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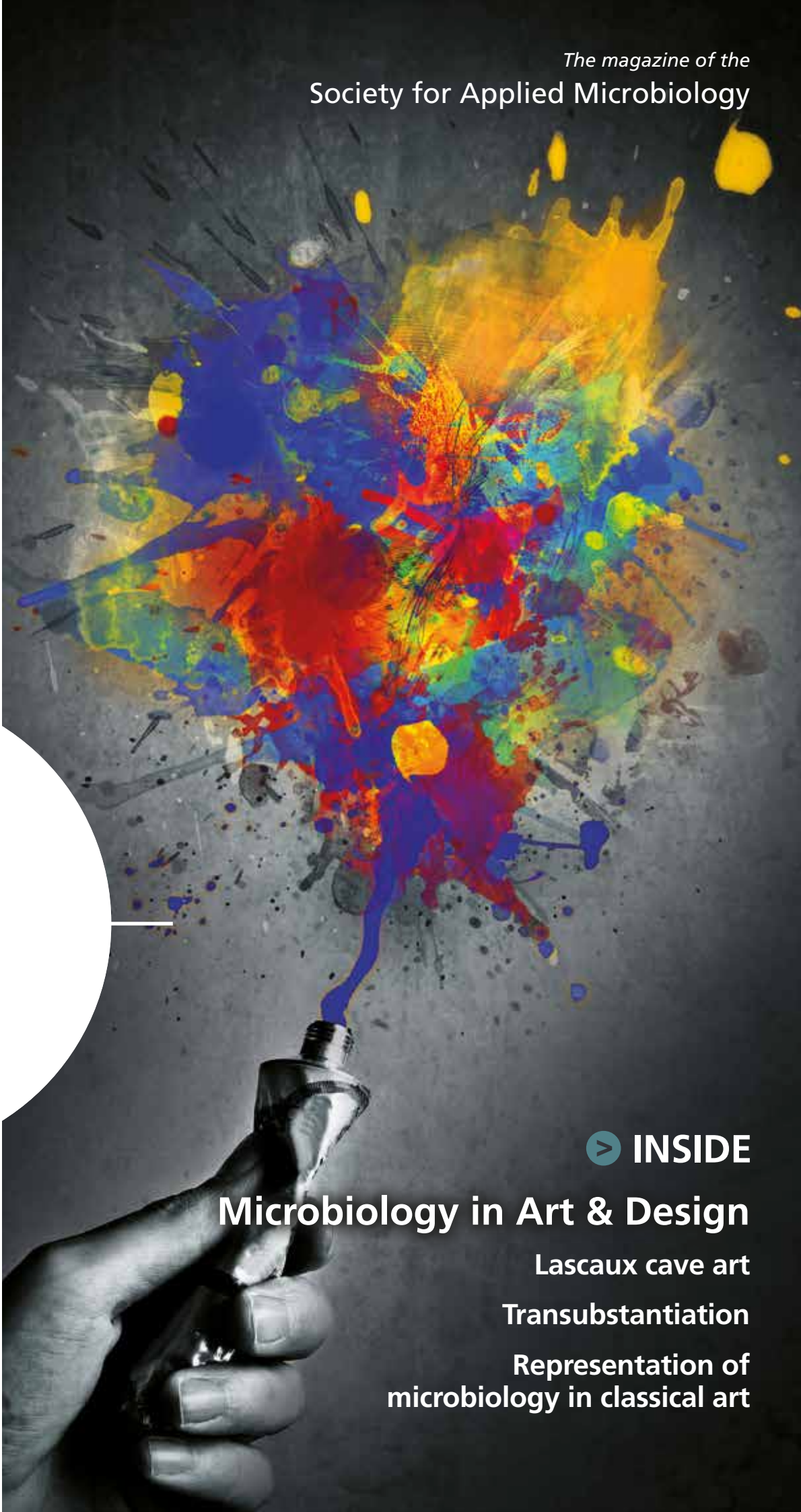

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CONTACTPOINT

Society Office Staff

CHIEF EXECUTIVE:
Dr Lucy Harper
email: lucy@sfam.org.uk
tel: +44 (0)207 685 2591

HEAD OF MARKETING, MEMBERSHIP & COMMUNICATIONS:
Dr Paul Sainsbury
email: paul@sfam.org.uk
tel: +44 (0)207 685 2594

FINANCE AND GRANTS CO-ORDINATOR:
Tina Sellwood
email: tina@sfam.org.uk
tel: +44 (0)207 685 2593

PRESS & MEDIA OFFICER:
Stewart Cumiskey
email: stewart@sfam.org.uk
tel: +44 (0)207 685 2595

POLICY OFFICER:
Dr Christopher Brown
email: christopher@sfam.org.uk
tel: +44 (0)207 685 2408

MARKETING & MEMBERSHIP OFFICER:
Rosie Stevens
email: rosie@sfam.org.uk
tel: +44 (0)207 685 2596

EVENTS & PROJECTS MANAGER:
Laura Lincoln
email: laura@sfam.org.uk
tel: +44 (0)207 685 2592

Society for Applied Microbiology
Charles Darwin House
12 Roger Street, WC1N 2JU,
United Kingdom
T +44 (0)207 685 2596
F +44 (0)207 685 2598
E communications@sfam.org.uk
W www.sfam.org.uk

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Editorial Group

Executive Committee

COMMITTEE MEMBERS

PRESIDENT:
Professor Christine Dodd, Division of Food Sciences, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, Leicestershire LE12 5RD
email: christine.dodd@nottingham.ac.uk

VICE PRESIDENT:
Professor Mark Fielder, School of Life Sciences, Kingston University, Penrhyn Road, Kingston upon Thames, Surrey KT1 2EE
email: m.fielder@kingston.ac.uk

GENERAL SECRETARY:
Dr Clare Taylor, School of Life, Sport & Social Sciences, Sighthill Campus, Edinburgh Napier University, Edinburgh EH11 4BN
email: cl.taylor@napier.ac.uk.

MEETINGS SECRETARY:
Professor Ian Feavers, National Institute for Biological Standards and Control, Blanche Lane, South Mimms, Potters Bar, Hertfordshire, EN6 3QG
email: Ian.Feavers@nibsc.org

TREASURER:
Mr Phil Wheat, Edinburgh
email: pfwheat@gmail.com

ORDINARY COMMITTEE MEMBERS UNTIL JULY 2017

Dr Tim Aldsworth, Applied Sciences and Health, Faculty of Health and Life Sciences, Coventry University, Priory Street, Coventry, CV1 5FB
email: tim.aldsworth@coventry.ac.uk

Dr Linda Thomas, Dorchester
email: drlvthomas@gmail.com

ORDINARY COMMITTEE MEMBERS UNTIL JULY 2018

Dr Mike Dempsey, School of Science & The Environment, Manchester Metropolitan University, Lower Ormond Street, Manchester, M15 6HB
email: m.dempsey@mmu.ac.uk

Ms Charlotte Duncan, Pro-Lab Diagnostics, 3 Bassendale Road, Bromborough, Wirral, Merseyside, CH62 3QL
email: cduncan@pro-lab.com

Mrs Claire Hill, Medical Wire & Equipment Co Ltd, Unit 29, Leafield Industrial Estate, Corsham, Wiltshire, SN13 9RT
email: chill@mwe.co.uk

ORDINARY COMMITTEE MEMBERS UNTIL JULY 2019

Professor Valerie Edwards-Jones, School of Healthcare Science, Manchester Metropolitan University, John Dalton Building, Chester Street, Manchester, M1 5GD
email: v.e.jones@mmu.ac.uk

Dr Brian Jones, Pharmacy and Biomolecular Sciences, University of Brighton, Moulsecoomb, Brighton, BN2 4GJ
email: B.V.Jones@brighton.ac.uk

Dr Simon Gould, School of Life Science, Faculty of Science, Engineering & Computing, Kingston University, Penrhyn Road, Kingston upon Thames, KT1 2EE
email: s.gould@kingston.ac.uk

Professor Stephen Forsythe, School of Science and Technology, Nottingham Trent University, Clifton Lane, Nottingham, NG11 8NS
email: stephen.forsythe@ntu.ac.uk

Paul Sainsbury reviews the content of this issue

microbiologist

The art of science and the science of art

Art and science have been inextricably linked throughout history. Whereas it may feel like science is kept behind closed doors, art is defined by the viewer engaging with it.

Reasons for engaging with the public extend beyond the benefits to the scientists themselves and many argue that if science is publicly funded, society has a right to be involved in decisions about how any discoveries are used. We often think of public engagement and science communication as relatively new arenas, but historical representations of science can be observed in narrative, imagery, artefacts, performing arts and cultural institutions. Links between the sciences and the arts and humanities are as old as humankind.

I was fortunate to be able to sit down and discuss the content of this issue with Jo Verran from Manchester Metropolitan University. For many years now, Jo has introduced a range of innovative, engaging assignments that have been incorporated into the microbiology component of the undergraduate biology/biomedical science curriculum at MMU and was able to give me many ideas for the content.

Proving her mettle as an expert in 'sci-art', Jo's excellent feature for this magazine takes us on a short journey of the importance of microbiology and disease and their impact on humanity, by considering how they are represented in classical art. As you can see on page 13 of this issue of *Microbiologist*, even Edvard Munch of *The Scream* fame got in on the act. In a waiting room, he observed a tear-stained mother with her dying child on her lap. The child was infected with syphilis. The little child's body is depicted with an abnormally large head, thin limbs and a red rash on its chest.

Creative uses of microbiology to invoke an opinion is also nothing new for Anna Dumitriu. Anna is a highly renowned artist who enhances science public engagement with microbiology. For this issue, she puts the spotlight on her favourite pieces of work.

Microbiological processes shown in art may have also inadvertently contributed to religious advancement. Simon Park explains how pictorial depictions of transubstantiation (the teaching of the Catholic Church in which the bread and the wine become the body and blood of Jesus) could have been attributed to the growth of *Serratia marcescens*.

Jane Wood and Angela Hartsock look at some creative industrial applications of bacteria and Brendan Gilmore investigates the longevity of the wall paintings within the magnificent Lascaux Caves.

...and we also show you how to dye wool with fungi!

NEWS IN BRIEF

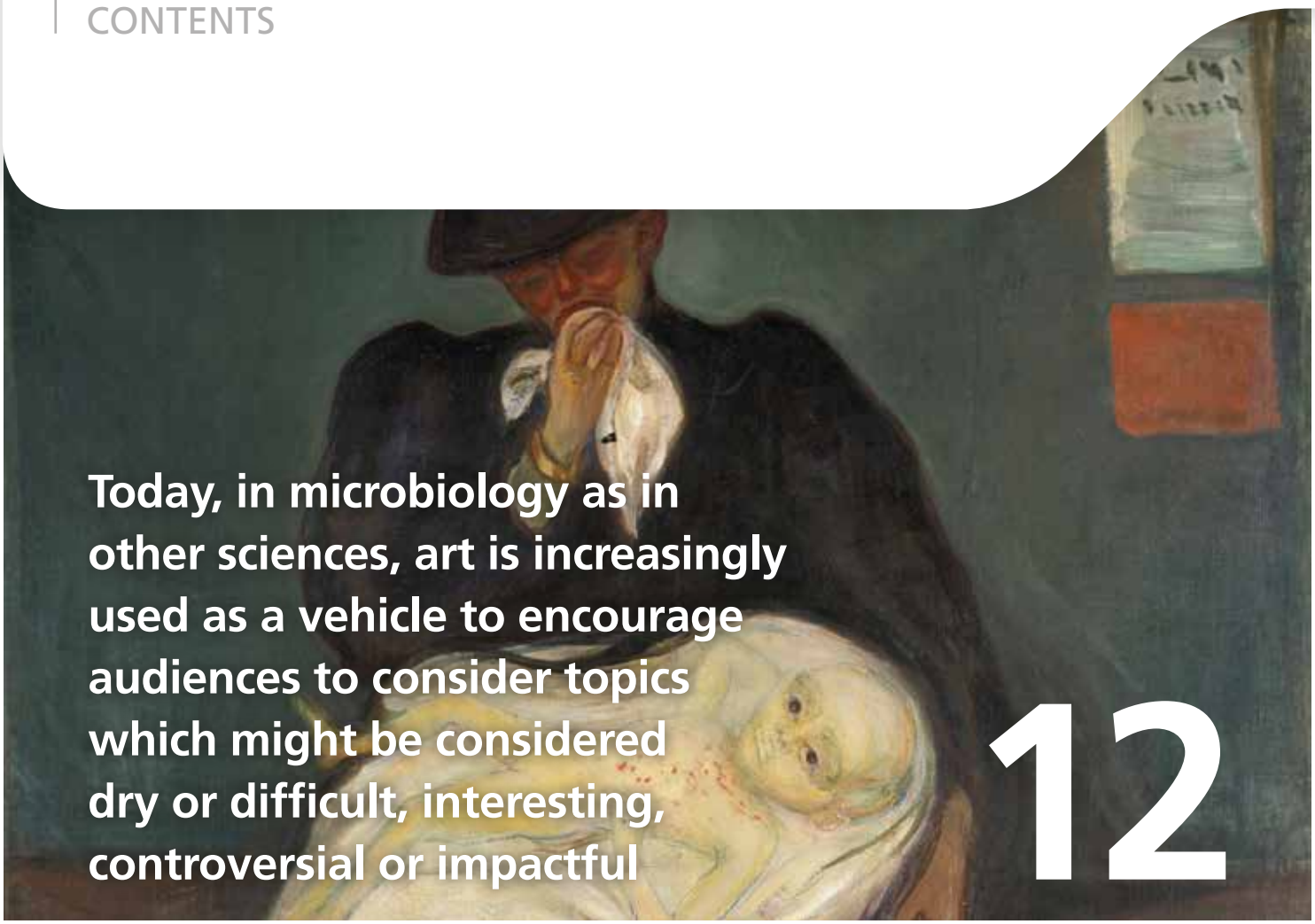
Dr Charlotte Warren-Gash, an Associate Professor and Wellcome Trust Intermediate Clinical Fellow at the London School of Hygiene and Tropical Medicine has been awarded the 2017 *Sf*AM / British Science Association Media Fellowship.

http://bit.ly/2qDvSgy

Scientists in Poland say they have developed a novel type of wound dressing that uses an antibacterial substance formed from chitosan extracted from the shells of crustaceans like shrimps.

http://bit.ly/2q2BR14

Paul Sainsbury
Editor



Today, in microbiology as in other sciences, art is increasingly used as a vehicle to encourage audiences to consider topics which might be considered dry or difficult, interesting, controversial or impactful

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COMMERCIAL

President's column

This being my last column for the *Microbiologist*, I have been given cause to reflect on the great many positive changes we have made to the Society over the last few years. As I step down as President this July, it's lovely to see that S*f*AM is in such great shape.

For many that have gone before me, I am told that the immediate benefit of stepping down is not being required to chair the Thursday conference session, held the morning after the boozy Society dinner. This is not the case for me. For me this is a chance to see the many faces of those I chose to represent – especially those who travel a great distance to join us for those days.

So, I find myself considering a life without being on the Executive Committee – of which I have been a member for 10 years – and contemplating changes to my university life as I move towards flexible retirement next year. My colleagues in the happy position of already having taken flexible retirement, tell me the great advantage of working one day a week is doing just the bits you enjoy and not the rest. However, I'm sure it will end up being the usual mix of duties.

The key decision will be choosing which aspects of my teaching to continue with.

For me, the practicals are by far the most enjoyable. Although they can be an extremely time-consuming part of my teaching, I have always believed that microbiology should be a very hands-on subject and that practicals should therefore remain a key part of future syllabuses. Certainly, past students have said that the practical training they get in my second and third year modules give them greater understanding of the subject as well as key skills that they have been able to use in later study or employment. An emerging concern amongst some academics is that future students may receive less hands-on experience in microbiology degree courses. The reasons cited can be several-fold: the work load and financial costs associated with running practicals, but also current pedagogical ideas of skills training and assessment may be an influence. How many times do you need to do a Gram stain to be considered competent? (*cp*, How many driving lessons do you need to be considered competent?)

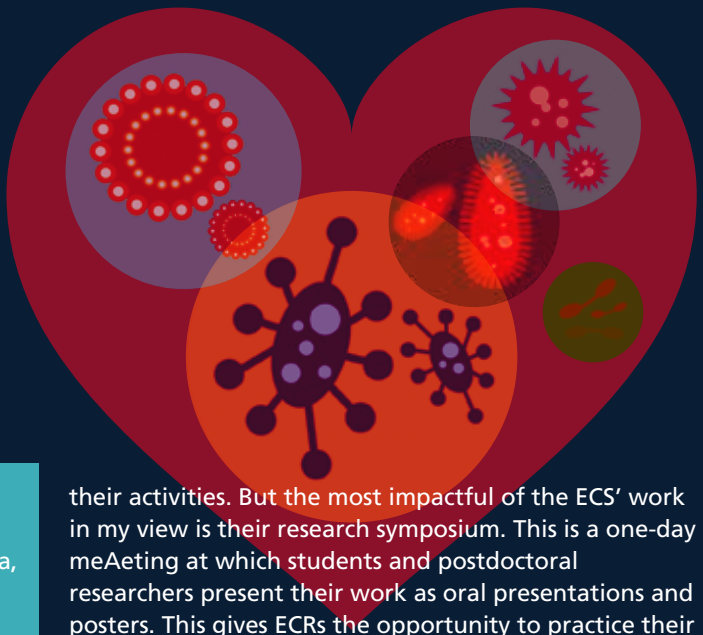
The desire to get practical experience is certainly evident in students and is reflected in the high number of applications the Society receives each year for its Students into Work grant, which provides the opportunity of laboratory experience for up to eight weeks. This is an area which the Society is pleased to support because it underpins our objectives for the development of early career scientists, and also promotes the applied nature of microbiology. I trust that the promotion of practical skills training is an area the Society will continue to champion in the future.

Finally, I would like to say thank you to all of you who have written in appreciation of receiving Life Membership of the Society. It has been a pleasure to read your messages and your reflections on what the Society has meant to you. Thanks also to my regular readers for making the effort to read this column.

Christine Dodd
President of the Society

Harper's Postulates

Notes from the Chief Executive



Microbes matter – and so does the next generation of applied microbiologists

One of the (many) reasons I love coming to work every morning is because every day I get to learn something positive about the good work that bacteria, viruses, fungi and protozoa do in the world.

From creating or enhancing the taste of our food and drink, to cleaning up pollution, enabling the creation of new products through synthetic biology, and providing us with ways to feed our growing population – when you consider all this good, microbes get a bad press.

People think of disease, germs, dirt and illness when they think of microbes and this needs to stop.

So you can think of my column this time as a call to action: you, our Members, are asked to make sure that at every opportunity, in some small way, you talk to people about the good that microbes do.

Talk to your friends over a drink, talk to your family over dinner, talk to the people you meet at your yoga class, your football match, your online networks. Spread the word about the fact that microbes are not only essential for human life, but that we humans have developed so many ways of putting their unique properties to good work which benefits the world more than most of us realize.

I was asked recently what we're doing to support the next generation of Members and for S*f*AM, that's a very easy question for me to answer.

For over six years, we've been able to benefit from the enthusiasm and energy of our Early Career Scientists Committee. For those of you unfamiliar with the ECS Committee, they are a group of Early Career Researchers (ECR) and S*f*AM Members who are (master's/PhD) students or scientists who have received their highest degree (BSc, MSc or PhD) within the past seven years. They run sessions at our Annual Conference to provide guidance and advice to ECRs on things like communication skills, the publication process and careers. They run social events to enhance networking and they hold their own committee meetings to discuss their activities. But the most impactful of the ECS' work in my view is their research symposium. This is a one-day meAeting at which students and postdoctoral researchers present their work as oral presentations and posters. This gives ECRs the opportunity to practice their presentation skills in a safe environment. This year, they also held workshops on the theme of the conference: Bioinformatics. The entire day is organized from beginning to end entirely by the ECS – from choosing a topic, to inviting speakers, sourcing a venue, through to the abstract submission and selection process, delegate registration and menu choices, it's all done by them. Attendance at these events is always a humbling experience for me as the events are so well-run, slick and professional. I've too long left the lab to comment on the quality of the science, but sufficed to say it's presented beautifully.

The ECS provide each other with a huge amount of peer support, skills development and networking opportunities which, as I heard at today's Wiley Executive Seminar, is exactly what's needed by this segment of our Members.

But not only are we supporting the ECRs within our membership through the ECS, we as a Society are benefiting hugely from their input. As the next generation of applied microbiologists, the ECS are our future, and when feeding into the Executive Committee they provide us with insight from a completely different perspective.

It's a win-win, and a vital one of which we're all extremely proud.

(You can read the latest from the ECS on page 08).

Lucy Harper
S*f*AM *Chief Executive*

Record breakers & conference makers

It has only been a few months since the last Research Symposium held by S*f*AM's ECS Committee and we're still reeling from the excitement of the day. Abstract submissions increased by 200% this year and everyone was incredibly excited to hear that we've broken all records from previous ECS Research Symposiums.

It seems that all the tweeting and emailing paid off. We were delighted to have received so many submissions from our International Members! The diversity and quality of the research that's being carried out by people so early on in their careers is amazing to see and very encouraging. We look forward to these symposiums continuing to expand with each year.

The popularity of this year's event could have been down to the excellent Bioinformatics hands-on workshop run by Dr Leighton Pritchard and Dr Nick Loman. I was particularly looking forward to learning more about a subject I had very little experience with. As an established area of science we knew there would be a lot of engaging content to cover and many attendees discovered that they have the necessary skills to forge a career in the subject.

The next S*f*AM event to look forward to is the Annual Conference held at the BALTIC Centre for Contemporary Art in Gateshead. This is an impressive building to begin with and the four-day event will run from the 3–6 July with an exciting programme that includes workshops, a quiz night, buffets and a vast array of interesting talks. This will be the first Annual Conference that I've attended and after a quick flick through the programme it looks like my time is going to be jam-packed with activities! For me, the 'ECS Icebreaker' is something to look forward to. It will be a chance to meet new people with similar interests and have a good laugh in the process.

After all, we'll be spending the next four days together!

As a soon-to-be-graduate I'd like to get an insight into what awaits me after I've thrown my cap skywards and said goodbye to the place that's been my home for the past three years. I'm very grateful to be part of the ECS Committee, because being involved in organizing the 6th ECS Research Symposium in April has given me responsibilities outside of the university bubble. Hopefully, the experience will help my transition from student to professional.

Since my chosen career is one in science communication, all the experiences I've gained from being on the ECS Committee are helping me to expand my horizons and engage with other young scientists from around the country.

After the Summer Conference, I'm thrilled to become the next Publications Officer of the ECS Committee, following on from Ali Ryan in the role. It's quite a responsibility and something that seemed unachievable before graduating! As Publications Officer, I'll be responsible for commissioning and editing the ECS articles for *Microbiologist*. Please feel free to contact me at **ECS@sfam.org.uk**.

sfam ECS EarlyCareerScientists

Jennie French
ECS Committee Member
University of Nottingham

POLICY Corner

Welcome to the first Policy Corner section of the *Microbiologist*. This is quite a timely addition to the magazine as in March we convened the Society's very first Policy Subcommittee meeting. Supported by a previous chair of the *Commons Science and Technology Select Committee* and ex-MP, Andrew Miller, the Policy Subcommittee work to boost the Society's involvement in science policy issues and to ensure your views are brought to the policymaker's table.

Over the coming months, we'll be working to engage proactively with the policy issues that impact upon applied microbiology in areas including AMR, food security and safety and – elephant in the room alert – Brexit. In the meantime, keep your eyes peeled for information and features online and in future issues of *Microbiologist*. If you would like to be involved in S*f*AM's policy work, or just want to know more about the Policy Subcommittee and our plans, feel free to get in touch.

Are microbes novel in food? Depends who you ask…

In March 2016, the *Microbiologist* ran a feature on the policy of novel foods and processes. Later on in the year, the Advisory Committee on Novel Foods and Processes (ACNFP) of the Food Standards Agency (FSA) appointed four new members, in recognition of a need to boost their expertise in a number of areas, including microbiology of the gut.

Among these, Dr Hamid Ghoddusi, BSc, MSc, PhD is bringing microbiology to the yard and will deliver considerable experience to the role. Other appointees are Rebecca McKenzie, Lesley Stanley and Anton Alldrick.

The ACNFP is a non-statutory, independent body of scientific experts that advises the FSA on any matters relating to novel foods (including genetically modified foods) and novel processes. If you wanted to market tongkat ali root extract in the UK (currently under review), it's the ACNFP's door you'd have to knock on. Why would you wish to wheel out tongkat? Traditionally, tongkat ali root was used as an aphrodisiac and a remedy for age-related sexual disorders and symptoms of andropause. There might be some mileage in that, but it's the ACNFP's job to check that it's safe.

We'll be working to engage proactively with the policy issues that impact upon applied microbiology

After completing a PhD in Food Science (Microbiology) at the University of Reading, Dr Ghoddusi worked as Assistant and Associate Professor at Ferdowsi University of Mashhad (FUM), Iran. He returned to Reading in September 2004, as a research fellow, before moving to London Metropolitan University, where he is currently the Head of the Microbiology Research Unit (MRU) and Director of the Food Science Postgraduate Programme. There, he lectures on food microbiology and safety, food science and microbiology, and microbial biotechnology.

Dr Ghoddusi has a broad interest in characterizing lactic acid bacteria, including probiotics and particularly bifidobacteria, and their potential applications in fermented dairy products. His current research focuses on functional foods including the efficacy of probiotics and prebiotics and the importance and impact of diet on the gastrointestinal ecosystem.

Chris Brown
Society for Applied Microbiology

BIOFOCUS

Looking to the future for innovation and research

The triggering of Article 50 in March means we now have a very tangible and definitive timeline for the UK's exit of the EU. During this time, the Royal Society of Biology will be working to represent the priorities of our members in the forthcoming negotiations, not only to ensure the best possible deal for scientists based in the UK, but also for those wishing to join in the future.

Looking towards the future has been a theme running through some of the RSB events this year. In March we saw *Voice of the Future*, a unique event that allows schoolchildren through to early career researchers to pitch their questions to the Government's top science policymakers and politicians, right in the heart of Westminster.

Young researchers from a wide range of membership organizations, including S*f*AM, discussed science policy

Closing the STEM skills gap is an endeavour that is vital for ensuring the longevity of our science and technology sector

with Jo Johnson MP, Sir Mark Walport, Chi Onwurah MP and members of the House of Commons Science and Technology Committee. It was encouraging to see young representatives asking meaningful and thought-provoking questions; questions that were indicative of their enthusiasm for science and research.

Earlier in the same week we were at Portcullis House, this time for *STEM for Britain*. This year saw the largest number of submissions ever, with over 250 STEM scientists presenting their research to MPs, policymakers and other academics. It was especially exciting to see a biologist receive the highest accolade of the event – the Westminster medal – for her research on developing a cost-effective device for the rapid detection of the drug mephedrone.

These events remind us that the decisions made in the next two years will resonate not only through the scientific community as it stands, but will also affect the lives of those sitting in classrooms, lecture theatres and libraries across the country, still perhaps unsure about pursuing a career in science.

For those who are still undecided, the RSB have developed a number of resources for pupils considering a career in biosciences. We are also supporting the STEM Insight programme, allowing teachers to complete placements in universities or industry and expand on their STEM skill sets and experience. Undoubtedly, the resources and support from RSB and across the sector will be more important than ever for those at the beginning of their science career or wishing to expand their acumen further.

With this in mind, we responded to the Science and Technology Select Committee's enquiry into closing the STEM gap. The UK requires an additional 104,000 STEM graduates and 56,000 STEM technicians each year to plug the deficit, and so far is struggling to do so.

Through schemes such as the RSB degree accreditation programme, the wider registration programmes for technicians and researchers and the new RSB Plant Health Professionals Register, we are working hard to raise the standards of education, offering more opportunities for researchers to develop their STEM skill sets, and recognizing the excellence of those already working in the biosciences.

Closing the STEM skills gap is an endeavour that is vital for ensuring the longevity of our science and technology sector, and one that RSB and all its member organizations will continue to address. It is imperative we ensure our current and future researchers are best placed to sustain and develop our UK science base in the months and years to come.

For those who are still undecided, the RSB have developed a number of resources for pupils considering a career in biosciences

It was particularly encouraging to be present for the launch of a report by Stephen Metcalfe MP, Chair of the Parliamentary and Scientific Committee, on his recommendations for science priorities for Brexit; a report that succinctly and clearly outlined several priorities that should be considered and addressed in the coming months.

The recommendations, focusing on people, investment, collaborative efforts and trade mirrored our priorities for ensuring that members of our UK science base are not confined in what they can do and achieve. We want the UK to remain a global leader in science and we need to remain as open and accessible as possible to retain this standard.

We hope that these recommendations, produced after lengthy discussion and drawn from evidence submitted by members of the science community, will be taken forward and form a foundation for the coming negotiations following the triggering of Article 50.

Dr Mark Downs CBiol FRSB
Chief Executive of the Royal Society of Biology

MICROBIOLOGY *in Classical Art*

The relationship between microbiology and art is surprisingly extensive. We can gasp at the beauty of microorganisms. We can marvel at the ingenuity of sci-art projects, where the collaboration between artists and scientists often provides a novel, revealing or provocative angle, enabling free-ranging discussion and engagement with non-expert audiences. Perhaps we also need to be reminded of the role of microorganisms in the deterioration and conservation of artworks and other items of cultural heritage such as textiles, film, ships and statuary. But in particular, we are often reminded about the importance of microbiology and disease and their impact on humanity, by considering how they are represented in classical art.

For centuries, art and design have been used to convey information about infectious disease to audiences, with 'disease inspiring and challenging art, and art exploring and revealing the disease'. Creative outputs reveal the impact of disease on populations as well as individuals, depicting the epidemics or infections of concern at a given historical period or location, providing a realistic supplement to lectures or research. Medieval portrayals of victims of plague, syphilis or smallpox are reminiscent of medical illustration imagery, providing visual information on symptoms and diagnosis. Woodcuts and printing technologies enabled image reproduction, thereby ensuring a higher number of viewers, and, potentially, an avenue for public information. Thus 'The Syphilitic' by Albrecht Dürer (1471–1528), a woodcut that warns of symptoms, with the man in the attire of a mercenary travelling across Europe, likely assisting in the spread of the disease which had only recently arrived on the continent.

More overt public information, which could be easily reproduced by engraving and, later, lithography, and disseminated through newspapers, fliers and magazines was often conveyed through cartoons, which – then, as now – challenged audiences to reflect on circulating opinions of the day. Gillray's famous cartoon of smallpox vaccination, entitled '*The Cow-Pock–or–the Wonderful Effects of the New Inoculation!*' (1851) lays bare the unfounded fear of transmission of some bovine properties via the vaccine. During 'the great stink', when in the warm summer of 1858 London was swathed in the odour of raw sewage, a cartoon by John Leech showed Father Thames presenting gifts of diphtheria, scrofula and cholera to Mother London (Father Thames, British Library). Poster art, using simple graphic images, is still used to warn specific audiences of the dangers of disease: in the past, sexual transmitted disease in wartime; at present, the impact of sugar on oral health, for example. There is a significant catalogue of posters about HIV/AIDS, directed at particular audiences and extended annually through the HIV awareness poster contest (**www.haartinc.org**).

For classical art, prior to the advent of reproductions, the audience was predominantly restricted to those who had time, social standing and funding to visit homes, exhibitions and galleries and view the art displayed. Classical paintings portray the impact of disease, particularly plague, which caused such dramatic loss of life in specific locations and populations such as Marseille, Venice and classical Rome. The Great Plague of Marseille was the last significant European outbreak of bubonic plague. An engraving of Marseille during

FURTHER READING

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'The Inheritance' *by Edvard Munch (1899)*

the plague of 1720, provides journalistic and geographic information about the impact of plague on specific city streets, complementing the recent research efforts to decode the genome of the Black Death pathogen (Callaway, 2011). Images of the effects of disease on individuals are more personal and poignant. Edvard Munch's *The Inheritance* (1897) depicts a devastated mother cradling her naked child, who presents the symptoms of syphilis – symptoms not apparent in the mother although she is clearly the cause of the child's illness. The reference to sex and sexually transmitted disease, coupled with the image reminiscent of the Madonna and child, was bold for the time. Cristobal Rojas' *La Miseria* (1886) revealed the poverty and despair that accompanied tuberculosis infection.

'The Syphilitic' *by Albrecht Dürer (1496)*

Today, in microbiology as in other sciences, art is increasingly used as a vehicle to encourage audiences to consider topics which might be considered dry or difficult, interesting, controversial or impactful. The journal, *Emerging Infectious Disease*, utilizes cover art for every issue, including information about the artist's interpretation and presentation of the disease or pathogen of concern. Microbiologists are exploring art to help interpret their science, encouraging their students to consider how art can help to communicate science, and collaborating with artists to generate creative and informative outputs. Artists are using and exploring microbiology to address, represent or challenge views on topics such as AMR, the human microbiome and oral health, whilst also producing objects of great beauty such as Luke Jerram's glass viruses. For the interested learner or teacher, sources of inspiration and examples of outputs are plentiful. Internet searches yield hundreds of articles and images that reflect our current and ongoing interest in the use of art to help to illustrate and interpret our manifold interactions with microorganisms.

Jo Verran
Manchester Metropolitan University

MICROBIAL DETERIORATION OF ART: THE CAVE PAINTINGS OF LASCAUX

Archaeologist Abbé Henri Breuil (1877-1961) was among the first to visit the Lascaux cave complex

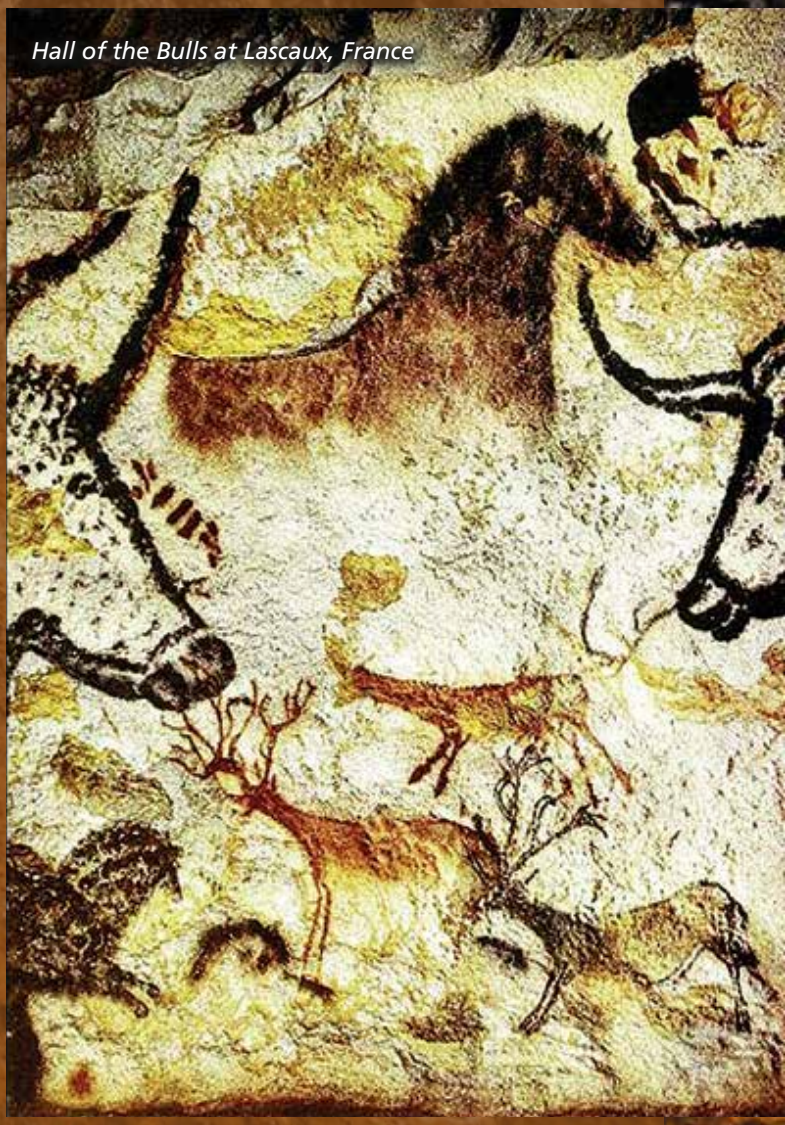
Cave painting of Chinese Horse, Lascaux, France

In September 1940, teenager Marcial Ravidat chanced upon one of the most exciting and culturally significant archaeological discoveries in history. Versions of the story of his discovery differ but, whilst walking in the woods near the village of Montignac in the Dordogne area of Southern France, Marcial uncovered the entrance to a secret world which had lain undisturbed for some 17,000 years. The previous winter's storms had uprooted a tree, gouging the earth beneath and revealing a small hole in the ground. Believing that the hole may be the entrance to a tunnel which, according to local legend, led to buried treasure, Ravidat widened the entrance and descended into the darkness of the caves beneath. The flickering light of an improvised lamp revealed walls decorated with hundreds of pristine rock paintings, dramatic, dynamic and narrative, of 'a cavalcade of animals larger than life', their forms and hues so vivid, brilliant and unfaded that 'they seemed to be moving'.

At the time of the discovery, the Montignac region was already well known for caves bearing prehistoric rock paintings, however, Lascaux was unique for the immaculate state of preservation of the parietal artwork's original forms and pigments. So well sealed were the caves that, to date, the original entrance used by these prehistoric artists remains undiscovered. The Lascaux Cave walls are festooned with over 600 paintings and 1,500 carvings dating from the Upper Paleolithic period. Depictions show the now extinct European Auroch and woolly rhinoceros, horses, stags, bison, lions and antelope, leaping and charging from the limestone vault.

The pigments (iron oxide reds, browns and ochers, and manganese oxide blacks) are in many cases as vivid and dramatic as when they were first deftly applied. The galleries leading from the main chamber revealed that the first humans practiced religious or magical rituals (a bird-headed shaman is painted in '*The Shaft of the Dead Man*' section of the caves), buried their dead and hunted the wild animals of the plain and tundra. In 2000, Dr Michael Rappenglueck, of the University of Munich, proposed that the cave bears evidence for prehistoric mapping of the constellations, possibly revealing the presence of the oldest known lunar calendar.

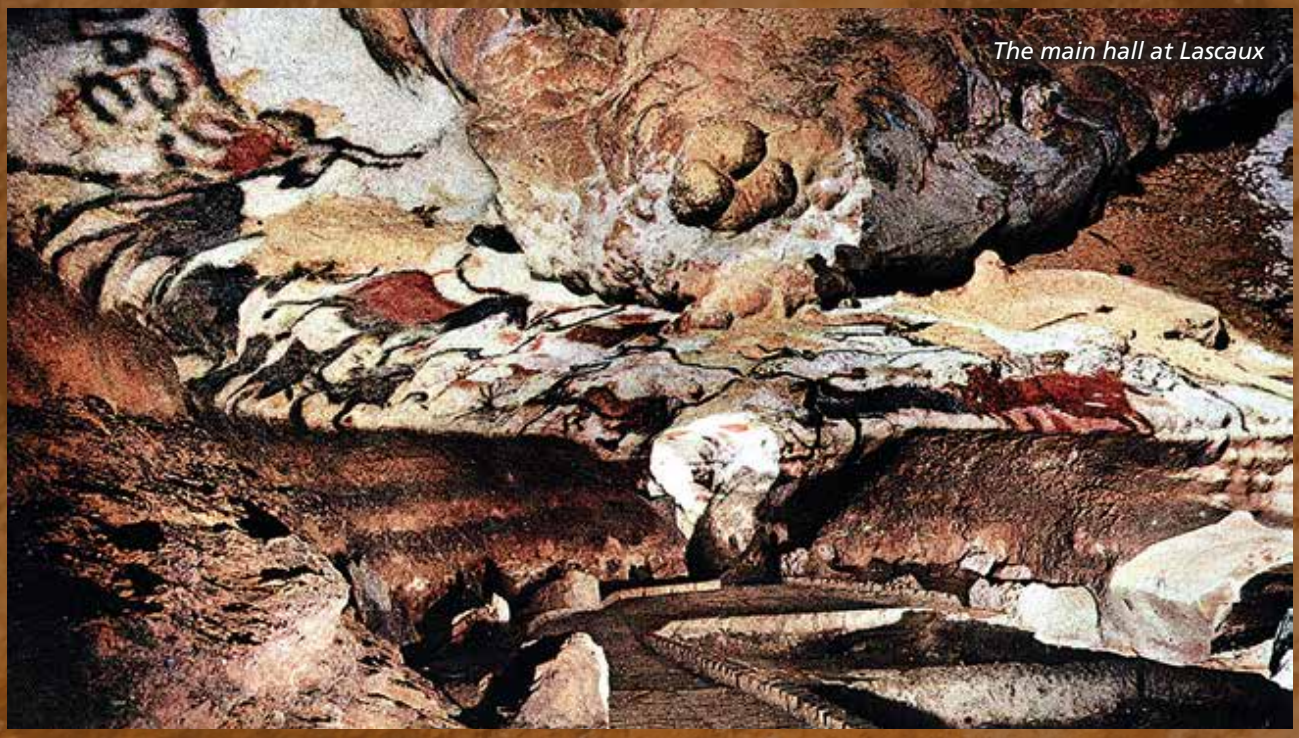
Following the discovery of the cave system and its uniquely preserved ancient rock art, news spread quickly and the caves became a 'must-see' destination for archaeologists, historians, artists, scientists and those curious to observe these prehistoric wonders. However, the influx of massive numbers of tourists (from around 1,200 visitors per day in 1948 to 1,800 per day by 1960) to view works of art which had been undisturbed for 17 millennia, was to exact a heavy toll, threatening the conservation and integrity of the site and of the precious art contained within. The outbreak of several waves of damaging microbial blooms led to the site being closed to the public in 1963 and ongoing efforts to control, maintain and preserve the caves. Lascaux has been designated a UNESCO World Heritage Site and a faithful replica of the caves in the Lascaux hillside 'Lascaux II', opened in 1983, attracting almost 300,000 visitors each year.



Hall of the Bulls at Lascaux, France

The microbiology and microbial crises of Lascaux Caves

Predictably, the huge interest in the Lascaux rock art fuelled a thriving tourism industry, bringing visitors to the site in droves. A general lack of scientific understanding of microbial deterioration (biodeterioration) and the potential impact of high volumes of human traffic (bringing with it moisture, microbes, carbon dioxide, heat and environmental pollutants) resulted in adaptations to the site (in 1947/8 and 1957/8) to facilitate tourists. This included installation of lighting systems and walkways to improve viewing and safety – both equally damaging to this important site and both imperilling the irreplaceable artwork.



The main hall at Lascaux

The opening of the site to visitors and the breath of the thousands who flocked there, altered the gaseous environment and humidity and either introduced new contaminating microorganisms or conditioned the existing environment for proliferation of environmental microbes capable of damaging or obscuring the artistic and anthropological wonders of the caves. To date, the caves at Lascaux have endured three major microbial outbreaks, or microbial crises, the most recent involving the proliferation of black stains threatening the parietal artworks.

Within a year of opening to the public, mould had appeared on the walls. Lighting installed had the unintended effect of promoting the growth of a green biofilm (referred to as '*la maladie verte*' or green sickness) covering some of the wall paintings in the *Hall of Bulls* and the *Axial Gallery* by 1960. The Minister for Cultural Affairs created a scientific commission to "*study the changes inside the cave, find remedies and bring the cave back to stable conditions*".

The offending organism was initially identified as the alga *Chlorobotrys* but later correctly as *Braceacoccus minor*, a green alga of the division Chlorophyta. This marked the first of a number of outbreaks of microbial contamination and growth and began the arduous task of implementing measures to conserve the site. In an attempt to control '*la maladie verte*' the walls and floors were sprayed with a mixture of antibiotics (penicillin and streptomycin) and biocide (formaldehyde). These measures appeared effective at first, however, by 1969 it proved necessary to repeat the process of disinfection and introduce periodic cleaning and maintenance. According to the present Curator of Lascaux Caves, Muriel Mauriac, "*Lascaux was unwillingly transformed into a place of experimentation, of heuristics, a laboratory for the conservation of parietal art*".

In Spring 2001, during a programme of work intended to kill lichens in the *Hall of Bulls*, a sudden outbreak of fungi, apparently spreading from an airlock at the cave entrance and proliferating in the decorated areas, was observed. Appearing as white filamentous growth, the second microbial crisis was referred to as '*la maladie blanche*' (white sickness). The fungi in question was identified as *Fusarium solani* (a natural cave symbiont) and biocidal treatment based on the quaternary ammonium compound benzalkonium chloride was initiated. Associated with the contaminating fungus was the bacteria *Pseudomonas fluorescens*, capable of the degradation of benzalkonium chloride. Therefore, a programme of combined biocide and antibiotic (streptomycin and polymyxin) decolonization was attempted. The bacteria proved resistant and in October 2001, the decision was reached to treat the floor sediments with quicklime (calcium oxide).

After two years of intensive spot treatment with benzalkonium chloride the *Fusarium solani* outbreak was apparently under control. By 2004, the quicklime was recovered and biocidal treatment replaced with the manual removal of visible microorganisms and improved air extraction and control. However, despite best efforts to restore balance in the microbiome of the cave system, a third microbial crisis was to follow.

In Spring 2006, black staining on the vault of the *Passageway*, *Apse* and *Nave* sections of the cave system was reported. These were fungal species belonging to the genera *Verticillium* and *Scolecobasidium*

(*Ochroconis*) and treated with manual cleaning and the use of biocides (benzalkonium chloride, miristalkonium chloride and 2-octyl-2H-isothiazole-3-one). Although the treatment proved somewhat effective, evidence that this approach led to irreversible damage of the cave walls emerged, leading to the cessation of biocide-centred control measures in 2007.

That same year, a study by Dupont and co-workers found that from areas of black staining, six fungal genera were represented: *Chrysosporium*, *Gliocoladium*, *Gliomastix*, *Paecilomyces*, *Trichoderma* and *Verticillium*. A later study confirmed the identification of *Scolecobasidium* from black stains, identifying two novel species *Ochroconis lascauxensis* and *O. anomala*. In the years between 2007 and 2010, *Scolecobasidium tshawytschae* has been frequently isolated from the black stains and is known to produce the black pigment melanin. Interestingly, Bastian *et al*. suggested that the products of biocide, specifically benzalkonium chloride, degradation (possibly by *P. fluorescens*) may be utilized by *Scolecobasidium tshawytschae* as a carbon and nitrogen source. Therefore, the suboptimal use of broad-spectrum biocides may actually drive the microbiota of the cave system in a manner which ultimately proves damaging to the caves.

In the most detailed microbiome study conducted, Bastain and colleagues identified the most abundant bacterial taxa and most representative fungal phylotypes in Lascaux Caves. In terms of bacterial taxa, the most abundant were of the genus *Ralstonia* (*R. mannitolilytica* and *R. pickettii*) and *Pseudomonas* (*P. saccharophilia* and *P. lanceolata*). Interestingly, bacterial genera which are potentially pathogenic in man, were represented in the top 10 most abundant taxa (*Legionella*, *Escherichia* and *Stentrophomonas*). The data presented by DuPont also pointed to another potentially interesting and important relationship within the cave ecosystem. The fungal genera identified correlated with entomopathological genera associated with arthropods, such as cave crickets. Interestingly, springtails (*Folsomia candida*) have been observed on and around black stains associated with fungal outbreaks. Springtails (wingless arthropods) are known to feed on these fungal masses and their faeces may act as a vector for fungal spores. Springtails are commonly encountered in disturbed ecosystems, such as that of Lascaux Caves, so perhaps their presence is unsurprising. However, their role in the dispersal of fungal species responsible for proliferation of black staining within the caves may be an important one and a potential target for future control measures.

Cervids painted on a cave wall, Lascaux, France.

The Lascaux Caves are a delicate, living ecosystem, which following many millennia of isolation, are susceptible to shifts in microbiota and biodiversity which may drive outbreaks of microbial species potentially damaging to the cultural heritage contained within it. Human influence has certainly had an impact on the conservation status of the artworks and archaeology of this important site and despite all attempts to restore the original conditions and ecosystem, it is unlikely that these alterations can be reversed. The impact of many years of biocide use, air handling systems and human traffic has potentially selected a microbial population harbouring pathogenic microorganisms and melanizing fungi. The future of Lascaux Caves, undoubtedly one of the most culturally, archaeologically and anthropologically important sites in the world, now rests in the hands of those tasked with stabilizing, monitoring and controlling the environment within the caves whose discovery marked a change in how we view our prehistoric ancestors.

Brendan Gilmore
Queen's University Belfast

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Controlled commodities

An artist's obsession with microbiology

'MRSA Quilt'**, Anna Dumitriu, in collaboration with Dr John Paul, Dr James Price and Kevin Cole, Modernising Medical Microbiology.* Image credit ***Anna Dumitriu

I originally trained in fine art and now develop and create my artwork as much in the laboratory as in the studio. My work fuses craft, sculpture and bioscience to explore our relationship with the microbial world, technology and infectious diseases. An obsession with the history and future of our attempts to overcome infection has led to a strange and interesting journey through romantic diseases, extremophilic bacteria, engineered life, whole genome sequencing and CRISPR DNA editing.

Storytelling is key to my work and the materials chosen must have a resonance, so that layers of meaning can be peeled away. I often work with antique objects that require alteration, or materials sourced from or created in the lab. Every single element has its role. The perversity of working with traditional crafts such as carving, engraving or embroidery is mirrored in an insistence in learning all the scientific techniques used and performing them myself. Understanding the intricacies of all the scientific methods used is key, making me better able to share the research and the history behind it.

My journey into this world began around 15 years ago, with an interest in the (strange) term 'normal flora' (the ubiquitous microorganisms that coexist with us). At the time, they were described as being 'of no commercial or medical interest' simply because we didn't have the tools to study them. It's been fascinating to observe how science has developed over these past 15 years as sequencing technologies have become far more accessible and we're understanding more about our coexisting bacteria.

These previously disregarded organisms have been rebranded as 'the microbiome' and are seen as the dawn of a gold rush of bioprospecting for novel microorganisms that might prove biotechnologically useful to us.

The 'MRSA Quilt' (pictured left) was my first work specifically focused on a human pathogen. It takes the form of a storytelling quilt and was created in collaboration with Dr John Paul, Dr James Price and biomedical scientist Kevin Cole (Modernising Medical Microbiology, University of Oxford). The piece was created by embedding squares of cotton calico in chromogenic agar. This bacterial growth medium contained a dye that was taken up by *Staphylococcus aureus* bacteria, causing them to grow blue in colour and stain the calico.

The patterns on the squares were created using different tools and techniques in the treatment and diagnosis of infections caused by this bacterium and its drug-resistant form, known as MRSA (meticillin or multidrug-resistant *Staphylococcus aureus*). The patterns include stripes and polka dots created using antibiotic susceptibility tests, such as vancomycin discs and cefoxitin strips. Embroideries were made using natural antibiotic dyed threads, such as turmeric. These techniques have reappeared subsequently in my work.

Quilts are a traditional way of passing down stories and can also be used as a tool to facilitate dialogue between the wider public and the scientific research team. We often create participatory workshops where members of the public can drop in and experiment with us. A key part of these are the relaxed, non-hierarchical environment of the workshops which means that members of the public feel free to ask questions and even share their own experiences of infectious diseases.

Working with *Staphylococcus aureus* led to hunting down the bug in my own body. It was exciting to find I was colonized by (at least) two species. As part of 'Sequence Project' which involved the MRSA Quilt collaborators and digital artist Alex May, it was necessary to train in the process of whole genome sequencing. This involved shadowing people involved at all stages of the pipeline, from sampling and DNA prep, to the application of bioinformatics techniques to assemble the bacterial genomes.

We created two artworks using the data from the sequencer, both in its raw visual form and its assembled computational form. One was '*The Sequence Dress*' (pictured right) – impregnated with 'my' *Staphylococcus aureus* (which is resistant to penicillin), MRSA and VRSA, and video mapped with the sequence data. The other was '*Sequence VR*' – a virtual reality experience of whole genome sequencing of bacteria.

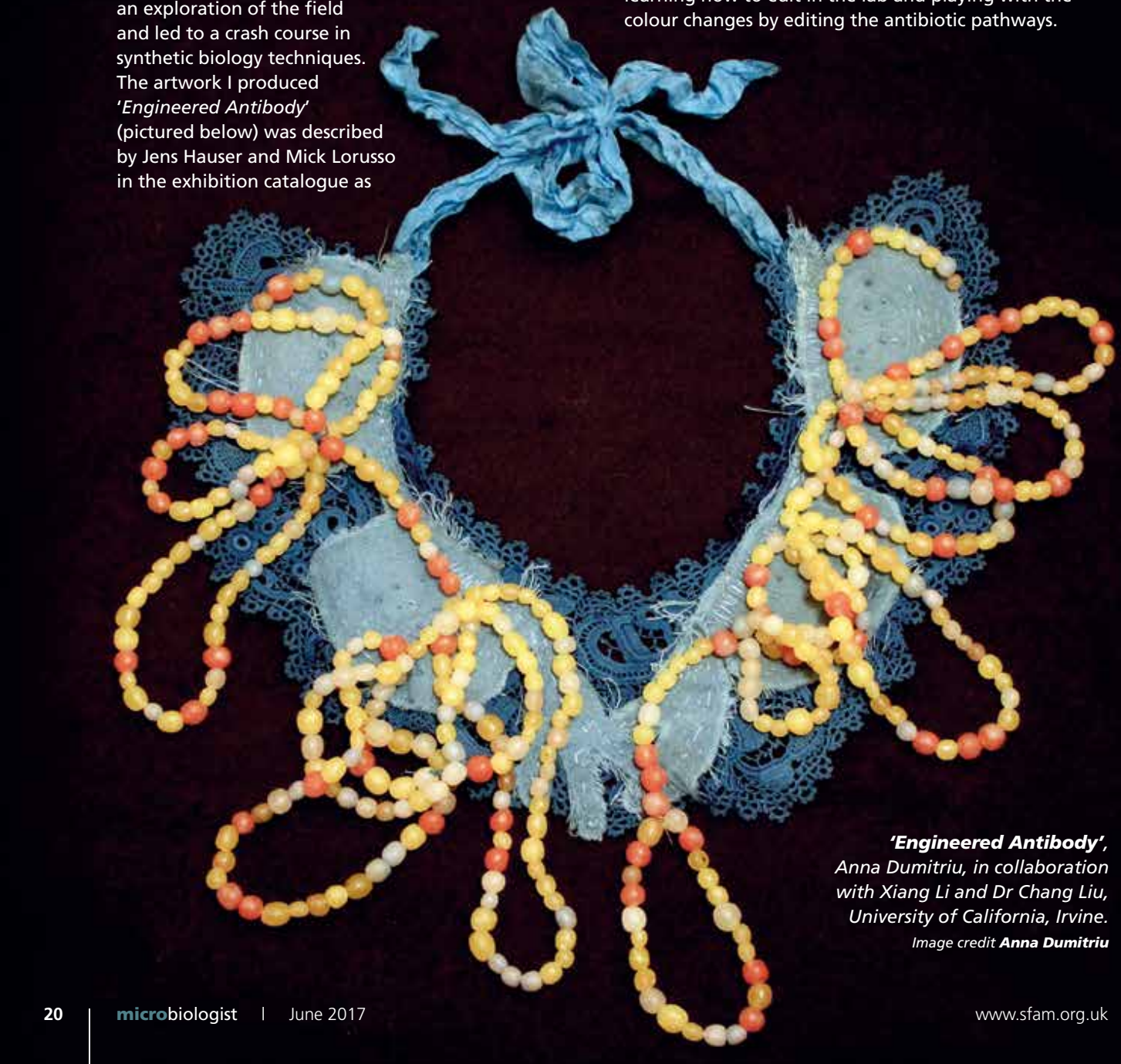
***'Sequence Dress'**, Anna Dumitriu, in collaboration with Alex May, Dr John Paul, Dr James Price and Kevin Cole, Modernising Medical Microbiology.*
Image credit ***Anna Dumitriu***

The sequencing work led to the field of synthetic biology, which is particularly interesting from a cultural and ethical perspective, as it has the potential to 'hack' the microbiological world. Synthetic biology is creating new solutions across a number of fields, as we become able to design the behaviour of bacteria or even mammalian cells. This can potentially lead to new materials, healthcare developments or environmental solutions.

With an understanding of complex systems comes a responsibility to understand the potential risks of intervening within living systems such as bacterial communities. The history of antibiotics shows us that for every action we take, there are consequences. In addition, there are also costs to not taking action; potential fatalities and environmental systems that could have been stabilized may collapse.

Working with scientists at The Liu Lab for Synthetic Evolution (University of California, Irvine) fuelled an exploration of the field and led to a crash course in synthetic biology techniques. The artwork I produced '*Engineered Antibody*' (pictured below) was described by Jens Hauser and Mick Lorusso in the exhibition catalogue as 'a beaded necklace based on lab member Xiang Li's research working with an antibody purified from the blood of an HIV positive patient. Made up of 452 handmade beads, it both represents and physically contains the actual 21 amino acids of the antibody in the precise order. The light chain and heavy chain of the protein structure have been folded into the exact structure of the antibody. An antibody is a protein that is produced by the immune system to combat foreign bodies and viruses, which it can bind to. Xiang Li is working to improve this antibody by engineering it to better block HIV infections through the introduction of an additional amino acid called sulfotyrosine.'

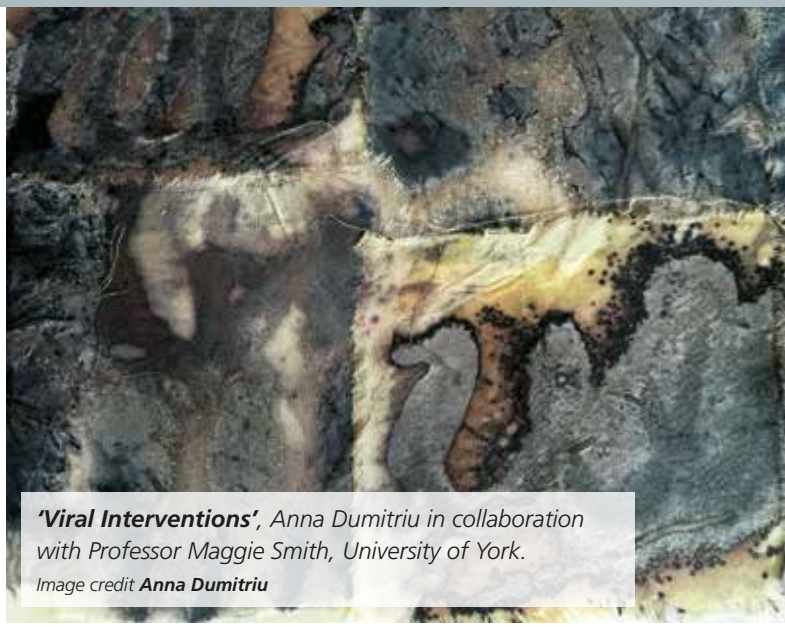
Subsequently I have worked in Professor Maggie Smith's lab (University of York) to explore how she works with phage integrases to edit the antibiotic pathways in Streptomyces bacteria, with the aim of creating custom-built antibiotic-producing organisms. I developed a series of works (pictured far right) using the bacteria, learning how to edit in the lab and playing with the colour changes by editing the antibiotic pathways.



'Engineered Antibody', *Anna Dumitriu, in collaboration with Xiang Li and Dr Chang Liu, University of California, Irvine.*
Image credit ***Anna Dumitriu***

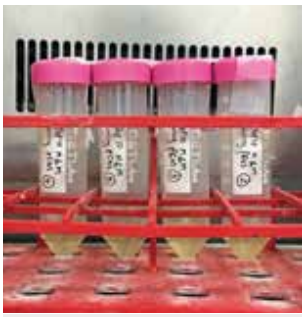
Most recently I worked with Dr Sarah Goldberg and Dr Roee Amit at the Synthetic Biology Laboratory for the Decipherment of Genomic Codes (Technion, Haifa, Israel). The lab is the lead co-ordinator on the EU Future Emerging Technology project MRG-Grammar which aims to devise a new strategy for deciphering the rules of gene regulation.

'*Make Do and Mend*' is an installation that references the 75th anniversary of the first use of penicillin in a human patient in 1941. It takes the form of an altered antique wartime dress with the mark CC41, the British Board of Trade's 'utility logo'. The holes and stains in the old dress are patched with silk which has had *E. coli* bacteria grown onto it using a dye-containing growth medium.



***'Viral Interventions'**, Anna Dumitriu in collaboration with Professor Maggie Smith, University of York.*
Image credit ***Anna Dumitriu***

Myself and Dr Goldberg worked together to edit genomes of TOP10 *E. coli* bacteria using CRISPR to remove an antibiotic resistance gene (for ampicillin resistance). This was accompanied by homologous recombination to scarlessly repair the break with a fragment of DNA encoding the wartime phrase 'Make Do and Mend'.



***'Make Do and Mend'** CRISPR experiment, Anna Dumitriu in collaboration with Dr Sarah Goldberg, Biotechnology and Food Engineering, Technion.*
Image credit ***Anna Dumitriu***

Ampicillin is part of the penicillin group of beta-lactam antibiotics, so it's conceptually and poetically true to say that, with this artistic genomic edit, today's latest technology has been used to 'patch' or 'repair' the organism back to its pre-1941, pre-antibiotic age state. Scientifically, it's far more complex, as the lab strain of *E. coli* used is very well characterized and has had many other modifications, so it will never really be the same as it was in 1941.

My new challenge for the year is to develop a better understanding of biochemistry, add to my patchy curiosity-driven knowledge and be inspired by the possibilities of new techniques for visualizing DNA. I've recently started to work with Dr Rob Neely (University of Birmingham) and who knows where this will take me next.

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Notes:

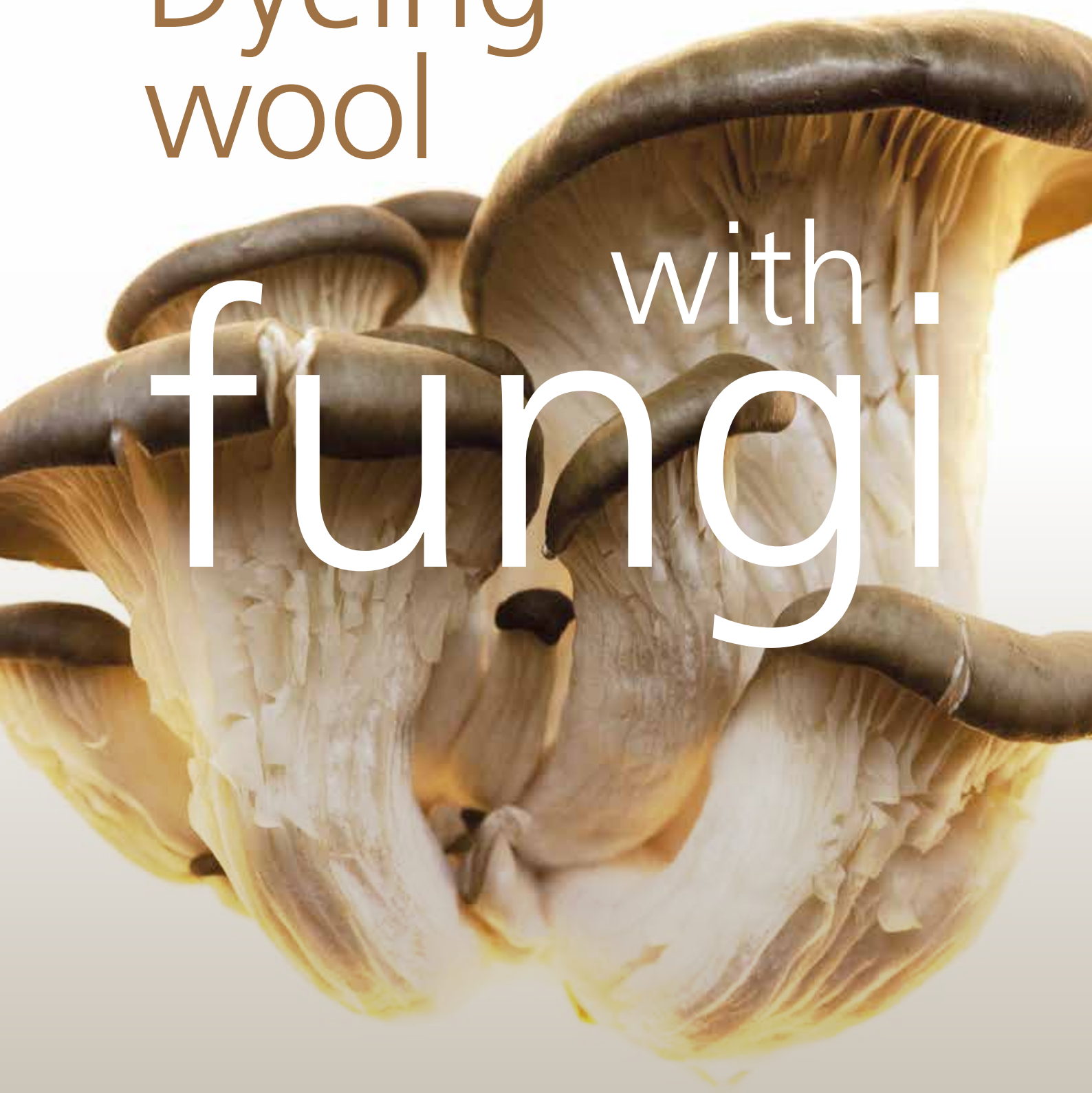
1. Work with Professor Maggie Smith was funded through the Artist in Residence Scheme 2016 of the Centre for Chronic Diseases and Disorders (C2D2) at the University of York. The scheme is supported by the Wellcome Trust [ref: 105624] and the University of York.

2. FEAT is an initiative of eutema GmbH (AT), Stichting Waag Society (NL) and youris.com (BE). It has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 686527 (H2020-FETOPEN-2015-CSA).

Anna Dumitriu

The Wellcome Trust Brighton and Sussex Centre for Global Health Research, The University of Hertfordshire, Modernising Medical Microbiology

Dyeing wool with fungi



This experiment shows you how fungi can be used to dye wool a variety of beautiful colours. The dyes come from chemicals that occur naturally in fungi. Different fungi contain different chemicals and so can give different colours.

Health and Safety

TAKE CARE WITH BOILING WATER!
ALWAYS WASH YOUR HANDS AFTER TOUCHING FUNGI

You will need:

- Approximately 100g clean mushrooms, coarsely chopped.
- Approximately 100g of light coloured natural wool.
- A large aluminium, tin or copper pot*.
- Approximately 3 litres of water (2 litres if using dried mushrooms).
- A mixing spoon.
- A straining spoon or sieve.
- A means of heating water.

** Note: natural dyeing normally requires a colour fixative or "mordant", such as alum (aluminium potassium sulphate). This is not necessary if you use an aluminium, tin or copper pot as the metal in the pot will take part in the dyeing reaction. However, if you use a non-stick saucepan, you should add a few copper coins to the mix.*

What to do:

1. Boil the water in the pot, add the mushrooms and simmer for 30 minutes.
2. Carefully remove the mushrooms using a straining spoon or sieve.
3. Add the wool to the water and simmer for 30–60 minutes (add more water if the volume is getting low).
4. Allow the wool to cool in the pot, wash in warm water to remove excess dye and dry (e.g., outside on a sunny day or in an airing cupboard).

Tips:

- Different fungi give different colours, so experiment!
- Try varying the amount of fungus to get different shades of colour.
- You don't have to use mushrooms – brackets, jelly fungi and boletes will also work.
- If there is no colour you have probably just been unlucky – not all fungi produce dyes so try again with a different species.

How can I find out more?

For advice on which fungi to use and the colours they produce:

www.mycopigments.com

To see some beautiful results:

www.somamushrooms.org/dyes

Louise Hill-King
Frimley Park Hospital

Serratia marcescens: the aesthetic bacillus

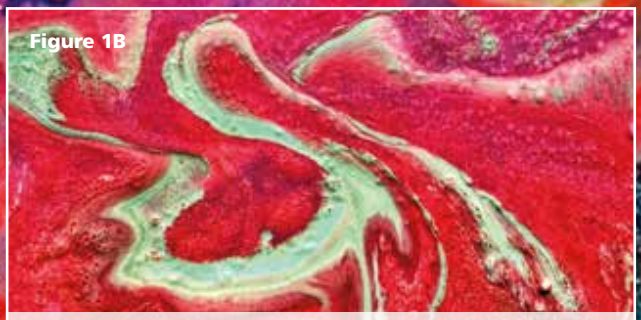


Figure 1B

Figure 1A, 1B. Automatic art generated by the bacterium *Serratia marcescens*
The red pigmented bacterium interacts with and moves the watercolours painted onto the agar surface by artist Sarah Roberts. Figure 1B, a close up image of *S. marcescens* interacting with a green watercolour.

Figure 1A

Amongst bacteriologists, the bacterium *Serratia marcescens* is very well known because of its production of the bright red pigment prodigiosin, and because of this, its colonies are of a characteristically bright red colour. This characteristic, and the bacterium's natural red aesthetic, has made it attractive to both scientists (as a marker organism) and artists alike, and it is difficult to imagine another microbe that has had a greater and more direct involvement in the arts.

S. marcescens has a predilection for growing on foodstuffs, particularly those rich in starch, and throughout history the combination of starchy Eucharist bread and damp churches would have provided it with many ideal opportunities for growth, and also to produce its blood-like red pigment. Consequently, many historical episodes of transubstantiation (the teaching of the Catholic Church in which the bread and the wine used in the sacrament of the Eucharist become in reality the body and blood of Christ) have been attributed to the growth of this bacterium. In one particular episode in 1263, 400 years before Antoni van Leeuwenhoek would first see microorganisms under a microscope, a priest in Bolsena, Italy, was celebrating mass when blood apparently appeared on the communion bread and dripped onto his robe. In 1264, to honour the miracle of Bolsena, Pope Urban instituted the feast of *Corpus Christi* (Body of Christ). Moreover, this was probably the first time that *S. marcescens* had directly influenced the arts, as the great master painter Raphael commemorated this apparent miracle in his fresco "*The Mass of Bolsena*".

The first 'artist' to knowingly use *S. marcescens,* with an awareness of the true bacterial nature of its red pigment, is famous but not necessarily for this reason. This artist was in fact Alexander Fleming, the discoverer of the antibiotic penicillin. Long before his discovery of penicillin, Fleming was admitted to the Chelsea College of Arts for his '*Germ Paintings*' which he painted using

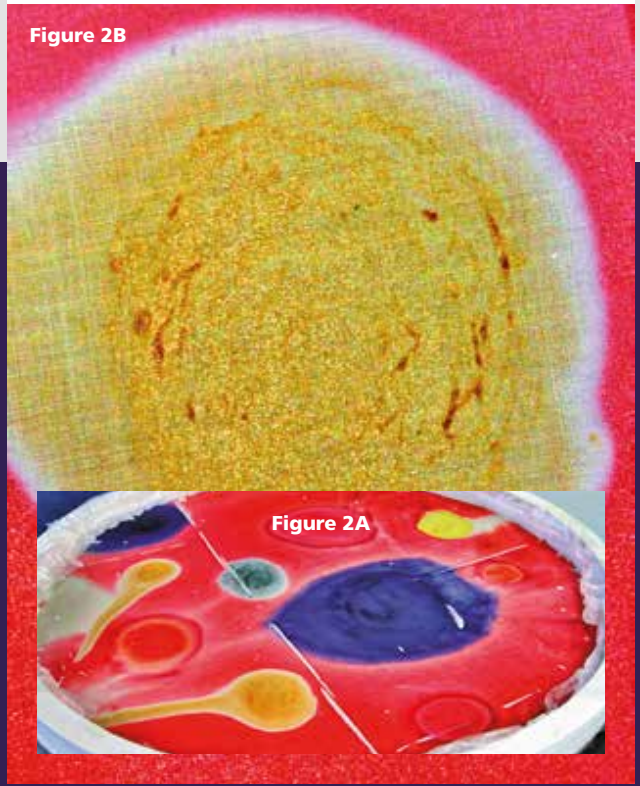
a palette of naturally pigmented bacteria. With its striking red colour, it's not surprising that Fleming frequently used *S. marcescens* as a red and living paint in his works.

S. marcescens continues to engage both artists and scientists today, and recent uses of it in art include Zachary Copfer's *Bacteriograms*, in which the bacterium is used to make photograph-like images of famous individuals. In my own practice and outreach activities with *S. marcescens*, I prefer to invert formal artistic practice so that this bacterium itself becomes a co-creator of the artworks. Take, for example my collaboration with watercolour artist Sarah Roberts, in which Sarah painted onto agar using her traditional water colours (except red) and instead using *S. marcescens* as a red and living paint. After an overnight incubation, not only does *S. marcescens* grow and swarm over the media, but it also interacts with, and moves Sarah's watercolours across the medium, generating an automatic form of art much like a painter from the Abstract Expressionism art movement would (Figures 1A, 1B). These striking and bacterially generated paintings are a manifestation of our modern scientific understanding of the complexity of bacterial behaviour: how bacteria swarm, communicate with each other: move together in a coordinated manner, form biofilms and build channels to irrigate large bacterial communities.

Finally, *S. marcescens* features again in another engaging artwork that this time explores and reveals the many ways in which bacteria interact with each other. Inspired by the military board games of my childhood, such as Risk, Campaign and Diplomacy, this work substitutes coloured plastic counters with living armies of brightly pigmented bacteria. After inoculation on to nutrient-enriched cotton material, the cultures are incubated and the designs result from the movements and interactions of the different species (Figures 2A, 2B). With its ability to move and swarm through the material, the 'red army' or *S. marcescens* always wins the game. However, some of the other pigmented bacteria produce antibacterial compounds in order to defend their territories (Figure 2B).

In conclusion then, *S. marcescens* is a remarkable bacterium, one that was probably responsible for one of the most celebrated miracles of the Catholic Church, and an organism that is still widely used to share the excitement and wonder of microbiology.

Figure 2A, 2B. Bacterial war games
An engaging demonstration of different bacterial characteristics and interactions. Various pigmented bacteria move or interact within a nutrient-enriched cotton circle in a 1m diameter Petri dish. The 'red army', *Serratia marcescens* has swarmed to occupy most of the territory. The darker red circles within its red growth represent the places where the bacterium was originally inoculated. Figure 2B is a close-up image of the interaction between *S. marcescens* and *Kocuria rhizophila*, and the white circle of unoccupied cotton suggests that the latter is producing an antimicrobial compound. Produced in collaboration with Alexander Penn, Clifford Pemberton, Kaylee Herbert, Elizabeth Saunders and Andrew Friend. Part of the MILES event at the University of Surrey.



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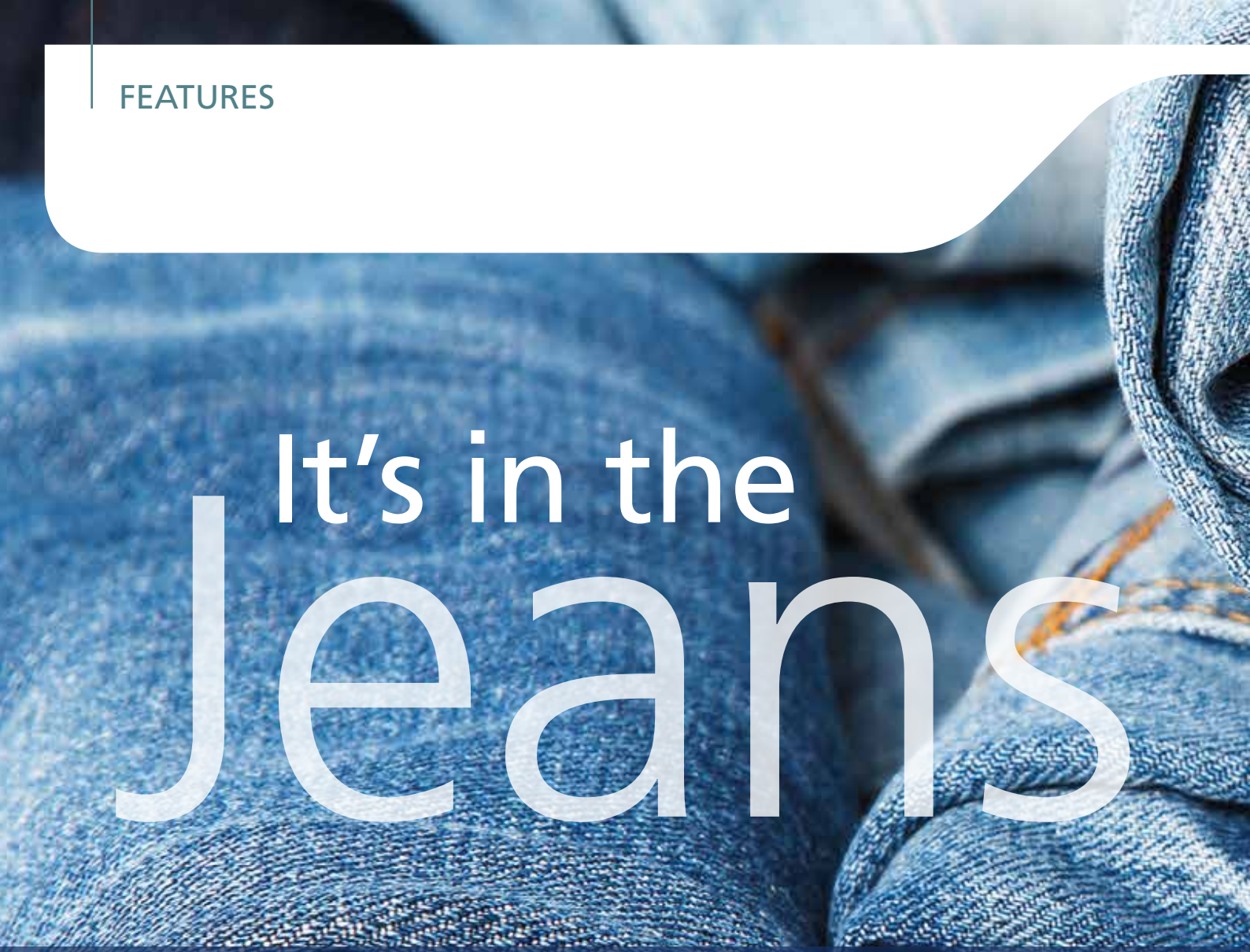
Simon Park
University of Surrey



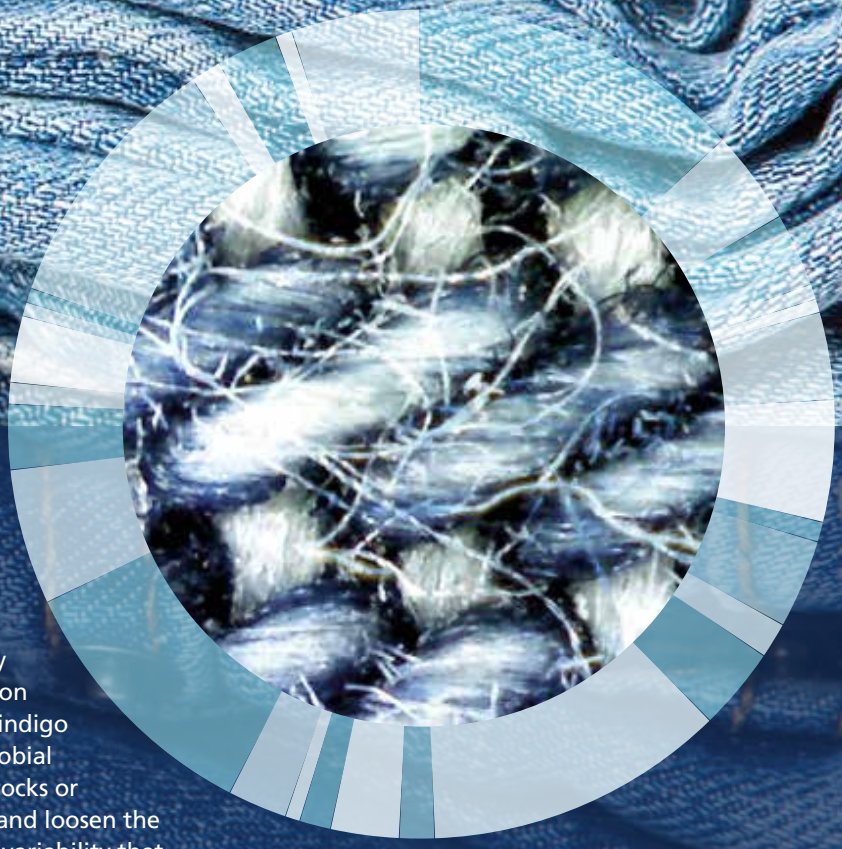
It's in the Jeans

If it surprises you to learn that microbes have hit the high fashion runways, you might want to consider updating your wardrobe. From iconic colours to desired textures, and from reimagined fabrics to bacteria-embedded clothing, microbes are taking the fashion world by storm. Regardless of your interest in fashion, almost everyone owns a pair of jeans, that classic blue denim with the durable yet soft texture. The classic blue is due to the dye indigo, which has a rich and vibrant history of its own. Originally isolated from plants in the genus *Indigofera*, by the late 1800s, the demand for indigo led to its chemical synthesis and mass production for clothing and textiles. Fast forward to today and thousands of tonnes of indigo are used annually in the production of blue jeans.

While the chemical synthesis of indigo has undergone refinements over the years, in 1983 microbiologists reported the accidental discovery of indigo production by a genetically engineered strain of *E. coli*. When moving the genes for naphthalene oxidation from *Pseudomonas putida* into *E. coli*, the researchers unexpectedly discovered that a subset of those genes resulted in the production of indigo. *E. coli* naturally produces the enzyme tryptophanase which converts tryptophan to indole. The cloned *P. putida* naphthalene dioxygenase converted the indole to cis-indole-2,3-dihydrodiol and voila, the spontaneous elimination and oxidation reactions that followed resulted in the production and export of indigo. Alas, after 34 years, bacterial indigo has not supplanted chemical synthesis

From iconic colours to desired textures, and from reimagined fabrics to bacteria-embedded clothing, microbes are taking the fashion world by storm

Dyeing jeans blue makes them easy on the eyes



due to insufficient yield, limitations in key metabolic steps and problematic by-products. But, rest assured, researchers will be working on it until they are, yes, blue in the face.

Now, dyeing jeans blue makes them easy on the eyes, but the traditional stiff cotton textile isn't so easy on the skin. Like the indigo story, this story also starts with non-microbial methods: either tumble the fabric with rocks or treat it with a harsh acid to breakdown and loosen the fibres. Both methods resulted in a lot of variability that prevented efficient mass production of softened jeans. But most jeans are made out of 100% cotton, which is basically pure cellulose, and there are plenty of fungi out there producing cellulases that could target those fibres. In fact, since the 1980s the majority of jeans have been softened using purified fungal cellulases. By controlled and limited application to cotton textiles, cellulases can be used to consistently and gradually soften and depill cotton, no rocks or acids required.

The industrial-scale stuff is interesting, but it's really at the intersection of microbiology and fashion design where things start to get wonderfully weird, or avant-garde if you will. Using microbes to enhance our somewhat standard textile and clothing production techniques is one thing, but using microbes to build our textiles from scratch or augment our clothing is another story.

Angela Hartsock
The University of Akron, Ohio, USA

Are **MICROBES** the future of fashion?

Microbiology has played a huge part in the evolution of textiles and is by no means a new phenomenon in the field. Research published in the Textile Research Journal in the early 20th century revealed the presence of mould fungi and mildew prevalent in sheep fleeces, which caused deterioration of strength and dyeing properties in the wool fibre. The soil organism, *Actinomyces dermatonomus* caused the condition 'lumpy wool' making the wool fibres impossible to process. Bacteria such as *Pseudomonas fluorescens* were also held responsible for the discolouration of fleeces.

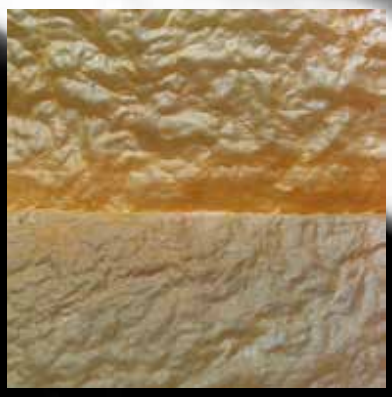
Research on cotton fibre revealed similar findings. Fungi types such as *Alternaria*, *Cladosporium herbarium* and *Fusarium* were isolated on cotton plants that were deemed 'weathered'. The general conclusions drawn were that the moulds and bacteria found in the fibre were capable of causing discolouration at best, and major structural damage at worst. In an attempt to counteract this microbial damage, developments were made not only in chemicals sprayed onto crops and animals during the growth cycles, but also in the additives used in the processing of the fibres after harvest. All of these chemicals had the sole purpose of removing any offending microbial activity to prevent attack and damage and promote higher growth yields.

Even textiles discovered as part of archaeological finds have been exposed to microbial attack in the soil which cause deterioration in terms of discolouration (either due to pigment-producing bacteria or changes in the pH which affect the dyes on the fabric), loss of strength and odours. This is despite many of the natural dyes used in these textiles exhibiting antimicrobial properties. Once retrieved from their historical hiding places, textiles preserved as museum pieces need to be stored carefully as airborne microorganisms can continue to attack these delicate pieces given the correct atmospheric conditions.

Whilst in terms of growth and preservation, bacteria and fungi have been seen as the enemy of the textile industry, some manufacturing processes have found microbes to be beneficial.

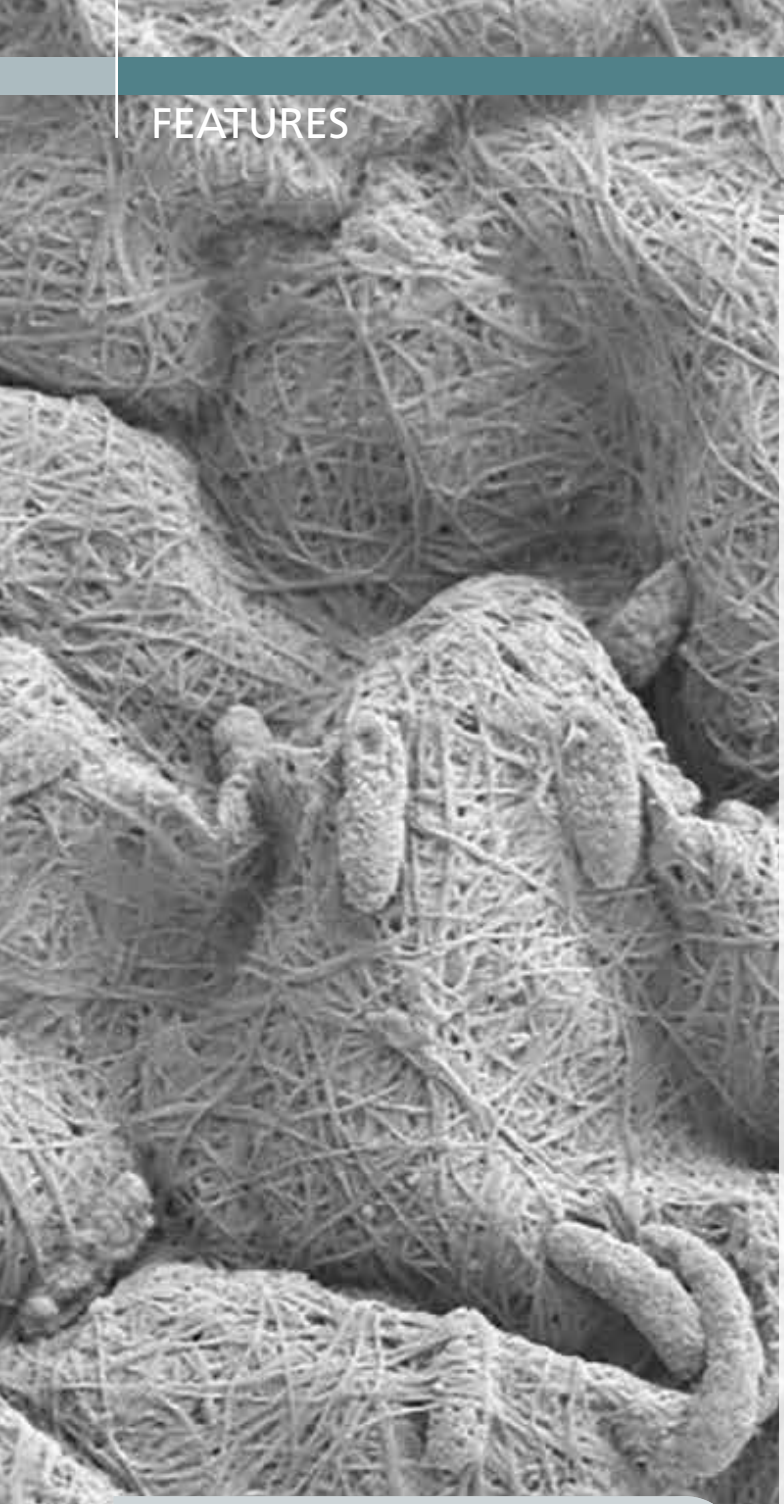
Dyeing and finishing has always been an important part of the textile production process, with natural dyes and finishes remaining popular, even with the development of their synthetic counterparts. Denim has been the most famous – with a 'true' denim product being that which is 100% cotton and dyed with natural indigo dyes. However, denim products are also famous for their varied finishing effects such as sandblasting and stone washing. Traditional techniques using sand and stone are deemed extremely hazardous to operatives and are not promoted in the modern textile production environment. However, cellulase enzymes have been used as an acceptable and effective replacement for finishing techniques where an aged look is required.

Sustainability and eco-friendliness are terms that are ever-present in modern life. The fact that the textile industry is becoming increasingly under scrutiny is hardly surprising given some of the practices mentioned above. Figures published in 2015 suggest global consumption of apparel fabrics was 400 billion m^2. This production consumed 7.5 trillion litres of water, 1,074 billion kWh of electricity and emitted 537 billion kg CO_2 (equivalent) in air pollution. Added to this, 20% of fabric production was deemed waste before ever leaving the manufacturing plant and 75% of manufactured garments will be disposed of in landfill. The industry still relies heavily on oil-based fibres such as polyester and nylon and it is difficult to even contemplate life without Lycra®.



Bacterial cellulose fabric skirt and close up

Perhaps the most exciting development is the actual creation of fabric for clothing using bacteria



Yet all this leads to a dilemma – whilst there is no denying that recent developments in man-made fibres and recycling processes have revolutionized the textile industry, is this rate of production – and of waste – really acceptable or sustainable?

It is therefore interesting that the next phase of the textile story is starting to see the reintroduction of microbes, once seen as the enemy.

In order to recycle waste there have been many reprocessing initiatives involving synthetic fibres. However, researchers at Kyoto University have adopted a completely different approach. They have isolated the bacterium *Ideonella sakaiensis*, a microbe that eats plastic, or more specifically PET (poly(ethylene terephthalate)), a synthetic fibre commonly found in clothing. The suggestion is that this newly discovered bacterial strain has evolved and mutated over time in effluent outlets near the fibre-manufacturing plants, enabling it to make use of the polymer food source. This is an exciting discovery as the potential of microbes 'eating' synthetic fibre that would once sit in landfill could solve a growing problem for the textile industry.

The idea that microbes can work harmoniously alongside traditional fabrics is one explored by the bioLogic project. This project examined the idea of microbes working alongside sportswear fabrics to modify properties and enhance wearer comfort. The collaboration between the Royal College of Art, MIT and New Balance uses a bioprinter to deposit a bio-hybrid film containing *Bacillus subtilis natto* bacteria. These bacterial cells have been found to expand and contract according to atmospheric moisture levels. The printed fabric behaves as a 'second skin' as illustrated by applications showcased in sports garments. The garments have the ability to sense when the body is becoming warmer through increased perspiration production. The behaviour of the bacteria due to this increase in moisture level activates ventilation zones within the garment, engineered at points to be most effective to allow perspiration evaporation. As the body cools, perspiration reduces, moisture levels drop and the bacteria contract, causing the ventilation zones to close allowing the wearer to keep warm. Garments such as these can truly be deemed 'responsive apparel'.

Perhaps the most exciting development is the actual creation of fabric for clothing using bacteria. One of the pioneers in this field is Suzanne Lee, the founder of Biocouture. Suzanne's aim was to look at how microorganisms might grow into suitable textile materials, to move the industry away from the use of petrochemicals and plant materials. Her initial focus was on fashion, but the ultimate goal is to develop fabrics relevant to all aspects of the textile industry.

FURTHER READING

Myers, W. (2012). *Biodesign: Nature, Science, Creativity*. Thames & Hudson: London.

Gunther, M. (2016). Plastic-eating bacteria show way to recycle plastic bottles sustainably, *Chemistry World* (accessed 10th March 2017) **https://www.chemistryworld.com/news/plastic-eating-bacteria-show-way-to-recycle-plastic-bottles-sustainably/9556.article**

Yao, L., Wang, W., Wang, G., Steiner, H., Cheng, C., Ou, J., Anilionyte, O., and Ishii, H. (2015). *bioLogic*,Tangible Media Group (accessed 10th March 2017)] **http://tangible.media.mit.edu/project/biologic/**

Kombucha fabric growing pot (above)
Kombucha based 'vegetable leather' in a jacket panel (left)
SEM bacterial cell image (background)

Her initial interest focused around Kombucha, a symbiotic culture of bacteria and yeasts. Kombucha has traditionally been used to brew tea, and as a drink purports health-giving and detoxifying effects (the jury is out in terms of evidence to support this claim). However, using Kombucha as a starter culture, supported in a growth medium of green tea and sugar, nanocellulosic fibres are produced through the fermentation process forming a dense layer on the surface of the liquid. This layer, once removed and dried, resembles the texture of fine animal leather – gaining the name 'vegetable leather'. The active microbe that is attributed to the production of the nanocellulosic mat is *Gluconacetobacter xylinum*. Current research at Manchester Metropolitan University is ongoing to assess the most effective growth mechanisms and conditions that can engineer specific properties of the 'vegetable leather' and make this fabric a natural, effective alternative to synthetic technical textiles. The initial experimentation demonstrated a fabric that can be grown to shape (therefore no waste) in completely natural media, is flexible, can be stitched or form self-adhesive seams and can be composted at the end of its useful life. However, one major drawback is high levels of hygroscopicity and unsolicited decay over time.

The application of bacterial species in colouration and finishing of textiles has also been explored. In a project led by Dutch designer Jelte van Abbema, alternative printing inks such as those made from soya or natural plant pigments were challenged by using a selection of bacteria to 'grow' the prints. Traditional textile printing techniques such as screen and block prints were still used, but various bacterial species (such as *E. coli*) were deposited onto the fabric. The result was a 'living' print which developed, changed colour and died over time. This may not currently have a place in clothing, but it has been used widely as an art form and has been picked up as a useful marketing tool.

Another project, this time at Central Saint Martins, by Amy Congdon, looked at the concept of bioink jet printing (also known as rapid cell modelling). In the medical field, this idea is being explored as a method of printing replacement organs. However, Amy suggested this idea could be used to 'grow your own fashion' through her project the Biological Atelier. This project raised questions regarding the potential impacts of biotechnology in fashion. Could we grow victimless ivory? A cross-species fur? A hybrid material for a specialist end use? Do these materials need to have a 'use' or could they be grown purely for the aesthetic? This project was truly a case of biotechnology engineering meeting high fashion.

The use of microbes in the textile industry is becoming more widespread and researchers are increasingly adopting novel approaches to their use. Whilst this presents exciting research opportunities, there is some concern being voiced with using microorganisms of which we know relatively little. Is the modification of these microbes to suit our own purposes an area in which we truly understand the potential future impacts on the planet?

Jane Wood
Senior Lecturer in Textile Technology
Manchester Metropolitan University

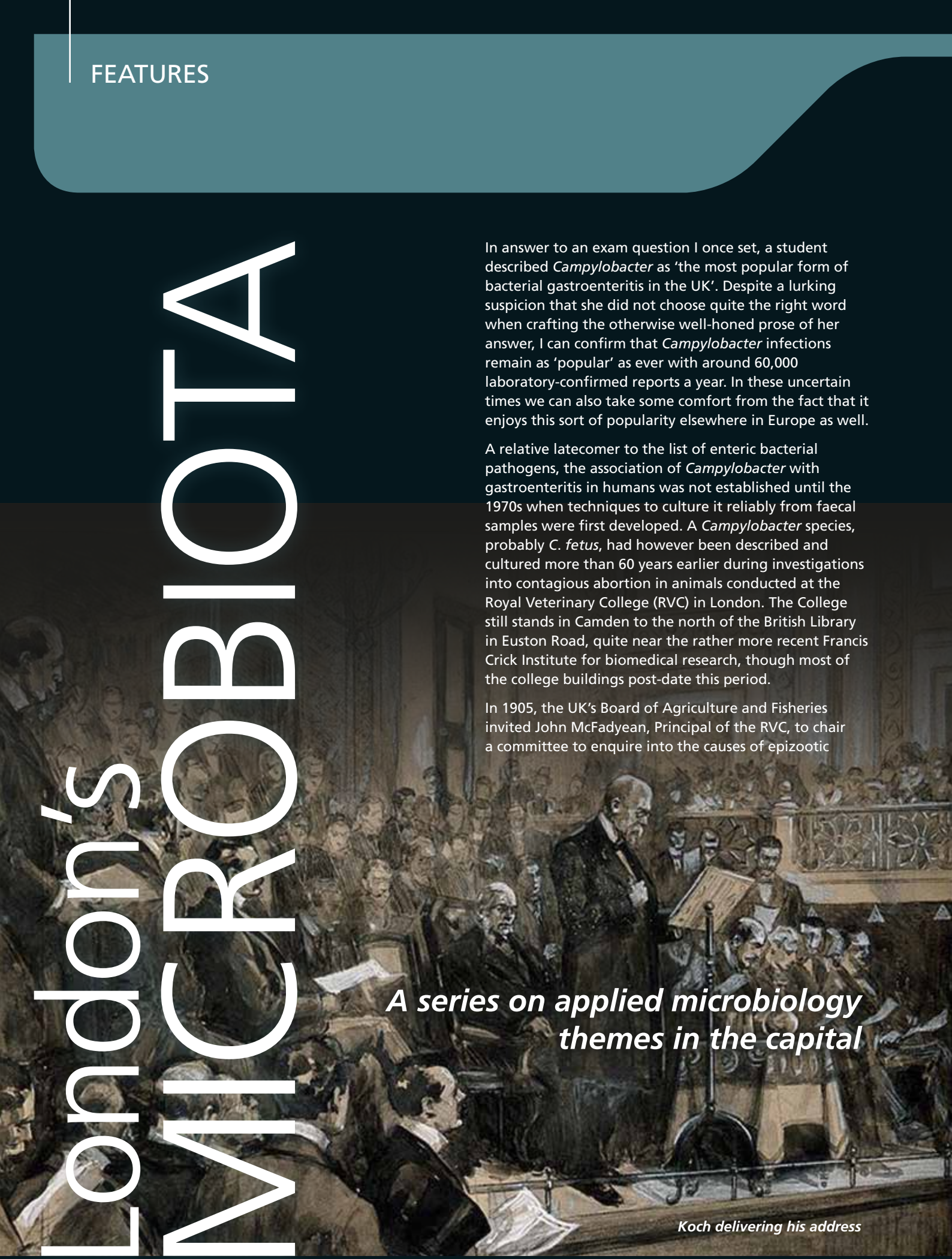
London's MICROBIOTA

A series on applied microbiology themes in the capital

In answer to an exam question I once set, a student described *Campylobacter* as 'the most popular form of bacterial gastroenteritis in the UK'. Despite a lurking suspicion that she did not choose quite the right word when crafting the otherwise well-honed prose of her answer, I can confirm that *Campylobacter* infections remain as 'popular' as ever with around 60,000 laboratory-confirmed reports a year. In these uncertain times we can also take some comfort from the fact that it enjoys this sort of popularity elsewhere in Europe as well.

A relative latecomer to the list of enteric bacterial pathogens, the association of *Campylobacter* with gastroenteritis in humans was not established until the 1970s when techniques to culture it reliably from faecal samples were first developed. A *Campylobacter* species, probably *C. fetus*, had however been described and cultured more than 60 years earlier during investigations into contagious abortion in animals conducted at the Royal Veterinary College (RVC) in London. The College still stands in Camden to the north of the British Library in Euston Road, quite near the rather more recent Francis Crick Institute for biomedical research, though most of the college buildings post-date this period.

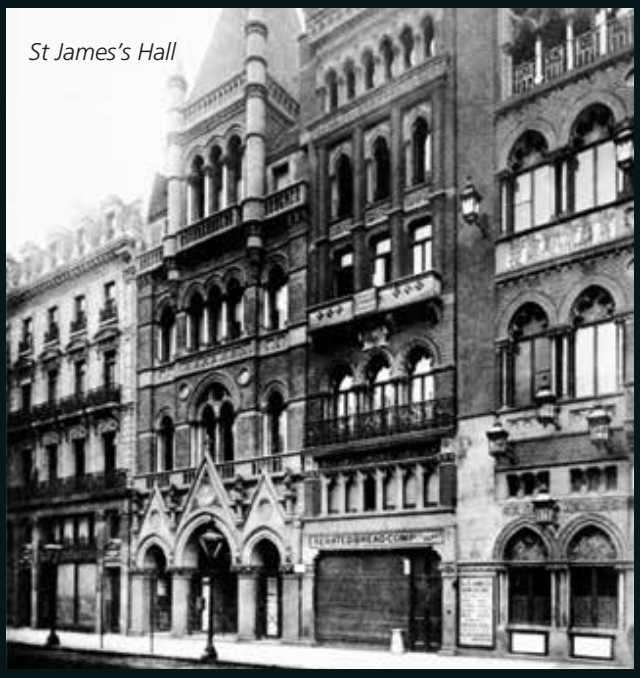
In 1905, the UK's Board of Agriculture and Fisheries invited John McFadyean, Principal of the RVC, to chair a committee to enquire into the causes of epizootic



Koch delivering his address

abortion in sheep and cattle. McFadyean was a Scot who trained as a veterinarian in Edinburgh but moved to London in 1895 to become Dean and Professor of Pathology and Bacteriology at the RVC, later rising to Principal. A year into their work, McFadyean, with a fellow member of the committee, Stewart Stockman, (the Chief Veterinary Officer and, incidentally, McFadyean's son-in-law), were examining samples from a flock of sheep suffering high rates of abortion. From tube cultures of a medium that had been solidified with agar after inoculation, they isolated an organism that grew just below the surface, in the microaerophilic zone. These conditions also favoured the growth of another agent of contagious abortion in cattle, *Brucella abortus*, but this isolate was motile and possessed the now well-known aspects of campylobacter morphology – the presence of spirillar and coccal forms. The organism was more fully described a little later by Theobald Smith and Marian Taylor in the United States where it was named *Vibrio fetus*, the genus *Campylobacter* not coming into common parlance until the 1960s.

Despite a considerable reputation as the founder of veterinary pathology in the UK, McFadyean is a somewhat neglected figure in the history of applied microbiology. Earlier in his career, in 1901, he had also made an important contribution at a major international congress on tuberculosis (TB) held in London. The principle venue for the meeting was St James's Hall in Piccadilly. The building is long gone, having been demolished in 1905, and the site is now occupied by a large hotel, but at the time it had been the premier concert venue in London for 50 years and had hosted concerts, given by the likes of Tchaikovsky and Dvorak, and readings by Charles Dickens. In a plenary session on the second day of the congress, the near legendary figure of Robert Koch questioned the received wisdom that TB was transmissible from cattle to humans and whether it was necessary to take measures against bovine tubercule bacilli in milk and meat, describing in support his lack of success in experiments to infect animals with human TB. His address was immortalized in a gouache painting by F. C. Dickinson now in the care of the Wellcome Collection. A written account of this address and of McFadyean's response two days later appear in *The War Against Consumption,* a popular handbook describing the congress, published shortly after. In his talk, McFadyean systematically addressed the points Koch had raised with counter evidence and commentary. Although initially appearing very deferential to Koch, McFadyean ended his talk saying, "*We ought not concede to the milkmen the right to sell us tubercle bacilli even if we were assured that – like Dr Koch's experimental pigs – we had nothing to fear beyond the development of 'little nodules here and there in the lymphatic glands' of our necks, and 'a few grey tubercules in our lungs*." McFadyean was certainly not a lone voice criticizing the master. He had some eminent



St James's Hall

allies including Lord Lister who had chaired the session at which Koch had spoken and had raised some objections at the time.

The War Against Consumption reflects contemporary knowledge and attitudes to a disease that, though very much still with us, loomed much more ominously over life in the pre-antibiotic era when the main treatment for TB was based on a combination of fresh air, sunshine, rest and good nutrition. The limited remedies available serve as a chilling reminder of the gravity of the threat currently posed by increasing antibiotic resistance. Novel chemotherapies discussed at the Congress included fearsome intra-tracheal injections of the disinfectant Izal and the inhalation of formaldehyde. At the back of the book there are a number of advertisements which give a further sense of how the war against TB was being waged at the time. These include the promotion of several sanatoriums, the 'Sanichief', a disinfected handkerchief for the receipt of sputum, a variety of inhalants and other patient medications, Scotch whisky and heroin! More prosaically, 'Sanitas sawdust' is advertised to be used 'in all cuspidors'. Regardless of how useful this might have been, it must at least have been quite economical since the Sanitas company was based in Bethnal Green in the East End of London which was then a centre for furniture manufacture, so sawdust would have been plentiful and almost certainly very cheap, if not free.

Martin Adams
SfAM *President 2011–2014*

ANTIMICROBIAL RESISTANCE
Meeting the Challenge

Charles Darwin House | 12 Roger Street | WC1N 2JU

Antimicrobial resistance (AMR) is recognized as one of the most important global issues for human and animal health and the global spread of antimicrobial resistance threatens to undo many of our medical advances. Systematic misuse and overuse of these drugs in human medicine and food production have put every nation at risk. The Society for Applied Microbiology joins the Royal Society of Chemistry and the Academy of Pharmaceutical Sciences in responding to the global call on Governments to help tackle this AMR crisis.

This **2-day conference** presents solutions through key note presentations, case studies, expert opinion and panel discussions, and invites you to join in the AMR discussion. The conference will concentrate on areas spanning human health, diagnostics and agriculture where urgent action is required.

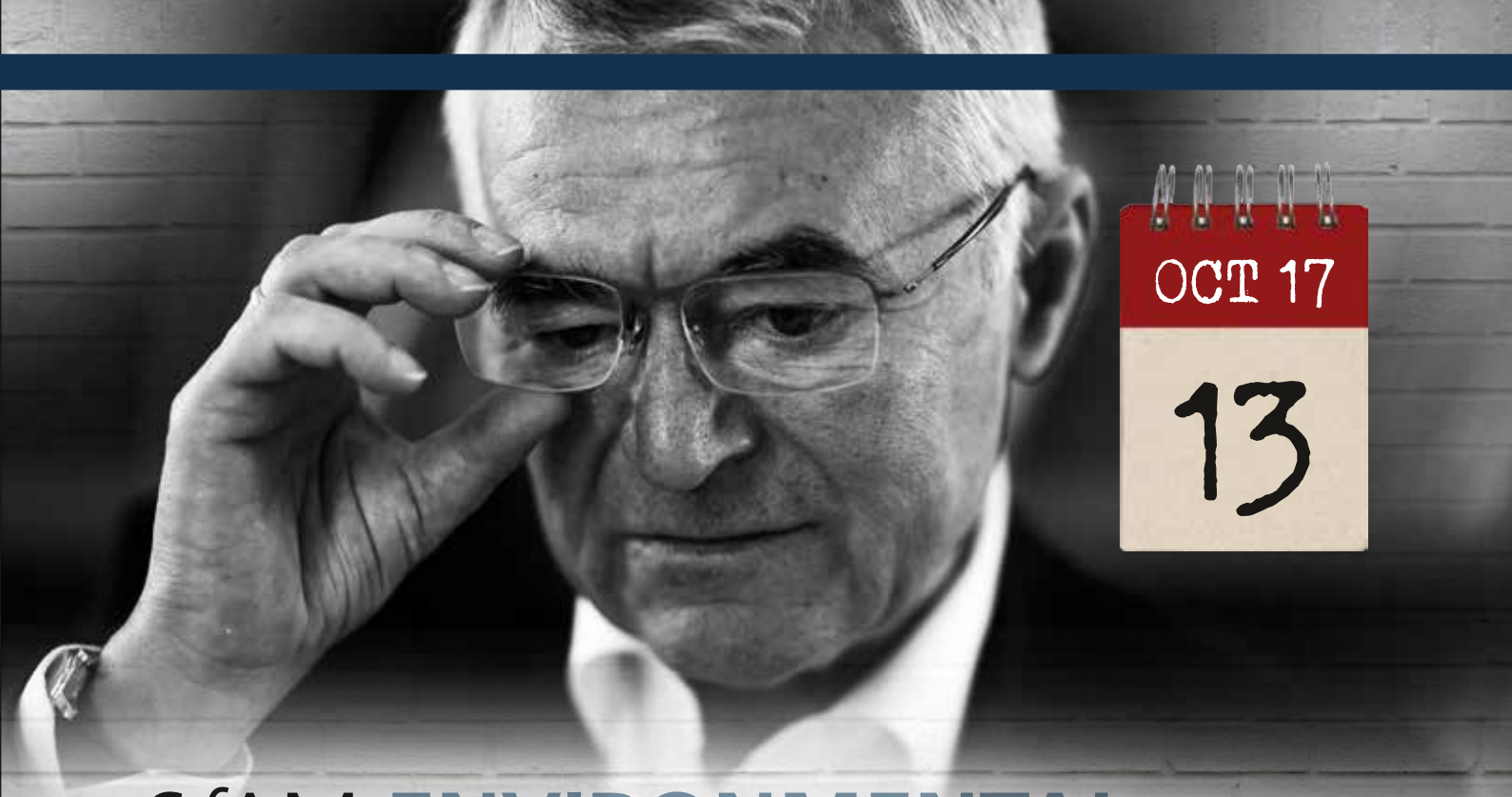
DAY 1: 23 November 2017
AMR: Clinical Diagnostics and Human Health *(in conjunction with the Academy of Pharmaceutical Sciences)*

DAY 2: 24 November 2017
Antimicrobial Resistance in Wastewater *(in conjunction with the Royal Society of Chemistry)*

Fees before 01 November 2017
(includes £60 Early bird discount):

Member	£110
Non-Member	£225

The conference will also offer a light lunch and refreshments for all participants and attendees. Please help us ensure the event's success by registering as soon as possible.



SfAM ENVIRONMENTAL MICROBIOLOGY Lecture 2017

Vaccines for a 21st century society Dr Rino Rappuoli

The Society for Applied Microbiology is delighted to announce that its 10th Annual EMI Lecture will be given by world-renowned scientist Dr Rino Rappuoli, who will speak on his lifetime's devotion to the development of vaccines. This year the lecture will take place at 1 Great George Street, London, on 13 October 2017.

The Italian biologist reached his first breakthrough in 1993 while at the Sclavo Research Center in Siena, a prominent laboratory known for vaccine development. Seeking to develop vaccines against infections that resisted traditional vaccine designs, Rappuoli used genetics to engineer vaccinations from cellular building blocks.

He used only specific parts of bacteria cells, namely surface sugars known as polysaccharides and attached them to carrier proteins, prompting a strong immune system response.

These new 'conjugate vaccines' were the first jabs to build immunity against tricky infections such as diphtheria, whooping cough, haemophilus influenza and helicobacter. Thanks to this success, Rappuoli is now championed as one of the co-founders of cellular microbiology – the intersection of cell biology and microbiology.

Rappuoli made history by developing and patenting the first-ever vaccines for each strand of meningococcal meningitis (A, B, C, Y and W-135). While forging this work, he also fuelled a new style of laboratory technology.

"*Vaccines are now no longer based on grown agents, but are designed on the computer using genomics*," explains Rappuoli. His carefully devised serum only contains the precise components necessary for immunization, which minimizes serious side effects.

In short, Rappuoli has revolutionized the world of infection prevention and his vaccinations against diseases such as diphtheria, bacterial meningitis and whooping cough have been administered to millions worldwide as part of routine vaccination programmes. First released in 1993 by California-based biotechnology company Chiron, Rappuoli's vaccine against pertussis (whooping cough) eradicated the disease in Italy within 24 months.

Today, Rappuoli is the Chief Scientist at global pharmaceutical manufacturer GlaxoSmithKline (GSK) Vaccines and his current research consists of finding vaccines for Respiratory Syncytial virus, Cytomegalovirus and emerging infectious diseases.

The Annual EMI Lecture is a free event open to all SfAM Members.

SfAM ANNUAL CONFERENCE 2017

New insights into food safety

BALTIC Centre for Contemporary Art | Gateshead | Tyne and Wear

Monday 3 July 2017

10:00 – 17:00 **Registration**

11:00 – 14:00 **ECS Workshop: Science Communications**

14:00 – 17:00 **Workshop: HACCP**
Susan Bornstein-Forst, *Marian University, USA*

18:00 – 19:00 **Journal of Applied Microbiology Lecture: *The gut microbiota in health and disease; potential for probiotics and prebiotics***
Koen Venema, *Beneficial Microbes Consultancy and Maastricht University*
The JAM Lecture will be followed by a drinks reception and small buffet.


Koen Venema

19:30 – 20:30 **Students and Early Career Scientists' icebreaker, with buffet and wine**

20:30 **Quiz night**

Dorothy Jones Memorial Lecture: **Listeria**

Clare Taylor
Edinburgh Napier University, UK

Tuesday 4 July 2017

08:30 – 09:00	**Registration**
09:15 – 09:50	**Foodborne disease – the current UK situation** Sarah O'Brien, *University of Liverpool, UK*
09:50 – 10:25	**The cost of food borne disease (TBC)**
10:25 – 10:45	**Tea, coffee, posters and exhibition**
10:45 – 11:20	**Campylobacter** Marja-Liisa Hänninen, *University of Helsinki, Finland*
11:20 – 11:55	**Genomic variation of Salmonella: epidemics, evolution and pathogenesis** Robert Kingsley, *Quadram Institute (Institute of Food Research), UK*
11:55 – 12:10	**Innovations for qPCR microbial testing in water and food** Antonio Martinez, *Murcia Genetic PCR Solutions™, Spain*
12:10 – 12:55	**Lunch, posters and exhibition**
12:55 – 13:30	**Dorothy Jones Memorial Lecture: Listeria** Clare Taylor, *Edinburgh Napier University, UK*
13:30 – 14:05	**Pathogenic *E.coli* and evolution of the virulence potential: implications for food safety** Stefano Morabito, *Istituto Superiore di Sanità, Italy*
14:05 – 14:20	**Understanding the environmental conditions affecting the expression and function of the GAD system in *L. monocytogenes*** Andreas Karatzas, *University of Reading, UK*
14:20 – 14:50	**Tea, coffee, posters and exhibition**
14:50 – 15:25	***Clostridium botulinum, Clostridium perfringens* and *Clostridium difficile*** Mike Peck, *Quadram Institute, Institute of Food Research, UK*
15:25 – 16:00	**Risk assessment of *Staphylococus aureus* in the food chain** Alexandra Fetsch, *Federal Institute for Risk Assessment, Germany*
16:00 – 16:15	**Microbiological assessment of fresh dairy along informal value chains in Ghana reveal process failures and the presence of enteropathogens** Angela Parry-Hanson, *Kunadu University of Ghana*
16:15 – 17:15	**Attended poster session**
17:15 – 18:15	**Students and Early Career Scientists' session**

This year's Annual Conference will bring together the leading names in Food Safety Microbiology

17:15 – 19:00 **Exhibition with wine, buffet and a competition**

19:00 **Students and Early Career Scientists' social event**

Wednesday 5 July 2017

08:30 – 09:00 **Registration**

09:00 – 09:35 **Antimicrobial resistance risks in the food chain**
Paul Cook, *Food Standards Agency, UK*

09:35 – 10:10 **Foodborne viruses**
Marion Koopmans,
Erasmus MC, The Netherlands

10:10 – 10:25 **Microbiological quality of tomatoes (*Lycopersicon esculentum*)**
Akua Obeng Forson,
University of Ghana, Ghana

10:25 – 11:00 **Tea, coffee and posters**

11:00 – 11:35 **CRISPR-cas and capsular profiling of *Cronobacter pathovars***
Steve Forsythe,
Nottingham Trent University, UK

11:35 – 12:10 ***Mycobacterium* in the food chain – a new health threat?**
Cath Rees, *University of Nottingham, UK*

12:10 – 12:45 **Tailoring food safety education**
Ellen Evans,
Cardiff Metropolitan University, UK

12:45 – 13:30 **Lunch, posters and networking**

12:45 – 13:15 **Early Career Scientists Committee AGM**

13:30 – 14:30 **Student Member oral presentations**

Effects of *Zygosaccharomyces rouxii* entrapment in water-oil-water double emulsion on its interaction with *Tetragenococcus halophillus*
Putu Virgina Partha Devanthi,
University of Birmingham, UK

13:30 – 14:30 **The effect of the timing of exposure to *Campylobacter jejuni* on the inflammatory response of broiler chickens**
Geraldine M. Lafontaine, *University of Nottingham, UK*

13:30 – 14:30 **Application of qPCR for the detection and quantification of *Escherichia coli* O157 in irrigation water**
Bernardino Machado-Moreira, *Teagasc Food Research Centre & National University of Ireland, Ireland*

13:30 – 14:30 **Utilization of bacteriocin-producing bacteria, isolated from the mushroom production environment, as a biocontrol option for *L. monocytogenes* biofilm formation**
Lionel Kenneth Dygico,
Teagasc Food Research Centre & University College Cork, Ireland

14:30 –15:05 **SfAM New Lecturer Research Grant Lecture TBC**

15:05 – 15:35 **SfAM New Lecturer Research Grant Lecture TBC**

15:35 – 16:00 **Tea, coffee and posters**

16:00 – 16:35 **W H Pierce Prize Lecture TBC**

16:45 – 17:15 **Annual General Meeting**

19:00 **Drinks reception and conference dinner**

Thursday 6 July 2017

08:30 – 09:00 **Registration**

09:00 – 09:35 **Risk assessment: past, present and future**
Gary Barker, *Quadram Institute, Institute of Food Research, UK*

09:35 – 10:10 **Photons to electrons: the rapidly evolving food irradiation technologies and consumer perceptions**
Suresh Pillai, *Texas A&M University, USA*

10:10 – 10:25 **Reducing human pathogens on food products with in-pack ozone generation technology**
Louise Crozier, *Anacail Ltd, Glasgow, UK*

10:25 – 11:00 **Tea and coffee**

11:00 – 11:35 **Cold plasma technology**
Paula Bourke, *Dublin Institute of Technology, Ireland*

11:35 – 12:10 **The use of Bacteriophages in food production**
Jason Clark, *Fixed Phage, UK*

12:10 **Lunch and depart**

*Sf*AM AGM Agenda

86th Annual General Meeting of the Society for Applied Microbiology

5 July 2017, 5.15 pm BALTIC Centre for Contemporary Art, Gateshead, UK

1. **Apologies for absence**
2. **Approval of minutes published in the September 2016 issue of the *Microbiologist* of the 85th Annual Meeting held in Edinburgh, 2016**
3. **Matters arising from the previous minutes**
4. **Report of the Trustees of the Society 2016:**
   (i) Objectives and Activities
   (ii) Achievements and Performance
   (iii) Financial Review
   (iv) Plans for the Future
5. **Adoption of the 2016 Annual Report**
6. **Election of new Members (including Honorary Members), deaths and resignations**
7. **Nomination and election of Trustees:**
   i) President
   ii) New Executive Committee Members
9. **Any other business***

**To ensure the meeting keeps to time, items of any other business must be raised with the General Secretary at least 24 hours before the start of the meeting.*

Life as a Healthcare Scientist

I've worked as a Healthcare Scientist at Great Ormond Street Hospital Foundation Trust for over 12 years, but many people might not know what a Healthcare Scientist is. In fact, as an official title, the term Healthcare Scientist hasn't been in use for that long. In the past, scientists within the different areas of healthcare all had their own professional titles and were not considered as a single group.

So what is a Healthcare Scientist?

Although it is difficult to define within the limited space here, Healthcare Scientists fulfil quite a number of different roles, mainly within the NHS. There are nearly 50 specialities, which are split into Physiological, Physical and Life Sciences. Within Physiological Sciences most scientists work directly with patients in areas such as audiology and sleep science. Physical Scientists have wide-ranging roles, from clinical engineering to medical imaging. I work within Life Sciences where most careers tend to be laboratory-based. As well as working within different specialities, Healthcare Scientists have different focuses. As a Clinical Scientist, within Healthcare Science, my focus is on being the interface between clinical teams and the laboratory.

What is the job of a Clinical Scientist in Infection Prevention and Control like?

The great thing about my job is that every day is different. I work as part of a multi-professional team consisting of nurses and doctors and I liaise with other scientists every day. Unlike many Healthcare Scientists within Life Sciences, my job has a lot of patient-facing components and broadly has three main branches: clinical work, research and education.

My clinical work involves both responding to cross-transmission of infection and implementing national policies on their control. All of the research I do is targeted at making the clinical part of my role more effective. How can we intervene differently? Are there new scientific techniques we could be using? How can we establish an evidence base for what we are currently doing? Finally, a large part of my role is being involved in education, as changing practice doesn't work if you don't bring people with you.

How did I get here?

I came to my current post via a very circuitous route. When I teach, many people ask me whether I always knew I wanted to be a scientist. I answer honestly that, as a child, I always wanted to be an actress. So how did I end up in what I now know to be the best job in the world?

I started my scientific career by reading Zoology at Liverpool University. I loved the subject but when I got to the end of my undergraduate degree I didn't really know what to do next. I loved the theoretical aspects but I really didn't see how I could make a difference using what I had learned. Upon graduation I therefore thought that science was behind me and, despite reservations, I would be forced to settle for an office job. Instead I was offered the opportunity to undertake an MRes in BioPhysics.

The most useful thing to say about this was that I hadn't studied physics since GCSE and it is a perfect example of why you should say yes to all opportunities offered to you, no matter how scary. During my MRes I undertook a dissertation on the application of nanoparticles to catheter surfaces to prevent urinary tract infections in spinal injury patients. It was this project that changed my view of science entirely and put me on the path to where I am now.

I always loved studying science but I had never found a way to relate it to what I knew I wanted to do as a career, which was to make a difference, and obviously to win an Oscar! I suddenly realized there was an area of science I could work in where I could use science to make a difference for patients. Not in 20 years, but in a relatively short time frame.

As I was finishing my MRes a friend showed me a job advert for a Trainee Clinical Scientist in Microbiology and I realized that this was what I wanted to do for the rest of my career. Luckily, they gave me the post.

What training do you have to undertake?

You can probably tell I did not end up as a Healthcare Scientist as part of some grand career plan. However, once I had found my career, I was prepared to work hard to succeed and it is true that succeeding as a Healthcare Scientist does require commitment. For me, getting the job was the start of 12 years of training to enable me to get Fellowship of the Royal College of Pathologists (FRCPath – my clinical qualification), a PhD (my scientific qualification) and a postgraduate certificate in education (my education qualification). It is the combination of these three that enables me to do the job that I now have.

For those entering the training programme now the structure is much more defined with two training programmes: the Scientist Training Programme (STP), which takes you through to the end of Clinical Scientist training, and the Higher Specialist Scientist Training (HSST) programme, which takes you through to completion of a taught doctorate and FRCPath. These two programmes can be taken consecutively and all the information is available on the NSHCS website.

So what is the future?

In 2016 I was fortunate enough to be awarded an NIHR Clinical Lectureship. This is the next step in enabling me to develop into a clinical academic. This is a position that is open to those medically trained but is less available to Healthcare Scientists at present. The post enables you to undertake research for 50% of your time whilst still undertaking your clinical post for the other 50%. This means that you can bridge the gap between the amazing work that is being undertaken in academia and clinical practice, speeding the adoption of work and ensuring that the questions that need resolution in healthcare are being addressed by those undertaking research. It is a real privilege to be in the vanguard of this position within Healthcare Science and it only fuels my excitement about the future of my profession and how it will impact on improving patient care.

It is a real privilege to be in the vanguard of this position within Healthcare Science

Elaine Cloutman-Green
Great Ormond Street Hospital

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Michael A. Zasloff

An interview with

Michael A. Zasloff

Scientific Director
MedStar-Georgetown Transplant Institute, Georgetown University Hospital

Stewart Cumiskey
Society for Applied Microbiology

The unearthing of pollen's microbiome has potential for helping us understand the biggest threats to the environment and may change the way we view and treat allergies in the near future.

Research published in *Sf*AM's *Environmental Microbiology* journal is the most comprehensive study of pollen microbiology to date. We spoke to Michael Zasloff, Scientific Director of MedStar-Georgetown Transplant Institute to find out more about this…

What aspects of this research were exciting for you?

I have forever wondered why we suffer from seasonal allergies. Regardless of the hypotheses that have been proposed, it just hasn't made sense. It's become even more unclear as we come to understand how our immune system recognizes substances against which we have to mount a defence.

I've always thought our body is fighting off pollen because it doesn't want a plant to take root! I've laughed at that, but there's a much deeper explanation and it's because every pollen grain is a vaccine. That is the miracle.

It's the most perfect nasal vaccine. If you wanted to develop a mucosal response, in other words, you wanted to direct your mucous membranes to deal with an antigen – could be a virus, but in this case it's a pollen grain – you would in some way, couple it to a microbe. The body doesn't care about pollen. What the body cares about are the bacteria attached to that pollen.

When our immune system sees a microbe it immediately organizes the equipment within the immune system to deal with the assault which depends upon the portal, or the barrier that's being invaded.

And from my perspective, now I understand why pollen allergy is so common. That's a big deal.

Pollen has a Microbiome!

Could this research lead to better treatment for allergies?

It could be that we educate the immune system against the bacteria, the microbe associated with the common pollen species. Might that have an impact? What I'm getting at is that there's a lot of research needed. This is not a cure for allergy. You can't use this right now and say, 'here's a shot of this, that's the end of your allergy'.

There are virtually no methods to supress allergy effectively, once it's developed. We DO have better methods to prevent the onset of allergy, for example – the whole peanut allergy story is now being approached from another direction. Expose the child from a very young age – to peanuts.

My training position, as a paediatrician, was to keep kids away from certain foods. The idea was to keep them from peanuts and eggs, tomatoes and bunch of other things. But it turns out – it's making it worse.

How many of the allergies we have compared to our pets isn't the same thing? The dander on a cat? I mean, come on! If you looked at the dander particle, you know what that dander's going to look like, it's gonna have colonies of microbes on it. It's changed the way we're thinking about inhaled allergies.

What other discoveries could stem from this?

Every flowering plant has this population and has a particular affinity for certain organisms. What does perturbation lead to? I don't know. It's like a new field. That's why it's so exciting.

One of the most amazing things is that it takes an enormous amount of energy that all plants spend, to create and manage genes that play a role in defending various parts of the plant against microbes – because that's all they have. You take a tree, a redwood tree or ANY tree that's been living for thousands of years. It can't move. It has to stay where it is. The antimicrobial defences that it requires are basically the same type that the bee is using. And very similar to what we use.

God knows what happens if the wrong microbes are on that pollen. Do you alter the outcome of that fruit? What happens to the overall lifecycle of that plant? Maybe you can't kill a microbe that enters the embryo. Maybe that seed becomes weak. It's so complicated. It's not often that you get a paper with this much behind it – it's amazing.

Michael A. Zasloff is an American doctor, immunologist, medical researcher, professor and geneticist. He is currently Scientific Director, MedStar-Georgetown Transplant Institute, Georgetown University Hospital.

This interview was in response to a research article published in Environmental Microbiology titled 'Bacterial microbiota associated with flower pollen is influenced by pollination type, and shows a high degree of diversity and species-specificity'.

JournalWATCH

Highlights and featured articles from the SfAM journals

Journal of Applied Microbiology

http://www.journalappliedmicro.com

Pathogenic factors in *Candida* biofilm-related infectious diseases

K. Hirota, H. Yumoto, B. Sapaar, T. Matsuo, T. Ichikawa and Y. Miyake

Candida albicans is a commonly found member of the human microflora and is a major human opportunistic fungal pathogen. A perturbation of the microbiome can lead to infectious diseases caused by various microorganisms, including *C. albicans*. Moreover, the interactions between *C. albicans* and bacteria are considered to play critical roles in human health. The major biological feature of *C. albicans*, which impacts human health, resides in its ability to form biofilms. In particular, the extracellular matrix (ECM) of *Candida* biofilm plays a multifaceted role and therefore may be considered as a highly attractive target to combat biofilm-related infectious diseases. In addition, extracellular DNA (eDNA) also plays a crucial role in *Candida* biofilm formation and its structural integrity and induces the morphological transition from yeast to the hyphal growth form during *C. albicans* biofilm development. This review focuses on pathogenic factors such as eDNA in *Candida* biofilm formation and its ECM production and provides meaningful information for future studies to develop a novel strategy to battle infectious diseases elicited by *Candida*-formed biofilm.

http://onlinelibrary.wiley.com/doi/10.1111/jam.13330/full

Probiotic roles of *Lactobacillus* sp. in swine: insights from gut microbiota

V. D. V. Valeriano, M. P. Balolong and D.-K. Kang

The use of lactobacilli as probiotics in swine has been gaining attention due to their ability to improve growth performance and carcass quality, prevent gastrointestinal infection and most importantly, their 'generally recognized as safe' status. Previous studies support the potential of lactobacilli to regulate host immune systems, enhance gut metabolic capacities and maintain balance in the gut microbiota. Research on swine gut microbiota has revealed complex gut microbial community structure and showed the importance of *Lactobacillus* to the host's health. However, the species- and strain-specific characteristics of lactobacilli that confer probiotic benefits are still not well understood. The diversity of probiotic traits in a complex gut ecosystem makes it challenging to infer the relationships between specific functions of *Lactobacillus* sp. and host health. In this review, we provide an overview of how lactobacilli play a pivotal role in the swine gut ecosystem and identify key characteristics that influence gut microbial community structure and the health of pigs. In addition, based on recent and ongoing meta-omics and omics research on the gut microbiota of pigs, we suggest a workflow combining culture-dependent and culture-independent approaches for more effective selection of probiotic lactobacilli.

http://onlinelibrary.wiley.com/doi/10.1111/jam.13364/full

Letters in Applied Microbiology

www.lettersappliedmicro.com

Copper as an antibacterial material in different facilities

J. Inkinen, R. Mäkinen, M. M. Keinänen-Toivola, K. Nordström and M. Ahonen

The efficiency of copper as an antimicrobial material has been noted in laboratory studies and in the hospital environment. The present study further shows that copper exerted an antibacterial effect in different facilities, i.e., in a hospital, a kindergarten, an office building and in a retirement home for the elderly. The study suggests that copper has potential use as an antibacterial material and therefore might serve as a means to lower the incidence of transmission of infectious agents from inanimate surfaces in different facilities, with everyday functions.

http://onlinelibrary.wiley.com/doi/10.1111/lam.12680/full

Inactivation of foodborne pathogenic and spoilage microorganisms using ultraviolet-A light in combination with ferulic acid

A. Shirai, T. Watanabe and H. Matsuki

Microbial contamination is one of the most serious problems for foods, fruit and sugar-thick juices. UV light is suitable for the non-thermal decontamination of food products by inactivating the contaminating microorganisms. However, UV-A exposure is insufficient for disinfection. This study demonstrates that the combination of UV-A LED light (350–385 nm), which is not hazardous to human eyes and skin, and ferulic acid (FA), a known phytochemical and food additive, provides synergistic antimicrobial activity against foodborne pathogenic and spoilage microorganisms. Therefore, FA addition to UV-A light treatment may be useful for improvement of UV-A disinfection technology to prevent food deterioration.

http://onlinelibrary.wiley.com/doi/10.1111/lam.12701/full

Microbial Biotechnology

www.microbialbiotech.com

Editorial Series: the microbiome as a source of new enterprises and job creation

The human microbiome: an emerging tool in forensics

Jarrad T. Hampton-Marcell, Jose V. Lopez and Jack A. Gilbert

http://onlinelibrary.wiley.com/doi/10.1111/1751-7915.12699/full

Yeast's balancing act between ethanol and glycerol production in low-alcohol wines

Hugh D. Goold, Heinrich Kroukamp, Thomas C. Williams, Ian T. Paulsen, Cristian Varela and Isak S. Pretorius

Alcohol is fundamental to the character of wine, yet too much can put a wine off-balance. A wine is regarded to be well balanced if its alcoholic strength, acidity, sweetness, fruitiness and tannin structure complement each other so that no single component dominates on the palate. Balancing a wine's positive fruit flavours with the optimal absolute and relative concentration of alcohol can be surprisingly difficult. Over the past three decades, consumers have increasingly demanded wine with richer and riper fruit flavour profiles. In response, grape and wine producers have extended harvest times to increase grape maturity and enhance the degree of fruit flavours and colour intensity. However, a higher degree of grape maturity results in increased grape sugar concentration, which in turn results in wines with elevated alcohol concentration. On average, the alcohol strength of red wines from many warm wine-producing regions globally rose by about 2% (v/v) during this period. Notwithstanding that many of these 'full-bodied, fruit-forward' wines are well balanced and sought after, there is also a significant consumer market segment that seeks lighter styles with less ethanol-derived 'hotness' on the palate. Consumer-focused wine producers are developing and implementing several strategies in the vineyard and winery to reduce the alcohol concentration in wines produced from well-ripened grapes. In this context, *Saccharomyces cerevisiae* wine yeasts have proven to be a pivotal

strategy to reduce ethanol formation during the fermentation of grape musts with high sugar content (> 240 g/l). One of the approaches has been to develop 'low-alcohol' yeast strains which work by redirecting their carbon metabolism away from ethanol production to other metabolites, such as glycerol. This article reviews the current challenges of producing glycerol at the expense of ethanol. It also casts new light on yeast strain development programmes which, bolstered by synthetic genomics, could potentially overcome these challenges.

http://onlinelibrary.wiley.com/doi/10.1111/1751-7915.12488/full

Whole cell biocatalysts: essential workers from Nature to the industry

Carla C. C. R. de Carvalho

Microorganisms have been exposed to a myriad of substrates and environmental conditions throughout evolution resulting in countless metabolites and enzymatic activities. Although mankind have been using these properties for centuries, we have only recently learned to control their production, to develop new biocatalysts with high stability and productivity, and to improve their yields under new operational conditions. However, microbial cells still provide the best known environment for enzymes, preventing conformational changes in the protein structure in non-conventional medium and under harsh reaction conditions, while being able to efficiently regenerate necessary cofactors and to carry out cascades of reactions. Besides, a still unknown microbe is probably already producing a compound that will cure cancer, Alzeihmer's disease or kill the most resistant pathogen. In this review, the latest developments in screening desirable activities and improving production yields are discussed.

http://onlinelibrary.wiley.com/doi/10.1111/1751-7915.12363/full

Environmental Microbiology

www.env-micro.com

Formation of propionate and butyrate by the human colonic microbiota

Petra Louis and Harry J. Flint

The human gut microbiota ferments dietary non-digestible carbohydrates into short-chain fatty acids (SCFA). These microbial products are utilized by the host and propionate and butyrate in particular exert a range of health-promoting functions. Here, an overview of the metabolic pathways utilized by gut microbes to produce these two SCFA from dietary carbohydrates and from amino acids resulting from protein breakdown is provided. This overview emphasizes the important role played by cross-feeding of intermediary metabolites (in particular, lactate, succinate and 1,2-propanediol) between different gut bacteria. The ecophysiology, including growth requirements and responses to environmental factors, of major propionate- and butyrate-producing bacteria are discussed in relation to dietary modulation of these metabolites. A detailed understanding of SCFA metabolism by the gut microbiota is necessary to underpin effective strategies to optimize SCFA supply to the host.

http://onlinelibrary.wiley.com/doi/10.1111/1462-2920.13589/full

All together now: experimental multispecies biofilm model systems

Chuan Hao Tan, Kai Wei Kelvin Lee, Mette Burmølle, Staffan Kjelleberg and Scott A. Rice

Studies of microorganisms have traditionally focused on single species populations, which have greatly facilitated our understanding of the genetics and physiology that underpin microbial growth, adaptation and biofilm development. However, given that most microorganisms exist as multispecies consortia, the field is increasingly exploring microbial communities using a range of technologies traditionally limited to populations, including meta-omics-based approaches and high-resolution imaging. The experimental communities currently being explored range from relatively low diversity, for example, two to four species, to significantly more complex systems, comprised of

several hundred species. Results from both defined and undefined communities have revealed a number of emergent properties, including improved stress tolerance, increased biomass production, community level signalling and metabolic cooperation. Based on results published to date, we submit that community-based studies are timely and increasingly reveal new properties associated with multispecies consortia that could not be predicted by studies of the individual component species. Here, we review a range of defined and undefined experimental systems used to study microbial community interactions.

http://onlinelibrary.wiley.com/doi/10.1111/1462-2920.13594/full

Environmental Microbiology Reports

www.env-micro-reports.com

Temporal variability of bacterial communities in cryoconite on an alpine glacier

Andrea Franzetti, Federico Navarra, Ilario Tagliaferri, Isabella Gandolfi, Giuseppina Bestetti, Umberto Minora, Roberto Sergio Azzoni, Guglielmina Diolaiuti, Claudio Smiraglia and Roberto Ambrosini

Cryoconite holes, that is, small ponds that form on glacier surfaces, are considered the most biologically active environments on glaciers. Bacterial communities in these environments have been extensively studied, but often through snapshot studies based on the assumption of a general stability of community structure. In this study, the temporal variation of bacterial communities in cryoconite holes on the Forni Glacier (Italian Alps) was investigated by high-throughput DNA sequencing. A temporal change of bacterial communities was observed with autotrophic Cyanobacteria populations dominating communities after snowmelt, and heterotrophic Sphingobacteriales populations increasing in abundance later in the season. Bacterial communities also varied according to hole depth and area, amount of organic matter in the cryoconite and oxygen concentration. However, variation in environmental features explained a lower fraction of the variation in bacterial communities than temporal variation. Temporal change along ablation season seems therefore more important than local environmental conditions in shaping bacterial communities of cryoconite of the Forni Glacier. These findings challenge the assumption that bacterial communities of cryoconite holes are stable.

http://onlinelibrary.wiley.com/doi/10.1111/1758-2229.12499/full

Coastal bacterioplankton community response to diatom-derived polysaccharide microgels

Joe D. Taylor and Michael Cunliffe

Phytoplankton-derived polysaccharide microgels, including transparent exopolymer particles (TEP), are a major component of the marine organic carbon pool. Previous studies have made correlative links between phytoplankton material and bacterioplankton, and performed experiments that assess general responses to phytoplankton, yet there is a lack of direct empirical evidence of specific bacterioplankton responses to natural phytoplankton polysaccharide microgels. In this study, we used diatom-produced TEP in controlled incubation experiments to determine the impact of polysaccharide microgels on a coastal bacterioplankton community. Quantification of bacterial 16S rRNA gene transcripts showed that the addition of TEP caused an increase in bacterioplankton activity. Similarly, high-throughput sequencing of RT-PCR amplified bacterial 16S rRNA gene transcripts showed that active bacterioplankton community structure and diversity also changed in response to microgels. Alteromonadales and Rhodobacterales increased in abundance in response to TEP, suggesting that both bacterioplankton taxa utilize diatom-derived microgels. However, through assessing ^{13}C-labelled TEP uptake via RNA Stable Isotope Probing, we show that only the Alteromonadales (genus *Alteromonas*) assimilated the TEP carbon. This study adds utilization of diatom-derived TEP to the metabolic repertoire of the archetypal copiotrophic bacterioplankton *Alteromonas*, and indicates that the Rhodobacterales may utilize TEP for other purposes (e.g., attachment sites).

http://onlinelibrary.wiley.com/doi/10.1111/1758-2229.12513/full

Melissa McCulloch
Wiley-Blackwell

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Redipor® Prepared media - A comprehensive range of prepared media including Petri dishes, contact plates, gamma irradiated media, injection vials, broth in bags and ampoules: all available in a variety of packaging options and with flexible order quantities. Cherwell also specialise in offering bespoke prepared media solutions to meet customer specific requirements.

Microbial Air Samplers – Cherwell now distribute the state-of-the-art range of ImpactAir® microbial air samplers. ImpactAir is designed for continuous monitoring in high-grade areas, where high accuracy sampling of viable particles is critical. Cherwell still offer the range of SAS air samplers designed for routine environmental monitoring routine sampling regimes, including portable hand held units, a compressed air sampling device and an isolator specific unit.

Cleanroom Bio-decontamination - Suitable for use in pharmaceutical cleanrooms and other critical areas, the combination of dry fog technology and cold sterilants ensures effective and efficient bio-decontamination for surfaces, confined spaces and cleanroom suites. The range incorporates the highly effective Minncare® Dry Fog 2 and Mini Dry Fog systems plus Minncare and Actril Cold Sterilants.

Further Information

Visit: www.cherwell-labs.co.uk
Tel: +44 (0)1869 355 500
Email: sales@cherwell-labs.co.uk

Unique options enhance Whitley Anaerobic and Microaerobic Workstations

From routine, day-to-day monitoring of a variety of cultures to specialist research applications where fastidious anaerobes are incubated in strict conditions, we know that microbiologists use their workstations in very different ways. Don Whitley Scientific is continuing to add new features and options to the range so we have the ideal workstation for every customer's application.

Conditions Monitoring

With the Whitley Anaerobic Conditions Monitor and the patented Catalyst Monitoring System, customers can be assured of stable, reliable incubation conditions. These systems monitor oxygen concentration and catalyst performance within the workstation, alerting the user when attention is required. They provide additional assurance that anaerobes will be incubated under ideal conditions.

HEPA Filtration

Some Whitley Workstations can be equipped with HEPA filtration to reduce particle counts inside the chamber to levels exceeding the requirements of 14644 Class 3. The entire workstation atmosphere passes through the filter hundreds of times an hour, which ensures the chamber environment is cleaned quickly.

Biological Containment

As a further option, the Whitley Enhanced Biological Containment System greatly reduces the release of bacteria and other potentially harmful particles from the workstation into the surrounding environment.

Further Information

Visit: www.dwscientific.co.uk
Tel: +44 (0)1274 595728
Email: sales@dwscientific.co.uk

Sigma SP™ *Patent Pending*

MWE has just launched Sigma SP™, a powerful but user friendly mucolytic solution, intended for the liquefication of sputum for diagnostic testing, but which would have applications in other fields of research.

Sputum is notoriously difficult to work with. While various reagents have been tried, some of these reagents must be prepared in caustic solutions, and have limited stability. They are normally kept lyophilised until required.

Modern clinical laboratories use automated processing platforms, but current methods of preparation of sputum are unsuitable. Specimens are loaded in large numbers, and may wait for several hours before being processed. Reagents such as dithiothreitol are detrimental to important pathogens such as *Haemophilus influenzae*. Sigma SP™ resolves these issues. Sigma SP™ contains a novel reagent which is a more powerful mucolytic, yet comes in a simple, ready to use solution, in vials compatible with the automated platforms. It is not directly harmful to the target bacteria, so specimens can wait for several hours. The solution has a neutral pH, and can be safely stored at ambient temperature for many months.

Further Information

Visit: www.mwe.co.uk
Tel: +44(0)1225 810361
Email: sales@mwe.co.uk

Probiotic gum for healthy gums

NCIMB is collaborating with leading probiotics manufacturer Protexin in an Innovate UK funded project that aims to identify strains of bacteria that could reduce the harmful effects of dental biofilms.

Dental biofilms, in the form of plaque, are commonly associated with tooth decay and gum disease. Regular brushing is recommended to remove plaque, however it has been found that it reforms quickly after brushing, and many people do not brush thoroughly or frequently enough to avoid problems.

This project is investigating strains held within the NCIMB culture collection for their potential to shift the composition of oral biofilms towards a healthier oral flora, and reduce the possibility of dental caries. Strains found to be effective could be delivered in the form of a lozenge or gum.

NCIMB manages the UK's National Collection of Industrial Food and Marine Bacteria and offers microbiology, chemical analysis and biomaterial storage services to industry and academia. We collaborate with companies, universities and research organisations to carry out research and development projects and are particularly interested in investigating novel uses of our strains.

For more information contact Dr Samantha Law
s.law@ncimb.com

Further Information

Visit: www.ncimb.com
Tel: +44 (0)1224 711 100
Email: enquiries@ncimb.com

Neogen's NF Certified One Broth One Plate *Listeria* Protocol

Neogen and Lab M have developed an NF certified protocol for the detection of both *Listeria* spp. and *Listeria monocytogenes*, in food and environmental samples, using just one enrichment broth and one plate.

With results in as little as 48 hours and enhanced sensitivity versus the traditional ISO 11290-1 method, the One Broth One Plate protocol provides an ideal solution for those looking to simplify their workflow and reduce time to result, whilst still maintaining classical microbiology.

Neogen's LESS Plus media is compliant to ISO 9001:2008 and serves as a highly selective enrichment broth for the detection of *Listeria*, whilst Lab M's Listeria Chromogenic Agar (LCA) is a selective medium, formulation compliant to ISO 11290-1:2014 according to Ottaviani and Agosti, and performance compliant to ISO 11133:2014. The LCA media produces clearly visible colonies for *Listeria* spp. which display a distinct opaque halo when Listeria monocytogenes is present for easy differentiation.

Both the enrichment broth and detection media are available in various sizes and formats designed to support your laboratory's requirements.

Further Information

Visit: www.neogeneurope.com
Tel: +44 (0)1292 525 625
Email: microbiology_uk@neogeneurope.com

Thermo Fisher Scientific

To enable food microbiology laboratories to improve operational efficiencies, a new range of Thermo Scientific Bagged Enrichment Media is designed to reduce hands-on preparation time. The bags contain pre-weighed, ready-to-hydrate media that is gamma-irradiated during production meaning no further sterilization is required before use.

In addition to saving time, the ready-to-fill format of the Thermo Scientific™ FitBag™ Enrichment Media can also help laboratories to save space compared with prepared media. They offer the flexibility to be filled when convenient and mixed when required, reducing preparation time to around 10 minutes.

For added convenience, the Thermo Scientific™ QuickBag™ Enrichment Media are supplied with water pre-filled. The medium is prepared by simply breaking the dividing seal and mixing.

The QuickBag and FitBag Media formats are a response to customers who already appreciate the benefits of the large volume Thermo Scientific™ Dry-Bags™ Enrichment Media. By offering these convenient formats in lower volumes, laboratories of all sizes can avoid the time-consuming weighing and autoclaving steps, and alleviate any bottlenecks associated with traditional media preparation.

The QuickBag and FitBag Media Formats are available in a choice of volumes: 2.7, 4.5 and 9 liters.

Find out more by visiting www.thermofisher.com/enrich

Further Information

Visit: www.oxoid.com
Tel: +44 (0)1256 84144
Email: oxoid.orders@thermofisher.com

PRO-LAB DIAGNOSTICS

Celebrating 21 years of unparalleled success!

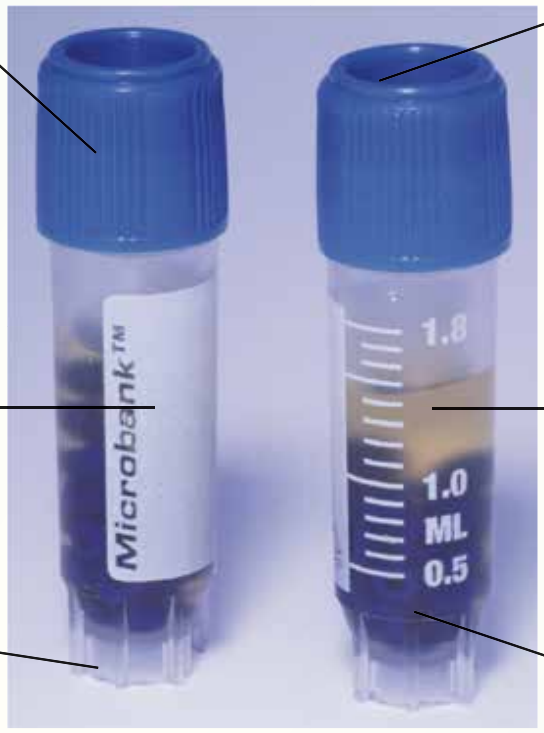
Microbank™ Bacterial & Fungal Preservation System

Microbank™ is a convenient, ready-to-use system designed to greatly simplify the storage and retrieval of bacterial cultures. It is composed of a unique cryovial system incorporating treated beads and a special cryopreservative solution.

Microbank™ has proven performance and is now the natural choice for microbiologists world-wide and for many specific reference culture collection centres. Microbank™ is a more reliable method for maintaining important cultures than repetitive subculture, which can result in altered characteristics, lost organisms, or contaminated cultures. Microbank™ is much simpler than traditional methods of lyophilization or glycerol broth.

Large 2 ml vials with triple depth external threaded cap which reduces the possibility of contamination. Wider tube diameter provides more room for mixing to ensure beads are properly coated.

Available in five colours to provide laboratories with a system to colour-code different bacterial species.



Larger writing area allows for complete coding and reference data.

Specially formulated preservative ensures longer survival of fastidious bacteria and higher quantitative recoveries.

Industry-standard robust cryovial can withstand snap freezing with liquid nitrogen.

Chemically treated beads improve bacterial adhesion.

Microbank™ World Wide Performance Portfolio

Microbank™ has enjoyed many years of success as the method of choice for storage and retrieval of bacterial and fungal cultures. Extensive reference data are available from customers, centres of excellence, and reference collection sites around the world detailing up to 21 year's successful storage of an extensive range of cultures. Full details can be obtained in the Microbank™ World Wide Performance Portfolio available on the Pro-Lab website.

Pro-Lab Diagnostics U.K.
3 Bassendale Road
Bromborough, Wirral, Merseyside
CH62 3QL
United Kingdom
Tel: 0151 353 1613
Fax: 0151 353 1614
E-mail: uksupport@pro-lab.com

Pro-Lab Diagnostics Canada
20 Mural Street, Unit #4
Richmond Hill, ON L4B 1K3
Canada
Toll Free: 1-800-268-2341
Tel: (905) 731-0300
Fax: (905) 731-0206
E-mail: support@pro-lab.com

Pro-Lab Diagnostics U.S.A.
21 Cypress Blvd., Suite 1070
Round Rock, TX, 78665-1034
U.S.A.
Toll Free: 1-800-522-7740
Tel: (512) 832-9145
Fax: 1-800-332-0450
E-mail: ussupport@pro-lab.com

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Medical Wire and Equipment. Corsham, Wiltshire, SN13 9RT, U.K.