to marine, SMEs and large multinationals
- Host 4 workshops across strategic themes to facilitate knowledge exchange, business assist and networking
- Grow university and identified strategic partners with an expertise in biofilms research and innovation
- Recruit >14 Interdisciplinary Research Fellows (IRFs) and establish the NBIC Doctoral Training Centre in Biofilms Innovation, Technology and Engineering (BITE)
- Develop international collaborations with centres of excellence in biofilms
- Raise awareness of NBIC and its mission at the ASM Biofilm Conference in Washington, USA and Eurobiofilms, UK
- Establish key governance structures and a fully staffed operational team

ACTIVITIES

INTERDISCIPLINARY RESEARCH
Establishing a joined-up UK research strategy aligned with UKRI and industry strategies

Interdisciplinary working across research and industry sectors

Achieving a critical mass and infrastructure capability

Deepening scientific understanding of the prevention, detection, management and engineering of biofilms

Investing early in new science that show 2-4 TRL (Technology Readiness Level)

TRAINING & OUTREACH
Providing interdisciplinary training through dedicated MSc, MRes and PhD programmes to develop the next generation of scientifically agile, 'industry-ready' leaders

Delivering entrepreneurial training - from ICURe to SETsquared (#1 university-led incubator in the world) or as appropriate

Engaging with the wider biofilm community and media, regulatory bodies and policy groups, existing and new industry partners, KTN workshops and the public through outreach events and educational activities

Host an international **World Biofilms Summit** to cement NBIC as a centre of global thought leadership in biofilms

RESPONSIBLE INNOVATION
Responsibly innovating in business through commercialising R&D to generate economic benefit in the form of increased market share, GVA and high value jobs

Facilitating more industry-academic partnerships, with £5m flexible funding available to support between 80-120 projects over initial 5 years

Providing a connected innovation space for partners and industry to come together

Supporting development of biofilm management technologies through translational Proof of Concept (POC) funding

STRATEGY

OUR APPROACH
All activities will be led by a forward-thinking, interdisciplinary approach, underpinned by excellence and our values; collaborative, transparent, innovative, flexible, responsive and responsible. Through collaborating to advance relevant research, training future academics and investing in innovation responsibly, our activities will build the environment and mechanisms to efficiently explore and solve unmet sectoral needs, develop strong networks, build roadmaps, influence key stakeholders (regulators, funders and society), exploit emerging breakthroughs and take advantage of new, diverse market opportunities estimated to be worth £45bn in the UK and $4tn globally.

HOW WE WILL DELIVER

PREVENT | DETECT | MANAGE | ENGINEER

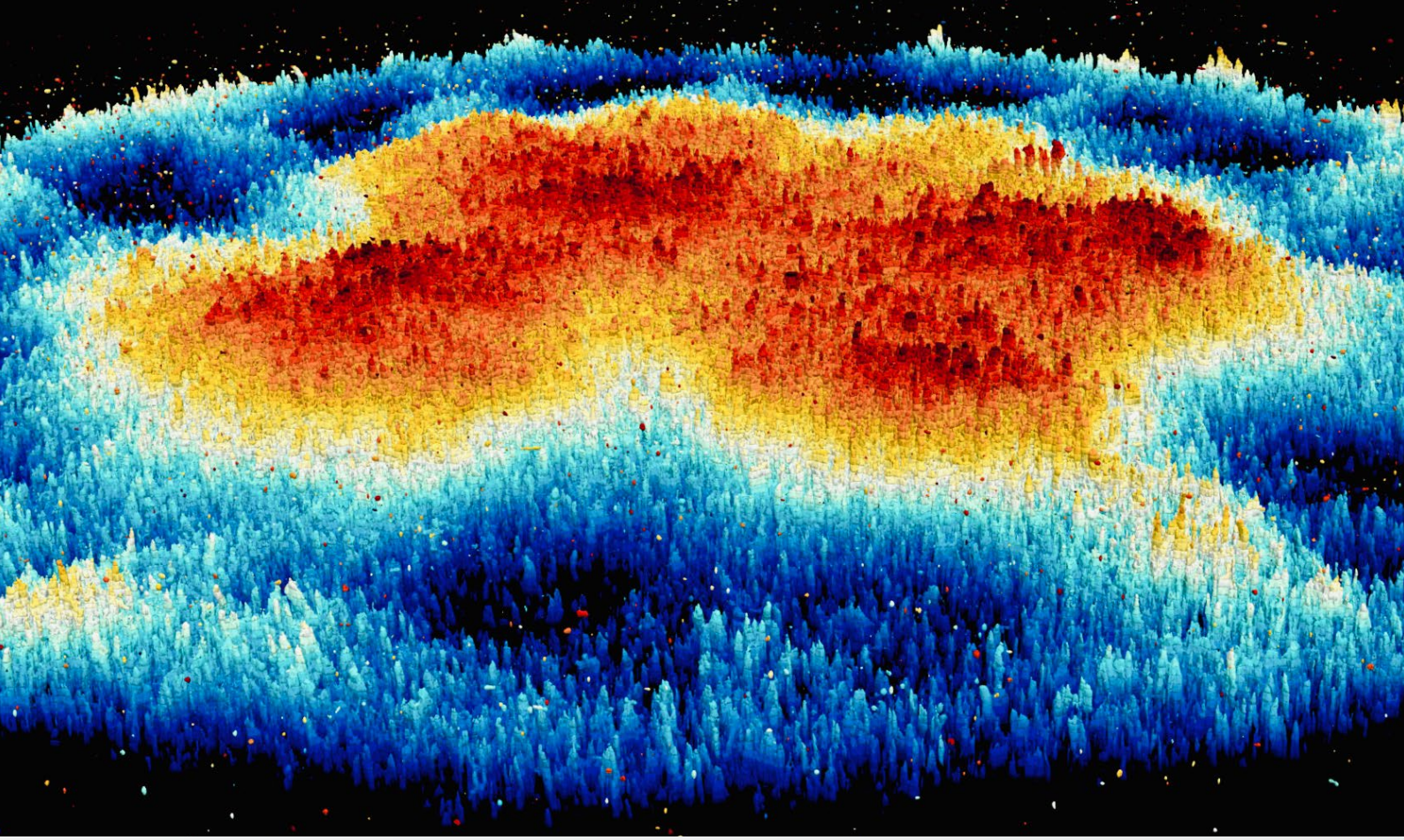
KEY INPUTS

FUNDING
£26m investment in NBIC from BBSRC, Innovate UK and the Hartree Centre, 45 UK research institutions/universities and support from industry (>100 businesses and growing)

KNOWLEDGE & EXPERTISE
>100 researchers, including scientists, engineers, technology translators and clinicians

ASSETS & CAPABILITIES
World class strategic facilities (worth >£300m) provided by university and industry partnerships with state-of-the-art research platforms such as Predictive Modelling, Next Generation Imaging & Sensing

OPERATIONAL TEAM
A dedicated and growing NBIC operational team, providing leadership, management and support across partners and collaborators



International Strategy

FACILITATING INTERNATIONAL ENGAGEMENT AND COLLABORATION IN BIOFILMS

The overall goals and strategic intent of NBIC international collaboration is to leverage our current position within the global scientific biofilm community and prioritise outreach to key developed and emerging regions. NBIC's first governing principle is to promote excellence in science. Therefore, our international strategy strives for a balance of:

- Working with biofilm academic centres that are prominent and striving to advance the field
- Acquiring new contacts in other regions supported by international grants for the developing world

Therefore, whilst we will actively explore new opportunities for biofilm research in Pakistan and China, we will also continue to build on our existing relationships with India, SCELSE/SNBC in Singapore, and CBE in the USA to explore academic, industrial and regulatory synergies.

We also aim to establish international industrial contacts where these can stimulate the growth of the UK science and industrial base in translational biofilm research. This will further expand the reach of our collective scientific expertise and the relevance we can offer to our internationally operating industrial partners through demonstrating our global awareness.

Our aim, as a consortium of 63 UK universities, is to become a strong partner to a larger, powerful and influential international network of industry and academic partners.

INTERNATIONAL BIOFILM STANDARDS TASK GROUP

Since our first Biofilm Detection workshop in 2018, we have heard a recurring need across all industrial sectors for NBIC to pioneer wider engagement with regulators and other stakeholders in the need for both a better definition of standards and policy developments in the field of biofilms. NBIC has a role to play in helping to develop a consensus view and to lead on development of standards and in influencing regulators.

Driven by this need, in February 2020 NBIC, along with the USA Center for Biofilm Engineering, the Singapore based SCELSE Centre and an EU Cooperation in Science and Technology (COST) action group, formed an International Biofilms Standards Task Group (IBSTG) to drive the international development and acceptance of standardised biofilm test methods in health care, the built environment and industrial systems. Our goal is to enable informed and consistent decision making on the international regulation of anti-biofilm products.

The group has published it's purpose and mission across all partner websites and forums.

MISSION

To guide the international development and acceptance of standardised biofilm test methods in health care, the built environment and industrial systems.

GOAL

Enable for informed and consistent decision making on the international regulation of anti-biofilm products.

AIMS

- Educate regulatory decision makers on the importance of using biofilm methods for biofilm-specific label claims.
- Promote to public officials the need to set global biofilm standards through a consortium of established and recognised regional expert organisations.
- Standardise and validate biofilm test methods that are referenced in regulatory guidance documents.
- Promote the use of statistically validated biofilm methods when regulating products with a "kills" or "prevents" biofilm label claim.
- Leverage the global nature of the consortium to adapt testing methods across geographies.
- Engage industry, research institutions, and academic stakeholders in the method development process.
- Champion biofilm methods in country and industry specific standard setting committees.
- Promote international consensus in the biofilm methods recognised in regulatory guidance documents.

ACHIEVEMENTS AND PROGRESS TO DATE

In June 2020 NBIC joined the BSI CH/216 - Chemical disinfectants and antiseptics committee to lobby for development of standards for assessment of these agents in the presence of biofilms.

In December 2020 NBIC secured funding from the UK Department for Business, Energy and Industrial Strategy (BEIS) to progress the development and characterisation of standardised biofilms with a view to developing a joint platform methodology with SCELSE in Singapore.

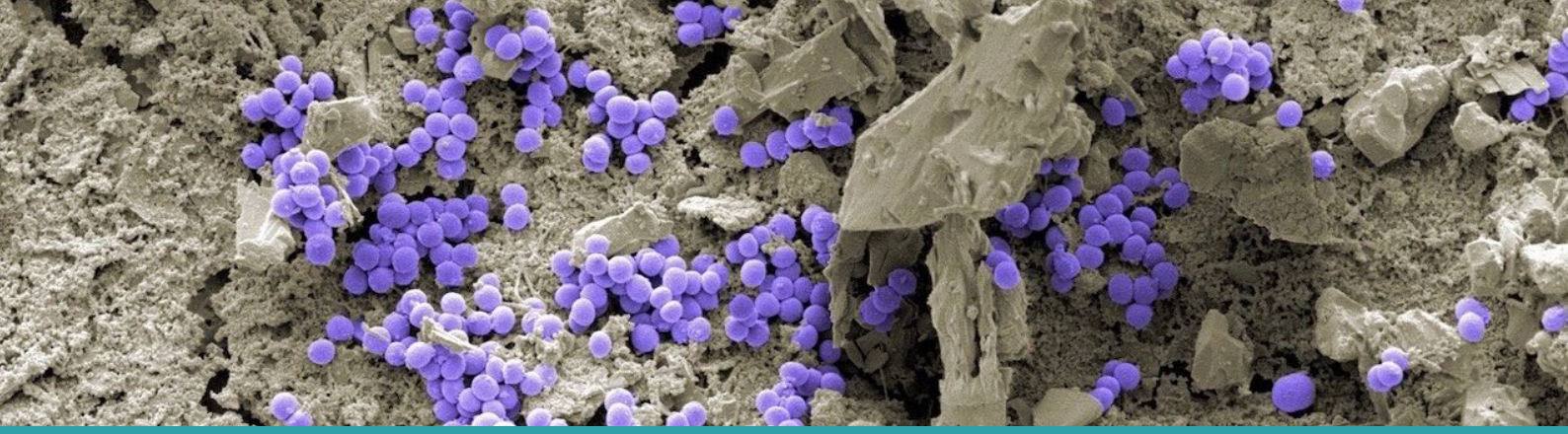
In June 2021 the committee agreed to launch a working group to begin the process towards agreeing and validating consensus methodology with a view to a UK and CEN standard.

FUTURE PLANS

The IBSTG is working to set up a central database of all current methodologies and standards that do exist in whatever sector and whatever term they use to call biofilms e.g. "slime and the microbiome."

In September 2021 the IBSTG is leading a session at the International Biodeterioration and Biodegradation Symposium (IBBS) on "Closing the gap: the role of regulatory standards in biofilm research & industry innovation".

Establish preferred protocol for the BSI CH/216 group in UK and carry out lab evaluation in multiple sites.



Priority Questions

FOR MICROBIAL BIOFILMS EXERCISE

The Priority Questions for Microbial Biofilms is a joint exercise from NBIC, the Center for Biofilm Engineering (CBE), Singapore Centre for Environmental Life Sciences Engineering (SCELSE), COST AMiCI Consortium and the ESCMID Study Group for Biofilms (ESGB). We called on the international biofilms community to help us identify priority questions that, if answered, will make a considerable impact on the fundamentals of the field of microbial biofilms, to innovation in approaches to prevent, detect, manage and engineer biofilms, or which would be expected to have an impact in influencing policy makers and funders.

To date, there has not been an international and community-wide synthesis of key questions and priority research or innovation areas for the biofilm field. Such exercises can play a critical role in bridging the gap between the data generated by researchers, and the information needed by policymakers to make funding or regulatory decisions. We called for questions that are unanswered, could be answered (including through high-risk and blue-skies research), and that could be tackled by a research programme.

BACKGROUND

In May 2019, 29 scientists with expertise in various subdisciplines of biofilm research met in the USA at an event designated as the '2019 Biofilm Bash'. The goal of the meeting was first to identify knowledge gaps, and then to come up with ways of how the biofilm community can fill these gaps. Among the outcomes of this meeting, it was identified that increased interdisciplinary and international networking would be beneficial and that the larger centres can and should play a role in catalysing these interactions, which would bring additional value (e.g. in leveraging international funding initiatives). A joint meeting of biofilm centres was held in Arlington, USA in February 2020, during which they agreed that the core international partners, NBIC, CBE, SCELSE, AMiCI and ESGB would work together with the community to coordinate a priority questions exercise.

GOALS

- To stimulate discussion amongst the biofilm community and identify areas of research and innovation that would have a substantial scientific and societal impact.
- To encourage researchers to think beyond the limits of their own sphere of research or discipline and consider the most important basic or applied research that could possibly be carried out.
- To illustrate the most impactful and beneficial research in the field and its overall importance to funding agencies, policy makers, regulators and the wider public.
- Our definition of microbial biofilms is as inclusive as possible and includes communities of bacteria that may be surface or interface-associated or suspended as aggregates, comprising single-species or polymicrobial consortia, and relevant to any fundamental or applied context in which biofilms are studied.

THE PROCESS

Participants were asked to submit their questions anonymously in April 2021 and were also given the option to leave their contact details if interested in participating further with the activity. We received 309 questions in total, from across every continent.

The team have completed the process of pre-screening submissions for duplication, and those who showed interest in supporting the initiative are currently organising subsets of related questions to finalise our set of priority questions. These will form the basis for a position paper, which will be published as a resource for the field. This is expected to help set the agenda for future research in the field of microbial biofilms as well as have impact in areas of policy and outreach.

Collaborative International Webinars

UK-INDIA BIOFILM SYMPOSIUMS

NBIC first met two researchers from India, Snehal Kadam and Karishma S Kaushik, at the excellent Eurobiofilms event organised by Professor Gordon Ramage in Glasgow in September 2019. Since then, we have hosted three open online biofilms symposia between NBIC biofilm researchers from across the UK academic community, and also from the newly formed India Biofilms Society. We have seen an amazing diversity of work and many opportunities for collaborations. You can find out more about our collaboration in the case study on **page 39.**

MARINE BIOFOULING WEBINARS

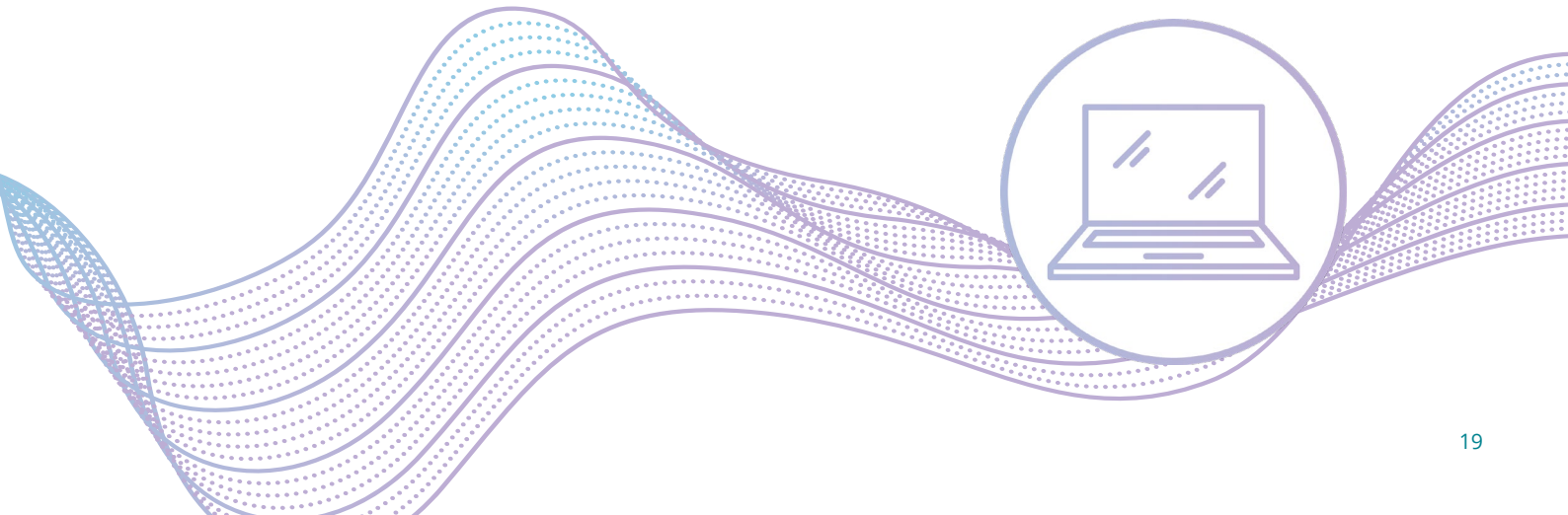
In October 2020, together with the Singapore Centre for Environmental Life Sciences Engineering (SCELSE) and the Plymouth Marine Laboratory (PML), we hosted a series of three webinars focused on the challenges and opportunities presented by marine biofouling. The first 'Biocide use in Antifouling Coatings – The Regulatory Framework' presented a summary of the regulatory landscape relating to marine biocides in the EU and Asian markets. Presentations gave a great amount of detail on existing approved biocides as well as detailing the process for anyone looking to register a new one.

The second event, 'The challenges and opportunities of antifouling biocide regulations - An industrial perspective' focused on how regulations and other emerging factors are driving new product development in the antifouling industry. Finally, 'Biofilm control – what's next?' gave several NBIC and SCELSE members the opportunity to present new technology created to answer the unmet industry need and tightening regulations presented in the first two webinars.

AIR MICROBIOME WEBINARS

It is becoming widely accepted that the air microbiome, especially in light of Covid-19 transmission, can be managed and influenced for environmental and human impact. Our first joint webinar with SCELSE and the Singapore National Biofilm Consortium (SNBC) and Singapore's Covid-19 Cleaning and Disinfectant Task Force (CDITF) took place in March 2021. 'Studying and Controlling the Microbiome of the Air' was designed for anyone in industry and academia with an interest in the transmission of bacteria and viruses in both outdoor and built environments. The webinar featured talks from industry professionals and academics from both regions and explored what the evidence is starting to tell us about the composition of the air microbiome and how it changes due to temperature, climate and other factors.

Our second webinar 'Bioaerosol Characterisation, the Air Microbiome and Covid-19 Transmission' was designed for anyone in industry and academia with an interest in either studying or directly influencing or intervening in the air microbiome in these different contexts and climatic conditions. The webinar featured presentations from the UK and Singapore on a number of aspects of bioaerosols and the air microbiome and the impact on public health. Beyond scientific sharings, members of the Singapore CDITF were on hand to share their practical experiences and advice in usage of surface disinfectants during the pandemic.



NBIC International Biofilm Markets Report

WHAT IS THE ECONOMIC SIGNIFICANCE OF BIOFILMS?

Wherever microbes either cause a problem, or create an opportunity, to humans, animals or the environment, then the communities in which they live (biofilms) have a role to play. NBIC carried out a study in 2020 to quantify the value of the markets in which biofilms are involved. We conservatively estimate this is £45bn in the UK and $4tn globally. All of these markets have a need for research and innovation, to either overcome problems or exploit opportunities, and a few examples of these are given below.

- **Human health –** The challenges of antimicrobial resistance, wound healing and device related infections are all major contributors to the $387bn impact on health;
- **Personal care -** $91bn of this sector is associated with biofilm control;
- **Oral care -** $48.9bn of mainly human but also some animal oral care is linked to biofilm reduction;
- **Home care -** $161bn is spent managing the domestic environment including eliminating biofilms;
- **Built environment -** $48.6bn to ensure that institutions are clean and hygienic;
- **Food and agriculture -** $324bn to manage biofilms from agriculture to the consumer (from "farm to fork");
- **Water -** $117bn mostly spent ensuring there is access to safe drinking water but also in using biofilms as part of wastewater and sewage treatment;
- **Bioenergy -** $5.3bn of energy from landfills and anaerobic digestion plants that use biofilms to decompose putrescible material;
- **Marine -** $34.2bn mostly the cost and losses associated with the fouling of the hulls of ships and marine structures, but also in the contribution to aquaculture;
- **Corrosion -** $2,720bn linked to the pervasive issue of microbially influenced corrosion.

Our study has shown that although biofilms are diverse in their impacts on humans, animals and the environment, there are scientific and technological challenges that are common to many sectors as described in the NBIC interventional themes of Prevention, Detection, Management and Engineering. These common challenges underpin the need for the research and innovation occurring across all these sectors to be well connected as a community via NBIC so that early breakthroughs can be exploited and solutions form one sector considered in other fields. We exist to match solutions and needs in an effective and efficient manner. This is critical in order to achieve economic and societal benefits as well as developing the scientists and technologists to understand and solve both problems and the opportunities.

We created eight infographics to reflect the results of this study, and to show the huge impact that biofilms have on our global economy. You can download the infographics from the **International Biofilm Markets page** on our website.

NBIC Policy Reports

WHAT WE HAVE PLANNED

In line with current NBIC priorities, we have put more focus on our policy-making efforts and have assembled a working group, striving to progress NBIC's influence.

The working group within NBIC, composed of members of the Executive Management Team and Operational Management Group, has conducted brainstorming meetings also with partners and attended information gathering sessions in order to better understand the UK policy-making landscape and to understand where NBIC fits into the landscape, and how best it can utilise its current resources for maximum impact to the benefit of our stakeholders needs.

Demonstrating this so called soft power, according to Joseph Nye (1991) builds on common interests and values to attract, persuade and influence (shaping preferences through appeal and attraction rather than coercion). NBIC foresees playing a part in the UK fully exploiting its strength in biofilm research and advancing its reputation internationally. Via promoting and facilitating science cooperation in the area of biofilms (as NBIC for example undertakes with the CBE and SCELSE in its International Biofilms Standards Task Group) it helps to promote a truly Global Britain.

We are currently collating policy papers on priority areas and will engage with, and make these available to our partners for input.

In order to help our partners and collaborators better understand and navigate the policy-making landscape in the UK, we have prepared the **NBIC Policy Noticeboard** on our website, which provides some helpful links with free training provided by the Knowledge Exchange Unit of the UK Parliament, with guides on how to write a policy brief and further information regarding UK and Devolved Nations' policy-making processes. We also use this page to highlight upcoming events and opportunities.

Establishing Global Standards in Biofilms

NBIC STANDARDISATION ROADMAP

A critical unmet need for innovation across industry sectors is the infrastructure and support needed to demonstrate alignment to relevant standards and the associated analytical competencies. Our national and international academic-industry road mapping has consistently identified the establishment of global standards in biofilms as a priority need.

NBIC is actively addressing this need by establishing networks and collaborations and engaging in a variety of initiatives and research projects:

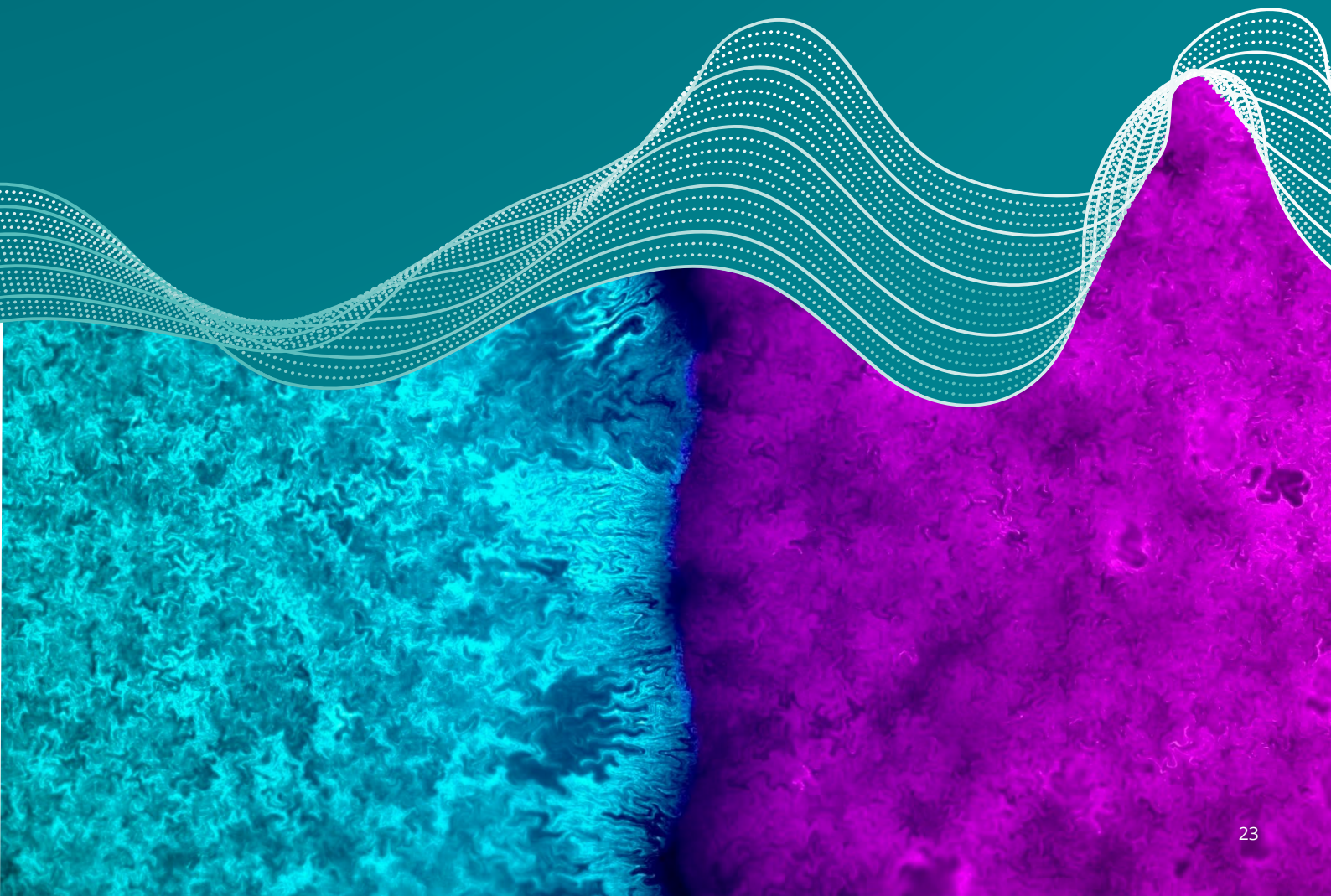
- The International Biofilm Standards Task Group, a multi-centre collaboration between NBIC, USA Center for Biofilm Engineering, the Singapore Centre for Environmental Life Sciences Engineering (SCELSE), and an EU Cooperation in Science and Technology (COST) action AMICI was formed in 2020 to guide the international development and acceptance of standardised biofilm models and test methods in healthcare, environment and industry.
- We were successful in our application for a UKRI BBSRC-funded partnering award.
- Participation in the EU COST action: Euro-MIC 'European Microbially Influenced Corrosion Network – New Paths for Science, Sustainability and Standards' and is also co-developing a proposal for a COST action tackling the reproducibility of biofilm-related methods.
- Co-organisation of a focus session on biofilm standardisation, at the 18th International Biodeterioration & Biodegradation Symposium (IBBS) at Montana State University, USA in September 2021.
- Membership of the British Standard Institute (BSI), contributing to the CH/216 committee on 'Chemical Disinfectants and Antiseptics', where NBIC's CEO Mark Richardson will be chairing a newly established working group on biofilms, set to explore possible new areas of standardisation work.
- Research collaborations with the UK's National Measurement System institutes.

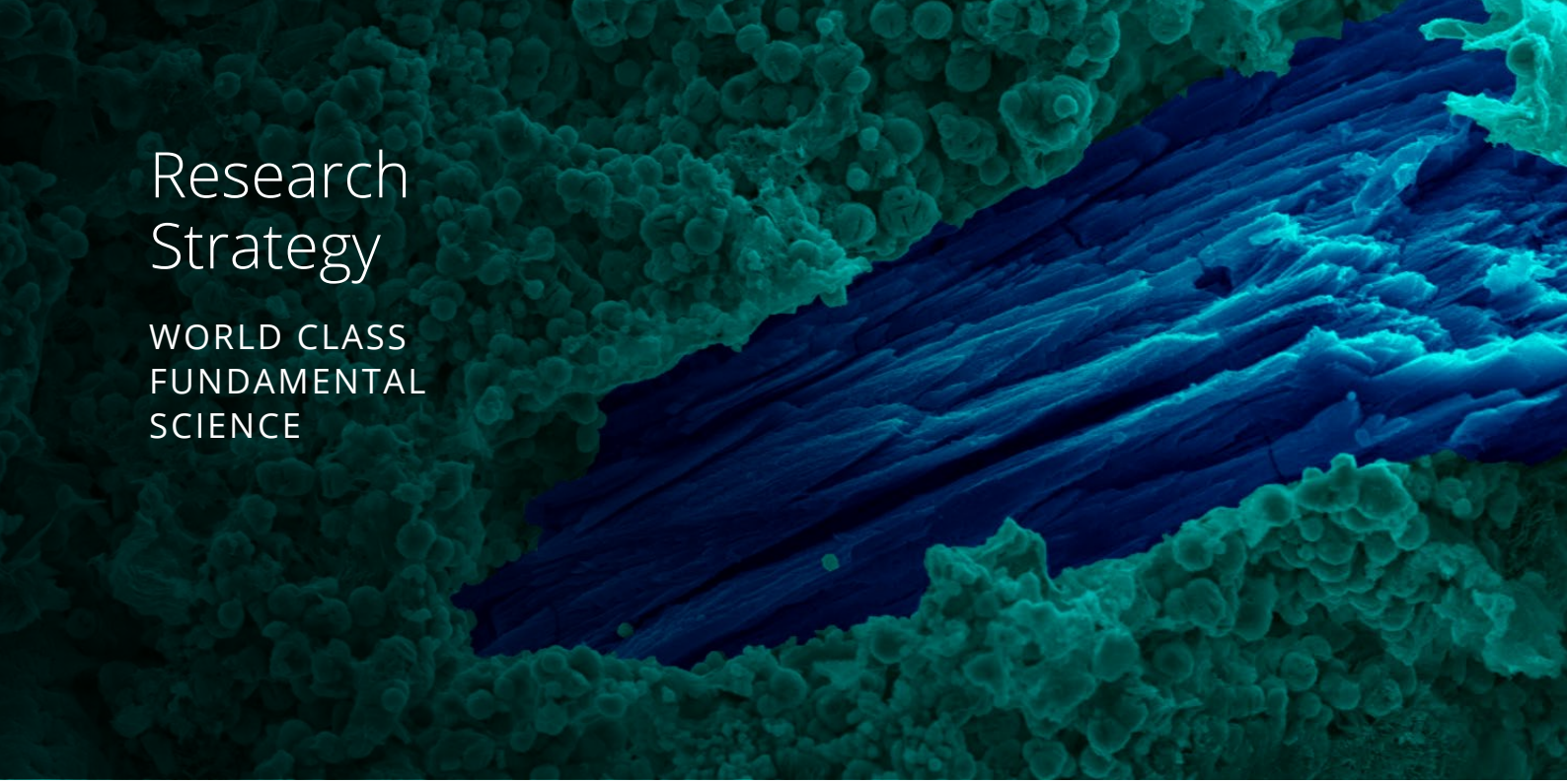
  These include:

  (1) The development of biofilm reference materials with LGC, funded by the NBIC POC4 programme.

  (2) Collaboration with National Institute for Biological Standards and Control (NIBSC), part of Medicines and Health Regulatory Agency (MHRA), on development of biofilm preservation technologies.

  (3) Department for Business, Energy and Industrial Strategy (BEIS) funded project, in the first quarter of 2021, carried out together with the National Physical Laboratory, piloting the development of reproducible biofilm models.





Research Strategy

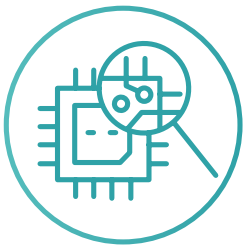
WORLD CLASS FUNDAMENTAL SCIENCE

NBIC is addressing four interventional themes: **Prevent, Detect, Manage, and Engineer** biofilms, by capitalising on world class underpinning research and infrastructure to address sectoral challenges identified together with our industry partners. It dedicates the resource of our Interdisciplinary Research Fellows (IRFs) to support the NBIC fundamental research and training strategy (60% time), and who also conduct focused collaborative industry projects (40% time). Our IRFs are working with industry, funders and policymakers to refine the national research and industrial strategy agenda, shape public funding initiatives and contribute to our strategy for industrial pre- and post-competitive research. We are also developing a dedicated programme of training to build a pipeline of scientifically agile, interdisciplinary, 'industry-ready' graduates.

INTERVENTIONAL THEMES

PREVENT

Knowledge-based design of surfaces, interfaces and materials

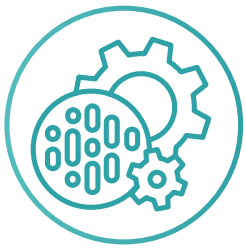


DETECT

Innovative sensing, tracking and diagnostic technologies

MANAGE

Kill, remove or control established biofilms from exploiting their life cycle dynamics



ENGINEER

Control and direct complex microbial community processes in process applications

Working with industry and stakeholders to define the national research strategy, NBIC's approach is informed by our industry partners, leading to new projects that support the development of shared sector roadmaps which identify a clear path to successful creation of value from biofilms research. Key to this is that our IRFs, who are engaged in delivering our scientific priorities, also work with our industry partners, providing greater connectivity across the innovation space and adding value through integrating the national community and infrastructure. Connecting our four core-funded universities, Edinburgh, Liverpool, Nottingham, and Southampton, and our associated partner institutions, forms a powerful critical mass of capabilities and infrastructure that provides additionality among the UK biofilms community.

PREVENT

The Prevent theme focuses on the prevention of early stage microbial adhesion and colonisation events at surfaces and interfaces, and curtailing the development and maturation of early stage biofilms. Both aspects provide a powerful strategy to stop the problem at the onset. Specifically, NBIC provides a unique forum for accelerating academic-industry partnerships that allows prevent-based research approaches to be translated into innovation across multiple industrial and healthcare sectors. Prevent is a broad theme and NBIC's activities are concentrated in a number of key areas. A major focus is the design of surfaces, coatings and materials to prevent microbial adhesion, microbial transfer and/or biofilm formation. Intrinsically anti-adhesion surfaces that rely on designed chemistries, rheology or topographies are being created for medical devices, marine anti-fouling, paints and personal care applications. Allied to this effort is the use of novel actives, repurposed drugs, etc. to create novel antimicrobial coatings. A second focus is the use of physical, chemical or electrochemical perturbations with applications involving light-based, plasma, ultrasound and ozone delivery systems to prevent biofilm survival. Such applications are being developed for healthcare, food and agriculture, and construction applications. The Prevent theme also exploits bio-inspired and biomolecule based approaches e.g. hijacking quorum sensing or nutrient uptake mechanisms. Integral to this theme is the use and development of advanced physical and biological characterisation techniques to lay down the foundations of knowledge-based design. For example, the Prevent theme exploits a range of surface and materials characterisation techniques combined with biological imaging and bioassays to create knowledge-based correlations that can be iterated to high performance interfaces.

Lead Organisation: University of Liverpool

DETECT

NBIC's Detect theme focuses on the requirement for accurate, quantitative biofilm detection and metrology across multiple scales through innovative sensing, tracking and diagnostic technologies. Key to this ambition is the identification and use of new biofilm-specific biomarkers including those relevant to biofilm-associated antimicrobial resistance (AMR). There is an urgent need to develop the capability for non-destructive real-time detection and NBIC is developing new biofilm detection capabilities that will exploit the discovery of biomarkers and that will engineer more sensitive detection systems. The development of low-cost, easy-to-manufacture, portable/wearable/implantable devices that have a long-life span and require minimal maintenance also offers considerable opportunities for innovation. Addressing these challenges will bring exciting new technologies for safer medical devices, better healthcare, and early intervention and control strategies across a range of biofilm challenges from water contamination and microbial induced corrosion to antibiotic resistant infections.

Lead Organisation: University of Southampton

MANAGE

The mission of the Manage theme is to understand the mechanisms governing biofilm life cycle dynamics and development, their physicochemical properties, and levels of complexity, in order to enhance the ability to kill, remove or control established biofilms across a range of environments. Through development of bespoke biofilm model systems, the integration of multiple omics, state of the art imaging, rheology analysis of biofilms of increasing complexity with modelling and *in situ* validation we will gain a unique understanding of the mechanisms governing the interaction between biofilms and their environment. This knowledge will guide the design of novel strategies including the use chemical, biological and physical interventions coupled with robust delivery systems which can effectively interfere with the development and viability of complex biofilms in their natural environment.

Lead Organisation: University of Nottingham

ENGINEER

The vision of the Engineering theme is the control of biofilms in industrial environments and large-scale infrastructure, and the engineering of bespoke biofilms for targeted applications, potentially with the additional benefit of synthetic biology tools and approaches. The ability to engineer bespoke microbial communities is in its relative infancy and requires a top-down and bottom-up understanding. By working with industries across sectors, we are building a top-down understanding of existing microbial platforms, and acquiring data to expand our understanding of community composition, function and ecology. By performing fundamental interdisciplinary laboratory research we are also developing a bottom-up understanding of how communities are formed, and the factors that underpin their function and stability. The ability to craft, control and eliminate biofilms on demand has been identified through the Engineering workshop, the Manage workshop, and the Metals and Microbes workshops as a high priority challenge area for our industry partners.

Lead Organisation: The University of Edinburgh

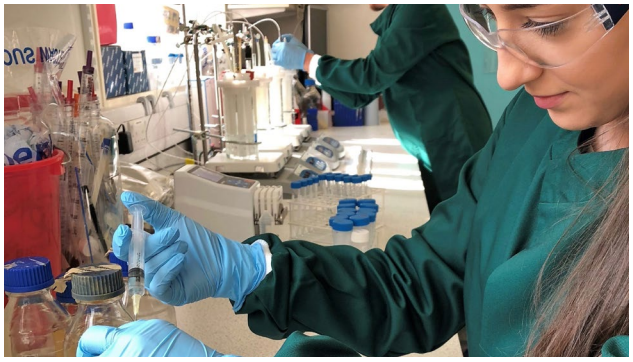
The NBIC Doctoral Training Centre

BRINGING TOGETHER RESEARCH, TRAINING, AND ENTREPRENEURSHIP

The NBIC Doctoral Training Centre in Biofilms Innovation, Technology and Engineering (BITE) was established in early 2019. It is a world class integrated pipeline of interdisciplinary training, involving a partnership between the universities of Edinburgh, Liverpool, Nottingham and Southampton, alongside international institutes and industry partners. It is the UK's first graduate training centre to address the skills and knowledge gap in the biofilm field. The first cohort of 12 students started in October 2019.

The Doctoral Training Centre draws on over 70 academic supervisors from physical, mathematical, engineering, life and clinical sciences within the partner universities to provide a unique, multidisciplinary and inter-sectorial training experience to the next generation of research leaders, innovators and entrepreneurs, to deliver breakthrough science and technologies in this field. Graduates are supported to develop broad innovation horizons and seamlessly transition from research into technology and impact arenas. Entrepreneurship Bootcamps are also offered, with the most promising commercial projects progressed to the ICURe accelerator programme, part of SETsquared, rated the world's best university business incubator. We also partner with Alderley Park and their Accelerator Programme, to provide bespoke entrepreneurial training to our students.

The Doctoral Training Centre provides a unique and diverse environment to students, with opportunities to network with experts in other disciplines, engage in peer-to-peer learning and participate in collaborative problem solving, as well as partake in student exchanges with international centres of excellence, attend summer schools, joint-nature conferences, and secondments and masterclasses showcasing frontier thinking.



By combining the expertise of four partner universities, the Doctoral Training Centre provides the synergy, critical mass, and the breadth and depth required to deliver an ambitious training programme in biofilm science, engineering and technology.

AREAS OF SPECIALISMS

University of Edinburgh Soft and Active Matter Biological Physics; Complex Fluids and Rheology; HPC Modelling; Biofilms Architecture; Synthetic and Systems Biology.

University of Liverpool Functional Surfaces and Materials; Smart Nanotechnology; Plasma Engineering; Imaging; Omics and Bioinformatics; Microbiorefinery; Infection Control; Modelling for Healthcare.

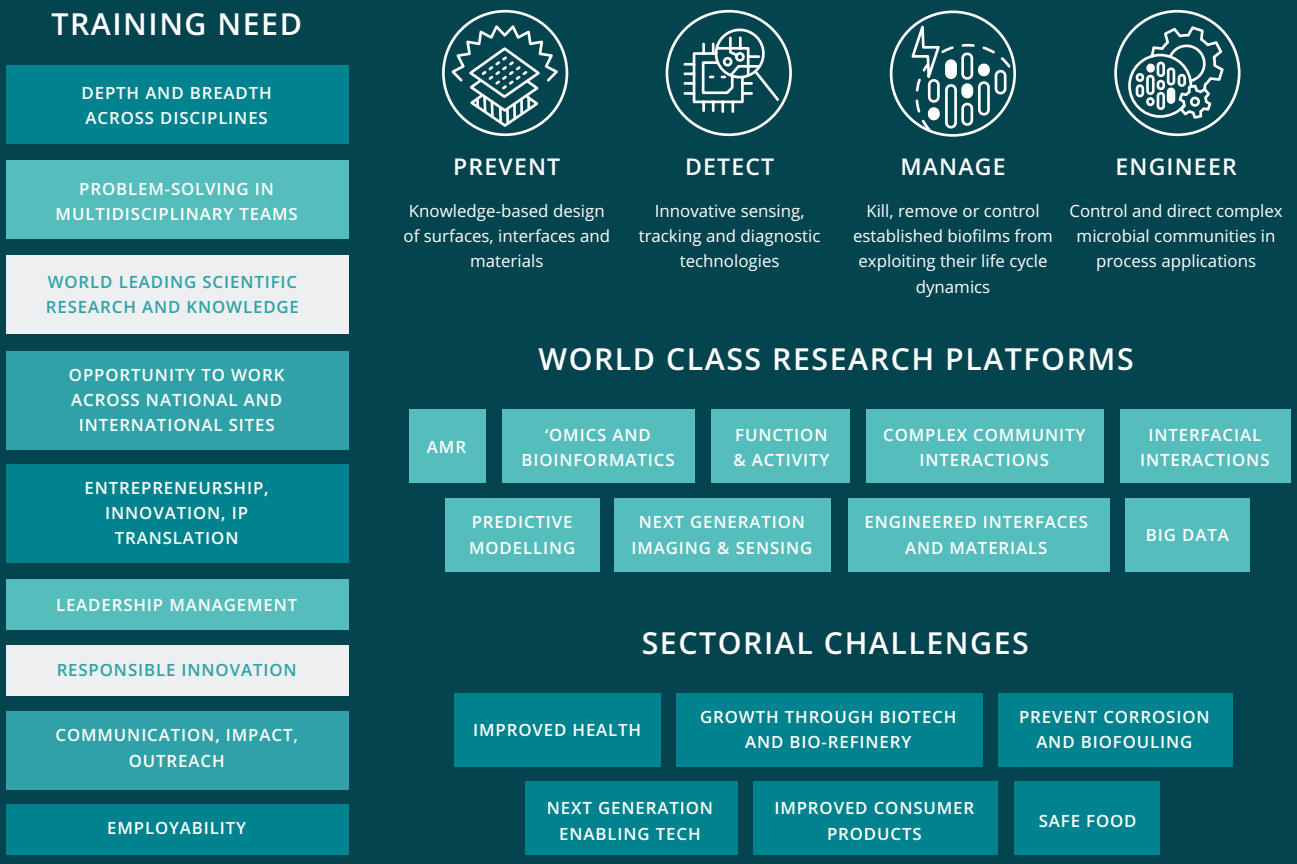
University of Nottingham Quorum Sensing and Signaling; Molecular Recognition; Drug Discovery; Polymer Discovery; Biomedical Engineering; AMR; Modelling; Synthetic Biology; Advanced Microscopy.

University of Southampton Microbial Ecology and Evolution; AMR; Hybrid Biodevices; Nanoelectronic and Photonic Devices; Bioenergy.

QUOTES FROM BITE PHD STUDENTS

> *"I believe that the most exciting part of the BITE programme is the possibility to learn and develop transferable skills and share this experience with a group of fantastic PhDs."*

> *"I was positively surprised by the ICURe Innovation-to-commercialisation programme. I really enjoyed this training, which helped me see the potentiality of my project and the steps I should take for its commercialisation. I believe that it is not common to have the opportunity to access courses about entrepreneurship, and hence, I was really grateful for that."*



NBIC Training

BUILDING ENTREPRENEURIAL SKILLS

NBIC BITE INTRODUCTION TO COMMERCIALISATION CPD PROGRAMME

The Introduction to Commercialisation programme comprised of a 2-day cohort workshop to introduce doctoral candidates to innovation, entrepreneurship, the basics of business acumen; how to build collaboration and networks and, overall, to encourage delegates to see things from different perspectives. Our intent was to keep this programme as a 'gentle' informative but also a fun introduction to various aspects of the commercialisation process that delegates are likely to experience in their future work and career.

NBIC provide entrepreneurial training for early career researchers and established academics. We have strong links to:

ALDERLEY PARK ACCELERATOR

The on-site incubation and acceleration team specialises in the start-up and scale up of biotech and life science businesses by providing the programmes, networks and support required for success. NBIC have jointly run a pre-accelerator programme for our community as a prelude to offering a full follow-on 8-week accelerator programme for best performing pre-accelerator Early Career Researchers and academics selected in a competitive process.

ICURE AND SETSQUARED

NBIC is working with ICURe and SETsquared to offer our researchers training and mentoring to bring research ideas and ability through commercialising processes to the marketplace.

THE SOFTWARE SUSTAINABILITY INSTITUTE

At the end of 2020 we ran two online software workshops organised by the Software Sustainability Institute. The Software Carpentry Workshop focused on fundamental data skills needed to conduct research, included writing, managing and automation of code for conducting more robust and reproducible research. The Data Carpentry Workshop was aimed at researchers in the NBIC community who have little to no prior computational experience, and explored best practices for data management and organisation using spreadsheets, data cleaning using OpenRefine, and data analysis skills in R.

Industry Engagement

WORLD CLASS FUNDAMENTAL SCIENCE

NBIC exists in order to expand, catalyse and harness the UK's academic and industrial strengths in biofilms for the benefit of the UK. We aim to deeply understand unmet needs in our industrial partners' contexts and markets.

Through ongoing engagement, we then aim to demonstrate the ability of NBIC research partners to address these needs, hence driving opportunities for industry and academic collaboration, investment and income.

Our strategy is to match unmet industrial biofilm needs with possible solutions in order to become an essential part of our industrial partners network or open innovation pipeline. We listen, understand and explore needs and/or capabilities, and then create and support connections. We also find ways of progressing these connections either through our own funding routes (Proof of Concept calls) or helping signpost to other opportunities.

Each month we carry out partner searches where we aim to "matchmake" an unmet need to an opportunity or solution (bilaterally between industry and academics) either via a personal contact through our innovation team or emails targeted to our wide network.

In summer 2021 we launched our **Open Innovation partnering platform**, hosted by Innoget. Through this platform on our website, industry and academic partners have exclusive access to directly post technology calls and technology offers, respond to other member's postings and generate connections and collaboration opportunities. Partners also have the ability to access to Innoget's Open Science and Innovation network of over a hundred thousand experts to further explore collaborations outside of NBIC's partner consortium.

The four workshops we designed and led have seen 236 attendees with an approximate mix of 60:40 academics and industry partners. These have all taken the format of exploring the key unmet needs from industry, how the current state of the science and technology landscape could address these requirements and in doing so developed a shared understanding of the opportunities and challenges. The outputs from our four workshops are summarised below. Three of these represent 3/4 of our key strategic themes: Detect, Manage and Engineer biofilms. The last is a workshop we ran on Microbe - Metal Interactions in conjunction with the Center for Biofilm Engineering. Our fourth NBIC key strategic theme, Prevent, will be the subject of an NBIC workshop in November 2021.

Key Findings

FROM NBIC WORKSHOPS

BIOFILM DETECTION

Unmet needs:

- Rapid, *in situ*, point-of-use context for a range of new and emerging technologies.
- Biomarkers that are definitive for biofilms (e.g. blood, industrial fluids, other secondary media).
- To detect/characterise when a biofilm transitions from a "healthy" to an "unhealthy or "pathogenic" state.
- To detect and confirm the presence of a biofilm in a standardised reproducible manner acceptable to regulatory agencies.

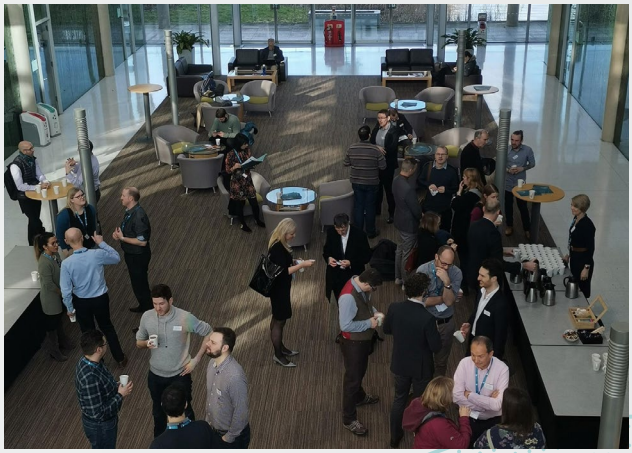
BIOFILM MANAGEMENT

Unmet needs:

- Improved models and methods for characterisation, visualisation and detection of biofilms: relevant (real world context), standardised and accessible.
- Improved cross-disciplinary collaboration (industry, academia, regulators and cross-sectors).
- Clarification of pathways from industry regulators. NBIC has a leading role to play here.

Challenges to overcome:

- Fundamental research on understanding biofilm behaviour and control, to give us new leads and insights is required.
- Data centralisation and management.



BIOFILM ENGINEERING

Unmet needs:

- The need to engineer biofilms for benefit in a human or an animal.
- Creation of a bespoke biofilm community for a defined process, outcome or benefit.
- Improved approaches for investigating, enhancing, monitoring or studying biofilms in the engineering setting.

Challenges to overcome:

- The development and standardisation of experimental and monitoring methods including real-time, high throughput, large scale and multi-variable.
- Developing improved model systems.
- Improved methods for manipulation of an existing biofilm are critical to achieve relevant end products or results.

MICROBE - METAL INTERACTIONS

Unmet needs:

- Achieving improved risk assessment, prediction, and modelling (e.g. being able to predict and understand where, when, and why biofilms form in a particular system).
- The elucidation of coupled microbial metabolisms and potential novel bio-markers. Improved understanding of the interplay between microbes and the surface may lead to identifying key markers.
- Creating improved methods for detection of biofilms and monitoring of systems (e.g. deployable, accurate, sensitive biofilm and corrosion sensors).
- Identifying improved concepts to prevent biofilm formation (e.g. new materials/surfaces/coatings to disrupt biofilm life-cycle dynamics).

Key areas of emerging science:

- Mechanisms and models of the metal-microbe interactions: In all fields of biofilm study including microbially influenced corrosion (MIC) there is a need for improved models that can truly recreate the real-world situation or model it in such a way that accurate predictions can be made and interventions realistically assessed.
- Surface science: Technologies for understanding the metal surface with the ability to measure, interrogate, visualise and modify it.
- Sensor technologies: Groups discussed the need for early detection and monitoring of biofilm formation and MIC occurrence. Sensors are a key tool to achieve this but have to be deployable, accurate and sensitive if they are to be of use to industry.
- Materials/coatings: Approaches that enhance a surface's ability to prevent biofilm formation are critical for addressing unmet needs. These could be improved surface designs, treatments and/ or coatings.

Next steps:

- A consortium with multiple industry and academic partners is needed to move ahead and impact on the challenges identified.
- Many of these are either training - based or exist in the precompetitive space and could be developed into a series of joint projects.

The connections and support we create via our workshops, visits and partnering can lead to a range of collaborations, including fully funded joint projects between a company and an academic, a fruitful long-term relationship or even an application to one of our Proof of Concept (POC) calls. The value of these associations is shown in the various case studies in this annual report.

Collaborative Industry Webinars

BIOFILMS IN PERSONAL CARE WEBINARS

Skin microbiome claims are becoming a trend in many consumer product categories, yet the science is in its relative infancy. Together with Cosmetics Cluster UK (CCUK) we held a joint webinar 'The science behind the skin microbiome and biofilms – evidence and claims'. The webinar included presentations and discussions covering the market, research and innovation, and addressed questions like "can pro/prebiotics be used in cosmetics?" and "how can the claims be credible and relevant to the consumers?". The webinar brought together at times divergent themes of 'skin microbiome friendly' testing and certification for skincare brands. The emerging science behind personal care products affecting skin microbiome was explored paired with explanation of where biofilms occur on the human body, how to use *in vitro* biofilm models and how to manage biofilms with ingredients/technologies fitting into the cosmetics regulatory framework. Additionally, the area of what product claims to make was discussed as well as the magnitude of this exciting opportunity and the ongoing shift in thinking the 'skin microbiome trend' in personal care presents. Our second joint webinar with CCUK looked at innovation trends and market opportunities in deodorants, translational research in skin microbiome/biofilms, *in vitro* alternatives to animal testing, new technology and small brand perspectives and promoting consumer health and sustainability. A third webinar in this successful series will take place in autumn 2021 and will focus on women's health and *in vitro* skin models in personal care.

MICROBES AND BIOFILMS IN THE FOOD INDUSTRY WEBINAR

Our joint full day webinar with the Society for Applied Microbiology (SfAM) was designed for anyone working in either the production of food or researching/controlling the role microbes and biofilms play in the whole food chain. The webinar featured talks from industry professionals and academics discussing the current challenges facing the food industry in managing microbes and biofilms and the evolving regulatory context of achieving microbial control using interventional approaches.

INDUSTRY FOCUS GROUP

There is a well-established need for improved biofilm models in a range of contexts. At NBIC, we became aware of a potential use for a combination of existing techniques from two emerging technology companies which may help address this need. The two technologies are the Cellevate Microcarrier and the Cellexus CellMaker airlift bioreactor. The companies believe these technologies could be used together to cultivate biofilms in a radical 3-dimensional way and came to NBIC to access our network of leading biofilm researchers, to assist in advising them on how they can better design this system and whether our researchers see that it has useful potential.

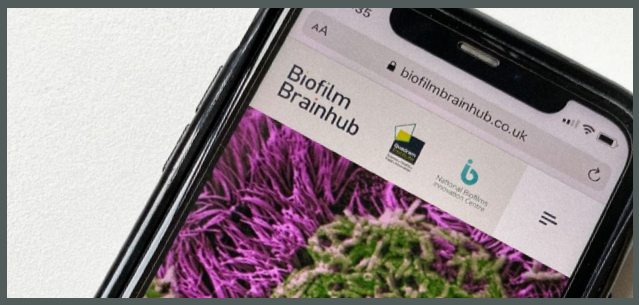
Our focus group with Cellevate and Cellexus in June 2021 was aimed at those working in the field of biofilm culturing, with an interest in developing improved model systems. The session featured presentations from the two companies on the two technologies and how they might be combined. This was followed by an open discussion on thoughts, ideas and suggestions as to how this concept could be further developed for its improved use as a research and applied tool.

Communications and Outreach

RAISING AWARENESS OF BIOFILMS IN THE UK AND BEYOND

Public Engagement (dialoguing with the public about our research) and Outreach (raising science aspirations of the younger generation) about biofilms are extremely important activities to maximise the impact of NBIC, and for society to gain an understanding of what biofilms are and how they relate to daily life. NBIC has a Public Engagement and Outreach Officer and a Committee in place to support these activities. NBIC are conducting a wide range of activities across the UK (from biofilm dances to biofilms in a train station or at IKEA).

We want to deliver our vision for Public Engagement and Outreach, laid out in the strategy we developed in 2020. We want to reach the public with an active interest in biofilms related topics, such as home hygiene and healthcare, to inspire young people, and support everybody in NBIC in undertaking these activities. We are regularly developing appropriate resources for wider use to lead and inspire projects and through our dedicated grant scheme, we offer up to £3,000 for public engagement or outreach projects. Any NBIC affiliated individual or group can apply for this funding, and they can also seek guidance and support directly from NBIC's Public Engagement and Outreach Officer for their own projects. In 2020/21, we funded 7 projects, including diverse activities such as a 'Biofilm Brainhub' website for the wider public, a microbiology themed card game and educational books.



National Biofilms Innovation Centre
#BIOFILMAWARE

#BIOFILMWEEK

In August 2020 we launched our biofilm awareness campaign. Through a blend of content, events and outreach activities #BiofilmAware works to raise awareness of NBIC and its research, and the societal and economic impact of biofilms. Activities have included:

- Creation of a **campaign hub**, containing a variety of educational resources, downloadable social media assets and a campaign guide.
- Priority Questions for Microbial Biofilms exercise with international partners. You can find out more about this initiative on **page 18**.
- **Coccus Pocus 2020** – Biofilms and AMR Scary Story Competition.
- Creation of the International Biofilm Markets **infographic pack** and outreach resource.
- Bad Bugs Bookclub: World Antimicrobial Awareness Week.
- Biofilm Hunt activities (Edinburgh, Nottingham and Southampton).
- Two national biofilm photography competitions.
- **Biofilm Brainhub** website in partnership with the Quadram Institute.
- **MicroBattle (µB) card game**: A microbiology themed competitive card game with the aim to win battles of simulated microbial biofilm growth against your opponent. The MicroBattle Project was funded by our NBIC Public Engagement Grant 2020-2021.
- The launch of our **Open Innovation partnering platform**, hosted by Innoget.
- #BiofilmWeek: Our first biofilm awareness week took place between 16 – 22 August 2021 and promoted the economic and physical impact that biofilms have on our world and highlighted research taking place to prevent, detect, manage and engineer biofilms across our partner institutions and beyond. A dedicated **#BiofilmWeek webpage** included tools and resources to support scientists in industry and academia to create their own content in order to showcase their research and technologies throughout the week.

The #BiofilmAware campaign has been well received and supported, with NBIC receiving coverage across both our academic and industry networks. Highlights include:

- An article by NBIC IRF Susana Direito, focused on biofilm awareness in a time of Covid-19, titled 'Breaking down barriers'. The article featured as the cover story in the summer 2021 issue of 'The Biologist' magazine (digital and print) from the Royal Society of Biology.
- A feature on NBIC in the December 2020 issue of 'The Microbiologist' online magazine from the Society for Applied Microbiology (SfAM).
- An article with Loughborough University in The Engineer (online) 'Fighting back: tackling biofilms on the frontline of healthcare', which explores three areas of research looking to help in the battle against biofilms.
- 724 mentions of the #BiofilmAware hashtag across all social media channels since the start of the campaign in August 2020.
- 420 mentions of the #BiofilmWeek hashtag across all social media channels throughout the awareness week in August 2021.

#BIOFILMAWARE PHOTOGRAPHY COMPETITION

Our two national NBIC photography competitions which formed part of the campaign ran from January through to the end of May 2021. 'Biofilms in Real Life' received 53 entries and 'Biofilms in the Lab' received 42.

Our diverse panel of 6 judges took into account creativity, originality, composition, imagination used, scientific value and the overall artistic impression and Amazon gift cards were awarded to first, second and third place in both competitions. A selection of images from our photography competitions are displayed in our **Biofilm Image Gallery** on our website.

Photo Competition Judging Panel

Chris Denning Director of the University of Nottingham Biodiscovery Institute

Susana Direito NBIC IRF and Public Engagement and Outreach Committee member, University of Edinburgh

Paul Maguire Freelance Photographer, with a background in earth science and exploration

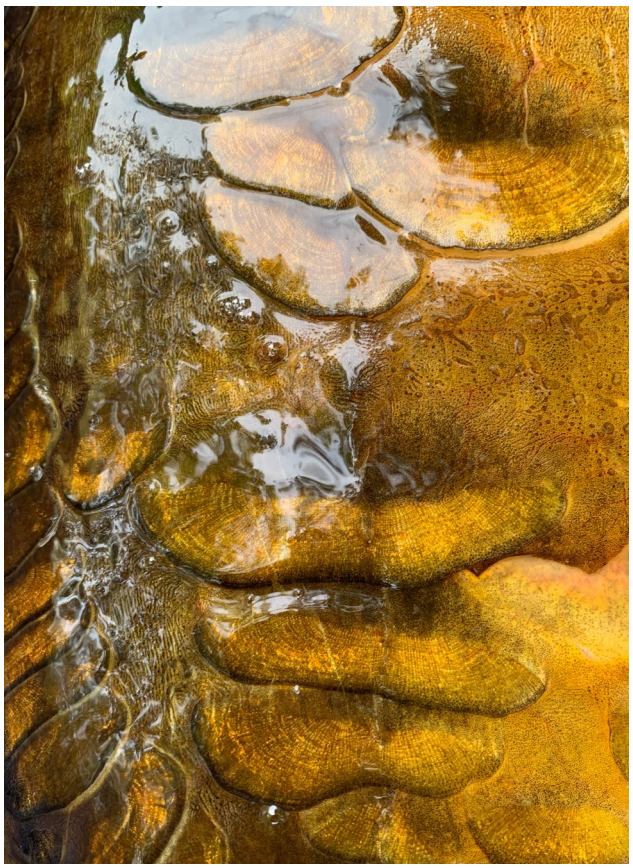
Neil Parry R&D Programme Director of Biotechnology and Biosourcing at Unilever and NBIC International Advisory Board member

Laura Pritchard Senior Innovation Manager, BBSRC, and former NBIC Non-Executive Board member

Tim Self Head of School of Life Sciences Imaging (SLIM), University of Nottingham

Photography Competition Winners

BIOFILMS IN REAL LIFE

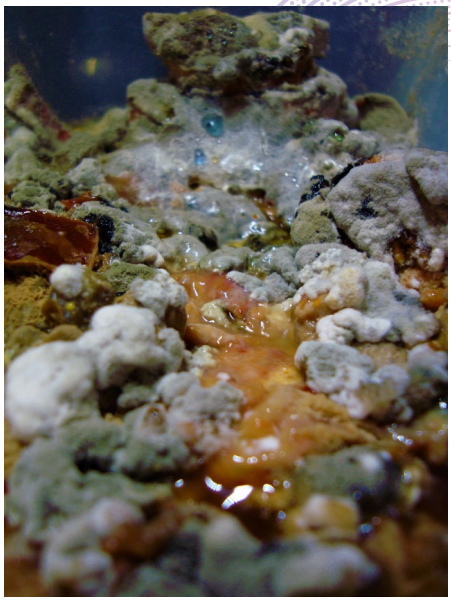


1ST PLACE

Mark Burton, University of Southampton

'MIRROR, MIRROR'

This is a close-up image of the biofilm that covers the scales of a Mirror Carp caught by myself, from a private estate lake in Southampton. The mirror carp have beautiful scale patterns that are distinct to each fish. The mucus biofilm that covers the scales can clearly be seen with the reflection of the sky above glistening in the sun, almost acting as a mirror, hence the title Mirror, Mirror. When catching these beautiful fish, the biofilm is preserved by unhooking on padded wet mats and all fish are returned safely to the lakes after photography, as the mucus biofilms are colonised by beneficial bacterial forming a hydrogel interface and favourable microenvironment which support the barrier to the fish from the outside environment.



2ND PLACE

Callum Highmore, University of Southampton

'TINY KINGDOM'

I sculpted a landscape out of food (various) and incubated it for a few weeks, adding extra food and spraying with sugary water at different times, to get a range of microbes growing. Image brightness and contrast adjusted slightly.

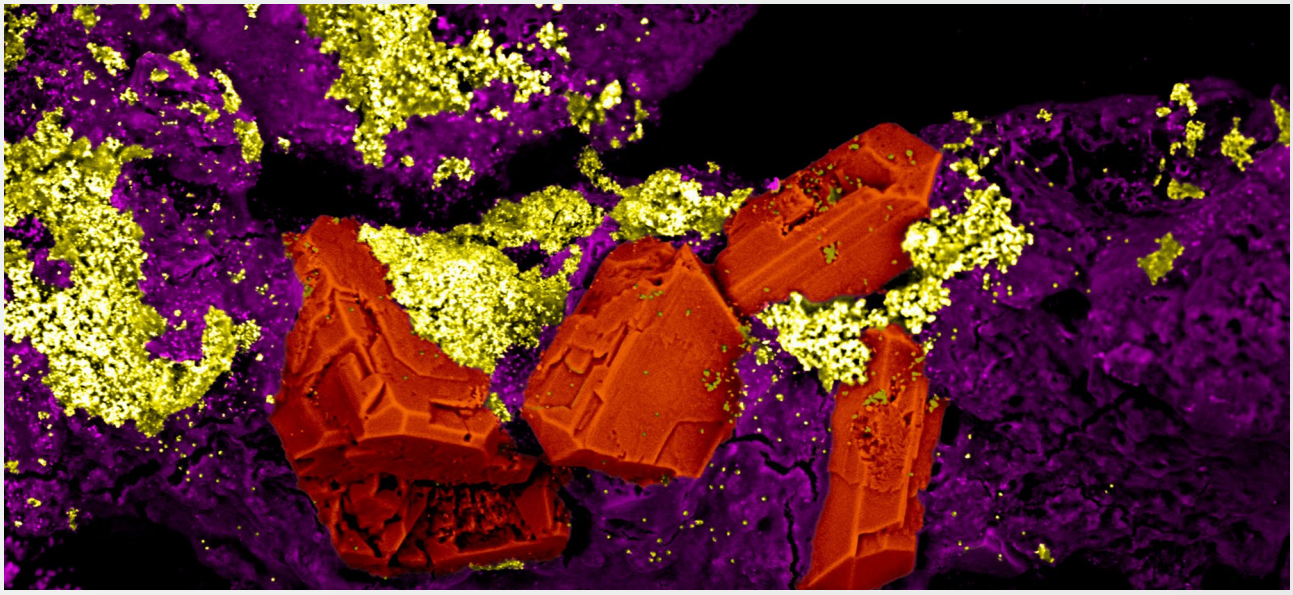
3RD PLACE

Jennifer Dewing, University of Southampton

'PAINT ME A SLIM ESCAPE'

This photograph was taken at a small, quiet lake in chandlers for, Hampshire. At the shallow end of the lake this bright orange 'slime' collects along the edges of the water as a result of bacteria that oxidises the iron released from the ground water. The reflection in the water of the blue sky above balances the bright oranges and yellows of the slime.

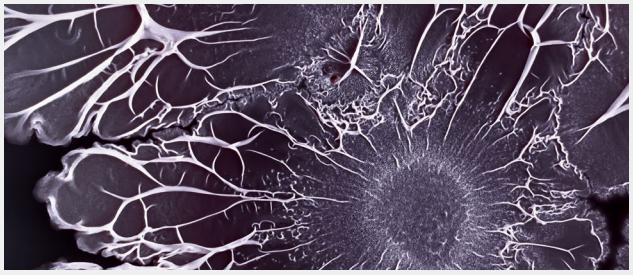
BIOFILMS IN THE LAB



1ST PLACE

Kiril Kalenderski, University of Nottingham

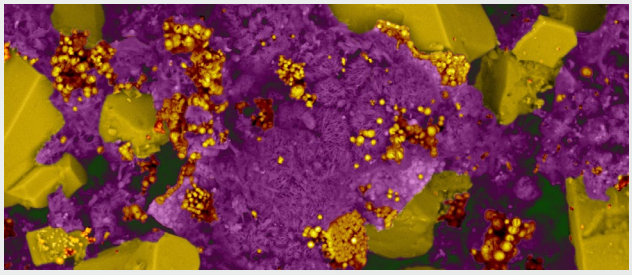
'CLINICAL BIOMINERALIZED BIOFILM FORMED ON A URINARY CATHETER DEVICE'
A coloured environmental scanning electron microscope image (ESEM) of a biomineralized biofilm formed on a clinical urinary catheter device. Struvite minerals are coloured in orange, apatite minerals are coloured in yellow, and the biofilm structure is coloured in purple. Magnification- 500x. Image Production: Kiril Kalenderski and Nicola Weston. Nanoscale and Microscale Research Centre, University of Nottingham.



2ND PLACE

Maria Paula Huertas Caycedo, University of Dundee

'BACILLUS SUBTILIS BIOFILM FORMATION'
Biofilm formation of *B. subtilis* on LBGM medium.



3RD PLACE

Kiril Kalenderski, University of Nottingham

'STRUVITE AND CALCIUM CARBONATE MINERALS ENMESHED WITHIN A URINARY CATHETER BIOFILM'
Large struvite (yellow) and circular calcium carbonate (orange) minerals enmeshed within a biofilm (purple) formed on a urinary catheter (green). Calcite (calcium carbonate) and struvite (magnesium ammonium phosphate) are among the most common types of minerals associated with biofilms linked to symptomatic CAUTI manifestations. Magnification: 1000x. Image Production: Kiril Kalenderski and Nicola Weston. Nanoscale and Microscale Research Centre, University of Nottingham.

Case Study

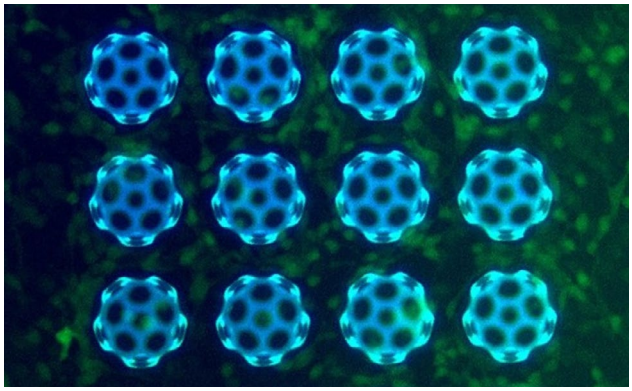
ESTABLISHING A BIOFABRICATION CENTRE

Assisting the academic community to find the right industrial partner

In 2018, the University of Nottingham identified additive biofabrication as a priority research area and established an Interdisciplinary Research Cluster (IRC) in Additive Biofabrication, led by Professors Ricky Wildman and Felicity Rose. The focus of the IRC was to stimulate discussion and pump priming activities amongst researchers at Nottingham, and with international collaborators. The project came about following a joint studentship funded by the EPSRC/MRC CDT in Regenerative Medicine.

Additive biofabrication is the use of three-dimensional (3D) printing technologies to create structures that can direct the behaviour of biological systems. Being able to exercise control over biology offers routes to having real impact not only in basic research but also for further medical and environmental applications. In addition, cell-based therapies are a growing market, and Wildman and Rose aim to produce structures that can support and direct cell growth and provide the basis for functional clinical products in the future.

Wildman and Rose asked NBIC to raise the profile of their capability in additive biofabrication at Nottingham through their industrial network. Through a partner search, NBIC facilitated a connection to the Knowledge Transfer Network (KTN), which resulted in a joint webinar in November 2020 focussed on informing industry about this technology. NBIC also introduced Wildman and Rose to the Centre for *In Vitro/In Vivo* Translation at GSK, and since then have been in discussion about the application of 3D bioprinting to the development of *in vitro* models; and have been successful in securing a BBSRC iCASE award (£95k) to start in October 2021.



3D printed porous microparticles interacting with mammalian cells in culture.

Professor Wildman said,

"The NBIC industrial network has been integral to the success of the KTN event and the BBSRC iCase award with GSK, providing us with an opportunity to explore collaborations with individuals who might have been outside our reach without NBIC".

Wildman and Rose are currently establishing a dedicated 3D bioprinting laboratory within the Nottingham Biodiscovery Institute and have secured funding from the EPSRC to purchase state of the art 3D printing equipment for biological applications, which will be operational towards the end of 2021. Although the centre was originally conceived from the application of additive manufacturing to regenerative medicine, Wildman and Rose believe that this technology could provide tools and solutions for a number of challenges. Significant commercial exploitation opportunities also exist through the generation, robust protection and exploitation of intellectual property and contract research with industry.

Professor Felicity Rose

Professor of Biomaterials and Tissue Engineering at the University of Nottingham, Head of the Division of Regenerative Medicine and Cellular Therapies, and Deputy Director of the Nottingham Biodiscovery Institute (BDI).

Professor Ricky Wildman

Professor of Multiphase Flow and Engineering at the University of Nottingham. His research develops scientific understanding of additive manufacturing processes in order to exercise control over function.

Case Study

TREATING POLYMICROBIAL BIOFILMS

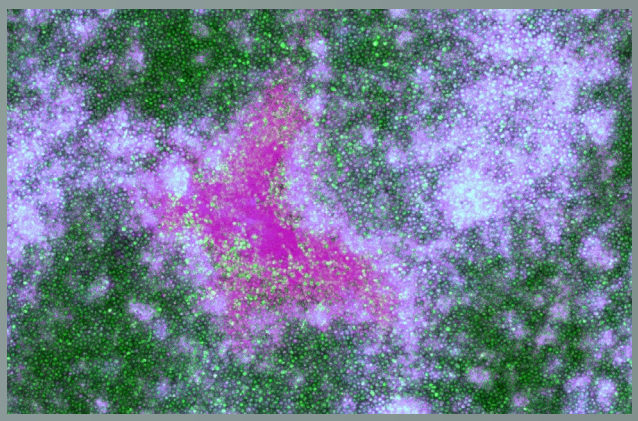
Assisting the academic community to find the right industrial partner

Deep bone biofilm-mediated infections from trauma or surgery are difficult to treat and can be life threatening, affecting up to 100 per 100,000 people per year with up to 64% of long bone fracture patients treated for infection. *Pseudomonas aeruginosa and Staphylococcus aureus* are commonly found in the nosocomial environment, and they are responsible for causing severe bone infection (osteomyelitis) which can result in months of hospitalisation due to poor effectiveness of antibiotics.

In 2020, Md Anirban Jyoti returned to research following a career break with the support of the Daphne Jackson Trust. He was awarded a fellowship funded by the University of Nottingham and is now part of a Nottingham research group focused on addressing these issues by investigating the synergistic effectiveness of Quorum Sensing Inhibitors (QSI) with antibiotics, in the treatment of polymicrobial biofilms, through their delivery from a ceramic bone graft.

Before submitting his fellowship application, Jyoti contacted Professor Felicity Rose and NBIC Co-Director Professor Miguel Camara at the University of Nottingham to discuss the idea for this research project. NBIC connected Jyoti and the team with Ceramisys Ltd who came on board as an industrial partner, providing the bone graft materials for the project and co-funding for his fellowship. Jyoti said,

"The NBIC platform provides excellent support for career development in science and industry and has been critical in securing industrial collaboration for this fellowship".



Polymicrobial biofilm of Staphylococcus aureus (magenta) and Pseudomonas aeruginosa (cyan).

The first 6 months of the project involved establishing microbial biofilms and their characterisation and obtaining biological data - such as cytocompatibility of the bone graft material and the inclusion and release of antibiotic from the material. Jyoti said,

"Being co-hosted by the NBIC laboratory at Nottingham under the guidance of Professor Camara and the NBIC Innovation Research Fellows network has given me access to state of the art technologies and is an opportunity to regain practical skills following my career break on the study of polymicrobial biofilms and bacterial quorum sensing signalling".

By the end of the 2-year fellowship the group aim to have established if the inclusion of QSI inhibitors can potentiate the action of antibiotics released from the ceramic, which will be assessed using a 3D osteomyelitis *in vitro* model, also to be developed by the team. A successful outcome of this project would translate to the reduction in the costs of hospitalisation, time for treatment and prolonged antibiotic usage, and ultimately in a better quality of life for patients.

Md Anirban Jyoti

Md Anirban Jyoti has a PhD in Medicine from Soonchunhyang University, South Korea. His broader research interests are on drug development, drug delivery, intelligent design of biomaterials, mode of action of antimicrobials and finding efficacious, cost effective, environmentally friendly treatments.

Case Study

PROMOTING BIOFILMS IN PERSONAL CARE

Assisting the academic community to find the right industrial partner

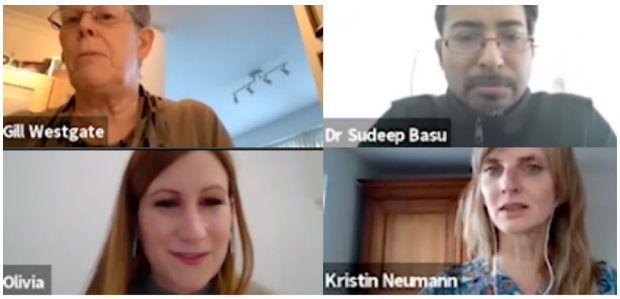
Biofilm science is strongly emerging as key to understanding human health and many companies are now building technology into products that respect the skin microbiome and biofilms.

Cosmetics Cluster UK (CCUK) is the UK's first business cluster, wholly focused on the cosmetics sector and its diverse supply chain. Innovation is at the heart of this sector and CCUK was delighted to be asked to partner with NBIC to promote innovation in biofilms relevant to skin, hair, oral and deodorant products.

CCUK and NBIC teamed up in 2020 to jointly host a series of webinars on this topic, and CCUK were able to reach out to brands, suppliers, testing houses and key opinion formers in the cosmetic and personal care sector to bring a diverse range of international and global speakers. NBIC introduced its network of biofilm-related industries and academics to CCUK.

The events were co-promoted to both audiences. The Covid-19 pandemic meant having virtual meetings, which facilitated great attendance from across the UK, and beyond. In total, the two joint events, were attended by 180 delegates. Dr Westgate, CCUK Co-Founder and Director said,

"CCUK's mission is to be a 'network of networks' and our collaboration with NBIC over the last year has certainly helped us achieve this".



Screenshot captured at the first joint NBIC and CCUK webinar, 'The science behind the skin microbiome and biofilms: evidence and claims.' Speakers included: L-R, Dr Gill Westgate from CCUK, Dr Sudeep Basu, Frost and Sullivan, Olivia Santoni from Bloom Regulatory, and Dr Kristin Neumann from MyMicrobiome.

Outcomes include an increase in personal care, cosmetic and skin health-related applications to NBIC's Proof of Concept grants and the creation of new partnerships between industry and academia. Dr Westgate said,

"The commitment of UKRI to biofilms research through funding NBIC is hugely important as a driver of innovation, as well as to the development of new links between industry and academic research. CCUK is delighted to have been part of this journey".

What's next?

NBIC and CCUK will continue to work together on joint webinars and activities associated with biofilms in personal care. The next, is a webinar planned for autumn 2021, which will focus on women's health and *in vitro* skin models in personal care.

Dr Gill Westgate

Dr Westgate is Co-Founder and Director of Cosmetics Cluster UK (CCUK), a networking organisation for the sector and brings over 30 years industry experience, research leadership skills, access to university experts, funding, facilities and mentoring. Dr Westagte works at the University of Bradford where her role is to develop sustainable partnerships between industry and academic research in life sciences and to help translate science into business opportunities.

Case Study

A GLOBAL BIOFILM NETWORK

Connecting scientists and companies across continents

The annual international Eurobiofilms conference is an opportunity for scientists, clinicians and industry partners with an interest in biofilm-related problems to exchange novel information on clinical, environmental and basic elements of microbial biofilms. At Eurobiofilms 2019 in Glasgow, NBIC were delighted to meet Dr Karishma S Kaushik and Snehal Kadam, two biofilm researchers from India. Dr Kaushik said,

"During the conference, we had the opportunity to interact with the Directors of NBIC, and researchers from several of their partner universities. NBIC's holistic vision for biofilm research, collaborative approach, with industry partnerships in particular, as well as commitment to foster future scientific leaders, was both insightful and inspiring!"

Returning from the meeting Kaushik and Kadam attempted to connect with biofilm researchers in India via Twitter and email, and the response from the community was tremendous. As a result, they established the India Biofilms Society (IBS) - a platform for biofilm researchers in India with a focus on establishing opportunities for scientific exchange, identifying gaps and partners for collaborations, and mentorship for students and doctoral researchers in the country.

NBIC and IBS set up a series of three joint online symposiums, as a platform for researchers in both communities to present and discuss their work. There was a large academic and industry audience from both countries, watching diverse talks such as,

Snehal Kadam and Dr Karishma Kaushik at Eurobiofilms 2019 in Glasgow.

"The Development and Testing of 3D Printed Biofilm Bioreactors for Biotransformation Reaction" and "Denture Biofilms", creating many opportunities for collaborations.

The symposium series blossomed into mutual grant applications and plans for a series of collaborative sessions with our other international partners, the Singapore Centre for Environmental Life Sciences Engineering and the Singapore National Biofilm Consortium, to further share capabilities and opportunities.

Kadam has now moved to the UK to study for her PhD at the University of Hull, an NBIC partner institution, and continues to now be an active part of both NBIC and IBS. Despite the global challenges of 2020 and 2021, the global network of connected researchers continues to establish itself, and NBIC is proud to be able to help continue to build the community.

Dr Karishma S Kaushik

Dr Kaushik is a physician-scientist at Savitribai Phule Pune University, India, where she leads an independent research group that focuses on employing human-relevant approaches to study biofilms.

Snehal Kadam

Snehal Kadam is a PhD student at the University of Hull, focusing on antibiotic resistance in skin wound infections.

Case Study

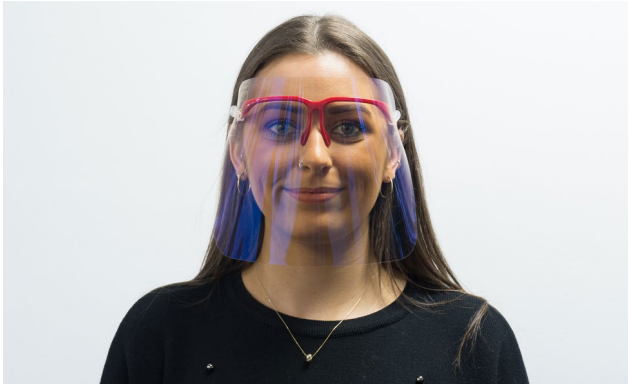
NEW GENERATION COATINGS WITH INTRINSIC ANTIMICROBIAL ACTION

Helping industry find academic partners to solve unmet needs

An NBIC funded Proof of Concept project led by the University of Liverpool, in partnership with Gencoa Ltd, focused on development of anti-microbial coatings using magnetron sputtering technology. The collaborative project enabled a new generation of coatings to be created. Liverpool's analysis pro-vided X-ray Photoelectron Spectroscopy (XPS) data on the relative concentrations of the elements present in the near surface region and the local chemical environments/states of the elements in different coatings. Atomic Force Microscopy (AFM) data enabled the surface topography of the coat-ings to be imaged. Surface bioassays revealed that specific coatings possessed high anti-bacterial performance.

The coatings methodology and know-how developed during the project formed the basis of two Innovate UK projects submitted by Gencoa, Liverpool and other partners, to develop anti-bacterial and anti-viral coatings for high touch surfaces, therefore expanding Gencoa's portfolio of products. Both applications were successful (combined total grant value ~£500K) and work on both projects has commenced. Two main applications have been targetted: first, anti-viral coatings to create reusable face visors and goggles with high optical performance; and second a transparent anti-viral touch screen coating for ticket machines used widely in public transport and healthcare. Dr Monaghan, MD of Gencoa, said,

"The success of our grant applications with the University of Liverpool and other partners is the springboard we needed to provide the scientific information of how these surfaces quickly kill viruses and bacteria. We aim to apply this technology around



Reusable face visor with anti-viral coatings and high optical performance.

the world in consumer and healthcare settings to help fight infections that are a result of cross-contamination from hand contact with surfaces".

The combination of advanced coating technology created by Gencoa, with advanced characterisation techniques used by Liverpool, enable differences in antimicrobial performance to be correlated to fabrication conditions and the resultant surface chemistry and topography. This new technology mitigates the potential of the virus to spread from surfaces that people come into regular contact with and show great societal benefits in terms of saving lives and the economy. Professor Raval, NBIC Co-Director said,

"Anti-viral surfaces are at the frontline of Covid-19 control and new surface-based technologies have the potential to break and contain chains of transmission. This project creates an excellent opportunity to translate our state of the art surface science research into UK's innovation pipeline and help our SME companies to create new products that will enable key sectors in the UK to open up safely".

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1. **Professor Rasmita Raval, NBIC Co-Director**
2. **Dr Dermot Monaghan, Gencoa Ltd Managing Director**
3. **Victor Bellido-Gonzalez, Gencoa Ltd R&D Manager**

Project Summaries

Both projects address a clear unmet need in the current pandemic relating to transmission of SARS-CoV-2 (Covid-19) via the touching of contaminated surfaces in areas such as hospitals, train stations, restaurants and shops. The virus has proven to be particularly resilient, remaining active on plastic and glass surfaces for several days, which poses a significant barrier to resuming public services, reopening hospitality and welcoming workers back to their offices.

Case Study

EXPLORING NOVEL ANTI-BIOFILM TECHNOLOGY USE IN NEW AREAS

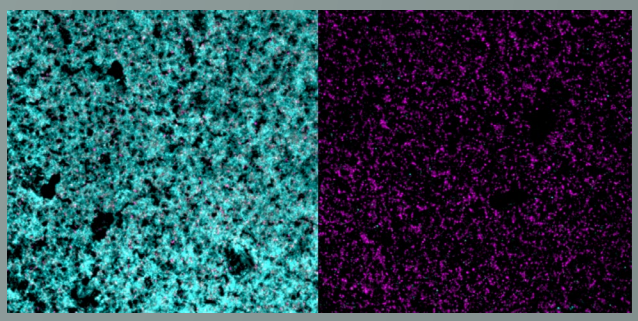
Deepening the interaction between academics and industry

In early 2020 Dr Paolo Pantalone was an NBIC Associate Doctoral Researcher at the University of Nottingham and had been working in association with Unilever on elucidating the mechanism of action of novel agents (Unilever's lactam technology) for *Pseudomonas aeruginosa* biofilm prevention. The opportunity arose via the NBIC FTMA scheme to exploit potential novel applications of the Lactam compounds beyond the Unilever core sectors.

Dr Pantalone worked on their use in combination with unique coatings for the prevention of catheter associated urinary tract infections developed at Nottingham. Also called CAUTI's, these cost the NHS £99m per year. According to a House of Commons Select Committee Report, these require an extra 638,000 extra bed days.

Various physical techniques were employed at both Nottingham and in Unilever's Materials Innovation Factory based at the University of Liverpool. These aimed to characterise the anti-fouling properties of lactam-treated materials using established techniques such as Liquid chromatography-mass spectrometry and confocal microscopy on a state of the art biofilm model. Dr Pantalone said,

"The project facilitated development of my current knowledge surrounding the lactam anti-biofilm technology and helped me to translate these agents into a previously unexplored area – applying the lactam material to commercial catheters. This required creative thought and problem solving to deliver insights and areas for opportunities in an efficient manner".



Left: Untreated silicone (showing biofilm). Right: Lactam treated silicone (showing no biofilm) on catheter sections in artificial urine, 48h S. aureus SH1000 eGFP 24h + P. mirabilis DsRed 24h.

Dr Pantalone's work also allowed his professional network to be enhanced and to work more closely with Unilever development teams and in their facilities. The project allowed Unilever to gain access to skills they required to develop their technology in an area outside of their current fields of use. Unilever recently created a spin-out company (Penrhos Bio Ltd) as a joint venture with the life sciences investment group Innova Partnerships to market the technology outside its normal market sectors. Dr Pantalone has now been successful in securing a job with Unilever, demonstrating not just his ability, but also the opportunities offered by collaborative programmes such as the FTMA for researchers to work alongside industry.

Lactams, rather than killing bacteria, prevent micro-organisms from forming biofilms on surfaces by disrupting their communications systems. Through Proof of Concept funding, NBIC has funded other projects to allow Penrhos Bio Ltd to explore and prove, or disprove, other Lactam applications, for example marine antifouling with the Plymouth Marine Laboratory.

Dr Paolo Pantalone

Dr Pantalone graduated at the Università degli Studi dell'Aquila, Italy in biotechnologies followed by a MSc in medical biotechnologies completed Cum Laude. During his PhD in molecular microbiology and postdoctoral positions at the University of Nottingham, he focused on quorum sensing and biofilm inhibition.

Case Study

BIOFILM RESEARCH INFORMS MARINE COATINGS DESIGN

Supporting academic and industrial partnerships to tackle global biofilm problems

Biofilms, and other marine organisms such as barnacles and algae, often accumulate on underwater surfaces and result in 'biofouling'. This increases drag resistance, and thus causes greater fuel consumption and greenhouse gas emissions, and can cause the spread of invasive marine species. Preventing microbial biofouling from occurring in an environmentally sound and economical fashion is one of the key targets of NBIC and our Proof of Concept funding programme.

Current fouling control coatings, such as low adhesion paints or biocidal antifouling paints, help prevent organisms attaching themselves to ship hulls. These save the shipping industry around $60 billion per year, but researchers and ship owners are continually seeking new ways to further reduce the effects of biofouling.

Marine coatings specialists International Paint Ltd are part of the world's largest paints and coatings company, AkzoNobel. A new device to help understand the drag caused by biofilm growth on ship hulls, was developed by Dr Jennifer Longyear at International Paint Ltd and Professor Paul Stoodley at the University of Southampton, alongside Dr Stefania Fabbri at AkzoNobel, and Dr Simon Dennington at Southampton. Using a £73,000 grant via the UK Biofilms Programme funded by BBSRC and Innovate UK, the researchers built a marine biofilm flow cell to see how different surface coatings, such as antifouling paint, affect how biofilms grow and cause drag.

Alongside the flow cell, the team further advanced a small scale, high volume rheometry testing method developed in the Stoodley lab. Discs of around 40mm in diameter are attached to a shaft, which is spun by a motor. When the spinning discs are submerged in a tank of water, the torque, or resistance to the motor, is measured. The discs used by the team are much smaller than the ~30cm discs, which have been more widely used in marine fouling studies. The smaller scale allows for experimental flexibility, and multiple coatings can be screened with replication within one sea exposure of a board mounted with many discs. This 'rapid screen' is a more efficient and cost-effective way for coatings companies to screen expensive or difficult-to-apply coatings, such as patterning, without having to coat a much larger disc. Professor Stoodley said,

Despite current antifouling measures, removal of slime and other marine organisms still incurs significant costs for the shipping industry.

"It's been a very successful project. I really hope it continues and I'm really interested to see what International Paint want to do with this".

Further Proof of Concept funding from NBIC, supported by BBSRC, Innovate UK and STFC's Hartree Centre, has allowed the group to continue their research and develop new materials which behave like biofilms, with which they have been able to refine the system.

Dr Jennifer Longyear

Dr Longyear joined International Paint Ltd in 2010. She obtained her PhD in Engineering at University of Southampton in 2020, researching methods for quantifying marine microfouling.

Professor Paul Stoodley

Professor Stoodley was Professor of Microbial Tribology within Engineering and Physical Sciences at the University of Southampton, before moving to Ohio State University to become Professor of Microbial Infection and Immunity and Director.

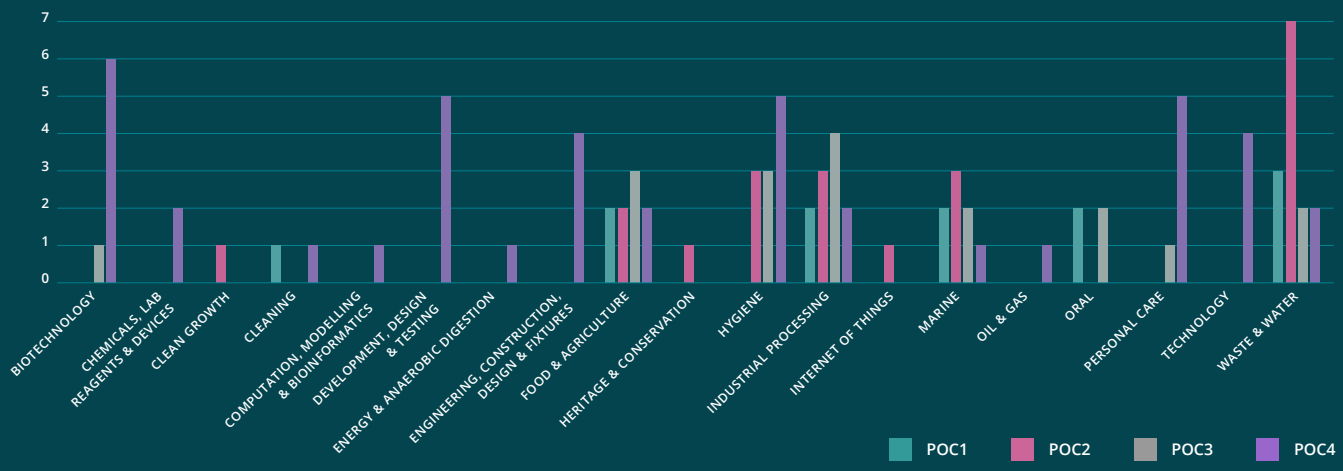
Proof of Concept Projects

SUPPORTING TRANSLATIONAL ACTIVITY

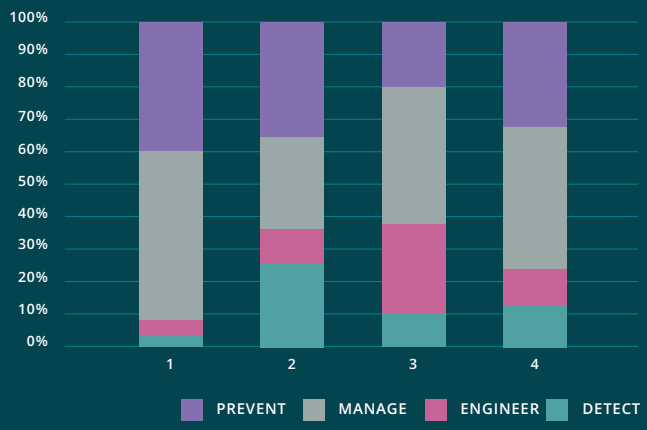
Our investment in biofilm innovation

To date, we have run four Proof of Concept (POC) calls attracting 207 applications from which we awarded funding to 81 projects. This represents an investment of £4.4m from NBIC and £6.7m total value when we also consider funds from companies either in cash or in kind. These applications have involved 39 research institutions, 140 companies and of these companies more than 50 are SMEs. These applications have shown a spread across our four key interventional themes with each successive call showing a more even balance as our outreach takes effect. In addition, they have seen engagement from a diverse set of industrial sectors demonstrating the broad impact of biofilms. A full list of projects are provided in this report from **page 46**.

Proportion of applications to NBIC POC calls to date shown by industrial sector

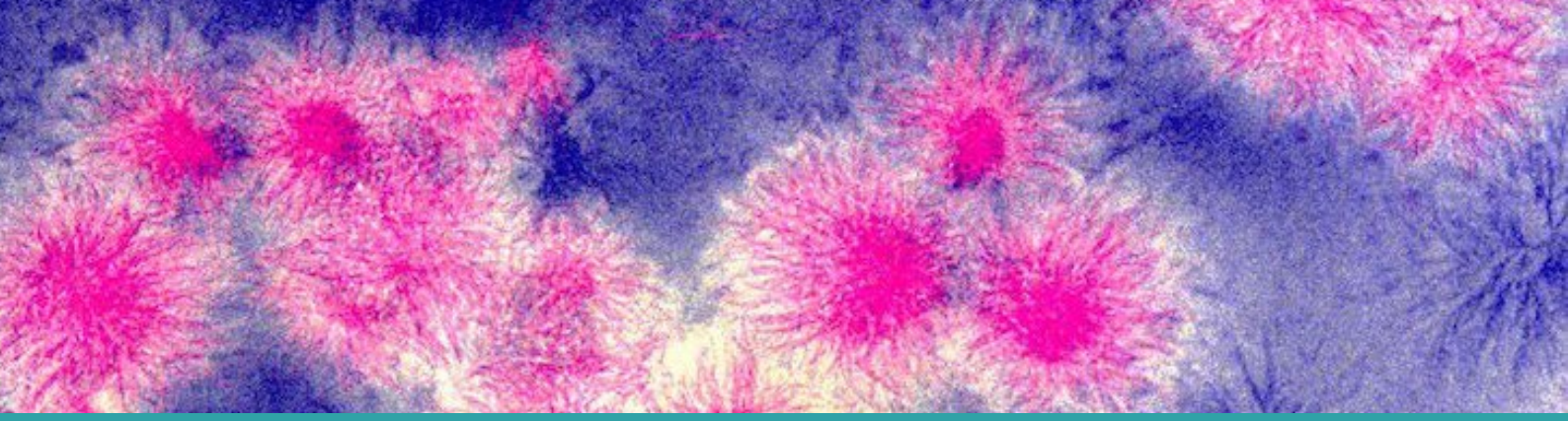


Proportion of applications to NBIC POC calls to date shown by interventional theme



The projects establish the feasibility of a concept, idea or technology from any application sector which is aimed at preventing, detecting, managing or engineering biofilms. The scope was for projects at Transfer Readiness Level 2-4 which were a collaboration between a member UKRI and an industrial partner to transfer technology IP and/or know how from the academic base.

Through our work with universities and companies since our formation in 2017, we can evidence the impact engagement has had through the broadening of the number of universities and companies awarded projects.

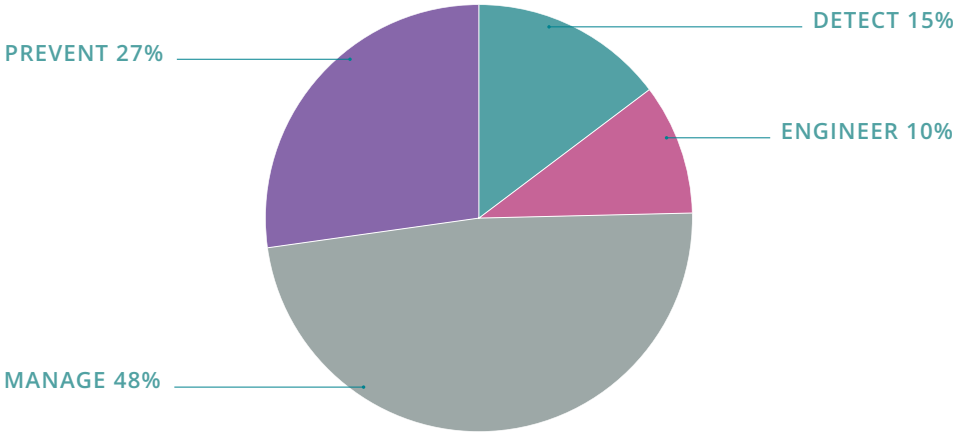


In POC1 for example we had 15 RI and 30 companies who jointly applied. By POC4 we received 61 applications from 31 different research institutions involving 69 companies. There was also wider sectorial spread and an improved balance of interventional themes (Prevent, Detect, Manage and Engineer) from POC1 to POC4.

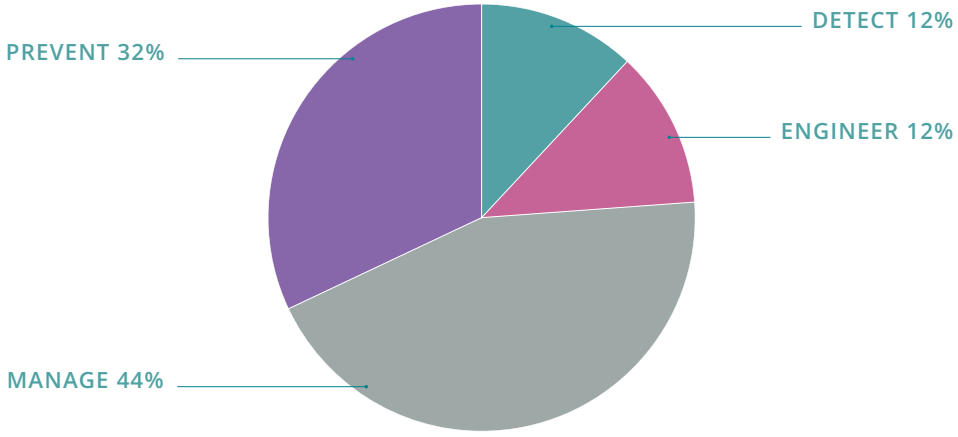
This fourth group of projects continues to address a wide range of sectors and challenges across health, hygiene, industrial processing, food, water, oral care, personal care, anaerobic digestion, waste and wastewater and biotechnology. Our total portfolio of funded projects is now 81 across diverse companies, sectors and research institutions. As our first two groups of awarded projects come to completion and mature, we are now looking to see their further progress and how NBIC can help.

In the current Covid-19 affected science landscape we continue working with holders of active projects to understand how NBIC can be flexible and help them ensure their projects successfully complete.

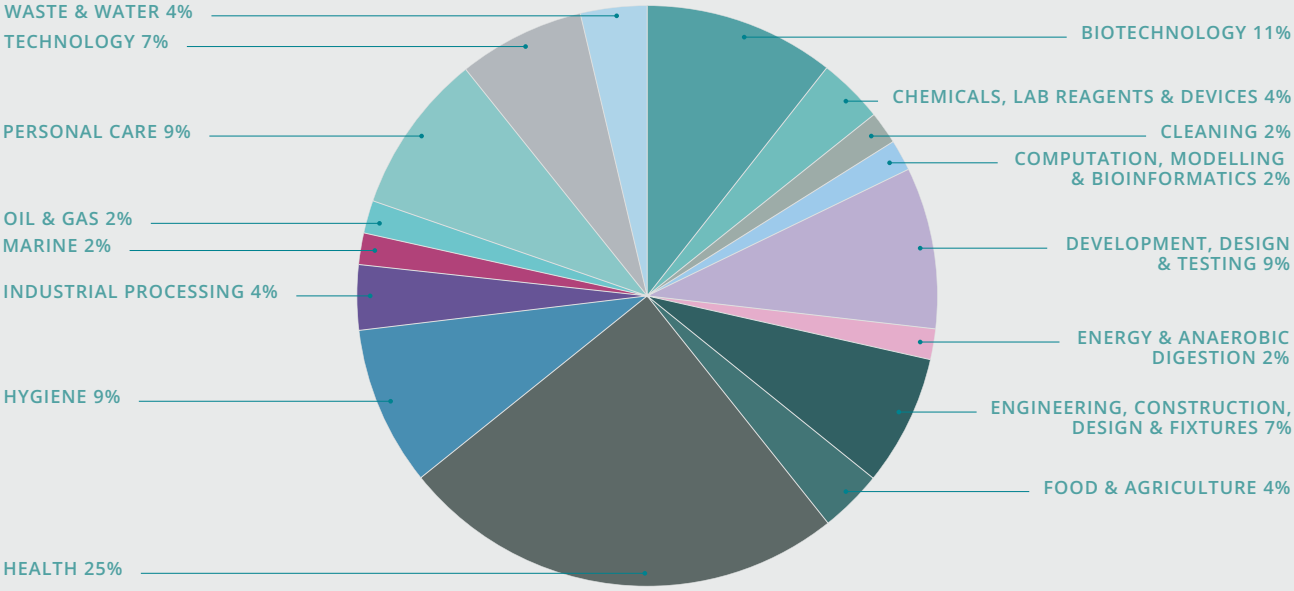
POC4 APPLICATIONS



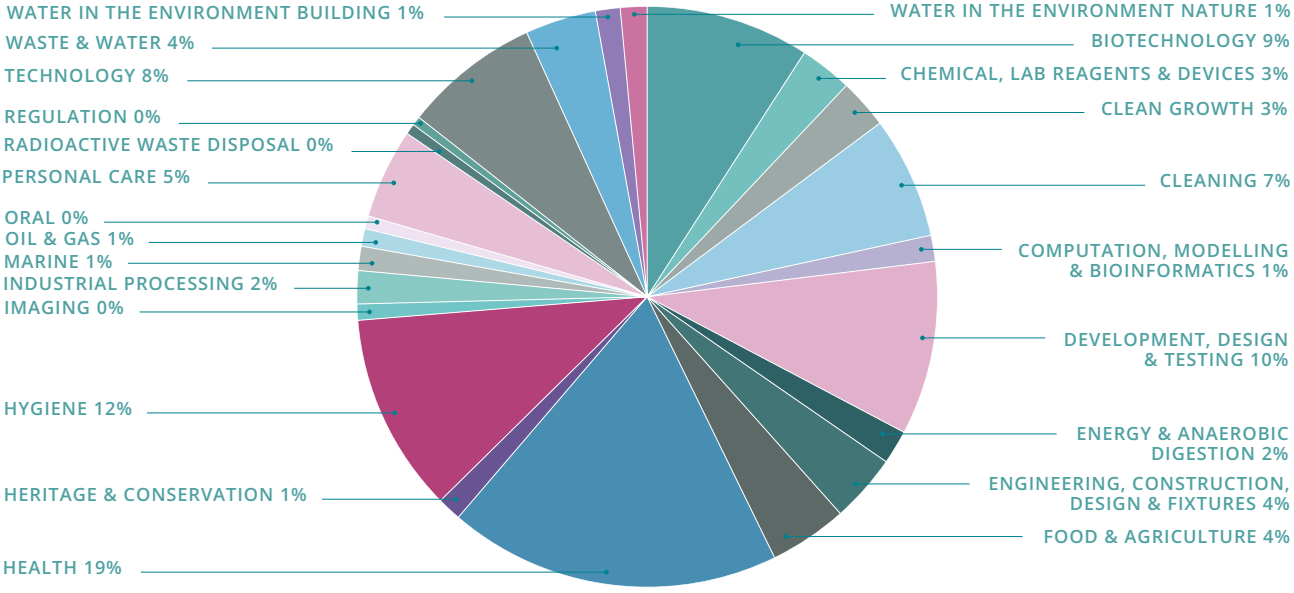
POC4 Applications by Interventional theme



POC4 Awarded by Interventional theme



POC4 Applications by Sector



POC4 Awarded by Sector

Proof of Concept 1

AWARDED OCTOBER 2018

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Managing aquatic biofilms via surface manipulation	Biofilms within distribution pipes present a major risk to drinking water safety. In marine environments, coatings have successfully altered surfaces to mitigate biofilm risks. This project explores the novel application of marine-coatings to drinking water pipes to prevent/limit and manage biofilms by comparing biofilm behaviour using innovative analytical techniques.	University of Sheffield	International Paint Ltd (AkzoNobel) and Dŵr Cymru Welsh Water (DCWW)
Accelerating antisense PMOs to the clinic	We plan to hijack a mechanism used by bacterial pathogens to uptake essential nutrients, to deliver synthetic RNA fragments which can switch off the expression of specific genes required for survival and kill these pathogens in a biofilm. This innovative technology could potentially have a strong impact in combating AMR.	University of Nottingham	Belfry Therapeutics
A model oral system for oral healthcare risk assessment	Hundreds of microorganisms live in the mouth, many are harmless while others cause caries and gum disease. This project will utilise an *in vitro* model system to investigate how oral hygiene products may affect this complex oral microbiome to better predict product efficacy.	University of Southampton	Unilever Safety and Environmental Assurance Centre (SEAC)
PlasmaHeal: cold plasma to control biofilms in wound dressings and at the wound/ dressing interface	Biofilms are a major problem in non-healing and infected chronic wounds due to their recalcitrance to immune clearance and antimicrobial agents. Cold plasma technology is highly effective against biofilm contamination. This project will bring together expertise in biofilms, wound care and plasma to develop a novel 'plasma activated wound dressing'.	University of Liverpool	5D Health Protection Group Ltd
BIOFILMer: a super-resolution platform for the analysis of crystalline biofilms in urological devices	Urological devices are widely used in the clinic to treat kidney stones, tumours, and incontinence. They however suffer from biofilm formation, causing severe side effects. In this project, we will establish the first platform for super-resolution analysis of biofilms in urological devices, enabling development of safer and biofilm-resistant treatments.	University of Southampton	Oxford Nanoimaging Ltd (ONI) and Center for Biofilm Engineering (CBE), Montana State University
Development of a Moving Membrane Bioreactor (MMBR) for the automated cultivation and harvest of algae grown as a biofilm	Many microalgal species are grown commercially to produce a range of sustainable bioproducts, with further product diversification hindered by high production costs. This consortia has developed a membrane based technology to cultivate algae as a biofilm, reducing production costs and opening the possibility to cultivate novel high value strains.	Plymouth Marine Laboratory	Varicon Aqua

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Development and evaluation of a dual function dressing to combat biofilm infection and exudate in chronic wounds	Dressings have been designed to separately address problems associated with chronic wounds including exudate (wound fluid) and biofilms (microorganisms growing on surfaces that are highly tolerant to antimicrobials). This project will assess the anti-biofilm efficacy of a newly developed wound dressing capable of absorbing high levels of exudate.	University of Manchester	Systagenix Wound Management
The effect of low frequency ultrasound on urinary catheter biofilms: a crossover study	Finding ways to reduce infections caused by catheters (tubes) in the bladder is a top priority in the NHS. We have evidence that an ultrasound device (Uroshield) that clips onto catheters could prevent infections. In this study we will use proven methods to find out if it really works.	University of Southampton	Nanovibronix Inc (Ideal Medical Solutions UK)
New generation colour-encoded coatings for surgical tools with intrinsic antimicrobial action	This project optimises technology to produce intrinsically antimicrobial coatings for surgical tools. This addresses an important NHS-identified need for self-cleaning surfaces, combined with distinct colour and lustre required for end-user compliance within surgical theatres. Detailed surface chemistry and biological testing will accelerate commercialisation of existing IP.	University of Liverpool	Gencoa Ltd
Measuring biofilm formation in venous catheters	The placement of catheters into a patient's veins is widespread in hospitals, but poses a serious infection risk due to biofilm formation. We will measure biofilm formation on a range of catheters provided by Kimal Plc, to determine how catheter design can be improved to reduce the risk of biofilm formation.	University of Edinburgh	Kimal Plc
Corneal biofilm models and anti-biofilm nanoparticles	Bacterial and fungal keratitis is a major problem in many low/middle-income countries (LMIC). There is a need for stable and affordable treatments that can control diverse eye infections. Antimicrobial nanoparticle formulations can provide the antimicrobial and physical properties needed to destroy biofilm structures without damage to sensitive eye tissue.	University of Sheffield	Tecrea Ltd and Blueberry Therapeutics
Low dose nitric oxide for the effective treatment of chronic wounds	Wounds that don't heal are associated with bacteria in communities known as biofilms which are resistant to antibiotics. We have shown that low dose nitric oxide can help disperse lung biofilms win patients with cystic fibrosis. This project will test whether nitric oxide can also disperse biofilms from infected wounds.	University of Southampton	Smith+Nephew Ltd
Blue light treatment of *Listeria* under environmental conditions	*Listeria monocytogenes* is an important foodborne pathogen, causing recent fatal outbreaks across Europe and South Africa. *Listeria* can persist in food factories in biofilms despite sanitising procedures. Blue light (~405 nm) could be an additional operator-safe disinfection measure, however its impact against *Listeria* in factory conditions is unknown.	Quadram Institute	Chilled Food Association

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Evaluating an innovative plasma (fourth state of matter) technology for prevention and management of biofilms in the food industry	In the food industry, increased resistance of biofilm-forming bacteria such as *Listeria* has led to a need for new approaches for decontamination of food and food processing surfaces. This project will evaluate an innovative plasma (fourth state of matter) technology for biofilm prevention and management on food and hard surfaces.	University of Surrey	Fourth State Medicine Ltd
A novel laboratory biofilm model to accelerate the commercialisation of anti-biofilm products for the benefit of patients with chronic wounds	Organisation of bacteria as communities called biofilms in wounds delays healing. In the UK, currently one million patients live with the physical and emotional discomfort caused by non-healing wounds. This project will help bring to the clinic a unique, revolutionary cure that will accelerate wound healing by removing biofilms.	University of Sheffield	Neem Biotech and Welsh Wound Innovation Centre
Facile fabrication of a disruptive titanium technology using a polydopamine capturing platform	Titanium dental implants to replace damaged or missing teeth can sometimes get infected. We have taken inspiration from how edible mussels attach to rocks, jetties etc. by applying a thin film of the adhesive used by mussels on titanium. The film in turn can "hook" suitable agents to minimise infection.	University of the West of England (UWE), Bristol	OsteoCare
Biofilm fluorescent antibiotics assay	The ability of antibiotics to penetrate the biofilm matrix is key to their clinical success, but hard to measure. We will assess a novel method to detect how well antibiotics penetrate biofilms in chronic lung infections. We will use fluorescently-tagged antibiotics within clinically relevant and UKAS accredited biofilm methods.	University of Warwick	Perfectus Biomed Ltd
Development of synthetic biofilm for calibrating the effect of coatings on reducing marine viscoelastic drag	Marine fouling biofilm contributes to thousands of tonnes excess fuel usage in the shipping industry. We will develop a test system that can more accurately predict how a coating may reduce biofilm viscoelastic drag to aid in the design and application of better, environmentally friendly coatings for marine vessels.	University of Southampton	International Paint Ltd (AkzoNobel)
QuorumClean	This project aims to develop a novel marine antifouling technology that outperforms conventional approaches, but with a reduced environmental impact. The approach works by disrupting cell-to-cell communication between marine microbes. Potential applications of the technology are diverse and include protection of ship hulls, marine sensors, desalination membranes and aquaculture infrastructure.	Plymouth Marine Laboratory	Unilever R&D Port Sunlight

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Advanced testing platforms to address key performance variables for antimicrobial products on domestic surfaces	Unravelling the effects of soiling events and surface chemistry on bacterial adhesion and biofilm formation over domestic surfaces under realistic environmental conditions. Moving away from model surfaces to add hierarchical levels of complexity: surface materials (hard surfaces initially); and biological inputs (single bacteria to multi-species colonies and associated soils).	University of Liverpool	Unilever R&D - Homecare Division
Treatment of zinc-contaminated slurry in steel production by BioElectrochemical Systems	In Steel industry, Basic Oxygen Steelmaking (BOS) generates significant amount of dust with high Fe contents. The presence of zinc limits Fe recovery as it would cause operational issues, leading to large amounts of dust being stockpiled. We propose a novel and sustainable BioElectrochemical System (BES) to tackle this challenge.	Newcastle University	Tata Steel Europe
Novel pharmaceutical agents (XF-drugs) to prevent and proactively manage bacterial biofilm and fungal infections in dynamic model systems	Antibiotic-resistant bacteria, particularly within biofilms and fungi pose a significant healthcare threat including respiratory conditions (e.g. Cystic Fibrosis) and chronic wounds such as diabetic foot ulcers (DFU). The purpose of this NBIC study is to examine the effectiveness of a novel antimicrobial-drug series in two mechanistically-distinct and clinically relevant model systems.	University of Southampton	Destiny Pharma Plc
Development of next generation synergistic antibiofilm treatments for wounds	Over 50% of chronic wounds develop localised infection due to biofilms, impeding wound healing. Current antimicrobials in wound care have limited effectiveness against biofilms. The aim is to determine the feasibility of combining new synergistic antimicrobial and antibiofilm agents into one formulation for incorporation into a hydrogel-based low adherent fibrous wound dressing.	University of Leeds	T-EDTA Ltd, Medipure Ltd and 5D Health Protection Group Ltd
Influence of phosphate dosing to prevent plumbosolvency on biofilm formation in drinking water distribution systems	Phosphate is added to drinking water to minimise lead dissolution from household pipes. However, phosphate, can favour microbial biofilm formation in drinking water systems. To optimise the way this chemical is used by water utilities we need to understand its impact on biofilm formation and on water quality and safety.	University of Sheffield	Dŵr Cymru Welsh Water (DCWW)
Biofilm evolution in microbial fuel cells fed Yeo Valley wastewater	Yoghurt production generates wastewater that requires considerable energy to clean. This project will look at cleaning dairy waste using bacteria that release electricity as a by-product. We will examine which groups of bacteria (biofilms) are best at producing power and where to find them in Yeo Valley's wastewater treatment plant.	University of the West of England (UWE), Bristol	Bio Loop

Proof of Concept 2

AWARDED JULY 2019

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Algae-powered microprocessors	We have shown that algal biofilms can generate small amounts of electrical power, which can be used to run small electronic devices. We aim to prove the concept that we can use a conveniently sized algal biofilm to power a microprocessor - a computer powered by algae.	University of Cambridge	Arm Ltd
Development of the first ESPRIT-AM antimicrobial self-sealing vascular access graft	Implanted medical devices improve quality of life for millions of people. However, a major complication of these devices is biofilm infection. Current implantable devices offer little resistance to biofilm formation. This project will develop novel anti-biofilm medical device coatings to reduce the incidence and severity of biofilm infection.	Nottingham Trent University	ESP Technology Ltd and Harman Technology Ltd
Enhanced biofilm detection methods and the use of UVC light in their remediation and control on historic buildings and artefacts	Biofilms growing on historic buildings and artefacts can cause serious damage, with critical implications for their conservation. This collaboration with Historic England will investigate novel on-site biofilm detection methods and the use of UV-C as a cost-effective, reliable and non-destructive remediation tool for many endangered historic buildings.	University of Portsmouth	Historic England and Isle of Wight Heritage Service, Isle of Wight Council
e-Biofuels from CO2 conversion using microbial electrosynthesis	e-biosynthetic fuels from alternative resources rather than petrochemicals are essential to transition to a low carbon future with reduced green gas emission to tackle climate change, whilst meeting energy security. Microbial electrosynthesis is a promising way using microorganisms and renewable energy to convert CO2 to fuels and chemicals.	Loughborough University and Newcastle University	Shell Research Ltd
Electrical sensors for environmental & civil engineers: *in situ* online biofilm characterisation	Quantifying biofilms in drinking water pipe networks currently relies on removal of samples for laboratory analysis, which suffers from limits-of-detection, and is intrusive, costly and time-consuming. We propose a new electrical sensor to detect and quantify biofilms *in situ* and in real-time, validating against current state-of-the-art laboratory measurements.	University of Sheffield	Environmental Monitoring Solutions Ltd, Water Industry Process and Automation & Control
Gas plasma for the prevention and management of osteomyelitis biofilms	Osteomyelitis is a biofilm infection of bone which is difficult to treat. This project will develop a novel laboratory testing model to evaluate and optimise a plasma treatment for osteomyelitis biofilm infections.	University of Hull	Adtec

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Examining the potential of pharmaceutical agents (XF-drugs) to prevent and proactively manage bacterial and fungal infections in a dynamic *ex vivo* ocular model system	Antibiotic-resistant bacteria and fungi pose a significant threat in ophthalmic e.g. microbial keratitis, resulting in vision impairment and blindness particularly in lower to middle income countries. The purpose of this study is to examine the effectiveness of novel antimicrobial-drugs, against clinically relevant bacterial and fungal species in a model system.	University of Sheffield	Destiny Pharma plc
In situ underwater optical sensors	There is a growing market in the Marine and Freshwater sector for *in situ* sensors to monitor water environments. A significant bottleneck is rapid instrument failure due to biofouling of sensor windows. This project will: (i) create smart antibiofouling windows; (ii) modify and upgrade current sensors for underwater biofilms identification.	University of Liverpool	Chelsea Technologies Group Ltd
Branched functional polymers for disrupting bacterial biofilms	Biofilms in wounds and on medical devices are a major problem that prevent the treatment of infection. They are produced by infecting organisms and protect it from treatment with antimicrobials and antibiotics. In this project awe are using nanotechnology to disrupt these films to expose the organisms to treatment.	University of Bradford	5D Health Protection Group Ltd
The effect of electrospun nanofibre diameter and conditioning film on controlling active biofilm formation in wound dressings	Biofilm formation leads to significant failure of wound dressings, due to poor nanofiber design. This prolongs healing and increases the risks of invasive disease. In collaboration with Hybrisan, we will fabricate nanofibres of different diameters changing their morphology (size / shape) improving antimicrobial properties and colonisation resistance of wound dressings.	Swansea University	Hybrisan
HullSense	We will design, build and test a working prototype biofilm sensor that will sense microfouling, in real time on ship's hulls. This direct measurement of biofilm will allow in-water hull cleaning to be correctly scheduled to: extend longevity of coatings, reduce fuel consumption and reduce green-house gas emissions.	Plymouth Marine Laboratory	Valeport Ltd
Development of new antibiofilm agents through repurposing of existing licensed drugs	We have recently demonstrated the potential to repurpose existing drugs already used in human medicine as antibiofilm agents. This project will provide a comprehensive screen of available drugs to identify the best candidates for repurposing as antibiofilm agents, with an initial focus on catheter associated urinary tract infection.	University of Bath	Public Health England and King's College London
Detection of biofilms that give rise to wound infection; development of a prototype point-of-care device based on rapid detection and analysis of microbial volatiles	Wound infection results in poorer outcomes for patients and higher costs for the NHS. We aim to detect the gases produced by microorganisms that cause wound infection using nanomaterial based sensors. This Proof of Concept device could potentially lead to future production of a novel point-of-care diagnostic tool.	University of the West of England (UWE), Bristol	University Hospitals Bristol NHS Foundation Trust and Altered Carbon

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Impact of ozone application on *Listeria monocytogenes* biofilms on drain covers under food processing relevant conditions	*Listeria monocytogenes* is a food-borne bacterium that can cause serious and sometimes fatal disease in humans. Food factory drains can harbour *Listeria* biofilms, hence the need for thorough cleaning techniques. This project will test the extent of reduction of *Listeria* by Anacail's high-dose ozone in factory-relevant conditions on drain covers.	James Hutton Institute	Anacail Ltd
Bacterial networking; why it's not always beneficial to build bridges and make connections	Bacteria in wastewater treatment works can form complex network-like structures that can be detrimental to the treatment process. In this Proof of Concept project, we will perform experiments and computer simulations to understand the mechanisms by which these structures form. The insight gained will help us inhibit their occurrence.	University of Edinburgh	Veolia UK
Developing passive RFID technology to monitor *Candida albicans* biofilm growth on medical devices	Pathogenic yeasts can grow as biofilms on materials used to make medical implants, this represents a significant infection risk to vulnerable patients. We will develop methods to detect biofilm growth on medical devices within patients and in real-time using radio-frequency identification (RFID) technology, this will help improve diagnosis and treatment.	University of Kent	Smiths Medical International Ltd
Label-free multimodal imaging platform for detection of biofilms	Biofilms are groups of bacteria that are very difficult to detect. We're combining powerful chemical and molecular technologies in a volumetric imaging platform to analyse biofilms quickly through their unique characteristics. This will help in diagnosis, treatment avoiding anti-microbial resistance and remove or promote biofilms in health and industrial applications.	University of Southampton	M Squared Life Ltd and University Hospital Southampton
Rapid screening platform for shortlisting coatings against infection	Urological devices are widely used to treat kidney stones, tumours, and incontinence. However, they significantly suffer from biofilm formation, causing severe side effects. Here, we will develop the first microfluidic platform for rapid screening of coatings that prevents/addresses biofilms, enabling development of safer urological devices and with wider potential applications.	University of Southampton	Public Health England and Center for Biofilm Engineering (CBE) Montana State University
Advanced biofilm removal mediated by targeted microbubbles generated by fluidic oscillation	In this proposal we will develop an innovative multidisciplinary approach to identify key components of bacterial physicochemical characteristics of both static and dynamic biofilms, which will provide a biomarker for biofilm stability and a target for biofilm removal using our patented novel technology of microbubbles generated by fluidic oscillation.	University of Sheffield	Perlemax Ltd
Automated *in situ* detection and monitoring of marine biofilm erosion and mechanical properties via custom optical coherence tomography (OCT)	This project aims to adopt a uniquely designed automated *in situ* testing rig to detect and monitor marine biofilm erosion and study their mechanical properties. This would address the influence of biofilms on the drag on marine vessels with the aim of improving development of anti-fouling coatings to reduce fuel costs.	Newcastle University	International Paint Ltd (AkzoNobel) and University of Southampton

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Validation of the Oxi-Cell Ozone System for the elimination of biofilms	Oxi-Tech have developed the ozone producing technology Oxi-Cell to combat bacterial biofilms. Oxi-Cell is fitted in-line to water systems to inhibit microbial growth. To validate this technology and facilitate the commercial uptake of Oxi-Cell, we will quantify the antimicrobial effects of this system on planktonic and biofilm populations.	University of Southampton	Oxi-Tech Solutions
Plasma for the prevention and management of chronic wound biofilms	Chronic wounds are costly to treat and significantly affect a patients' quality of life. Bacterial biofilms (specific bacterial structures) play an important role in chronic wounds, and are responsible for many antibiotic treatment failures. This project will test an exciting new technology to remove wound biofilms and promote healing.	University of Hull	Fourth State Medicine
Development of a non-thermal plasma applicator for the decontamination of medical endoscopes	This project will develop a novel non-thermal plasma applicator system for the decontamination of medical endoscopes during re-processing within hospital facilities. This addresses the current clinical and economic need to ensure that endoscope devices are free from the risk of cross contamination and potential infection for patients.	University of the West of England (UWE), Bristol	Creo Medical Ltd and Pentax Medical
Standardised complex wound biofilm models - a robust antimicrobial screening tool	Biofilms are rarely found comprised of one single type of microorganism, yet the development of new antimicrobials tends to focus on testing one bacteria. This project aims to develop methods and testing platforms that will allow industry partners to develop an effective anti-biofilm compounds using a platform representative of wounds.	University of Glasgow	BluTest Laboratories
Rapid early and accurate diagnosis of wounds	To feasibility test an optical-fluorescence-based detection technique that seeks to quantitatively detect bacterial biofilms in infected wounds against a complex background of normal flora, and determine antibiotic susceptibility. The rapid single-step test, implementable at the bedside, can potentially transform wound care through improved clinical outcome and reduced costs.	Loughborough University	Smith+Nephew Ltd
Commercialisation of a burn wound biofilm model to provide a new service for pre-clinical research and testing in academia and industry	Biofilm formation in burn wounds is associated with treatment failure, poor clinical outcomes, and development of chronic non-healing wounds. This project will develop a UKAS-accredited pre-clinical model of burn wound infection, that can support both early-stage and commercial development of new products to control biofilm formation in wounds.	University of Bath	Perfectus Biomed Ltd

Proof of Concept 3

AWARDED MAY 2020

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Develop a computational tool for marine biofilm management	Computational biofilm modelling has potential as a rapid, low cost route to accelerate ship fouling control coating research & development. This project aims to develop a unique computational tool to predict experimental data on marine biofilm erosion, deformation and drag at mesoscale flow cell as a Proof of Concept.	Newcastle University	International Paint Ltd (AkzoNobel) & University of Southampton
Biofilm production of *Phaeodactylum tricornutum* for fucoxanthin	A membrane-based bioreactor system utilising biofilm forming microalgae has been developed to solve the economic and biological bottlenecks commonly associated with conventional microalgal production. This study will establish the economic viability of this novel process using the model marine diatom *Phaeodactylum tricornutum* for the production of the high-value pigment fucoxanthin.	Plymouth Marine Laboratory	Varicon Aqua Solutions
Novel XF drugs in the topical management of *Candida albicans* biofilms	Oral fungal biofilms are common and responsible for a significant burden of infection in people. Successful treatment is hindered by biofilm resistance and limited numbers of effective antifungal drugs. This project will evaluate the novel XF drugs in combatting *Candida* biofilms and reducing their infection risk using mucosal mouth models.	Cardiff University	Destiny Pharma
Development of molecular support to detect biofilm causing pathogens within chronic infections	The same species of microorganisms colonize skin and behave as pathogens. The biofilm phenotype has been proposed as a trigger for infection chronicity however organisms are not routinely screened for this. This project aims to identify genetic markers linked to biofilm that can be utilised by clinicians to detect biofilms.	University of Huddersfield	Perfectus Biomed Ltd
Rotating spiral biofilm reactor for reliable engineering and control of bacterial communities and environments for use in industrial biotechnology	This project extends an existing technology based on rotating spiral channels to the challenge of harnessing microbial biofilms for sustainable production of valuable chemicals currently uneconomical to synthesise through alternative routes. The constructed prototype will act as an enabling technology and open up new markets for the industrial biotechnology sector.	University of Sheffield	Unilever
Manipulation of gut biofilms dynamics for enhanced iodine bioavailability	Biofilm aggregates (diversity, function) influence nutrients bioavailability from complex food matrices. We will define how gut biofilm aggregates influence iodine bioavailability (nutrient of public health interest) from seaweed, an iodine-rich food. Defining how to sustain/ engineer these biofilms will enable the industry partners to develop safe evidence-based products.	University of Glasgow	Seaweed & Co
DNA origami nanostructures as a tool in the disruption of *P. gingivalis* biofilms	We aim to fight the bacteria that contribute to gum disease, by creating origami-like DNA nanostructures loaded with antibacterial enzymes or proteins. We will optimise the DNA origami to bind specifically to the target bacteria and to improve the penetration and disruption of the biofilms that they form.	University of Cambridge	Frontier IP Group plc

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
To incorporate a quorum sensing blocker (lactams) into wound dressing platforms to control biofilms	The general aim of this Proof of Concept of study is to develop and evaluate a pioneering wound dressing to be used as a new, smart technology for the effective management of biofilms in wounds, which has the potential to greatly enhance patient outcomes and reduce healthcare costs.	University of Liverpool	5D Health Protection Group Ltd, Penrhos Bio and Unilever
Biofilm disruption activity of absorbent sustained action alginate and iodine combined wound dressings	Potential methods to treat wound infections include using absorbent dressings containing alginate for antimicrobial sustained-release. Alginate-Iodine combinations have shown considerable promise against single-species biofilms. Here we evaluate disruption of persistent polymicrobial inter-kingdom and single-species wound biofilms utilising different formulations of absorbent sustained-action alginate/ iodine dressings in abiotic and biotic biofilm models.	University of Nottingham	Io-Cyte Ltd and University of Southampton
Novel hybrid biofilm technology to remove nutrients from wastewater	Nutrient removal represents a significant challenge to the water industry, housing development and local economy, particularly in the Solent region. This project aims to demonstrate a hybrid biofilm system in a full-scale prototype plant achieving total nitrogen and total phosphorus concentrations below 5 and 0.5 mg/L, respectively, in treated effluent.	University of Southampton	Plantwork Systems Ltd
Dry surface biofilms, understanding their formation and development of a test model for preventative surface cleansers	Surfaces within a healthcare environment can be coated with potentially infectious organisms which survive by forming a dry biofilm. The project seeks to further understand the form and function of these biofilms whilst generating a test method to assess preventative surface cleansers.	University of Huddersfield	Genesis Biosciences
Assessment of the effect of electrolysed oxidising water on biofilm removal from water supply systems in food and refreshments factories	Biofilms in water systems used in factories present a product spoilage and consumer health risk that must be controlled. Electrolysed oxidizing water (EOW) could offer an alternative to current approaches since it is non-toxic. This project will independently assess EOW for its suitability for implementation by Unilever in production facilities.	University of Manchester	Unilever

Proof of Concept 4

AWARDED JUNE 2021

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
An industrial whole organism assay for biofilms made by pathogenic bacteria without the use of laboratory mammals	Pharmaceutical companies require reliable biofilm assays. Current tests are performed in cultured cells. We will develop colour-based assays to monitor biofilm formation by the pathogen *Pseudomonas aeruginosa* in the transparent nematode *Caenorhabditis elegans*. Assays using fluorescent markers and health readouts in this animal will be faster and cheaper than mammals.	University of Kent	Magnitude Biosciences and Perfectus Biomed
Utilising biofilm-driven mineral precipitation for sustainable construction materials and a healthy built environment	This project will apply a bacteria-based construction technology (BBCT), driven by biofilm-formation, to improve the performance of a new eco-friendly, breathable plasterboard. BBCT can produce limestone films on material surfaces, and here we will use it to modify hemp particles for improved strength when added to the new plasterboard technology.	University of Bath	Adaptavate
Endolysin technology for selective management of MRSA biofilms on skin and wounds	Antibiotic-resistant bacteria (MRSA) are frequently found on the skin of hospitalised patients, leading to infection and poor wound healing. This project will test whether an enzyme (endolysin) is able to safely and selectively kill skin and wound MRSA without damaging the beneficial skin bacteria.	University of Hull	Cica Biomedical Ltd and Micreos
Targeted protein payload dispersal of vaginal biofilms	Bacterial vaginosis (BV) represents both a significant health and economic burden. Commonly associated with this infection is treatment failure due to the presence of microbial communities known as biofilms. In this project we aim to develop testing platforms to assess the efficacy of a novel therapeutic targeting BV.	Glasgow Caledonian University	CC Bio and University of Glasgow
Assessing the potential of a recombinant anti-biofilm protein as a cost-effective, environmentally-friendly treatment against souring and biocorrosion	This project investigates the potential of an abundant, naturally-occurring protein, increasingly used in clinical applications, for preventing and controlling industrial biofilms, to reduce problems such as toxic gas production and biocorrosion, and the need for biocides.	Heriot-Watt University	Virustatic
Developing novel antimicrobial surfaces preventing biofilms in the rail and transport industry	NitroPep and the University of Birmingham are developing a novel technology which could prevent bacterial adhesion and biofilm growth on frequent touch surfaces such as those in public transport in trains and buses.	University of Birmingham	NitroPep

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Organo-metallic HIPIMS-coated antibiofilm advanced wound dressings	This study will explore the application of antibiofilm nanoscale organo-metallic coatings to advanced woundcare dressing substrates using the low environmental impact processes of HIPIMS and aqueous application. This new class of wound dressings would have the potential to greatly enhance patient outcomes and significantly reduce healthcare costs.	Sheffield Hallam University	5D Health Protection Group Ltd
The standard biofilm: a reference measurement system to support routine manipulation, innovation and application	Methods and materials to support the standardisation of biofilm analysis which are lacking in all industrial sectors where biofilms are important. This project aims to address this need by developing methods to produce and characterise reference materials to validate biofilm analysis and technical approaches used in various industrial sectors.	University of Southampton	LGC Ltd
Novel approach to treat osteomyelitis biofilms combining innovative dual therapy and slow drug release	Osteomyelitis is a bone disease mostly caused by biofilms in bone injuries or surgical sites sometimes leading to bone removal. We will use a novel approach to treat osteomyelitis biofilms combining innovative dual therapy targeting bacterial communication mechanisms with antibiotics and slow drug release.	University of Nottingham	Ceramisys Ltd and Upperton Pharma Solutions
Evaluating the antimicrobial activity of herbal infusions: implications for consumer healthcare and well-being	There is an increasing demand for natural supplements in the consumer healthcare and wellbeing market, with more people taking a holistic approach to self-care. Herbal products are widely used in traditional medicines. This study will investigate the antimicrobial effects of Pukka herb products and establish optimal effective combinations.	University of Southampton	Pukka Herbs Ltd
Antibiofilm touch point plastics	This proposal explores developing plastics on which microorganisms will not grow, either in planktonic or biofilm state. The resultant plastics, processable by typical mass production techniques will enable a huge range of end products across plastics surfaces and touch points.	University of Warwick	5D Health Protection Group Ltd
Development of an *in vitro* human skin biofilm model for testing active ingredients for hand hygiene	There is a current need for realistic efficacy assays for screening hand disinfectant products that are simple, affordable and high-throughput. In this project, we will partner with Bear Valley Ventures and Aqualution to develop a human skin biofilm model that can be used for high-throughput testing of skin disinfection formulations.	University of Edinburgh	Bear Valley Ventures and Aqualution Systems Limited
To incorporate a quorum sensing blocker (lactams) into topical treatments to control mixed biofilms on keratinaceous infections	The general aim of this proof of concept study is to develop and evaluate a pioneering topical skin treatment to be used as a new smart technology for the effective management of complex biofilm infections. This has the potential as an alternative for anti-microbial resistant infections and reduce healthcare costs.	University of Glasgow	Unilever and Penrhos Bio

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	COLLABORATOR/S
Bioinspired protein technology for biofilm prevention on indwelling medical devices	Biofilm formation on indwelling medical devices, such as ventilators or catheters, contributes significantly to the chronicity of infections, posing a substantial healthcare and economic burden. This project will investigate incorporation of natural protein-based technology to indwelling medical devices, and its effectiveness against biofilm formation.	University of Liverpool	Virustatic
Accelerating innovation by designing water treatment biofilm media *in silico*	We should design water-treatment biofilms like we design Formula 1 racing cars: in a high-performance computer. From models of individual bacteria, incorporating realistic chemical and mechanical properties, we will show we can design a new generation of treatment biofilm media *in silico.*	Newcastle University	Veolia Water Technologies and Northumbrian Water Ltd
Development of novel biomimetic surfaces to prevent biofilm formation on catheters	This project aims to develop novel biomimetic antibiofilm surfaces for catheters without using antibiotics or other antimicrobial agents. This would address catheter associated biofilm infections with the aim of improving development of anti-fouling surfaces to prevent biofilm formation in the long-term.	Newcastle University	Teleflex Medical Europe Ltd and University of Southampton
Development of an electrospun antimicrobial coated tampon for management of bacterial vaginosis	Bacterial vaginosis (BV) affects women aged 15-44yrs but is difficult to treat during menstruation. This project will engineer a tampon with unique additional layers containing a smart antimicrobial protein that is released during use to manage the bacteria that cause disruption to the normal biofilm of the vagina causing BV.	University of Bradford	Virustatic
Rapid easy-to-use and affordable diagnostics for wound - 2	A point-of-care wound diagnostic test under development will be validated for rapid quantitative detection of bacterial load and antimicrobial sensitivity using clinical isolates of a range of wound relevant bacterial strains and wound samples. Successful validation will be progressed towards further optimization and clinical trial supported by an external grant.	Loughborough University	Smith+Nephew Ltd, Birmingham City University, Lancaster University and Cromerix Ltd

Image Credits

Front and back cover: *Bacillus subtilis* biofilm formation. Biofilm formation of *B. subtilis* on LBGM medium. Maria Paula Huertas Caycedo, University of Dundee.

Page 2: Biofilm found on water stagnation: Colourful biofilm on water stagnation found when hiking. Maria Paula Huertas Caycedo, University of Dundee.

Page 8: Bright orange 'slime' collecting along the edges of the water as a result of bacteria that oxidises the iron released from the ground water. Jennifer Dewing, University of Southampton.

Page 16: 'The building blocks of a biofilm'. A computationally generated output from a 3D dataset of a mature *E. coli* biofilm using the analysis package, BiofilmQ. Dr Liam Rooney, Heriot-Watt University.

Page 18: Scanning electron microscope image of a bacterial biofilm of *Staphylococcus epidermidis* growing on calcium sulfate. 2019 NBIC-UOS, Dr Robert P. Howlin and Dr Paul Stoodley.

Page 23: 'Clash of the colis'. A false-coloured mesoscopic image of two adjacent *Escherichia coli* biofilms acquired using the Mesolens, and subsequently deconvolved to increase the quality of the image. Dr Liam Rooney, Heriot-Watt University.

Page 24: Catheter associated clinical biofilm and mineralization. Mineralization (blue) enmeshed within a biofilm (cyan) formed on a urinary catheter. Kiril Kalenderski and Nicola Weston, University of Nottingham.

Page 28: Eurobiofilms 19. Goode Photography.

Page 30: Enginerring workshop illustrations, Tom Bailey.

Page 32: MicroBattle game artwork. Upgrade47, Yassine_Sey, Elangkarosingo, Olegtsoy, Abhimanyuartbot, Endless_Studio, Ryanprastian.

Page 33: Fluff shaped biofilm structures surrounded by round calcium carbonate minerals. Kiril Kalenderski and Nicola Weston, University of Nottingham.

Page 33: The Biologist Magazine, summer 2021 issue. Royal Society of Biology. Cover image of *Pseudomonas aeruginosa* colony biofilm (with extracellular matrix stained red), Scott Chimileski.

Pages 34-35: Credit as noted under images.

Page 36: 3D printed porous microparticles interacting with mammalian cells in culture. Professor Felicity Rose and Professor Ricky Wildman, University of Nottingham.

Page 37: Polymicrobial biofilm of *Staphylococcus aureus* (magenta) and *Pseudomonas aeruginosa* (cyan). Md Anirban Jyoti and Professor Miguel Camara, University of Nottingham.

Page 39: Snehal Kadam and Dr Karishma Kaushik at Eurobiofilms 2019 in Glasgow. Dr Karishma Kaushik, Savitribai Phule Pune University, India.

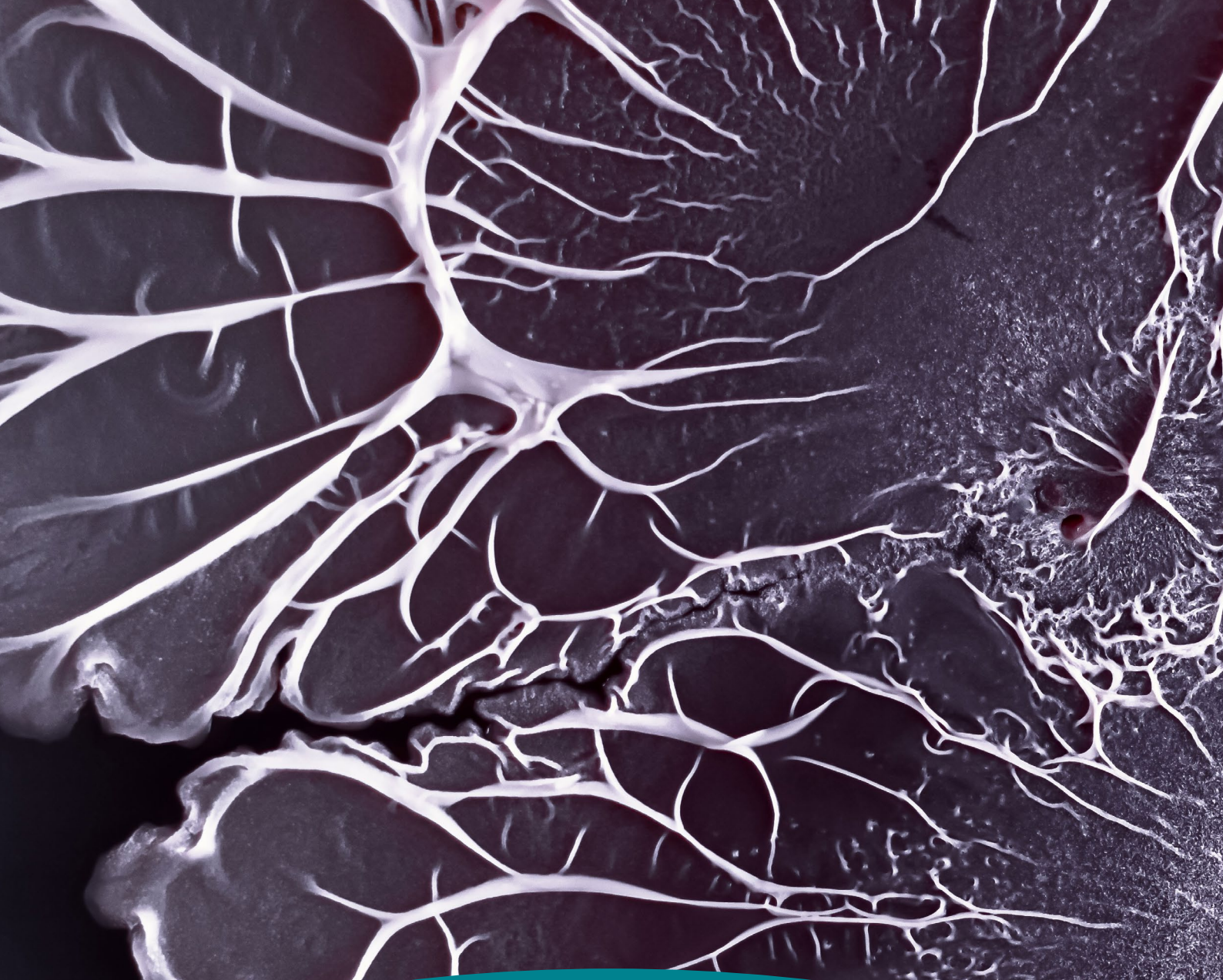
Page 40: Reusable face visor with anti-viral coatings and high optical performance. Professor Rasmita Raval, University of Liverpool and Dermot Monaghan and Victor Bellido-Gonzalez, Gencoa Ltd.

Page 41: Left: Untreated silicone (showing biofilm). Right: Lactam treated silicone (showing no biofilm) on catheter sections in artificial urine, 48h *S. aureus* SH1000 eGFP 24h + *P. mirabilis* DsRed 24h. Dr Paolo Pantalone, University of Nottingham.

Page 42: Antifouling on ship hull. Michael Elleray.

Page 44: 'The Meeting of Kingdoms.' Composite of confocal laser scanning microscopy images of a fluorescently stained inter–kingdom poly–microbial biofilm containing major wound pathogens. Dr Manuel Romero and Dr Shaun Robertson, University of Nottingham.

Page 59: 'Mirror, Mirror'. Close-up image of the biofilm that covers the scales of a Mirror Carp. Mark Burton, University of Southampton.



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