National Biofilms Innovation Centre

Annual Report 2020

HARNESSING THE UK'S ACADEMIC AND INDUSTRIAL STRENGTH IN BIOFILMS

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NBIC ANNUAL REPORT 2020

Foreword

A FEW WORDS FROM OUR CEO

The National Biofilms Innovation Centre (NBIC) is still a relatively young organisation but I am proud that we have achieved so much since our formation in late 2017. I reflect that our USA partner group, the Center for Biofilm Engineering (CBE) in Montana, is celebrating its 30th year! Our ambition is to be equally enduring. We were formed to support and connect the biofilm community across industry and academia in the UK. In the challenging circumstances we currently face globally, it's clear that never has the importance of innovation and science been so critical.

From day one it has been our intent to behave in a national, inclusive and transparent way to benefit our community. Our primary focus as we mature is to harness and translate the capability, knowledge and technology in the prevention, detection, management and engineering of biofilms across the UK. We have also worked to connect ourselves internationally, including forming alliances with the CBE in the USA and the Singapore National Biofilms Consortium (SNBC) so that we are able to facilitate collaboration between our academic and industrial partners beyond the UK.

I am delighted that our membership now includes 52 UK research institutions and that these academic partners share our desire to collaborate and connect with the (approximately) 250 companies we have talked to and visited across a range of sectors. 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 (Biotechnology and Biological Sciences Research Council, Innovate UK and the Hartree Centre) have asked us to establish, namely:

RESEARCH

Our funding has allowed us to recruit 12 Interdisciplinary Research Fellows (IRFs) across our founding core four universities who are now all actively engaged in a mixture of underpinning research and collaborating with industry.

INNOVATION

We have run three Proof of Concept (POC) calls, receiving 144 applications from companies and research partners, from which we have awarded 65 POC projects, representing a £3.6m investment from NBIC and a total value of £5.4m. In addition, we have run 4 themed workshops resulting in policy papers and multiple industry/academic collaborations and connections. All of this 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 have a cohort of 9 PhD students across our four core universities for whom we are running a core Doctoral Training Programme, which is also available to our IRF group. We are proud to be running our first entrepreneurial training and support programme in conjunction with Alderley Park.

As we enter our third full year, I see that everyone involved in NBIC across the UK is as committed as ever 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 2020

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 52 associate research institutions (RIs), support from a growing base of more than 250 companies, and an inclusive strategy to new companies and RIs.

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 research institutions. 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

DECEMBER 2017, NBIC ESTABLISHED
£26m investment from the Biotechnology and Biological Sciences Research Council (BBSRC), Innovate UK and the Hartree Centre with additional funding from industry and the support of 4 core partner universities: Southampton, Nottingham, Liverpool and Edinburgh.

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 approx. £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.

APRIL 2019, SECOND NBIC WORKSHOP HELD, SECOND PROOF OF CONCEPT CALL LAUNCHED & RECEIVED INTERNATIONAL WORKSHOP AWARD
Our workshop on Biofilm Engineering 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'd 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.

2017 — 2018 — 2019

FEBRUARY 2018, KTN BIOFILM WORKSHOP
NBIC attended and launched at a 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 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, WON BBSRC FTMA (FLEXIBLE TALENT MOBILITY ACCOUNT) AWARD
Won funding to facilitate PhD and Research Fellow mobility between academia and industry.

MARCH 2019, MOU SIGNED WITH THE SINGAPORE CENTRE FOR ENVIRONMENTAL LIFE SCIENCES ENGINEERING (SCELSE)
We signed an MOU with 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.

NOW,
Over 150 industry partners and growing.

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 includes the introduction of the UK's first #BiofilmWeek, to be held in July 2021 to coincide with an NBIC event.

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 academia and industry.

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) the National Biofilms Innovation Centre (NBIC; UK), 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
Our workshop on Biofilm Management 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 groups 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, at the Malmaison in the heart of 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.

JUNE 2020, FIRST ONLINE ENTREPRENEURIAL TRAINING COHORT
Run in collaboration with Alderley Park, NBIC members participate 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, which aims 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.

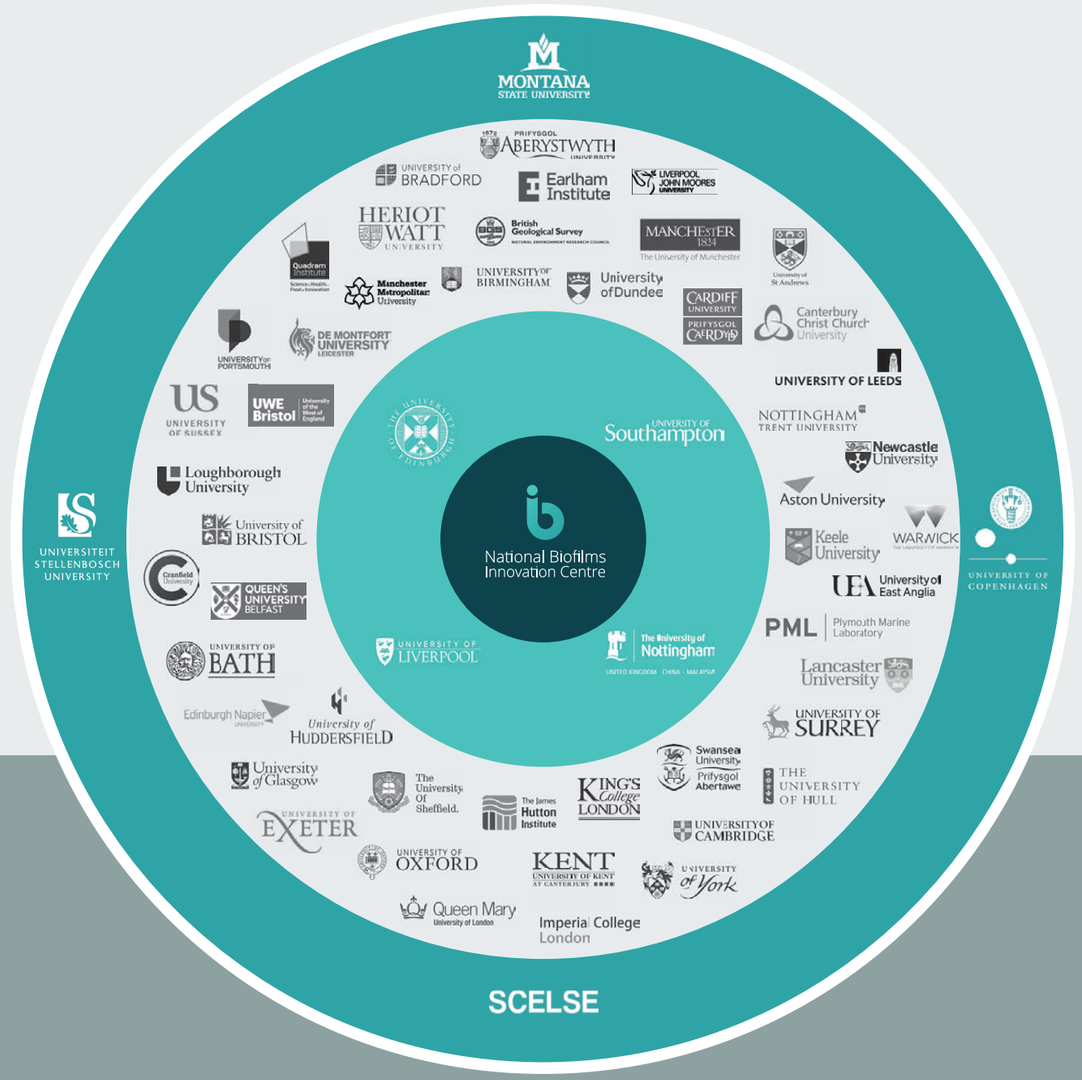
2020

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.

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. The panel deemed that NBIC was making good progress, the highest outcome that could be expected.

Building an International Community

OF BIOFILM RESEARCHERS



Our Key Objectives

NBIC AIMS TO DELIVER

1. World class science
2. Meaningful and productive interactions between academic and industry members
3. NBIC sustainability
4. Economic and societal value to the UK
5. The next generation of scientific leaders
6. 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
- ROI - 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 spinouts
- Increased academic-industry partnerships through workshops
- NBIC roadmap for biofilms established

INTERMEDIATE OUTCOMES OVER INITIAL 5 YEARS

SHORT TERM

CONCISE OUTPUTS OVER INITIAL 2 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 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

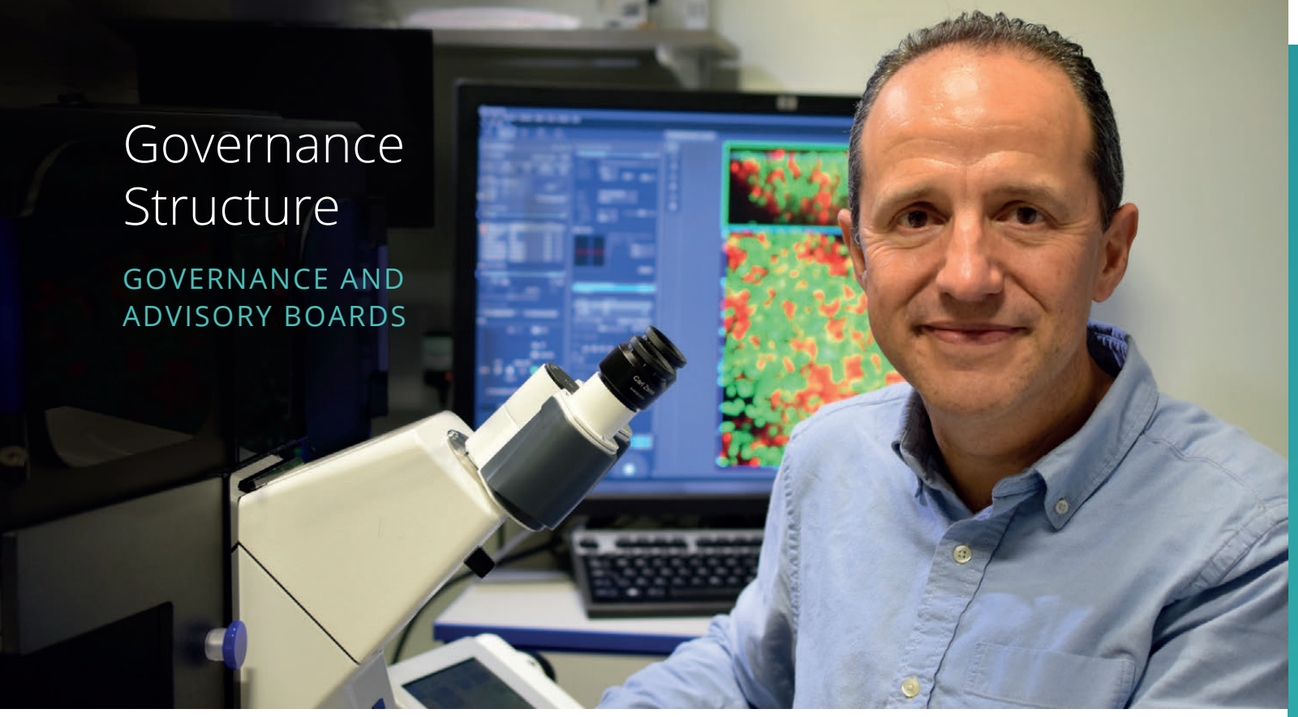
STRATEGY

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 >£2bn by 2020.

HOW WE WILL DELIVER

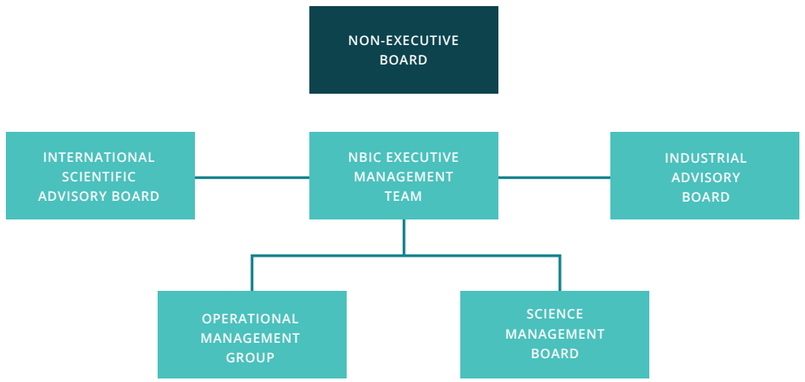
KEY INPUTS

PREVENT	DETECT	MANAGE	ENGINEER
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



Governance Structure

GOVERNANCE AND ADVISORY BOARDS



Our governance and advisory boards provide NBIC with guidance and advice on the direction of the centre and challenge the team. It is through regular face-to-face or online meetings that our governance and advisory bodies help NBIC to set out strategic direction and foundation for our research and outreach activities.

Non-Executive Board (NEB)

Consisting of the Chair, Ceri Williams (University of Leeds), Kath Mackay (Bruntwood SciTech, Alderley Park), Fiona Lettice (University of East Anglia), Gordon Ford (Innovate UK), Neil Parry (Unilever), Laura Pritchard (UKRI-BBSRC) and Hilary Lappin-Scott (Cardiff University).

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, as well as having oversight of the operation and management of NBIC and the implementation of the Consortium Agreement. All Board members are bound by Terms of Reference, which outlines their roles and responsibilities.

Industrial Advisory Board (IAB)

Consisting of the Chair, Neil Parry (Unilever), Stewart McKinlay (Smith & Nephew), David Bradshaw (GlaxoSmithKline), Kirsty Salmon (BP plc), Ken Johnston (Chilled Food Association), Steven Percival (5D Health Protection Group Ltd), Ian Archer (IBioIC) and Kevin Peel (Kohler).

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. The Terms of Reference outlines their roles and responsibilities, which include advising 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. Members of the Industrial Advisory Board (IAB) have been asked to enter into an appropriate written confidentiality agreement to protect the confidentiality of the information disclosed to them in respect of NBIC.

International Scientific Advisory Board (ISAB)

Consisting of the Chair, Hilary Lappin-Scott (Cardiff University), Rikke Louise Meyer (Aarhus University, Denmark), Tom Coenye (Ghent University, Belgium), Claire-Marie Pradier (Centre National de la Recherche Scientifique, France), Mark Van Loosdrecht (Delft University of Technology, Netherlands), Iñigo Lasa (Public University of Navarre, Spain), Agneta Richter-Dahlfors (Karolinska Institutet and KTH Royal Institute of Technology, Sweden) and Lars Dietrich (Columbia University, USA).

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 EMT on the opportunities for exploitation of the scientific profile and advances made by the centre. All ISAB members are bound by Terms of Reference, which outlines their roles and responsibilities.

Our Research Strategy

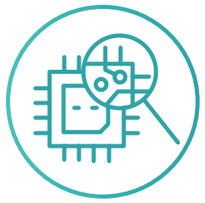
WORLD CLASS FUNDAMENTAL SCIENCE

NBIC is addressing four strategic themes to 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 12 Interdisciplinary Research Fellows (IRFs) to support NBIC's 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 and materials

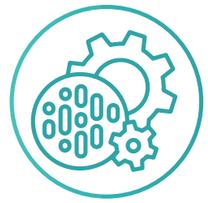


DETECT

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

NBIC's research strategy 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 engage and work with our industry partners, providing greater connectivity across the innovation space. Adding value through integrating and connecting the national community and infrastructure connecting our four core-funded universities – Edinburgh, Liverpool, Nottingham and Southampton – and our associated partner institutions, provides a powerful critical mass of capabilities and infrastructure that provides additionality among the UK biofilms community.

This includes:

- A Data Management Plan (DMP). This is a shared data resource index for the biofilms community. A key component of our DMP is to create an index of the data generated and shared by the consortium that provides reference to the relevant Digital Object Identifiers and points of contact to ensure data is easily identified, shared and accessed across the consortium.
- Mapping facilities and infrastructure across the UK. Our joint university and industry partnerships mean that world class strategic facilities and infrastructure are available and accessible to all NBIC partners. By mapping these facilities across the community, NBIC provides a focus for connecting researchers and industry to the right expertise and infrastructure, simplifying and accelerating knowledge transfer, and catalysing collaboration to address key issues in biofilms. We are currently creating an index and map of imaging capabilities and equipment across the UK that will be made available as a shared database.

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 nine students started in October 2019.

The Doctoral Training Centre draws on 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 core 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; Bioenergy; Host-microbe Interactions; Bacterial signal transduction; Imaging and detection; Translational biology; Clinically relevant biofilms.

TRAINING NEED

- DEPTH AND BREADTH ACROSS DISCIPLINES
- PROBLEM-SOLVING IN MULTIDISCIPLINARY TEAMS
- WORLD LEADING SCIENTIFIC RESEARCH AND KNOWLEDGE
- OPPORTUNITY TO WORK ACROSS NATIONAL AND INTERNATIONAL SITES
- ENTREPRENEURSHIP, INNOVATION, IP TRANSLATION
- LEADERSHIP MANAGEMENT
- RESPONSIBLE INNOVATION
- COMMUNICATION, IMPACT, OUTREACH
- EMPLOYABILITY

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 communities in process applications

WORLD CLASS RESEARCH PLATFORMS

- AMR
- 'OMICS AND BIOINFORMATICS
- FUNCTION & ACTIVITY
- COMPLEX COMMUNITY INTERACTIONS
- INTERFACIAL INTERACTIONS
- PREDICTIVE MODELLING
- NEXT GENERATION IMAGING & SENSING
- ENGINEERED INTERFACES AND MATERIALS
- BIG DATA

SECTORIAL CHALLENGES

- IMPROVED HEALTH
- GROWTH THROUGH BIOTECH AND BIO-REFINERY
- PREVENT CORROSION AND BIOFOULING
- NEXT GENERATION ENABLING TECH
- IMPROVED CONSUMER PRODUCTS
- SAFE FOOD

Training

BUILDING ENTREPRENEURIAL SKILLS

NBIC provides 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 a full follow-on 8 week Accelerator programme for best performing pre-accelerator graduates selected in a competitive process.

Innovation to Commercialisation of University Research

The ICURe Innovation-to-Commercialisation programme offers university researchers with commercially-promising ideas the ability to 'get out of the lab' and validate their ideas in the marketplace. From idea to scale-up, SETsquared offer a comprehensive range of programmes to help boost businesses to the next level.

Software Sustainability Institute

The 2019 NBIC workshop brought together 20 attendees from seven UK universities, plus Unilever, in a high-tech space at the Malmaison in the heart of Birmingham. We ran this event alongside the Software Sustainability Institute (SSI) in a bid to raise awareness of the need for sustainability in software, particularly when it comes to the potential risks to software reproducibility. This had become particularly apparent when reading the responses from the biofilm community to a BBRSC consultation on data intensive bioscience in the summer of 2019. Having discussed the responses to the consultation, we agreed to run a joint workshop to spread some best practice, and to help both organisations get an idea of how things stood in UK biofilms research and software.

The event was held on 28 November and involved four breakout sessions and short talks throughout the day. The sessions introduced participants to the idea of software sustainability, to how to achieve software that is accessible and reproducible, and to how software sustainability helps to drive data management, accessibility and reuse. Speakers took into account the broad range of experience in the room, with attendees ranging from microbiologists who work in Excel to physicists coding agent-based simulations in C. Breakout group responses were captured on flipcharts and on online forms. In some exercises the participants self-reflected on their own practice, and these thoughts were sent to them following the meeting.

It was a successful day for both NBIC and the Institute, and feedback from attendees was positive. Attendees came away with a range of techniques and best-practice tips to improve the sustainability of their research software. We are pleased to be planning further Data and Software Carpentry workshops in collaboration with the SSI, with an aim of supporting and developing skills and confidence to work with data.

Industry Engagement

INNOVATION AND COMMERCIALISATION

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 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 prove we have the right to be an essential part of our industrial partners' network or open innovation pipeline. We aim to listen, understand and explore needs and/or capabilities, and create and support connections. We 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 "match-make" an unmet need to an opportunity or solution (mainly company to research insitutions) either via a personal contact through our innovation team or emails targeted to our wide network. In late 2020 we will launch our Open Innovation partnering platform, hosted by Innoget. Through our website, industry and academic partners will have exclusive access to directly post technology calls and technology offers, respond to other members' postings and generate connections and collaboration opportunities. Partners will also have a choice to access 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 over 350 attendees with an approximate mix of 50:50 academics and industry partners. These have all taken the format of exploring the key unmet needs from industry, looking at how the current state of the science and technology landscape could address these requirements and in doing so develop 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 international themes i.e. Detection, Management and Engineering of Biofilms. The last is a workshop we ran on Microbe–Metal interactions in conjunction with the Center for Biofilm Engineering. Our 4th theme of Biofilm Prevention will be the subject of a workshop in the next 12 months.

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 “unhealthy or “pathogenic” state.
- To detect and confirm the presence of a biofilm in a standardised reproducible manner acceptable to regulatory agencies.

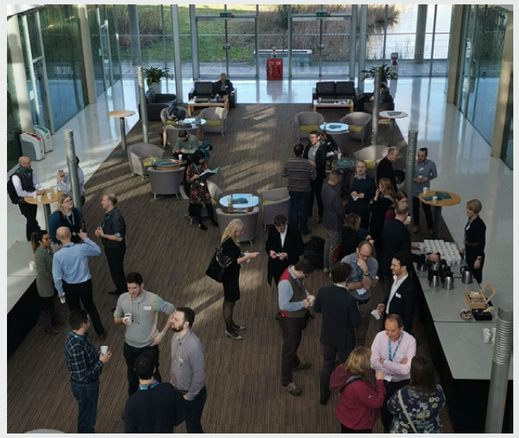
Biofilm Management

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/ 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.

Communications and Outreach

RAISING AWARENESS OF BIOFILMS IN THE UK AND BEYOND

Public Engagement and Outreach

Public Engagement (dialoguing with the public about our research) and Outreach (raising science aspirations of children) 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.

We have conducted a wide range of activities across the UK (from biofilm dances to biofilms in a train station or IKEA), and we will keep doing this. We want to deliver our vision for Public Engagement and Outreach, laid out in our strategy developed this year. We want to reach the public with an active interest in biofilms related topics (home hygiene, healthcare, etc), inspire young people, and support everybody in NBIC with undertaking these activities. We are continuously developing appropriate resources for wider use, and are leading and inspiring projects, for instance through our dedicated grant scheme, which offers up to £3000 for public engagement or outreach projects. Any NBIC affiliated individual/group can apply for this funding online, and they can also seek guidance and support directly from NBIC's Public Engagement and Outreach Officer for their own projects.

Communications

We recently launched our #BiofilmAware 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. A highlight of the campaign will be the introduction of the UK's first #BiofilmWeek, to be held in July 2021 to coincide with an NBIC event.

If you are interested in supporting the campaign, a range of digital resources are available on the NBIC website via the Campaign Hub.

Visit www.biofilms.ac.uk/biofilmaware to download and start sharing.

Since January 2020 our Twitter following has increased by 65%, and our LinkedIn following by 265% - with our overall social media engagement increasing by over 400%. As part of our #BiofilmAware campaign, we have launched NBIC Facebook and Instagram pages.

National Biofilms Innovation Centre
#BIOFILMAWARE

We have been looking at ways to improve the user experience, and traffic to the NBIC website. This has included the introduction of a blog page, with some fantastic contributions from NBIC team members and partners, the page currently ranks in the top 5 most visited pages on our site. Please get in touch with us if you would like to contribute.

Eurobiofilms 2019

NBIC HIGHLIGHTS

In September 2019 the NBIC team attended the Eurobiofilms conference in Glasgow. This was the first meeting we'd attended as a full NBIC team. It was a fantastic opportunity for us to meet our current partners and make new contacts.

We also had the honour to present at the final session on Friday 6 September 2019 and it was wonderful to see so many people in the auditorium nationally and internationally wanting to hear about what we do, how we do it and importantly why we do it! We are very proud that the UK is leading the way with a community like NBIC thanks to the support of our funders and that of the UK science and industry network. A number of other representatives from other countries approached us to discuss doing something similar.

Like the other sponsors and exhibitors, we engaged fully with the meeting and were made to feel very at home and welcomed by everyone.

Gordon Ramage and the Glasgow team had put on a great meeting in terms of the programme, location and events. The weather they couldn't fix!

The poster sessions were lively, the innovative elevator pitch session fun, and we learned a lot and met so many new connections. We added over 50 new contacts and gained more than 60 new Twitter followers due to the event. Thank you to everyone who came and engaged with us – we loved meeting you all.

Images courtesy of Goode Photography

Energy and Engagement

IN PAKISTAN

In March 2020 our CEO, Mark Richardson visited the Global Challenge Research Fund (GCRF) Affordable Healthcare Workshop in Pakistan.

He was joined by our university partners from Lancaster, Sheffield and Leeds to share our expertise in harnessing biofilms with healthcare professionals in the emerging nation and attendees even had an unexpected brush with the President of Pakistan, Arif Alvi, following a dinner invitation to the President's house.

The GCRF is a £1.5 billion fund launched by UK Research and Innovation (UKRI) in late 2015 to support cutting-edge research that addresses the challenges faced by developing countries. These challenges result in funding calls and ahead of an anticipated call involving UK and Pakistan, a three-day workshop was funded in Islamabad.

Mark Richardson said, "I met scientists from Pakistan, Sri Lanka, Iraq and those thinking about science, technology, patient involvement, policy direction and health economics – the energy and engagement was amazing".

The workshop brought together researchers, industry partners and decision makers to create a joint UK-Pakistan programme of expertise to support the translation of clinical, bio materials and biological science to low-cost healthcare products and innovative technologies that could be used locally in Pakistan.

This would be particularly by clinics to treat disorders of both soft and hard tissues. Existing products are currently unaffordable imports to most of the population, resulting in avoidable suffering and poor clinical outcomes such as amputations or death.

Mark Richardson continued, "Detecting and managing biofilms and infection is a key unmet need – before joining NBIC I worked for 25 years in industry in the wound healing field, so I appreciate how complex and costly current approaches are to solving this problem."

As a country of over 200m people, Pakistan has a 12% incidence of type 2 diabetes and around 7% of these will have a foot ulcer at risk of infection and possible amputation each year. Our NBIC network has an invaluable knowledge of the relationship between biofilms and diabetic foot ulcers and during the visit we were able to share this at the workshop to support the research into the prevention of these problems in Pakistan.

Both the UK and Pakistan's Governments shared vision is to create affordable high-quality healthcare products in Pakistan via indigenous sustainable resources with direct outcomes on patient healthcare. A common theme is the design, research and development of low-cost healthcare technologies that are clinically directed and for local need, based on simple cost-effective approaches for improving healthcare and the wellbeing of patients.

The workshop was a unique opportunity to work in diverse teams, generate new ideas and share best practice, which resulted in some exciting outline projects and as a result of this we've now created a virtual working group with connections made during the visit to develop a proposal and we hope to apply for a GCRF funding call soon.

NBIC

INTERNATIONAL STRATEGY

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 India, Pakistan and China, we also continue to build on our existing relationships with SCELSE/SNBC in Singapore, CBE in the USA, the Costerton Biofilm Centre in Denmark and Stellenbosch University in South Africa 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 52 UK Universities is to become a strong partner to a larger, powerful and influential international network of industry and academic partners.

NBIC membership of the International Standards Task Group

WITH CBE, SCELSE/SNBC AND COST

In February 2020 NBIC along with the US Center for Biofilm Engineering, the Singapore Centre for Environmental Life Sciences Engineering (SCELSE), and an EU Cooperation in Science and Technology (COST) action group formed a task group 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. Our collective aim will be to:

- Communicate to regulatory decision makers 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.

Case Study

TRANSFORMING 16S SEQUENCING

Supporting researchers in gaining industrial experience

Dr Chris Winnard joined Next Generation Sequencing (NGS) company YouSeq, on an NBIC funded internship in the summer of 2019, where he was tasked with taking a new prototype for a next generation sequencing (NGS) kit, for identifying bacteria in a mixed population, through to commercial product launch.

The kit is based on a method known as 16S sequencing, which reads a region of the bacterial genome known as the 16 rRNA and then identifies which bacteria are present based on genomic information. 16S sequencing already exists, however the workflows are cumbersome and require long, highly skilled hours on the benchside. YouSeq’s new prototype transforms that complex workflow into a very simple closed-tube system that any technician can perform with ease.

Performing detailed studies on sensitivity and specificity, Dr Winnard identified final issues and implemented improvements to make the new kit robust for commercial use and produced good quality data to satisfy the company’s quality standards, resulting in a successful product launch. He was also involved in the beta version of launch, with trials of the kit occurring in the USA, South Africa, Portugal and the UK, where he took part in commercial and technical discussions with the company’s first significant customer. During the product launch Dr Winnard also supported the marketing function, which included developing a website, the instructions-for-use and creatively contributed to printed content.

Dr Chris Winnard and YouSeq CEO Dr Jim Wicks presenting at NBIC’S Networking Event in January 2020 at the University of Southampton.

What’s next?

After completing his project with YouSeq in early January, Dr Winnard successfully found employment with Novagene, a global NGS service provider.

Dr Winnard said, “The internship was amazing and provided me the opportunity to not only gain valuable industry experience but also helped me develop my skills and knowledge of DNA sequencing.”

YouSeq are currently undertaking a marketing drive for the product with great hopes for significant commercial success that will bring further income and employment to the local community.

Dr Jim Wicks, YouSeq CEO said, “We believe that the product Dr Winnard has worked on will be a powerful research tool for the biofilm research community globally.”

Dr Chris Winnard

Dr Chris Winnard has a PhD in Clinical and Environmental Microbiology and a MBioSci (1st Class Honours) in Biomedical Sciences. His research interests revolve around DNA sequencing with a particular focus on the interplay between the microbiome and human health and disease. He is currently working as a Molecular Biology Scientist for a multinational sequencing service company specialising in RNA sequencing and library preparation.

Case Study

REDUCING BIOFILM FORMATION

Helping industry find academic partners to solve unmet needs

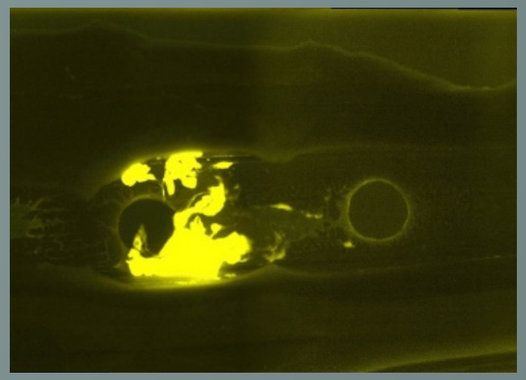
Central Venous Catheters (CVCs) are used in hospitals to deliver fluids, including medication, blood products, and nutrients into the veins of patients for extended periods of time. However, bacterial adhesion to the surface of catheters can lead to the growth of attached bacterial communities, known as biofilms.

Biofilm growth on catheters poses a serious infection risk for patients. In the UK alone, central venous catheter-related bloodstream infections account for 10-20% of hospital-acquired infections, increasing mortality, treatment costs and lengthy hospital stays.

Kimal PLC are a leading manufacturer and supplier of CVCs and dialysis catheters, providing disposable medical devices to hospitals around the world. At their innovation centre in Bromsgrove, their dedicated research and development team work on new products to improve patient outcomes.

Bacterial biofilm formation is complex and despite the severe infection problem that biofilms pose, there is little insight into how they form in venous catheters.

Through a Proof of Concept award from NBIC, researchers at the University of Edinburgh, Dr Susana Direito and Professor Rosalind Allen, worked with Kimal PLC to explore how three aspects of catheter design impact biofilm formation, using fluorescence microscopy, Scanning Electron Microscopy (SEM) and X-ray computed tomography; with a long-term goal of optimising their catheter products to reduce catheter associated infections.



Fluorescence microscopy' image showing a biofilm (Escherichia coli expressing Yellow Fluorescent Protein) within the lumen of a catheter, magnification: x2 Principal

The catheter design elements investigated were the shape of the lumen (interior tube), the size and shape of the skives (holes through which fluids exit the lumen) and the catheter surface coating.

The project was highly successful, and it identified immediate manufacturing steps that could be taken to improve catheter design and reduce biofilm formation.

To support future work with Kimal PLC, a PhD studentship was established through the Engineering and Physical Sciences Research Council (EPSRC) Soft Matter and Functional Interfaces (SOFI) CDT programme which works to provide industrially integrated post-graduate training in research, enterprise and innovation for future industry leaders. Further funding applications are also in the pipeline.

Professor Rosalind Allen

Principal Investigator

Professor Rosalind Allen is a Professor of Biological Physics at the University of Edinburgh. Her research interest is focused on how nutrientcycling microbial ecosystems establish themselves and maintain their function.

Dr Susana Direito

Co-Investigator

Dr Susana Direito is a part of the Edinburgh Complex Fluids Partnership team within the University of Edinburgh and is also an NBIC Interdisciplinary Research Fellow. Her research interests include biofilm formation and advancing antimicrobial technologies.

Case Study

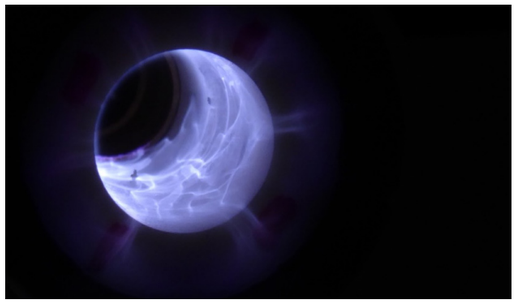
THE FOURTH STATE OF MATTER

Helping industry find academic partners to explore new applications for a known technology

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 collaboration between Fourth State and the University of Surrey will evaluate the efficacy of Fourth State's innovative plasma (ionised gas) technology for biofilm prevention and management on food and hard surfaces.

Fourth State is a micro-SME with ambitions of becoming a leading global provider of atmospheric pressure plasma solutions in healthcare and other adjacent markets. Plasma is the 'fourth state of matter' and consists of ionised gas. Examples in nature include lightning strikes, the aurora and the sun, while historical technological applications include etching of silicon chips for smartphones, advanced space propulsion systems and controlled nuclear fusion reactors. The company founders, Dr Thomas Frame and Dr Thomas Harle, saw an opportunity to use their technological expertise in spacecraft systems engineering and applied plasma physics to address urgent terrestrial needs, such as antimicrobial resistance. The team has since developed and patented an innovative platform plasma technology, and developed the company's first product, Nebulaskin®, for non-surgical cosmetic procedures with a number of leading Harley Street clinics. A disruptive wound care product is currently in development.

Dr Harle said, "Fourth State sees biofilm management and prevention as a future 'killer app' for plasma



Fourth State's technology harnesses plasma (ionised gas) for biofilm management and prevention.

technology across a wide range of sectors, so it's fantastic to be working with NBIC to accelerate development and market access for the technology. Access to NBIC Proof of Concept funding has allowed us to build out our network, explore the expansion of our technology into further sectors and provide us with a deeper understanding of the science behind the interaction of plasma and biofilm".

Dr Eirini Velliou, University of Surrey said, "I find the broadness of the NBIC network and remit fascinating. It allows the conduction of so many different types of research on biofilms and enables academics to network with other relevant groups at both a national and international level and encourages academics to work directly with industry to drive solutions to practical problems through fundamental research. This interaction is very valuable as we really see our research output accelerated from bench to every-day practice in industry".

Dr Eirini Velliou, Principal Investigator

Dr Eirini Velliou is Senior Lecturer (Associate Professor) of Bioprocess & Tissue Engineering, Principal Investigator and Founder of the Bioprocess and Biochemical Engineering group (BioProChem) in the Department of Chemical and Process Engineering at the University of Surrey. Her research focus falls within the engineering and validation of novel biomaterial based *in vitro* platforms for studying various biological systems and diseases, i.e. cancer, stem cells expansion and differentiation, formulation and communication of bacterial communities and bacterial-host interactions.

Case Study

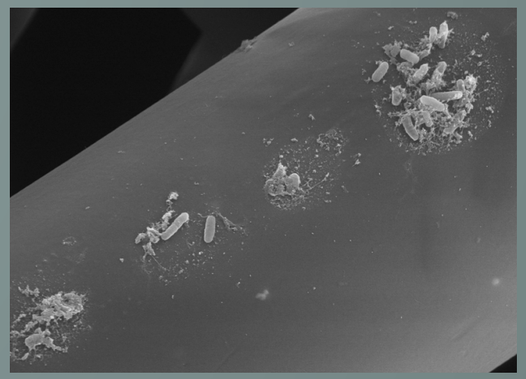
INNOVATIVE WOUND CARE

Helping industry find academic partners to explore new applications for a known technology

Two major clinical challenges in the treatment of chronic wounds are the management of wound exudate and the effective treatment of biofilm-related infections. Wound dressings are available to absorb exudate from highly exuding wounds and to treat wound biofilm infections; however, there is no commercially available single product, which collectively addresses both issues. To treat infected wounds with high levels of exudate a clinician currently uses two dressings; an anti-microbial dressing and a dressing to manage high exudate levels.

A Proof of Concept (POC) award from NBIC enabled researchers at the University of Manchester, Dr Gurdeep Singh and Professor Andrew McBain to work with Dr Helen Thomason, then Head of Scientific Research for Crawford Healthcare. Crawford Healthcare is a rapidly growing leader in developing innovative wound care and dermatological treatments and was acquired in 2018 by the world's largest wound care company, Acelity L.P. Inc.

The main aim of the project was to assess the anti-biofilm efficacy of combining an antimicrobial dressing with a wound dressing, capable of absorbing high levels of exudate, to facilitate the treatment of wound infection and to manage exudate with a single treatment. The project was highly successful, meeting all major aims, and a manuscript is currently in preparation.



Investigating the ability of super absorbent wound dressings to internalise and transfer bacteria. The image shows a section of a dressing imaged with Scanning Electron Microscopy

Science-based technology company 3M completed the acquisition of Acelity L.P. Inc. and its KCI subsidiaries in 2019. NBIC has recently supported the Dr Gurdeep Singh, Professor Andrew McBain and Dr Helen Thomason team to conduct further work on innovative wound care approaches, this time with 3M as the industrial partner.

The main aim of the research is to develop an *in vivo* wound model to assess the effects of biofilm formation and anti-biofilm dressings on single-cell spray-on skin therapy to promote healing. Spray-on skin therapy is a novel and effective way to promote healing of wounds such as burns and venous and diabetic foot ulcers.

Professor Andrew McBain, Principal Investigator
Professor Andrew McBain studied for his PhD in Medical Microbiology at the University of Cambridge with the Medical Research Council. Since 1999, his research at Manchester has focused on the responses of biofilms to antimicrobial treatments and the interaction of microorganisms colonising the skin, nasopharynx, oral cavity and intestine with the human host in health and disease.

Case Study

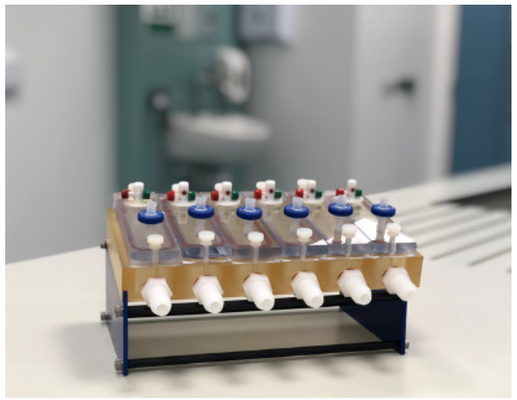
NEXT GENERATION WOUND TREATMENT

Helping industry find academic partners to explore new applications for a known technology

Annually over 18 million patients globally suffer from chronic wounds, of which over 50% will develop a localised infection due to biofilms, a major impediment to wound healing, and long-term health. This can lead to increased health service costs, morbidity and further complications for the patient, which ultimately includes amputation. The indicative annual cost for wound management in Europe accounts for 2–4% of healthcare budgets and has been estimated to be as high as €10 billion.

Current antimicrobials in wound care have limited effectiveness against biofilms. The project, 'Development of Next Generation synergistic antibiofilm treatments for wounds' was awarded an NBIC Proof of Concept (POC) award and in-kind contributions from 5D Health Protection Group Ltd, enabling process development work and prototype production to be carried out at the University of Leeds, whilst 5D Health Protection Group Ltd supplied raw materials and carried out antimicrobial and antibiofilm testing.

The innovative approach of the project was the development of a synergistic combination of both antimicrobials in combination with 5D's patent protected antibiofilm agents into one formulation, and its incorporation into modern hydrogel-based low adherent fibrous wound dressing. Two synergistic compositions, including metalised chelating agents applied to both carboxymethylcellulose and alginate substrates exhibited outstanding antibiofilm performance. With further development work, these technologies could be readily commercialised by companies operating in the advanced wound care space.



The model is used to reproduce biofilms on glass coupons under defined conditions suitable for testing the efficacy of antimicrobials and materials impregnated with antimicrobials. The model can be adapted to allow for the growth of biofilm on skin and wound dressings.

Dr Steve Law, Research and Innovation Manager, 5D Health Protection Group Ltd said, "The novel antibiofilm technologies had been developed to laboratory scale by 5D, but the NBIC award allowed the exploration of how the technologies could be applied on modern wound care substrates and also enabled evaluation of wound dressing prototypes in robust antibiofilm models".

The project has been successfully completed, with all outcomes achieved. Two routes for advancement of the project are being pursued: sharing of the results with targeted industry partner(s) with a view to generate collaboration and co-development projects, and to seek further funding based on further development of synergistic antibiofilm compositions and further development of deployment techniques.

Professor Stephen Russell

Principal Investigator
Professor of Textile Materials and Technology, and Director of the Clothworker's Centre for Textile Materials Innovation for Healthcare, at the University of Leeds.

Dr Steve Law

Industry Collaborator
Research and Innovation Manager at 5D Health Protection Group Ltd. Dr Law has over 25 years' experience in the innovation and development of polymeric materials.

Case Study

A NEW CLASS OF ACRYLATE POLYMERS

Helping to support biofilm models to assess novel interventions

Indwelling urinary tract catheters are the most commonly employed implanted medical devices. However, indwelling catheters promote catheter-associated urinary tract infections (CAUTIs) that, if left untreated, may lead to acute pyelonephritis, urosepsis and death. Treatment for CAUTIs usually depends on catheter removal and antibiotic therapy. Worldwide, 70-80% of the 150 million urinary tract infections reported annually are CAUTIs which impose both serious health problems and are a significant economic burden.

Attempts to reduce the likelihood of CAUTIs have focused on improved hygiene, intermittent catheterisation and the development of novel catheter materials. Efforts to develop biocompatible catheter materials that resist biofilm formation have focused on the incorporation of antimicrobial agents by impregnation into, or surface conjugation onto, the biomaterial. However, silver-coated catheters have been disappointing in clinical use while impregnation with antimicrobials suffer with loss of efficacy as the active agents leach away. They also increase the challenges associated with the emergence of multi-antibiotic resistant pathogens. Consequently, the ideal urinary catheter biomaterial should prevent biofilm formation in the first place.

Professors Morgan Alexander and Paul Williams are NBIC Co Investigators from the University of Nottingham. With support from the Wellcome Trust they have developed a high throughput polymer microarray methodology to screen for biofilm resistant polymers. Over 20,000 assays on 1300 unique co-polymers resulted in the discovery of a new class of acrylate polymers that resisted bacterial biofilm formation called BACTIGON®.

The Nottingham NBIC Innovation Research Fellows and the EPSRC-funded 'Next Generation Biomaterials' team in July 2019 at the Royal Society Summer Science Exhibition in London.

In collaboration with Professor Derek Irvine from the University of Nottingham, and NBIC partner Camstent Ltd, a polymer-coated urinary tract Foley catheter has subsequently been developed and manufactured, receiving CE mark approval in 2017 for clinical use in hospitals in the UK and Europe.

In collaboration with the Nottingham NBIC Innovation Research Fellows and the EPSRC-funded 'Next Generation Biomaterials' team, this topic was presented at the Royal Society Summer Science Exhibition in July 2019. The 'Great Greeting Experiment', a live research project developed by NBIC Co Investigator Dr Kim Hardie from the University of Nottingham, used UV iridescent powder and a UV light box to allow volunteers to observe transference and the effectiveness of hand washing. 'Stick or Slide' and 'Stop the Superbugs' exhibits illustrated how difficult it is to remove a biofilm and how our novel catheter biomaterials work to prevent infection.

Professor Paul Williams

Paul Williams is Professor of Molecular Microbiology at the University of Nottingham. He is a Wellcome Trust Senior Investigator and Director of a Wellcome Trust PhD Training Programme in Antimicrobials and Antimicrobial Resistance.

Professor Morgan Alexander

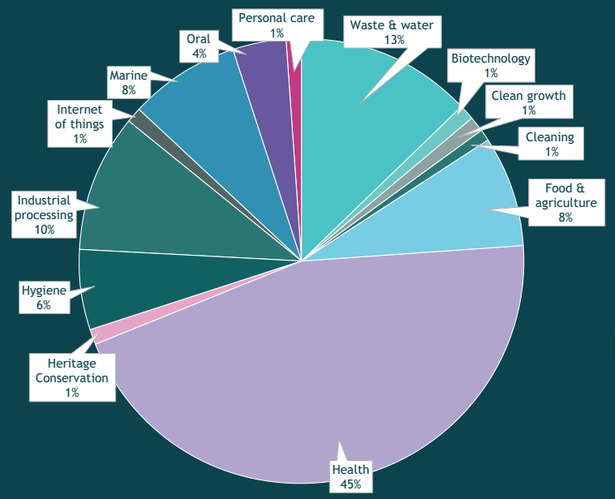
Morgan Alexander is Professor of Biomedical Surfaces at the University of Nottingham, Director of the EPSRC Programme Grant in Next Generation Biomaterials Discovery at the 3D OrbiSIMS facility and a Wellcome Trust Senior Investigator.

Proof of Concept Projects

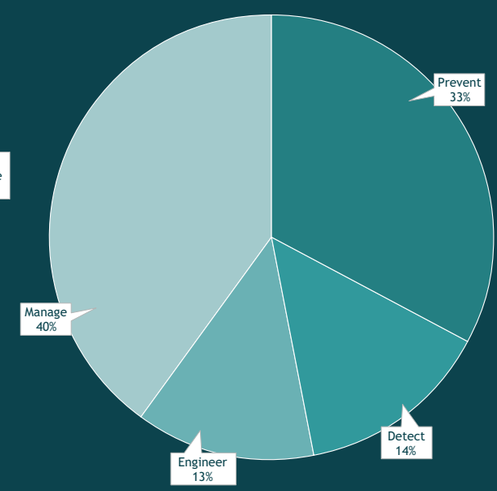
SUPPORTING TRANSLATIONAL ACTIVITY

Our investment in biofilm innovation

To date, we have run three POC calls attracting 144 applications from which we awarded funding to 65 projects. This represents an investment of £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. 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 annual report from page 34.



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

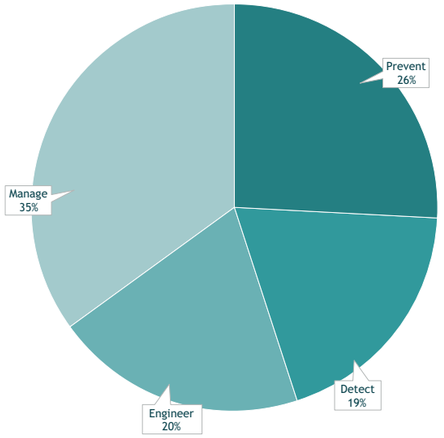
The projects establish the feasibility of a concept, idea or technology from any application sector which is aimed at preventing, detecting, managing or engineering biofilms. The scope was for projects at Transfer Readiness Level 2-4 which were a collaboration between a member UKRI and an industrial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

Through work with universities and companies since our formation we can evidence the impact this 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, and in POC2 there were 29 RIs and 31 companies (25 of which had not applied in POC1). There was also wider sectorial spread and an improved balance of interventional themes (Prevent, Detect, Manage and Engineer) from POC1 to POC2.

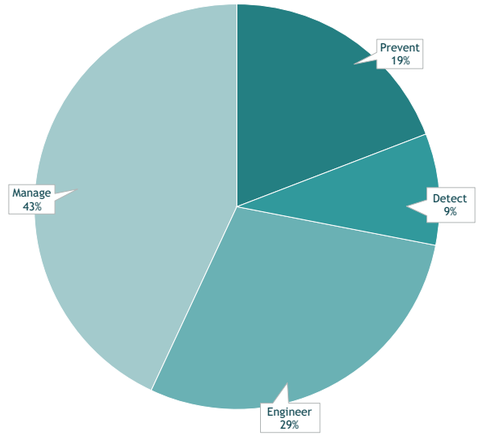
In POC3 we received 45 applications from 24 different research institutions involving 46 companies. This third group of projects continues to address a wide range of sectors and challenges across health, hygiene, industrial processing, food, water, oral care, personal care, anaerobic digestion, waste and wastewater and biotechnology. We had reserved 30% of funding for projects with an Engineering theme to build on our Biofilm Engineering workshop, which took place in Edinburgh in April 2019. In fact, we are delighted that over 40% of funding was awarded to projects with a clear Engineering theme (this definition for each project was checked by project reviewers). This demonstrates the impact our networking and workshops had on stimulating these applications.

This third set of awarded projects brings our total portfolio of funded projects to 65 across diverse companies, sectors and research institutions. As the first of our portfolio of 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 are working with holders of active projects to understand how NBIC can be flexible and help them ensure their projects successfully complete.

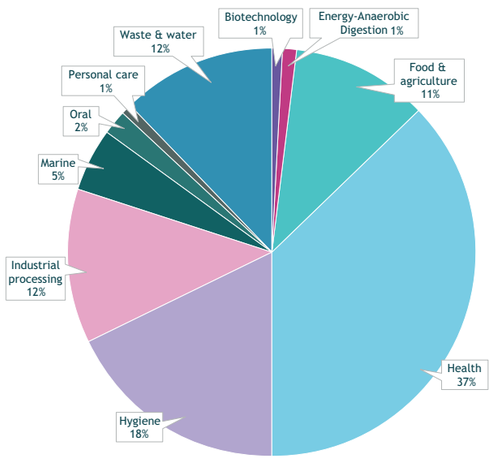
POC3 APPLICATIONS



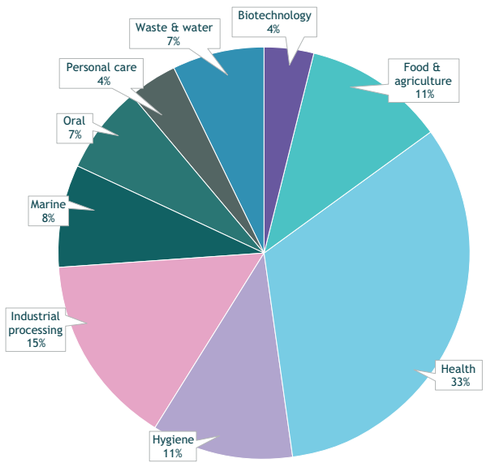
POC3 Applications
% of applications by interventional theme



POC3 Awarded
% of projects approved by interventional theme



POC3 Applications
% of project applications by industry sector



POC3 Awarded
% of project applications awarded by industry sector

We will run our fourth Proof of Concept project call at the end of 2020 and will consider later TRL levels as our portfolio and the needs of the community mature. In addition, with the £1m in-kind investment from the Science and Technology Facilities Council (Hartree) we will run a funding call for collaborative projects requiring data analysis and High-Performance Computing (HPC) power.

With our Academic and Industry partners, we are jointly establishing a consolidated and shared view of the key industrial biofilm challenges along with the status of the science in terms of emergence of possible solutions. In addition to deepening our understanding via direct contacts with researchers and practitioners we have followed two key work streams.

Building a shared language for dialogue.

We have spent time across our industry/ academic community understanding the language and terminology of biofilms and this has been captured as an ontology in Mindmap form on our website. This was developed in conjunction with 80 UK researchers (in industry and research institutions) to capture how they talk about and describe biofilm research, problems and opportunities.

Proof of Concept 1

AWARDED OCTOBER 2018

PROJECT TITLE	PROJECT SUMMARY	UNIVERSITY/ RESEARCH INSTITUTION	INDUSTRY 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	INDUSTRY 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	Crawford Healthcare
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.	Sheffield University	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	INDUSTRY 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	INDUSTRY 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	INDUSTRY 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	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	INDUSTRY 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	INDUSTRY 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	INDUSTRY 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
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
Development of an *in vivo* wound model to assess the effects of biofilm formation and antibiofilm dressings on single-cell spray-on skin therapy to promote healing	Spray-on skin therapy, using patient's healthy cells, is a novel technology for treatment of burns. However, this therapy can fail if infection develops. Antimicrobials may prevent infection, however, their effects on spray-on skin cells are unknown. This project will determine the effects of infection and antimicrobials on spray-on skin therapy.	University of Manchester	3M Healthcare
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
To develop a synergistic enzyme-antibiofilm composition to impregnate into a wound dressing to reduce slough and the biofilms in chronic wounds	To develop and evaluate a game changing (patent protected) smart enzyme-antibiofilm combination wound dressing the effective management of biofilms (via EPS breakdown) and slough (known to house biofilms, increase infection risks and delays wound healing) in wounds, helping to enhance patient outcomes and reduce healthcare costs.	University of Bradford	5D Health Protection Group Ltd, Penrhos Bio/ Unilever

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