MARCH 2019 | VOL 20 NO 1 | ISSN 1479-2699

microbiologist

Rubbish microbiology

An interview with SfAM Fellow Sir David Attenborough

Fatbergs

Pesticide contamination

sfam society for applied microbiology

microbiologist

Editorial Group

Society for Applied Microbiology
Charles Darwin House, 12 Roger Street
WC1N 2JU UK

+44 (0)207 685 2596
communications@sfam.org.uk
www.sfam.org.uk

Copy dates

Vol. 20. No. 2 June 2019
Wednesday 5 April

Vol. 20. No. 3 September 2019
Wednesday 3 July

Vol. 20. No. 4 December 2019
Wednesday 2 October

Vol. 21 No. 1 March 2020
Wednesday 8 January

Society Office staff

Executive Committee

Microbiologist is published quarterly by the Society for Applied Microbiology, a registered charity. ISSN 1479-2699.

Big fish, little fish, plastic bag

The effect plastic waste has in our oceans is a tragedy of modern life. Marine microbes carry out many of the basic functions that support life in the oceans and understanding what impact this pollution has on marine microbiomes is key to preserving the diversity of our oceans.

Unless you have been on another *Blue Planet*, you would have probably heard about Sir David Attenborough's spotlight on ocean plastic pollution. People listened in droves as Attenborough produced stories of sea turtles and other marine creatures drowning in plastic, mistaking plastic bags as food and ingesting them. According to research published in the journal *Science*, at least 8 million tons of plastic enter the oceans each year. That's like emptying a busload of plastic into an ocean every minute.

Although the harm caused by domestic, industrial and commercial pollution on larger organisms in the oceans is well documented, the impact on microorganisms is not as widely known. Microbiologists not only have a major task in investigating the role microbiomes play in ocean health, but also how bacteria and other microbes can potentially consume all this mess we keep putting into them. This issue of *Microbiologist* features several scientists who are doing just that. Fatberg, landfill and plastic-bag-eating bacteria are investigated, as is the potential of phage in tackling water pollution.

Our last issue reached over 10,000 readers and that special antimicrobial resistance (AMR) issue coincided with the launch of a 20-year vision and 5 year action plan by the UK government. The ambitious plan that aims to contain, control and mitigate AMR should help to focus efforts on the areas that require most urgent attention.

The government's plan reveals a number of priorities where the microbiology community will make a difference:

- The UK government commits to back an infectious intestinal disease (IID) study that gathers population-based data on the gut resistome.
- Over the next 5 years the government will support research to improve understanding of the hazards and risks from AMR in the environment.
- UK Research and Innovation (UKRI) commits to develop the scientific capacity needed to support and deliver ongoing high-quality research in infectious disease prevention and microbiology-related disciplines.

Microbes and microbiologists certainly have a crucial role in solving the wide range of problems facing humankind. It's crucial that we find a way to help them.

Paul Sainsbury
Editor

‘I know that microscopic organisms of one kind or another can eat plastic. That is one thing in this world that this poor planet needs. It needs something that eats plastic because, by God, there’s an awful lot of it out there. The situation is really dreadful.’

Sir David Attenborough
Fellow of the
Society for Applied Microbiology

SfAM Fellowship Reception
BMA House, London, UK
27 November 2018

News

Features

People & Places

Must-read Articles

Education & Public Outreach

Industry

Policy & Public Affairs

A non-siloed approach

The world of microbiology is an ever-changing place. It constantly provides new and interesting challenges that need to be understood, adapted to, or indeed, challenged.

This is evident with areas such as antimicrobial resistance (AMR) and understanding the importance of the microbiome. We need to think about how we engage, and then train, the next generation of microbiologists. Both individuals and societies have critical roles to play in engaging microbiologists of the future and the question that remains is, how young do they have to be for us to engage with them? I remember a number of years ago a professor of mine being equally scathing of talking to the public and also of teaching microbiology to young children. Rather than putting me off, this encouraged me to attempt to prove them wrong.

A colleague and I took a roadshow into local schools to discuss matters around the washing of hands and how not all bacteria are 'disease causing'. Now this is of course essentially public engagement, but it was also teaching, and we found it was possible to both engage and teach a subject such as microbiology to preschool children and all the way upwards to 16-year-olds. The key messages are of course the same, but the method of delivery varies markedly as one would expect. One of the important parameters regardless of age is making it relevant, making it real, whilst avoiding the question of 'so what?'

More recently, teaching undergraduate students has taken an interesting turn with the reality of AMR taking an important place within some curricula. This has allowed a truly multidisciplinary approach to teaching microbiology with the inclusion of subject areas such as biotechnology, chemistry (and biochemistry), genetics, evolution, pharmacy (pharmacology), one health and, further afield, subjects such as economics, anthropology and social sciences. The latter subject encompasses interesting aspects such as behavioural change and emotional drivers. These dimensions are now considered in terms of AMR and have become an important part of antimicrobial usage/resistance teaching. I celebrate this non-siloed approach to the way we need to teach microbiology.

On a separate topic I wanted to record my own personal note on the passing of the wonderful Professor Basil Jarvis. I was fortunate enough to have been guided, cajoled, encouraged and made to laugh out loud by this wonderful man. His advice always sage, his anecdotes always funny, his presence always reassuring. He was a stalwart of the Society, an elder and a fantastic character. At every function we both attended over the past few years we sought each other out to compare notes on our bow ties, and to debate our successes and failures when fly fishing. I will miss these encounters.

I can't think of a better way to end this column than by thanking Professor Basil Jarvis for everything he has done – including educating us.

Thank you 'Basil the Legend'. Respect.

Mark Fielder
President of the Society for Applied Microbiology

Women in microbiology

I've had too many conversations with female colleagues who still face significant barriers to career progression because they are women.

At the time of writing this article I've recently attended a Women's Engineering Society centenary event, and next month I will be talking to male and female sixth-formers who attend a local grammar school. As a female leader one of my key responsibilities is to support, nurture and promote female talent, and recently the Executive Committee of SfAM approved a strategic campaign entitled: 'Microbiology is Diverse'. This will make sure gender balance and other protected characteristics are considered, and put a framework in place so that diversity and inclusion are core to all activities of the Society.

There have been many notable female microbiologists in history. From Hattie Alexander (1901–1968) and her work on antibiotic resistance to Mary Bunting (1910–1998) who gained national attention in the USA for identifying a societal problem she called a 'climate of unexpectation' for girls. More recent female microbiologists who spring to mind include two of our EMI lecturers: Margaret McFall-Ngai and her pioneering work on bioluminescent squid, as well as environmental microbiologist, Rita Colwell. According to the UNESCO's Women in Science figures published in June 2018, just 28.8% percent of people working in research and development are, or identify as, women (39.8% for Arab States, 39.5% for Central and Eastern Europe, 48.1% for Central Asia, 23.4% for East Asia and the Pacific, 45.4% for Latin America and the Caribbean, 32.3% for North America and Western Europe, 18.5% for South and West Asia and 31.3% for sub-Saharan Africa).

According to a report published by Credit Suisse, companies with more females at executive level are more profitable, and the benefits of diversity in the workplace as a breeding ground for innovation and change is well researched. SfAM is already an active participant in the Royal Society of Biology Diversity & Inclusion Working Group, and provided support for an Athena Scientific Women's Academic Network (SWAN) workshop in March 2018. SfAM is also a supporter of the All-Party Parliamentary Group (an interest group of politicians) on Diversity and Inclusion in science, technology, engineering and mathematics (STEM).

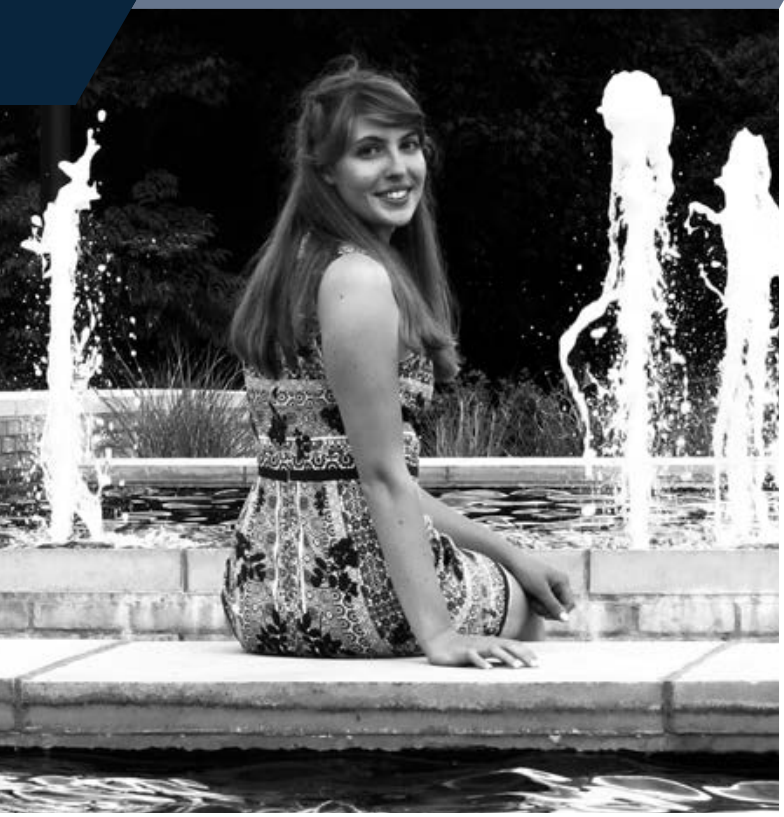
I really do look forward to a time when these conversations don't happen, and the initiatives are not needed – a time when gender is no longer a factor in the success of scientists worldwide.

FURTHER READING

UNESCO *Women in Science*.
http://uis.unesco.org/sites/default/files/documents/fs51-women-in-science-2018-en.pdf
[Accessed 4 February 2019]

CREDIT SUISSE *The Reward for Change*.
https://glg.it/assets/docs/csri-gender-3000.pdf
[Accessed 1 February 2019]

Lucy Harper
Chief Executive of the Society for Applied Microbiology



Attenborough and the hot plastic planet

I wonder if you can guess what my highlight from 2018 would be? If you guessed 'meeting Sir David Attenborough' then you are correct! Being lucky enough to share a stage with such an influential and inspiring man will no doubt be at the top of my 'greatest moments in my life' list.

While accepting his honorary fellowship, he told us a story about the majestic albatross, a bird that spends weeks out at sea gathering food for its chick. Sir David recalled his experience observing a group of albatrosses and how, after weeks of gathering food from the surface of the ocean, the parents of an albatross chick returned to deposit a gutful of plastic into the baying chick's mouth.

It was a shocking story and really highlighted the sheer volume of plastic out there since it was all this poor bird could find on the surface of the sea. After his story, he turned to us all, as microbiologists, to find the solution to the problem of this horrendous pollution and eluded to species of bacteria that can break down these man-made polymers.

This sparked my interest; plastics have only been present in the environment for a relatively short period of time and evolution has surely not yet been able to produce biological substances that can break down plastics. I was only partly wrong. In a review of the biodegradation of plastics, Shah *et al*. (2007) explain the processes by which fungi and bacteria can indeed break down plastics. The rate and ability of these microorganisms to break down these polymers into monomers depends on pretreatments where abiotic hydrolysis deforms the structure of the plastic. This aids biodegradation by extracellular and intracellular depolymerases found in species of *Alcaligenes*, *Pseudomonas* and *Comamonas*.

Finding a way to utilise these depolymerases on an industrial scale to tackle plastic pollution would solve at least one major problem highlighted by Sir David. The other major issue of climate change presents an even larger threat to life on this planet than plastic. Sir David presented his ideas for harnessing the sun's energy and tackling climate change in his response to questions posed to him during the event. His responses can be found in the podcast that I produced about the event on SfAM's website.

One important thing that I took away from the event was that, no matter what you are researching as early career scientists, you can help to solve at least one of the myriad of problems that we all face today and, as pointed out by Sir David, you can shape how we live in the future!

Jennie French
SfAM Early Career Scientist Committee Vice-chair

FURTHER READING

Shah AA, Hasan F, Hameed A and Ahmed S. Biological degradation of plastics: a comprehensive review. *Biotechnology advances* 2008; 26 (3), 246–265

We would like to warmly welcome the following

New members of the Society

Australia
M. Sullivan
M. Moffitt
N. Webster

Austria
D. Berry

Belgium
S. Vlaeminck

Canada
J. Shapiro

Czech Republic
C. Yeap

Denmark
N. Khan

France
R. Gopalan Nair
L. Rieusset
A. Danchin

Germany
E. Stukenbrock
A. Boetius

Ghana
K. Duedu

India
R. Kothari
K. Deore
S. Kannappan Mohanvel
M. Phukan
A. Hinsu
H. Wani
D. Manna

Indonesia
A. Mawarid

Ireland
A. Warda
M. Fallon
L. Reynolds

Israel
G. Schleyer

Italy
P. Bonfante

Japan
Y. Masuda
A. Kitichalermkiat

Kenya
J. Wachira

Korea, Republic of
Y. Cui
I. Bang

Malaysia
S. Puah
M. Abu Bakar

Malta
M.Darmanin

Morocco
J. Ibijbijen

Nepal
S. Bastola
T. Acharya

New Zealand
Z. Vahdati

Nigeria
T. Bitire
O. Ogunniran
I. Asilebo
O. Adewara
O. Olusola-Makinde
C. Ogbukagu
B. Sani
C. Edeani
D. Mela
F. Bamidele
N. Dibua
A. Adebayo-Oyetoro
N. Elelu
M. Stephen Popoola
F. Ezeamaramu
J. Igbinigie
O. Oalsunkanmi
T. Olajugbagbe
E. Odih
A. Comfort
I. Omoboyowa
T. Oderinde
A. Akinyele
S. Adewumi
K. Fasina
A. Ojo
A. Tolulope
C. Ilbezim
A. Ogunlade
O. Fasusi
T. Ajogwu
K. Adeoye
F. Olajubu
N. Onoyima
A. Olukorede

Pakistan
A. Rashid
S. Danish
M. Ali
N. Hassan

Poland
W. Chajęcka-Wierzchowska

Saudi Arabia
M. Adnan

South Africa
K. Alayande
N. Mfaniswa
L. Bothma
N. Uche-Okereafor
M. Adefisoye
H. Ogola
A. Adedeji

Spain
A. Prieto

Taiwan
B. Hsu

Ukraine
A. Bilan

United Arab Emirates
I. Saadoun

UK
A. Barratt
A. Fletcher
B. Crane
J. Cheng
T. Sbaffi
A. Dyer
U. Qadir
M. Stroyakovski
C. Hews
C. Spencer
J. Butler
L. Algora
R. Jerdan
R. Gallegos Monterrosa
B. Steel
L. Rooney
K. Ho
C. Sandoval
B. Usher
B. Oudova
R. Burton
M. Tarnowski
J. Henderson
R. Paudyal
R. McHugh
T. Kramer
A. Beaton
S. Alharbi
D. Mark
I. Centeleghe
I. Beck
A. Birke
S. Duggan
D. Noel
G. Williamson
M. Ajeigbe
P. Ingle
K. Edwards-Jones
I. Kean
C. Raisen
S. Ryder
M. Cunningham
A. Griffiths
K. Usman
J. Shepherd
M. Rafiq
A. Slate
J. Pessoa
L. Stewart
T. Hanford
M. Hassan
B. Blunk
H. Chick
E. Portal
U. Khan
C. Hasan
C. Dike
E. Quayson
B. Secker
M. Allsop
S. Bailey
J. Black
E. Sanchez Garcia
R. Duncan
K. Dyer
C. Donaghue
Z. Baazeem
J. Chuisseu
T. Blower
R. Quilliam
J. Pratscher
A. Allsopp
T. Walker
M. Dumont
I. Murillo
E. Heinz
R. Drummond
A. Hosie
S. Kenney
N. Gibbins
P. Matewele
H. Gao
L. Doolan
S. Ackers-Johnson
L. Ackers
I. Papandronicou
K. Wilson

USA
A. Angelova
K. Collins
M. de la Croix
A. Santoro
J. Lennon
A. Apprill
F. Stewart
F. Aylward
B. O'Banion

Uruguay
P. Scavone

What you get for your membership

Conferences
> Attend and participate in our conferences and meetings

Funding and grants
> Over £265,000 worth of grants awarded last year

Policy and voice
> Have your say on industry issues and stay updated on the latest news

Career development
> Engage with your peers and contribute on one of our committees

Magazine and journals
> Free access to all issues of our five journals and quarterly magazine

Discounts
> Up to 70% off events, books and membership

Community
> Over 2,600 members worldwide

Free gifts
> Receive small tokens of our appreciation

Awards and competitions
> Prizes to celebrate your achievements

Impact beyond the university walls

From early on in my career I knew I wanted to conduct research that had reach and impact beyond the confines of the university. I was also very aware that having an academic role would provide a platform for me to achieve this goal, as well as enabling me to nurture the next generation of scientists.

Working with industry

For many years, going as far back as my great-grandmother, the jobs/careers/businesses of my family have been in textiles, and before commencing my academic career I trained as a fabric technologist for Aquascutum. This involved testing textiles for their suitability for being made into particular garments, evaluating care labels and working with the designers in London. Although I loved this job I knew deep down that I wanted to be a scientist!

Therefore, I gave up what was a very good job and followed my real passion – 'science'. I gained a BSc in Biology and published my final-year dissertation. I then came to another crossroads. I was offered two PhDs: one unfunded but in an area of microbiology that inspired me (the use of natural products as antimicrobials) or another fully funded PhD in Composting Microbiology (interesting, but did not excite me). Once again, I took the more difficult path and chose to study what I was truly interested in and funded my PhD by working as a research assistant. My supervisor Carol Phillips was a great support and together we patented my PhD research.

My initial training and understanding of textiles later allowed me to combine two of my passions: textiles and microbiology! My current research centres on bacterial spore removal from industrially laundered NHS bed sheets, domestic laundering of healthcare uniforms and the product development of antimicrobial textiles. I work with the NHS, contract laundries and the antimicrobial textile coatings industry, as well as contributing to research and marketing material for Johnson Cleaners.

The research I have conducted is recognised worldwide by commercial brands such as Microfresh – suppliers to John Lewis, Marks & Spencer and PAL International. I also work closely with the UK Textile Services Association (TSA) and internationally with the European Textile Services Association (ETSA) and Textile Rental Services Association (TRSA) in the USA. In addition, I have developed products for cosmetic companies, looking at natural ingredients to combat acne.

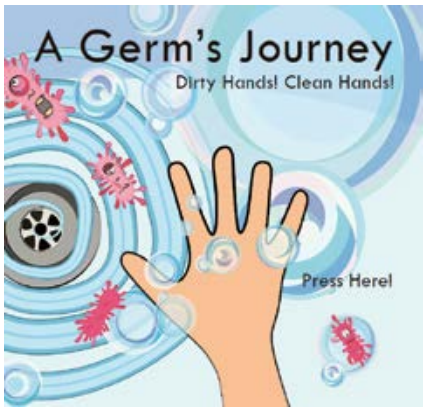
Katie Laird

Reader in Microbiology and the Head of the Infectious Disease Group at De Montfort University (DMU), UK

Educational resources for young children

I am the co-founder of *A Germ's Journey*, which is a global package of innovative educational resources for young children to learn about germs and handwashing and how this is linked to their health. A multidisciplinary team (microbiology, education and technology) have developed an interactive book and website (**www.germsjourney.com**); the global publication of these educational resources was funded by SfAM and included 1,000 copies for widening participation purposes. The issue of hygiene practice is particularly pertinent in developing countries, where poor practice can result in serious illness or death. Therefore, we have conducted workshops in India on *A Germ's Journey* that involved more than 350 children and 150 teachers who were trained in good hygiene practice. We have also created posters and parent guides for India, the Middle East and West Africa based on the book. Additionally, a successful crowdfunding campaign has raised money to translate the *A Germ's Journey* book into Gujarati; 900 books will be donated to schools, community centres and hospitals across the Gujarati region. A video of a song with actions about how to wash your hands has been created in collaboration with teachers in India and a UK song is being developed in a co-creation project with children.

The relaunch of the *A Germ's Journey* website has made all of the educational resources free at the point of access to children and teachers around the world, with Voluntary Service Overseas (VSO) adopting the resources to be used in refugee camps. Partners and collaborators on this project include #DMUlocal and Global, Manav Sadhna, the Sanitation Institute India (ESI), WaterAid, UNICEF, United Nations Educational, Scientific and Cultural Organization (UNESCO, PAL International, Q Shield, SAPHNA, VSO and local education authorities. In addition, we are working with the Thinktank museum in Birmingham on their co-creation children's project for those aged 5–8 years, where we are hoping *A Germ's Journey* will become a permanent feature.



Another interesting aspect of my career has been working with the media. This has included conducting the analysis and writing the science scripts for the programme *How Clean is Your House?* and appearing on *The Late Edition* alongside Marcus Brigstocke, after I had swabbed the BBC offices to ascertain how dirty they were. I have also been involved in filming a pilot show called *The Twinsitute* and a number of 'ask the expert' type pieces for TV and radio.

As one of the founding members of the PECS (Postgraduate and Early Career Scientists), now ECS (Early Career Scientists), Committee I was pleased when I was asked to write an article for the *Microbiologist* about my career because being part of SfAM and PECS helped to build the research career I have today and I believe networking and working with more-experienced scientists can inspire and help develop your future career.

A successful crowdfunding campaign has raised money to translate the *A Germ's Journey* book into Gujarati

Stemming the tide: plastics at Portsmouth

Joy Watts Michelle Hale
University of Portsmouth, UK

Plastics are safe and effective polymer materials that play critical roles in many industries and are essential in modern healthcare. Although the stability of these polymers is a major factor in their usefulness, poor waste management at a global level has led to accumulation of plastic in virtually all environmental systems. The widespread damage was brought vividly to the centre of public attention in *Blue Planet II*, the BBC documentary series with Sir David Attenborough. Media attention is having a positive effect, with the general public demanding a better understanding of the fate of plastics in the environment and the need for more innovative ways of reducing, reclaiming and recycling plastics. This public focus has resulted in the UK government setting an ambitious 70% target for recycling of plastic packaging by 2025.

Recently, microbiologists have isolated and identified a new species of bacteria capable of degrading plastics, *Ideonella sakaiensis*. At the Centre of Enzyme Innovation at the University of Portsmouth, Professor John McGeehan (CEI Director) and his group have been working with *I. sakaiensis* to solve the crystal structure of the enzyme responsible and, via mutation studies, improve the function of the PETase enzyme that is capable of digesting common plastics (see Figures 1 and 2). This approach has great financial and environmental merit, as mixed-waste plastics could be returned to their original monomer constituents and upcycled to potentially higher-value products. At the CEI, this approach is now being applied to a number of other common plastic waste products and the enzyme production scaled up for possible industrial applications. Producing a range of microorganisms or enzymes that could degrade plastics, and especially mixed-plastic waste streams, into constituent monomers is a highly attractive solution.

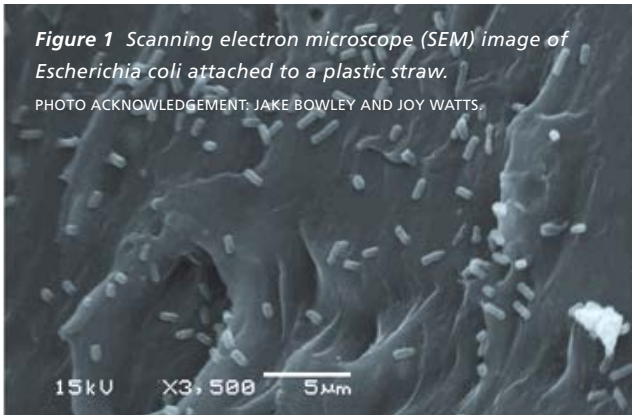


Figure 1 *Scanning electron microscope (SEM) image of Escherichia coli attached to a plastic straw.*
PHOTO ACKNOWLEDGEMENT: JAKE BOWLEY AND JOY WATTS.

As the University of Portsmouth is situated on the coast, the impact of plastics on the coastal environment is very apparent. Ongoing studies are focused on the environmental impact and global distribution of plastics using citizen science in innovative ways, such as The Big Microplastics Survey. Although the distribution of plastics is important, as with all solid surfaces in the aquatic environment, plastics and microplastics provide surfaces for high levels of microbial colonisation and possible biofilm formation. We have been examining the diversity of microbes attached to microplastics released from sewage

FURTHER READING

Austin HP, Allen MD, Donohoe BS, Rorrer NA, Kearns FL, Silveira RL *et al*. Characterization and engineering of a plastic-degrading aromatic polyesterase. *Proceedings of the National Academy of Sciences* 2018; 8, 115–119

The Big Microplastic Survey. **http://microplasticsurvey.org/** [Accessed 4 January 2019]

Yoshida S, Hiraga K, Takehana T, Taniguchi I, Yamaji H, Maeda Y *et al*. A bacterium that degrades and assimilates poly(ethylene terephthalate). *Science* 2016; 11, 1196–1199

treatment facilities and in other aquatic environments. As expected, many microbes attach readily and can stay attached for long periods of time (see Figure 2). This attachment has a number of implications for pathogen dispersal and survivability in the environment. A number of studies are underway to better understand the effects of microbial-contaminated microplastics in food chains and how they impact environmental health. For example, an ongoing laboratory study has been examining the effects of adding microplastics with different microbial loads to oysters and tracking their health and mortality in comparison with non-contaminated plastic exposure. Unsurprisingly, plastics with microbial contamination appear to have more negative effects on oyster health and mortality than non-contaminated microplastics. As Sir David highlighted in his recent SfAM Fellowship acceptance speech, as microbiologists we are central to finding new organisms capable of complex polymer degradation and better understanding the effects of microplastics on food chains and environmental systems. It is an exciting research area to be involved in!

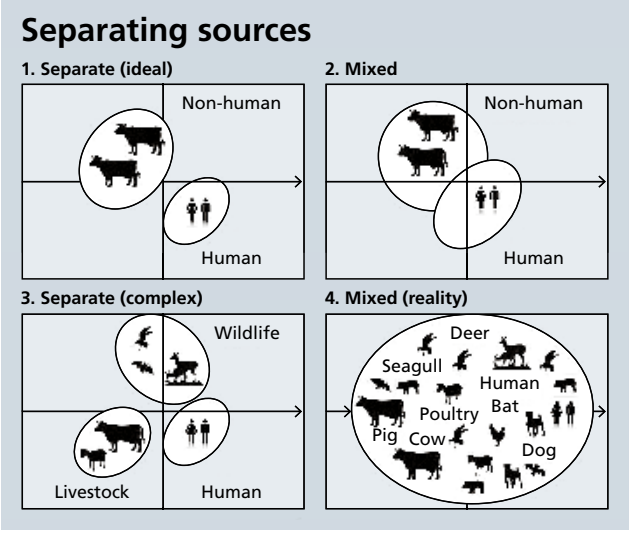
Figure 2 *above*
PETase crystal structure.
PHOTO ACKNOWLEDGEMENT: COURTESY OF PROFESSOR JOHN MCGEEHAN.

Tackling sources of contamination in water: the age of phage

James Ebdon

Reader in Environmental Microbiology and Leader of the Environment & Public Health Research and Enterprise Group (EPHREG), University of Brighton, UK

Microbial water quality is currently monitored in the European Union (EU) and throughout much of the world by identifying and enumerating specific groups of 'faecal indicator bacteria' (FIB), such as faecal coliforms and intestinal enterococci. However, although these FIB are shed by all warm-blooded mammals and indicate the presence of faecal contamination (and likely presence of certain pathogens), they tend to be less reliable indicators of viral pathogens, such as norovirus or adenovirus. Moreover, their inability to distinguish human from non-human sources of pollution in surface waters and groundwaters hampers the task of: (i) establishing the level of risk to public health; (ii) determining responsibility for remediation and (iii) identifying and targeting the most effective mitigation measures. Consequently, such limitations have driven global efforts to develop tools to identify the 'origin of faeces' and has led to the emergence of the field of microbial source tracking (MST) during the last 25 years.



Microbial source tracking

Researchers from the Environment & Public Health Research and Enterprise Group at the University of Brighton (in collaboration with colleagues from Barcelona University) have been at the forefront of this burgeoning field, developing novel low-cost bacteriophage-based MST approaches, with which to tackle a range of pressing issues affecting our water resources. The method is based on the detection of bacteriophages (phages) that attack common groups of bacteria, such as *Bacteroides* spp. found in our guts. Whilst high numbers of these obligate anaerobic bacteria are shed in our faeces, they do not survive for long once out in the environment. Fortunately, the phages which infect them fare much better once outside of the human gut and are not only highly host specific, but can also survive the journey through wastewater treatment plants. This means they have the capacity to indicate the presence of contamination from inputs such as treated wastewater effluents, sewer overflows and leaking septic tanks. Researchers in our group have also identified groups of phages that are restricted to certain non-human pollution sources, such as cattle and pigs. Our longer-term goal is to develop a 'toolbox' of phage-based markers, which will allow us to rapidly identify inputs from human, agricultural and wildlife sources.

Protecting water resources and human health

Interestingly, these phage-based tools are not only helping improve our understanding of the origin of different pollution sources, but are also shedding light on the very nature of phage–host interactions and on the behaviour of

Figure 1
Separating human and non-human pollution sources.

enteric viral pathogens in the environment and through engineered treatment systems (for example, wastewater treatment plants). For instance, working with the UK water industry (Thames, South East and Southern Water), an international non-governmental organisation (NGO) [Médecins Sans Frontières (MSF)] and numerous global research institutions we have successfully used phages to: (i) identify human contamination of river waters used for drinking water abstraction and recreation, (ii) elucidate human and non-human drivers of eutrophication (for example, harmful algal blooms) in drinking water reservoirs, (iii) assess the efficacy of emerging full-scale water reuse technologies used for irrigation and potential augmentation of potable water supplies, (iv) determine contamination sources impacting shellfisheries, (v) assess the efficacy of approaches for the containment and safe handling of human excreta in emergency settings (MSF), (vi) understand the human-to-human environmental transmission of typhoid fever in urban slums in India (Bill & Melinda Gates Foundation) and (vii) understand cattle-to-human transmission of childhood diarrhoea in rural Kenya (Medical Research Council).

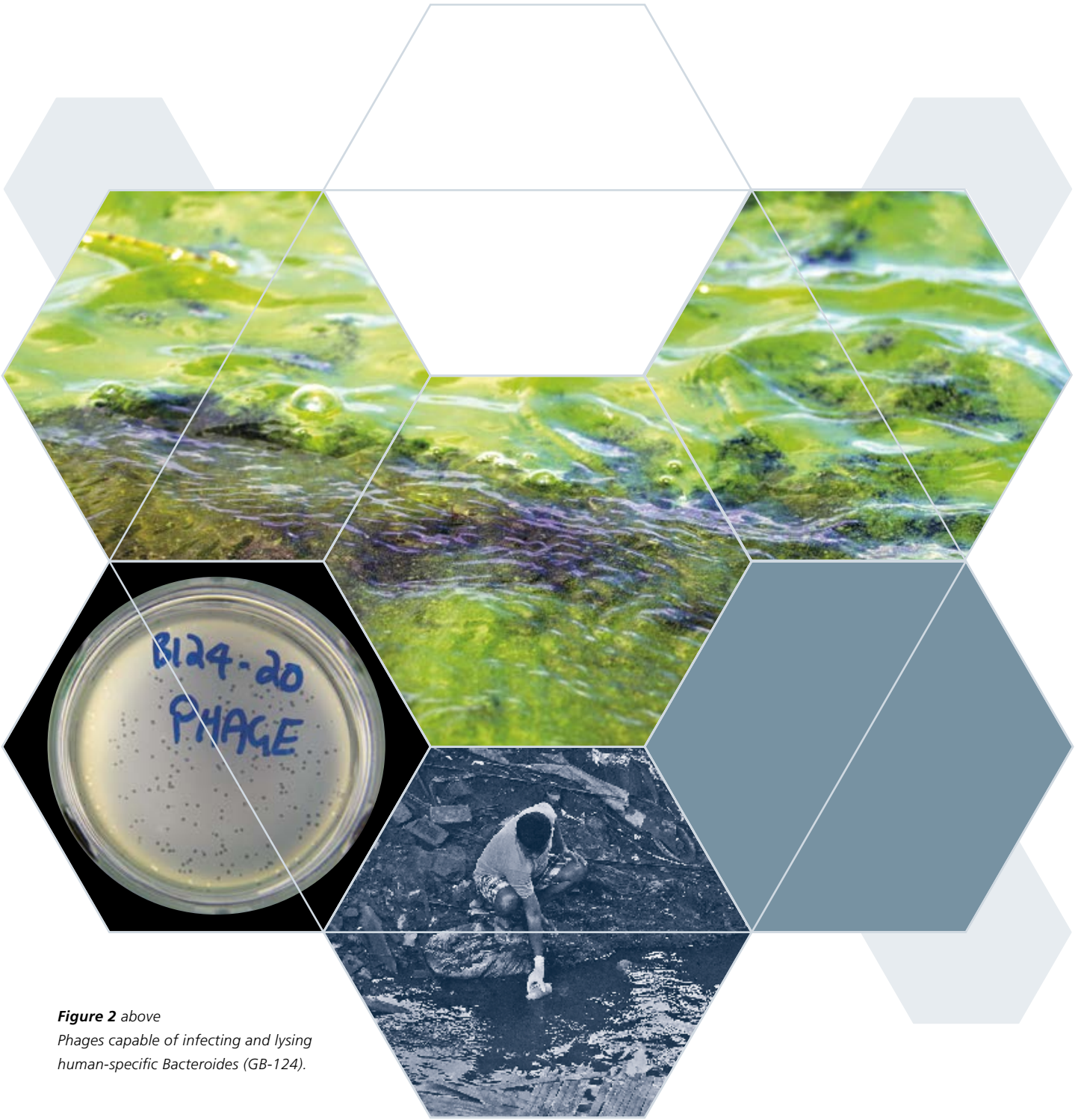


Figure 2 *above*
Phages capable of infecting and lysing human-specific Bacteroides (GB-124).

Wastewater reuse, South East London

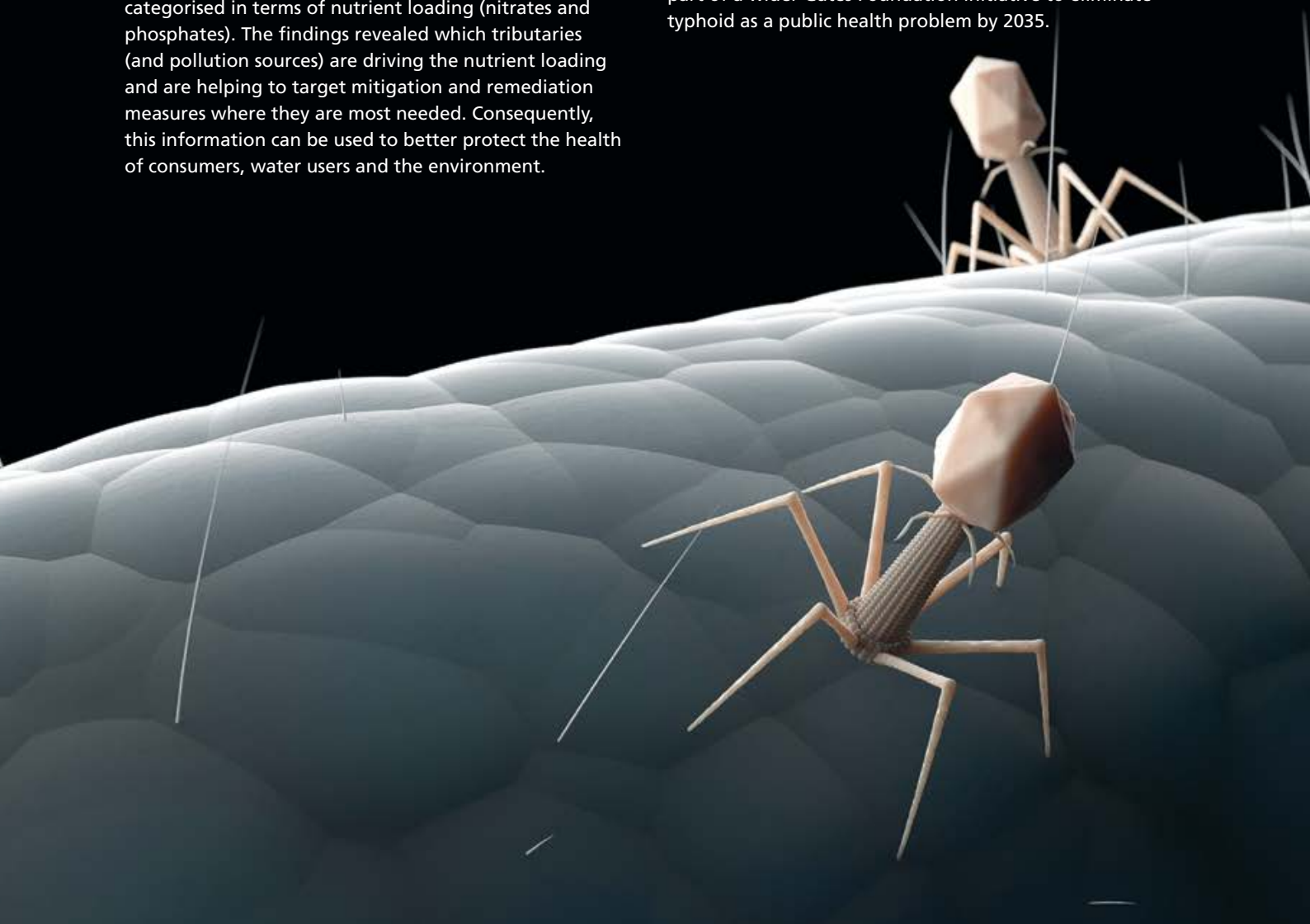
Working with Thames Water, we monitored pathogen and phage removal through the Old Ford wastewater reuse system [Membrane Bio Reactor (MBR)] at the former Olympic Park in East London (used at the time for park irrigation). We also challenged the MBR under 'worst-case scenario' conditions by spiking high titres of known phage into the system. Our findings highlighted what changes would be needed to the treatment system in the future in order to ensure potable quality (with respect to microbiological parameters) and helped to satisfy an International Panel of Experts that MBR technologies have the potential to adequately protect human health and reduce environmental contamination.

Reservoir protection, South East England

Working with South East Water, we have been elucidating the contribution of human faecal pollution sources to eutrophication processes responsible for algal blooms (Cyanobacteria) at two of their reservoirs in South East England. The catchments draining into each reservoir were assessed in terms of point and diffuse pollution inputs and categorised in terms of nutrient loading (nitrates and phosphates). The findings revealed which tributaries (and pollution sources) are driving the nutrient loading and are helping to target mitigation and remediation measures where they are most needed. Consequently, this information can be used to better protect the health of consumers, water users and the environment.

Contamination and disease prevention

Finally, phage-based methods are also being used to understand high-risk contamination pathways in low-income and emergency settings in India, Haiti and sub-Saharan Africa. For instance, we have used phages to help determine the efficacy of chlorine and lime-based methods for the safe containment and handling of human excreta in cholera treatment centres, Ebola treatment centres and refugee camps. These approaches are ensuring the NGOs are able to protect patients, staff and the environment from contamination and onward waterborne disease transmission. Phages are also helping us to identify human faecal transmission routes and should ultimately help prevent the environmental transmission of *Salmonella* Typhi and *Salmonella* Paratyphi A in Indian megaslums (Kolkata). Whilst direct pathogen detection is possible, high cost and technological difficulties mean that routine environmental surveillance can be challenging and/or prohibitively expensive. However, human-specific phages can help highlight hotspots of human contamination within the environment and target phage-based methods to replace existing expensive approaches. This project is part of a wider Gates Foundation initiative to eliminate typhoid as a public health problem by 2035.



The modern 'age of phage'

To summarise briefly, we are fortunate to be living in an exciting 'age of phage', where rapid advancements in metagenomic, metabolomic and bioinformatic technologies are fuelling improvements in our understanding of phage behaviour, abundance, diversity and function. What we as microbiologists do with this wealth of information remains to be seen – but one thing that is already clear is that phage can be used as a force for good when it comes to protecting both environmental and public health. By enhancing our ability to effectively target and mitigate environmental contamination at source, they are helping us to reduce the burden of waterborne disease and preventing the further degradation of our limited water resources.

FURTHER READING

Dias E, Ebdon JE, Taylor H. The application of bacteriophages as novel indicators of viral pathogens in wastewater treatment systems. *Water Research* 2017; 129, 172–179

Ebdon JE, Sellwood J, Shore J, Taylor HD. Detection of *Bacteroides* (GB-124) phages as a surrogate for pathogenic human enteric viruses. *Environmental Science and Technology* 2012; 46(2), 1163–1169

Ogilvie LA, Bowler L, Dedi C, Diston D, Cheek E, Taylor H, Ebdon J, Jones BV. Resolution of habitat-associated ecogenomic signatures in bacteriophage genomes and application to microbial source tracking. *International Society for Microbial Ecology Journal* 2017; 12(4), 942–958

Purnell S, Ebdon J, Buck A, Tupper M, Taylor H. Removal of phages and viral pathogens in a full-scale MBR: implications for wastewater reuse and potable water. *Water Research* 2016; 100, 20–27

Trajano Gomes da Silva D, Dias E, Ebdon JE, Taylor H. Assessment of recommended approaches for containment and safe handling of human excreta in emergency settings: how effective is it? *PLOS ONE* 2018; 13(7), 1–20

Pesticide contamination: what can microbiologists do?

James W B Moir
Department of Biology, University of York, UK

Agricultural production of food has more than doubled in the last century, enabled in part by use of pesticides and other agrochemicals. Each year over $30 billion is spent on the several millions of tons of pesticides used worldwide. A side effect of such crop protection can be contamination of the wider environment, impacting on the health of humans, other animals and ecosystems. Responsible governments thus have tight regulatory frameworks to monitor and control pesticide contamination, in the interests of maintaining both food security and water security. In the EU, this translates to tight regulatory limits on contamination of drinking water sources with pesticides.

What has any of this got to do with microbiology? Traditionally, very little. Preparation of raw (reservoir or river) water for drinking is treated as a physico-chemical rather than biological process. Regulatory analyses of pesticide fate in the environment do not take into account biological processes such as evolutionary adaptation, despite well-established evidence that accelerated biodegradation of pesticides arises in response to their historic or recent use.

Technology does not exist in a vacuum, and to inform and influence the development of technological solutions, microbiologists need to engage with stakeholders to understand the problems and consider the space in which solutions might exist. With respect to pesticides, these stakeholders include the water companies who are given responsibility for the provision of clean water, the farmers who use pesticides on their land, regulatory authorities who set out the policies for pesticide use, engineers who design water treatment plants and consumers who want clean water. The physical/chemical design and infrastructure of water treatment plants is just one element within a wider context of 'catchment management' in which water companies liaise with agricultural and industrial contributors to mitigate contamination risk.

Drinking water is not sterile and soil is the most microbiologically diverse structure known. Specialist soil bacteria that can degrade problem pesticides can be readily isolated and studied in the laboratory. It must be possible to harness the power of biological catalysis in this context to develop technological solutions to limit pesticide contamination. Three broad areas in which microbiologists might be able to use such natural resources to make an impact are: (i) treatment; (ii) diagnostics: and (iii) regulation and policy.

Treatment

We have been working recently on the pesticide metaldehyde, a cyclic ether that is not degraded by standard water treatment methods (such as granular activated carbon). However, bacteria that can degrade metaldehyde can be isolated and there is potential to use these in water treatment. There are considerable challenges with bioaugmentation of such organisms into water treatment plants, as the bacteria may not be retained or may not degrade the pesticide in the presence of other potential carbon substrates present in the water.

Feasibility of biological treatment needs testing at a variety of scales and using a variety of treatment settings, from municipal water treatment plants to the farm-scale field-side ditch. Knowledge and understanding of the underlying biological mechanisms will allow us to have smarter biological diagnostic tests of the degradation potential in a given setting. Imagine a quantitative PCR test for pesticide-degrading genes, which will add a new level of biological analytical richness to the water treatment process.

The persistence of pesticides in environments depends on physico-chemical factors and biological processes in the soil microbiome

Diagnostics

Current monitoring methods involve sophisticated logistics and laboratory-based high-end chromatography methods, which may not be translatable to field testing, or suitable for roll out to, say, developing countries with fragile institutional structures. Biological sensitivity and specificity offer the potential for the design of new biosensor-based diagnostics that can detect and quantify pesticide residues. Without completely presupposing the needs of stakeholders, microbiologists can set out a range of possible pathways to new diagnostics that might rely on microfluidics coupled to biophysical analysis methods, antibody-based sensors or strategies based on intact microbial cell live bioassays. A range of approaches for diagnostic development will enable us to develop tools that work in different settings, whether this is governed by cost, speed, robustness or other specifications that could be established by liaison with end users.

Regulation and policy

The persistence of pesticides in environments depends on physico-chemical factors in soils but also on biological processes in the soil microbiome. Taking into account the spatio-temporal variation in microbial activity will require collection of more data on the metagenomic predisposition for pesticide degradation and how this changes over time and across landscapes. This will also involve a paradigm shift for regulatory authorities, taking into account biological variables that have to date been sidelined in favour of the chemical/physical properties that have been easier to measure. Knowledge on degradation potential will also have the potential to impact on farmers' use of pesticides, to ensure best dose and most effective and sustainable use.

Ultimately, human chemical interventions in agriculture will continue to be required to achieve the increases in yield necessary to feed the world population. Application of microbiological research has the potential to enable sustainable use of pesticides and other agrochemicals, and to deal with the downstream contamination issues that arise.

FURTHER READING

To grasp the size and the complexity of the global use of agrochemicals, see

https://ourworldindata.org/fertilizer-and-pesticides

The effect of pesticide contamination was discussed eloquently over 50 years ago by Carson: Carson R. *The Silent Spring*. (New York, USA: Houghton Mifflin, 1962)

Fatbergs: microbes and the future of fats, oils and grease

Elizabeth Court [1] **Catherine Biggs** [2] **Graham Stafford** [1] **Raffaella Villa** [3]

[1] *University of Sheffield, UK*

[2] *Newcastle University, UK*

[3] *Cranfield Water Science Institute, Cranfield University, UK*

Background

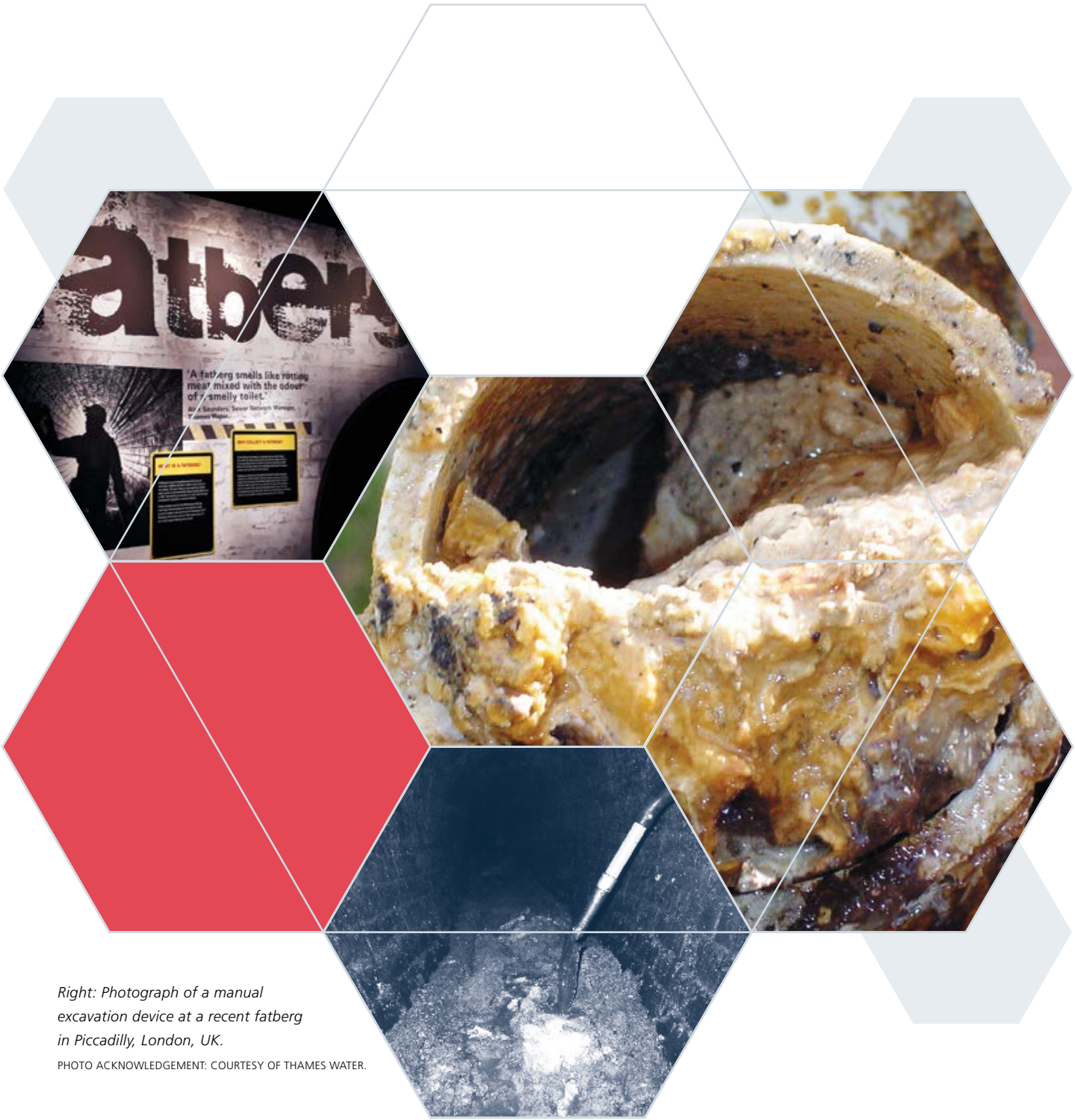
When fats, oils and grease (FOG) enter the wastewater system from both domestic and food-establishment sources they can lead, in conjunction with non-flushables such as wet wipes, to the formation of blockages, coined 'fatbergs' by Thames Water. These fatbergs have come into the national consciousness with the discovery of several high-profile mega-fatbergs, such as the Whitechapel Fatberg, now named by the public as 'Fatty McFatberg', which is on display at the Museum of London and was made famous in the Channel 4 *Fatberg Autopsy* documentary. This example reportedly weighed over 130 tons and was longer than Tower Bridge, measuring 250 m. In fact, Thames Water estimates that physical FOG removal costs over £1 million per month. In addition, blockages can cause flooding and release of sewage into the environment and thus pose public health and environmental risks alongside incurring extra costs and inconvenience to consumers.

The process by which fatbergs form after entering the sewer is still relatively poorly understood, but involves a dual process of solidification and saponification that results in deposits on sewer walls at water–air interfaces. Saponification is the process in which free fatty acids (FFAs) in the wastewater react, along with calcium and other minerals, to produce metal soaps that act as nucleation points for FOG, with further FFAs and minerals, alongside non-flushables such as wet-wipes and sanitary products, to cause blockages.

Current treatment and recycling regimes

When fatberg blockages form, the main procedure for removal and remediation is manual excavation, which essentially involves sending people into the sewers with a hose and a shovel to manually clear the blockage. This is dangerous, costly and time consuming; for example, trapped gas is a constant risk. The FOG material excavated from the sewers is usually discharged to landfill. However, Thames Water is currently collaborating with Argent Energy to process fatbergs to generate biodiesel as a new use for this otherwise waste product.

Clearly, a preferred solution would be to manage and reduce the FOG entering the sewer system and so stop the cause of the blockage at source. One solution is the use of grease traps or separators used by food service establishments (FSEs) to catch the FOG before they enter the sewers. These are containers, inside or outside the FSE premises, where the FOG are allowed to separate from the wastewater by gravity. The waste FOG collected from grease traps, and used cooking oil from fryers, are already used in many countries as renewable feedstocks for



Right: Photograph of a manual excavation device at a recent fatberg in Piccadilly, London, UK.

PHOTO ACKNOWLEDGEMENT: COURTESY OF THAMES WATER.

biodiesel production. In addition, some water companies have started social outreach and public education programmes to increase awareness of FOG's detrimental effects on the sewer system and, potentially, their water bills.

Microbiology: life at the tip of the fatberg

It will be no surprise to this readership that microbes may play a key role in the process of FOG deposition and may provide some solutions to the prevention and eradication of fatbergs in the future. It has been suggested that microbes play a part in the formation of the fatbergs, as it is the microbial production of FFAs and their leaching of calcium from the sewer pipe walls that provide the building blocks required for saponification to occur in the system. Isolates from sewer systems have been observed to form solid fat deposits when cultured with oil, suggesting some microbial activity may be involved in the formation of fatbergs.

Bacteria are able to degrade fats via the action of lipase enzymes that are secreted or present on the surface of the bacteria and cleave the fatty acids from the glycerol backbone. These released fatty acids are then transported into the bacterial cell via specific transporters and used in the cell metabolic processes. Inefficient or incomplete degradation of lipids can lead to the release of FFAs, which can contribute to FOG deposit formation.

However, the potential application of bacteria that degrade and completely remove FFAs from wastewater has great potential for bioaddition treatment. Numerous bacterial-based products have been used for FOG management, with many based on proprietary cocktails of bacteria used for other applications, such as lipase production or hydrocarbon degradation in the oil industry. These cocktails used by wastewater companies are largely based on environmental or type strains such as *Bacillus* and *Pseudomonas* species. Other products also exist that contain enzyme preparations but, since they may have short retention times and release FFAs with no onward degradation, their use has been limited. Many FSEs regularly use microbial additions for maintaining their kitchen drains free from deposits. In addition, bioadditives for FSE grease traps have been reportedly used successfully to increase the time between emptying.

Bioadditives have also been used in sewers to keep the pipes clean and to tackle the deposits, with mixed success, possibly due to inconsistent information on management, lack of stability in the environment in which they are to be deployed, and also a lack of technology transfer, that is, translation from lab 'ideal' conditions to a range of different and complex sewer environments. The main challenge is in translating bacteria's laboratory performances into predictions of efficacy in the wastewater system for how, when and where to use them; this is in need of more focused and in-depth research and development.

Bioadditives have been utilised in sewer systems for many years, where a variety of different products and application methods, including regular manual and automatic dosing in liquid and dry formats, have been used in the system and have been shown to be effective in reducing FOG in wastewater. However, so far, consistent prediction of the microbial activity of these products in different environments in the wastewater network remains a struggle and knowledge of how these products work in different sewer environments, such as pumping stations versus sewer pipework, is needed. One other factor is that there is very little information regarding the microbiology of this environment; nor have products been developed using bacteria actually sourced from FOG deposits.

Our work has begun to characterise the microbiome of fatbergs using next-generation sequencing techniques, uncovering a plethora of environmental bacteria residing at the fatberg surface, including *Aureimonas*, *Xanthomonas*, *Rhodobacter*, *Klebsiella* and *Acinetobacter*. Combining this information with a range of novel fat-degrading bacteria that our team has isolated from FOG deposits in London, including novel *Klebsiella* and *Serratia* species, we have also begun preliminarily testing the performance and efficacy of a FOG-degrading consortium in domestic wastewater rigs. This proof of concept highlights that a more targeted and tailored consortium approach to address the FOG problem might yield greater success.

FURTHER READING

Wallace T, Gibbons D, O'Dwyer M, Curran TP. International evolution of fat, oil and grease (FOG) waste management – a review. *Journal of Environmental Management* 2016; 187, 424–435

He X, de los Reyes FL, Ducoste JJ. A critical review of fat, oil and grease (FOG) in sewer collection systems: challenges and control. *Critical Reviews in Environmental Science and Technology* 2017; 47(13), 1191–1217

FOG detection: an oily issue

Finally, one aspect of FOG management in wastewater systems is in the detection of increased FOG in effluents. Surprisingly, accurate and easy detection of FOG is not simple, with specialised laboratories being needed to carry out these assays off-site. Again, bacteria may hold the answer, with many bacteria harbouring sensitive and accurate FOG detection systems, such as the Fad system of *Escherichia coli*. Given recent advances in biosensor and synthetic biology applications, it is possible that biological-based fat sensors with colorimetric outputs may have the potential for simple 'sewer-side' tests for levels of FOG in the environment. However, the challenge of translating these results from the laboratory to the real world still remains.

The potential for bacterial applications to FOG degradation and/or detection and the management or removal of fatbergs is great, offering exciting research, development and commercial opportunities. Further knowledge and investigation into fatberg (micro)biology, alongside engineering translation in a real-world context, would greatly increase the likelihood of a tailored product designed specifically for the different and complex environments in which it would be used.

This work is part of the EPSRC Grand Challenges Twenty65 programme investigating novel ways to innovate the water sector that positively impact public health, the environment, the economy and society.

Our work has begun to characterise the microbiome of fatbergs using next-generation sequencing techniques

An interview with

Sir David Attenborough

There was a ripple of barely controlled excitement when Sir David Attenborough stepped into the room at BMA House in London to accept his Fellowship from the Society for Applied Microbiology. People craned to see his snowy thatch of hair and then grinned with the giddy enthusiasm of toddlers meeting a superhero. Aled Roberts, Jennie French, Alli Cartwright and Temilola Olukayode (members of the Society's Early Career Scientist Committee) had the nerve-racking job of pitching their questions to Attenborough.

Aled: you have been in the field of conservation for a long period of time and have met many people. One of them is a good friend of mine and you met her in 1960 when she was 8 years old. It was a World's Most Dangerous Animal exhibition at a Wildlife Wetlands Trust. She was able to ask you what you thought was the most dangerous animal in the world. She expected to hear 'lion' or 'spider' or 'snake'. To her amazement you lifted her up, plonked her down in front of a mirror and said, 'You! You are the most dangerous animal on the planet.'

So, Sir David, after 60 years do you still agree with that?

Sir David: oh yes, on every level. The only time I've been really frightened is when I was faced with another human being, who spoke a different language to mine – and he had a gun. He had a little too much to drink. And he didn't like the look of me. That's a dangerous thing. I never met an animal that really frightened me more than that.

There are exceptions. Tigers will eat human beings, that's true. But for the most part, animals don't attack out of anger or aggression; they attack for a reason. The reason is either they are hunting, or you are threatening them. Well, you needn't threaten them. There are certain circumstances where you have to make it clear that you are not threatening them – if you are with a big gorilla, or even more so, with a big male chimpanzee. Gorillas are vegetarians. By and large, vegetarians aren't ferocious. But chimpanzees, they will eat anything. And they are very ferocious.

I once was extremely stupid. REALLY stupid. I'd been filming with chimps for a few days, and it was an habituated troop. I got used to them and they got used to me, in as much as what they did was nothing. They ignored me. One morning I was sitting with a group. They were sat in a line, involved in mutual grooming. I was sat at the far end watching them. Just stroking one another, picking off little beads of salt. I very foolishly touched the end chimp and there was a shriek of anger and the whole thing suddenly changed. It's a good job they didn't set about me, because they are very, very ferocious.

It was probably one of the silliest things I've done, but it's the only time I've really been endangered by an animal.

Jenny: do you get to choose any of the locations you go to?

Sir David: certainly in years gone by, when I would write scripts for a whole series I chose the loveliest places to go to. But these days, a programme like *Blue Planet* or indeed any of those big series, involves 30-odd cameramen, working for 3 years. And you can't be with 30-odd cameramen for 3 years.

My contribution to the series over the last 10 or 20 years has been almost entirely finding the right words to say and then recording them.

Temilola: how have you been able to sustain your passion over all these years?

Sir David: it's the easiest job in the world. Finding out what goes on, how it goes on and why it goes on is of tremendous interest to me. When I was younger, in my 20s and 30s, when I first started to travel and make natural history films, every opportunity was a privilege! Nobody had really exploited the natural world for film. When I went to Madagascar, in the mid-1960s, there was no film of any kind of any living creatures in Madagascar. Not a thing.

The only illustrations I could find were stuffed specimens in Paris, because Madagascar had been a French colony. When I wanted to look at things like indri, the biggest of the lemurs, that was the first time they'd ever been filmed. What a privilege! What a joy! What a delight!

Natural history films used to mean just big game: elephants, giraffes, rhinos and so on. Things like galagos or aardvarks, you wouldn't ever see them. The opportunities were wide open back then.

I had the time of my life, and I haven't stopped actually.

Jenny: what is the most unusual thing to happen in your career?

Sir David: I suppose if I take the question literally, the most unusual thing to happen to me was to become weightless. That's an amazing experience. I made a series called *Living Planet* and we looked at every biotope and every environment. I wanted to study the effect of atmospheric pressure on organisms.

I discovered that National Aeronautics and Space Administration (NASA) trained astronauts in a specially strengthened 707 aircraft that flew in a parabola. The speed at which you go down matches the gravity so that you actually float for about eight seconds. And that's exactly what we did. It worked like a charm too.

I can tell you that after about 18 or 19 times you've really had as much as you need. They had a team of volunteers who would call it the 'vomit comet'.

Temilola: if time travel were possible and you could go back in time, what would you like to see?

Sir David: I would like to go back to the Late Cretaceous to see the pterosaurs, the flying reptiles, the most famous of which, the pterodactyl, was relatively small. Pterosaurs, which is the name of the whole group, contained one creature called *Quetzalcoatlus northropi*. A wing bone, found in New Mexico, compared with the wing bone of other pterodactyls, estimated its wing span to be about 30 feet. 30 feet! Just imagine it! It would be remarkable. I can see how it glided, like an albatross. But how did it get into the air?

You can't beat wings as long as that, because you'll hit the ground. People say, 'Oh, well they lived on cliffs.' Really? Huge creatures like that? Lived on cliffs and had to get back to the cliffs? Sounds a bit strange. There is a possibility that they had enormous muscles in various parts of their legs, which would enable them to jump into the air and then in that moment spread their wings. But even that…anyway...Late Cretaceous, I'd go back there and see how *Quetzalcoatlus northropi* gets in the air.

Alli: what is the longest time it's taken you to capture an animal on film?

Sir David: about 10 minutes! Because I don't do the work. That is the terrible injustice of what I do. As I said earlier, 30 cameramen work on one of the big series. I don't use a camera at all now, marginally did in 1954, but I'm not a cameraman in the way these specialist guys are. They have the patience of Job. There was a time when snow leopards had never been filmed and one of my good friends, Dougie Allen, was despatched to the Himalayas. He worked solidly for about three months and still didn't even see one. The snow leopard stuff you see now is because scientists put on electronic tags. Then you know exactly where it is. So, we're getting better. The big advances of the past 10 or 20 years include electronic tags, heat sensitive film (and cameras), drones and night vision cameras.

Dylan Morse (12): Sir David, my question to you is, what challenge facing the conservation of our planet would you like to see solved by someone of my generation?

Sir David: convincing the people of the world, and that means a lot of people in China, India and Africa, as well as those in Europe and America, that producing energy by burning coal, oil or petrol is a disaster which is going to cause the world to heat up. The really sad thing is that, scientifically, we have all the energy we want from renewable resources (the wind, and the sun, and the sea, the tides). We know how to store it. We know how to transmit it. Although storing it is quite a big challenge. With electricity, we know it theoretically but what we need is the scientific engineers to work out the ways in which we can do it. Then we need to organise the world to collect energy from the sun, so that what shines in the Sahara in Africa, could be brought here with a minimum loss in terms of transmission and stored for us to use. If we do that all round the world, which is absolutely theoretically possible, we will stop heating up the atmosphere and stop climate change.

There's one thing that worries me about that answer. Do human beings have the common sense and self-control to use unlimited power (which is what would come from the sun) and use it for sensible things rather than foolish things.

They had a team of volunteers who would call it the 'vomit comet'

From molecules and cells to global images

Having failed Biology at O-level but being competent in chemistry, maths and physics, I chose to study for a BTech in Industrial Chemistry at Loughborough with a university apprenticeship from BP. I took subsidiary microbiology and persuaded BP plc to further support me as a research student at King's College London where I took a PhD and subsequently a DSc in Microbiology.

Origins of life

I studied hydrocarbon production by microorganisms and one of them, *Methylococcus capsulatus* growing on methane as its sole source of carbon, had 0.55% of its cell weight composed of squalene, which is the precursor of steroids and hopene. The definition at the time ruled that steroids did not exist in prokaryotic cells. In searching for them I found unusual methyl-sterol structures in the extensive membrane system of *M. capsulatus*. The fully saturated forms, steranes and hopanes, had been found in ancient oil shales and sediments, indicating that the methylotroph could have existed at that time and be one of the oldest life forms on the planet. A paper to *Nature* on the finding provided the groundwork for my career in applied microbiology.

Soils and plants

My first job was at the Letcombe Laboratory near Oxford where I was asked to investigate the formation in soil of a gaseous hydrocarbon, ethylene, which is a plant growth regulator. The fungus *Mucor hiemalis* was identified as the cause, using methionine in plant residues as the substrate, and this resulted in more papers to *Nature*. I investigated a range of other microbial processes affecting plants and developed research on lignocellulolytic processes, which could be harmful to plants but also beneficial to soils as composts, and demonstrated that a cellulolytic fungus which grows on straw, *Trichoderma harzianum*, could cooperate with an anaerobic bacterium, *Clostridium butyricum*, in the presence of polysaccharide-producing *Enterobacter cloacae*, to fix dinitrogen in a wide range of oxygen states. The process of rhizodeposition was also described, where ~40% of the photosynthate captured by plants is released by roots and made available to microorganisms. I became a part-time lecturer in soil microbiology at the University of Oxford and termed the course I delivered *Soil Biotechnology*, which was the first time the terminology had been used. The book based on the course had multiple printings in four languages.

Jim Lynch OBE

Distinguished Professor of Life Sciences,

Centre for Environment and Sustainability, University of Surrey, UK

Biocontrol, genetically modified microorganisms and microbiomes

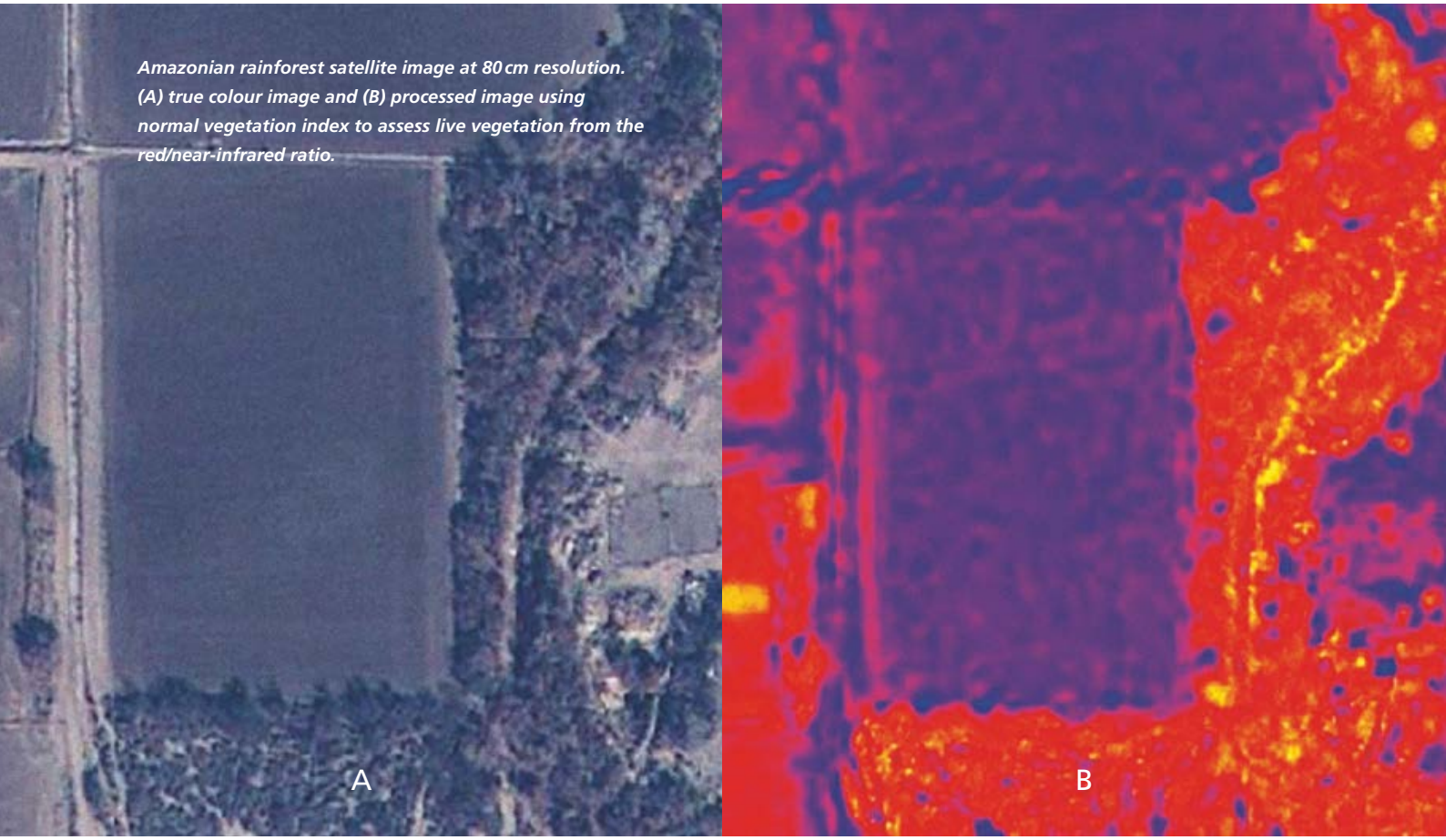
From Letcombe I moved to Littlehampton as Head of Microbiology and Crop Protection at Horticulture Research International (HRI), Visiting Professor of Biotechnology at King's College London and Visiting Professor of Soils at Washington State University and Oregon State University. The work on lignocellulolysis and the rhizosphere was continued. HRI was also effectively the National Mushroom Research Centre and mushroom production is dependent on effective composting. My focus at HRI was the rhizosphere and particularly how to use microorganisms to control plant diseases and stimulate plant growth using the concept of the microbiome. I quickly realised that the opportunity to achieve this might be enhanced by genetic modification but that the environmental impact would need to be assessed. As such, the first releases in the UK of a free-living genetically modified microorganism (GMMO) were carried out at sites in Littlehampton and Oxford, leading to many papers, including one in *Nature Bio/Technology*. I was then invited to become the Head of Biomedical and Life Sciences at the University of Surrey and while there I shared the UNESCO Microbiology Prize. The only other Briton to win this prize was Cesar Millstein for his work on monoclonal antibodies.

Sustainability

The Organisation for Economic Co-operation and Development (OECD) in Paris developed a Co-operative Programme on Biological Resource Management for Agricultural Sustainability and I was elected as co-ordinator over a period of 17 years. This involved visits three times per year for workshops in most of the OECD countries, as well as funding about 80 binational fellowships annually. This work led to the award of Order of the British Empire (OBE) by the UK.

Trees and Earth observation

I was invited to become Chief Executive of the Forestry Commission Research Agency while retaining my position at Surrey as Distinguished Professor of Life Sciences in the Centre for Environment and Sustainability. Tree diseases were a major issue and it seemed to me that the onset of disease might be detected from space using satellite technology. When I joined the Board of the European Forest Institute, it also became clear that Earth observation was the only sensible route to monitor the global sustainability issue of deforestation. Surrey Satellite Technology Limited was a world leader in building small satellites that could be used for such purposes and so I joined its subsidiary DMCii as Director of Forestry, writing



Amazonian rainforest satellite image at 80 cm resolution. (A) true colour image and (B) processed image using normal vegetation index to assess live vegetation from the red/near-infrared ratio.

a paper to *Nature* identifying that opportunity. Today, I am working with another Surrey company, Earth-i, as Head of Global Landscapes using the DMC3 constellation and others at very high resolution (less than 1 m), as well as constructing constellations with video imagery. I have also been Visiting Professor at the University of Helsinki and currently I am Visiting Professor of Sustainability at Imperial College London.

It may seem a strange path to move from looking at cells at the microscopic and molecular level to looking at images of Earth from space, but the skill base is connected, especially with the advent of machine learning and artificial intelligence, giving scope for a disease-free sustainable world. There is a significant place for microbiologists in an interdisciplinary world. Working as a Fellow of the Royal Society of Chemistry, the Royal Society of Biology, the Royal Geographical Society and the Royal Society of Arts, I have enjoyed interdisciplinary work greatly and this has given me the scope to produce over 300 papers and 16 books and to collaborate with many fine students and colleagues, as well as generating so many friendships nationally and globally.

FURTHER READING

Bird CW, Lynch JM, Pirt SJ, Reid WW, Brooks CJW, Middleditch BS. Steroids and squalene in *Methylococcus capsulatus* grown on methane. *Nature* 1971; 230, 473–474

De Leij FAAM, Sutton EJ, Whipps JM, Fenlon JS, Lynch JM. Field release of a genetically modified *Pseudomonas fluorescens* on wheat: establishment, survival and dissemination. *Bio/Technology* 1995; 13, 1488–1492

Lynch JM, Maslin M, Baltzer H, Sweeting M. Sustainability: choose satellites to monitor deforestation. *Nature* 2013; 496, 293–294

Lynch JM. Ethylene in soil. *Nature* 1975; 256, 576–577

Lynch JM, Harper HT. Ethylene and soil fungistasis. *Nature* 1974; 251, 259

Veal DA, Lynch JM. Associative cellulolysis and dinitrogen fixation by co-cultures of *Trichoderma harzianum* and *Clostridium butyricum*. *Nature* 1984; 310, 695–697

Earth observation was the only sensible route to monitor the global sustainability issue of deforestation

East London's microbiota: saving Churchill

Martin Adams
SfAM President 2011–2014

One might not expect the names of Winston Churchill and Dagenham to occur together in a word association exercise, but there is a notable microbiological connection between the two. It seems that Churchill, a pillar of the ruling class born in Blenheim Palace, may well have owed his life to this less exalted area of East London.

Dagenham has other claims to fame: the Becontree estate, at one time the largest area of public housing in the world; the Ford Motor Company, which, at its peak, employed 40,000 workers in a plant boasting its own steel foundry and deep water port; and it has also been the source of a long line of footballing talent including such luminaries as Sir Alf Ramsey, Jimmy Greaves, Terry Venables, Bobby Moore, Martin Peters and John Terry. But, more importantly for this story, Dagenham was the home of May & Baker (M&B), a company founded in 1834 in Battersea in South East London as a manufacturer of fine chemicals, and which moved to Dagenham in 1934. It was here that they developed the sulfonamide M&B693 claimed to have saved Churchill's life.

In December 1943, Churchill flew to Tunis in North Africa on an exhausting trip that had already included Tehran and Cairo and was planned to continue to Italy. In Tunis he complained of a sore throat and later developed a fever. A portable X-ray machine allowed his doctor, Charles Wilson (later Lord Moran), to diagnose pneumonia, recording in his diary, 'It means we can begin giving him M&B straight away'. In his war memoirs Churchill states 'The M and B... did the work most effectively. There is no doubt that pneumonia is a very different illness from what it was before this marvellous drug was discovered.' The drug referred to is generally said to have been the sulfonamide M&B693.

The first sulfonamide was Prontosil, a red azo dye discovered by Gerhard Domagk at Bayer in Germany while pursuing the mistaken hypothesis that coal-tar dyes that can bind preferentially to bacteria could be used to treat bacterial infections in the body. Domagk reported Prontosil's efficacy against the streptococci causing puerperal and scarlet fevers in 1935 and had patented his discovery 3 years earlier. Later work, however, at the Pasteur Institute established that the Prontosil molecule was in fact a pro-drug – one that is metabolised in the body to generate its active constituent – in this case, sulphanilamide. Sulphanilamide acts as a competitive inhibitor of dihydropteroate synthase, an enzyme involved in the production of folic acid, an important

It was here that they developed the sulfonamide M&B693, claimed to have saved Churchill's life

coenzyme involved in the biosynthesis of purines and pyrimidines. Humans and other mammals get their folate from dietary sources and are therefore less affected by the drug's action.

As a result of the French work, Bayer were unable to protect their discovery since the active component, sulphanilamide, was a relatively well-known compound and the subject of an earlier, expired patent of 1909. Thus a promising field of research was open to all, including May & Baker who started a programme under the direction of Dr Arthur Ewins in 1936. This followed a familiar but laborious course of synthesising numerous sulphanilamide derivatives and testing their clinical efficacy: a procedure for which they recruited Dr Lionel Whitby from London's Middlesex Hospital. On 2 November 1937 the aminopyridine derivative of sulfanilamide, compound number 693, was made and later shown to be effective in the treatment of pneumonia. In the following 6 years of research, 3,000 compounds were synthesised and May & Baker found a further five sulfanilamide derivatives with useful therapeutic activity.

Bench where M&B693 was first made.

PHOTO ACKNOWLEDGEMENT:
COURTESY OF VALENCE HOUSE ARCHIVES &
LOCAL STUDIES CENTRE, DAGENHAM.

> He was overweight, a heavy smoker and drinker (and, one presumes, a stranger to the gym)

Somewhat surprisingly, in view of the efforts now expended conferring suitably impressive names on new drugs, the laboratory name M&B693 persisted. Some attempt was made to give it a little more cachet when, in the 1940s in 'Notes on M&B Specialities', M&B693 sported the additional designation of 'Dagenan', presumably in misspelt homage to the town, but this was short-lived and in subsequent editions the name reverted to just M&B693.

As with so many things, the Churchill story is slightly more complex than is often told. In 1943 Churchill was in his 70th year and in what can fairly be described as a stressful job. He was overweight, a heavy smoker and drinker (and, one presumes, a stranger to the gym). He was clearly vulnerable and had had an earlier bout of streptococcal pneumonia in February 1943. According to a recent account of the February infection, based on the unpublished war diary of a nurse attending him, he was prescribed sulphathiazole (also known as M&B760) rather than M&B693. The same authors have also published an account of Churchill's December, more serious, pneumonia where, based on other unpublished sources – an autobiography and a war diary , they state that Churchill was in fact given sulfadiazine in Tunis, a drug introduced by American Cyanamid in 1940. This may change an oft-repeated story, though it remains that both Churchill and his doctor refer in their published accounts of the episode to 'M&B' (without designating a particular number). Whatever the truth in this instance, M&B693 undoubtedly saved many lives in the course of its use, since with the introduction of sulfonamides in the early 1940s, mortality from streptococcal pneumonia fell from 40% to 10%.

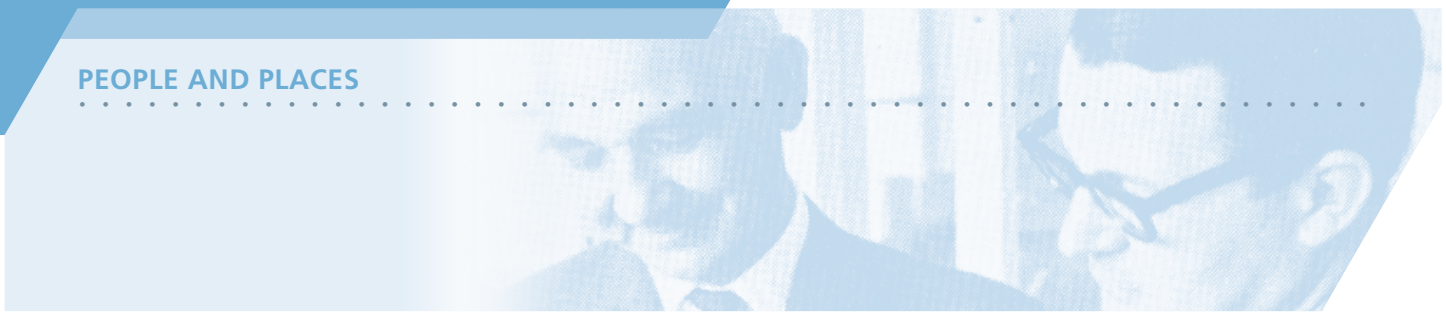
Though Ford remain in Dagenham in a much reduced presence, the May & Baker factory has gone. The company had become a wholly owned subsidiary of Poulenc Frères, later Rhône-Poulenc, in the 1920s and ended its life in Dagenham in 2013 as Sanofi-Aventis. The name lives on, however, in May & Baker Nigeria and in a Dagenham-based football team playing in the Eastern Counties League, from whose ranks, who knows, another Bobby Moore may emerge.

FURTHER READING

Vale JA, Scadding JW. *Journal of the Royal College of Physicians of Edinburgh* 2017; 47, 388–394

Lab test book recording M&B693 (Biological data is recorded on right hand page).

PHOTO ACKNOWLEDGEMENT: COURTESY OF VALENCE HOUSE ARCHIVES & LOCAL STUDIES CENTRE, DAGENHAM.

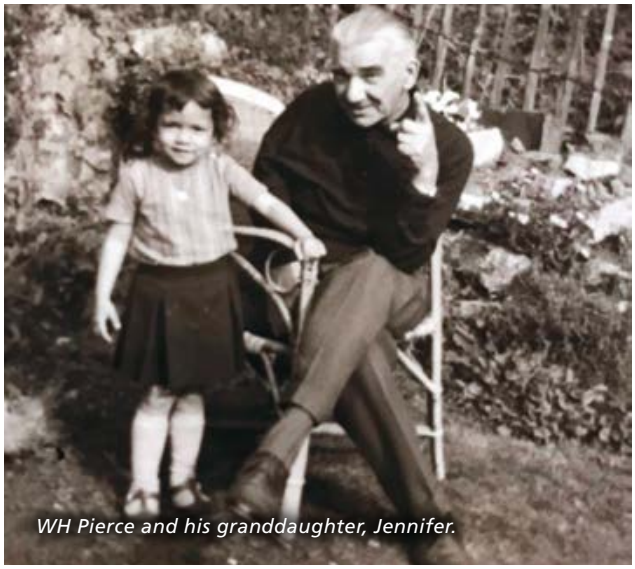


WH Pierce: the scientist behind the prize

Nicola Williams
Junior Research Scientist, Green Biologics Ltd, UK

Introduction

Every year, at the SfAM Annual Conference, a prize is awarded to an outstanding scientist who has made a 'substantial contribution to applied microbiology'. This prize is in honour of William Henry Pierce (known to many as Bill Pierce), who made a substantial contribution of his own to microbiology. His work at Oxo Ltd, developing dehydrated extracts for making bacterial culture media, had a significant impact on industry and made bacterial culture faster, more efficient and more reliable. His inventive and generous nature further increased the impact of his achievements, as many scientists directly benefited from media and culture samples he sent to them. In fact, scientists across many industries and countries still benefit from Bill Pierce's work today, as the dehydrated extracts that are now commonplace in laboratories have evolved from what Bill Pierce pioneered.



WH Pierce and his granddaughter, Jennifer.

All of this is of particular importance to me as Bill Pierce was my great-grandfather. As a current early-career member of SfAM, I have been able to learn more about the impact of my great-grandfather's work on applied microbiology and even meet with recent winners of the prize. I would like to share with you some more information about the scientist behind the annual WH Pierce Prize, which I hope will be of interest to all members of SfAM who can nominate for the prize through the SfAM website.

A 'cultural revolution'

Whilst working in the lab, I have taken it for granted that I can quickly prepare liquid culture media by simply mixing various dried extracts, for example tryptone and yeast extract, with water and then autoclaving. However, media preparation wasn't always this easy.

The development of the Oxoid dehydrated culture media ingredients that I use in the lab was a major part of my great-grandfather's work, starting when he joined the company in the early 1920s.

Oxoid culture media products originated from a method developed by the organic chemist Justus von Liebig, who developed a protein and vitamin-rich beef extract from boiling cattle meat for use as a nutritious, more affordable meat stock alternative to buying meat. This was later known as Liebig's Extract of Meat, which later went on to be sold commercially as LEMCO (Liebig Extract of Meat Company). The company later became Oxo Ltd, whose products included food derived from the beef extracts (the origins of the Oxo cube).

When my great-grandfather was working in the Oxo bacteriology group, a dehydrated version of the beef

extract was being developed that would be suitable for consumption by hospital patients. The aim of dehydrating the meat extract was to increase shelf life (compared with liquid broth) and to produce extracts in larger batches, which could be conveniently re-transformed into broth by dissolving the powder in water.

However, there were a few technical issues with the dehydrated beef extract. For example, it is said that the rehydrated broth didn't taste very pleasant! My great-grandfather then suggested that they could use this unappetising broth to grow bacteria; perhaps the bacteria would be less fussy?

It was a success; the bacteria loved this new broth and the dried extract was later marketed as dehydrated peptone. This led to a 'cultural revolution' of sorts, which aside from making culture media production far more efficient, had significant impact in many fields.

The dehydrated peptone had vital applications in food safety testing and diagnosing bacterial infections in hospital patients. Oxo used their new extract for testing their food products (Oxo), including tinned meats that were consumed by soldiers on the Second World War battlefields. It was also vital for diagnosing septicaemia;

in an emergency, no one could afford to wait for fresh extracts to be produced by boiling cattle meat. In this way, dehydrated beef extracts offered a life-saving solution.

The success of the new dried peptone led to a significant development in culture media production, leading to a new line of Oxo products. My great-grandfather went on to further develop and optimise the new dried extracts that were used to make culture media, eventually progressing to become chief bacteriologist at Oxo. When he retired, the company became Oxoid Ltd, continuing to produce the dehydrated extracts for culture media.

Some interesting stories

I would also like to share some interesting facts about my great-grandfather, involving his life outside of the laboratory. These were nevertheless invaluable assets for his career.

Aside from optimising the production of dehydrated extracts for culture media, my great-grandfather was an avid inventor. One example of his efforts was an incubator constructed from an old biscuit tin! The incubator consisted of a light bulb attached to the inside of the

biscuit tin, painted black to allow effective heat radiation whilst protecting any bacteria from light radiation. There was even a thermostat, which would turn the bulb off when the correct temperature had been reached. This served as a portable, simple but effective incubator that would be perfect if you were sampling microbes out in the field with limited resources (and perhaps a supply of biscuits).

My great-grandfather was also an expert in constructions using Meccano, a combination of miniature pulleys, gears and various other parts for budding mechanical engineers.

At the 2016 SfAM Annual Conference in Edinburgh, I was lucky to see a Meccano spiral plater. I showed my mother, to which she replied, 'That's so much like my grandfather!' Once again, this highlights the resourcefulness that is so invaluable to science, no matter what the era!

Another passion of my great-grandfather's was radios; he even referred to himself as 'radio mad'. By constructing his own radios out of various parts he observed the inner mechanisms of these machines, which no doubt helped him with his Meccano constructions and his role in research and development at Oxo. My family recalls that there was an entire room in my great-grandfather's house dedicated to his radios, at various stages of construction!

Bill Pierce had also progressed to chief bacteriologist at Oxo without any degree in science. His very first job was a general assistant at a Mercedes office; after that, he joined Oxo as a laboratory assistant and worked up the ranks. It is reassuring to think that the most important ingredients for groundbreaking research are passion for the subject and an inquisitive mind.

Aside from constructing Meccano creations and radios, my great-grandfather was a fantastic storyteller and artist. My mother recalls that he produced children's stories, with his own illustrations, and could invent stories for his grandchildren for hours on end. My grandparents also have some of his artwork, my particular favourite being a painting of two women working in a rice paddy field. I imagine that this creativity also inspired his inventions and science communication with others in his field.

To conclude, Bill Pierce was a bacteriologist who used his creative nature to make significant developments to bacterial culture methods. Whether it is in hospitals, food safety testing or small biotechnology labs, dehydrated media ingredients now have a vast number of applications worldwide. Additional traits that made Bill Pierce such an innovative scientist were his passion for microbes and machines, his creative mind and generosity towards fellow scientists. Such collaboration and openness add real value to science and accelerate progress across multiple fields, even today.

FURTHER READING

Dixon B. The media man. *British Medical Journal* 1994; 309, 545

Elstub J. *Oxoid Story* (article extract, unknown source)

Pierce WH. *An Unusual Industry*: talk to Southwark Council Executives and Chamber of Commerce, 1964

Pierce WH. A simple incubator. *Laboratory Practice* 1965; 14, 1058

Journal of
Applied Microbiology

Background levels of microorganisms in the busy urban environment of transport hubs.

Patel KV, Bailey CL, Harding A-H, Biggin M, Crook B. Background levels of microorganisms in the busy urban environment of transport hubs. *Journal of Applied Microbiology* 2018; 125, 1541–1551

Available at

https://onlinelibrary.wiley.com/doi/abs/10.1111/jam.14063

As busy commuters make their way through our crowded railway stations, how many of them are aware of the microorganisms to which they are exposed? In winter they will be fully aware of transmissible infections including coughs, colds and influenza, but what else is typically present?

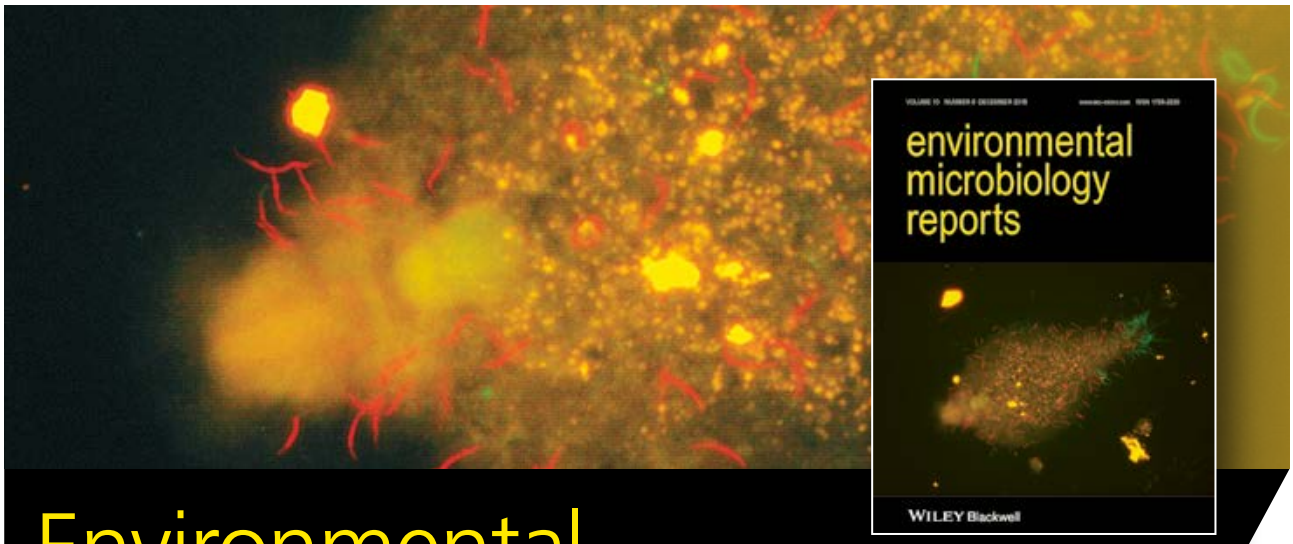
We constantly interact with microorganisms, mostly by inhaling them in highly populated public places, but data on everyday exposure to background levels is limited. Knowing the background levels of microorganisms to which people are exposed daily would provide a baseline against which to gauge high-level exposure and possible health consequences.

To address this, microbiologists from the UK's Health and Safety Executive (HSE) collected settled dust from railway stations and enumerated bacteria and fungi. Samples were taken from predetermined surfaces over a 52-week period.

The study generated a comprehensive database and the information will be used as a point of comparison to facilitate clean-up following possible contamination events.

An additional resource from the project is the archiving of the environmental samples which could be exploited in future work, such as using genomic sequencing to provide greater detail of microbial diversity.

Brian Crook Krusha Patel
HSE Science Division Microbiology Team, Derbyshire, UK



Environmental Microbiology Reports

Tuberculosis (TB) has plagued humans for millennia, culling Egyptian pharaohs and American presidents.

Sinha P, Hochberg NS. Crystal ball: the yesterday and tomorrow of tuberculosis. *Environmental Microbiology Reports* 2018 (Epub ahead of print)

Available at

https://onlinelibrary.wiley.com/doi/abs/10.1111/1758-2229.12726

The End TB strategy aims to cut TB deaths by 95%, decrease TB incidence by 90% and to eliminate the catastrophic costs incurred by TB patients and their families. The audacity of this enterprise is on a par with the mission to put human footprints on the moon. However, the End TB strategy might have fallen short by focusing largely on TB diagnostics, treatments and vaccine development.

Sir William Osler, who confronted TB before the invention of antimycobacterial therapies, concluded that TB was 'a social disease with a medical aspect'. Poverty, alcoholism, overcrowding and undernutrition have been well-established TB risk factors for decades. While HIV and diabetes mellitus (DM) have garnered increased attention as risk factors for TB disease, undernutrition remains understudied. This is a glaring knowledge gap as undernutrition has a population-attributable fraction larger than HIV and DM combined. Even as we develop novel tests and therapies for TB and integrate DM and HIV care into TB programmes, we imperil our efforts by ignoring Osler's insight.

This crystal-ball piece presents some of the evidence that connects undernutrition to increased TB incidence, severity, treatment failure and mortality. Further, it identifies the limitations of the existing data on nutritional supplementation as an adjunct to antimycobacterial therapy. Several questions concerning nutrition in persons with TB disease require elucidation. This review highlights some of these questions and makes some suggestions regarding research methodology.

The essay concludes by exhorting the global community of TB researchers, public health advocates and policymakers to recognise the interdependence of nutrition and TB as they harness unprecedented political will and global collaboration to end TB.

For this millennia-old epidemic to end, we may need to invest in meals as we do in medicines.

Pranay Sinha
Fellow Physician, Section of Infectious Diseases
Boston Medical Center, USA

Rubbish microbiology: filming *The Secret Life of Landfill*

Clare Taylor
Edinburgh Napier University, UK

I have taken microbiology to some diverse places – school classrooms, a shopping centre, science festivals and even a beer festival. However, the oddest place (so far at least) has to be a landfill site! This happened after I was contacted by Glasgow-based Tern TV, who were making a documentary for BBC4. The programme, *The Secret Life of Landfill*, aimed to make the audience think about modern society's 'out of sight, out of mind' relationship with domestic waste, and hoped to change perceptions of what 'waste' actually is. The team wanted to set up a pop-up lab on location at a working landfill site where they would run a variety of experiments ranging from material degradation tests to real-time microbiological analysis. At that point, they were not sure what the 'real-time microbiological analysis' would entail but after some initial discussion we came up with an interesting experiment.

For those not familiar with what happens at a landfill site, waste from a local area is, essentially, compacted and buried in the ground and covered to allow it to degrade naturally. Gas extraction wells capture gases, which form during breakdown, and these are used to generate electricity for the National Grid. As water falls onto the site, it passes through the waste, collecting liquids and solids and forming leachate, which is collected and treated before disposal.

There isn't a great deal known about the microbiology of leachate but it is considered to be toxic owing to the accumulation of heavy metals and other components. Thus we decided to investigate the microbial composition of leachate from the working landfill site. Given that we had no idea what would be in it, and the likelihood that many of the microbes would be unculturable, the obvious way forward was to attempt to do a real-time sequence analysis using Nanopore MinION technology. So that is exactly what I did! Obviously, I had to do a bit of road-testing in the lab first, with the potential stumbling block being the quality of the leachate sample and whether we could obtain enough microbial material for sequence analysis. Thankfully, the lab test was successful and I took a bunch of kit to the landfill site to set up the pop-up lab (including microscope, electrophoresis kit, microfuge and MinION kit) that would allow me to extract and analyse in a day. Of course, there were a few challenges – we had to hire a generator and, being on the coast, it was somewhat windy and we needed some shelter. However, the Tern TV team made the magic happen and we had a functioning 'lab' on site!

You are probably wondering about the outcome… As it happens, landfill leachate is teeming with microbial life. In a short 50 min sequencing run, we identified just over 3,800 reads comprising 5.1 Mb, with an average read length of over 1.3 kb. Of these, 700 were matched to sequences in the database. More than 3,100 reads were unclassified, suggesting that there could be a plethora of as yet unknown microorganisms lurking in the landfill site. Could we potentially identify microbes to help us break down our waste more efficiently? Who knows, but there is a wealth of data waiting for someone!

KEY FIGURES

READS ANALYSED:	**3,844**
TOTAL YIELD:	**5.1 Mb**
AVERAGE SEQUENCE LENGTH:	**1.3 kb**
READS CLASSIFIED:	**700**
READS UNCLASSIFIED:	**3,141**

LEACHATE MICROBIAL COMPOSITION

<1% ARCHAEA

87% BACTERIA

12% EUKARYOTA

The Secret Life of Landfill: a Rubbish History was first broadcast on BBC4 on 23 August 2018

Science solstice: sticky side up

Jennifer Shelton
Imperial College London, UK

The mould *Aspergillus fumigatus* leads a double life. In nature it plays an important role as a decomposer, recycling carbon and nitrogen from decaying organic matter, and thrives in the centre of compost heaps where temperatures can reach up to 50–60°C. Yet it is this preference for warmer temperatures that also allows it to thrive at 37°C – human body temperature – making it medically important as an opportunistic fungal lung pathogen.

We each inhale hundreds of *A. fumigatus* spores every day and the majority of us will feel no ill effects, but some individuals become hypersensitive to the spores and experience debilitating allergic reactions. If the spores are not dealt with by our innate immune system they can establish and grow in the airways or lung cavities, and in immunocompromised individuals this can develop into a severe lung infection called invasive aspergillosis (IA). IA requires long-term treatment with drugs containing compounds called azoles, which infections are increasingly becoming resistant to. Many patients with resistant infections have not received prior treatment with azoles so must have inhaled spores that were already resistant. It is believed that *A. fumigatus* spores in the environment are developing resistance as a result of exposure to agricultural fungicide sprays containing azoles, in the same way that *A. fumigatus* in the human lung develops resistance after prolonged exposure to medical azole drugs.

On 21 June 2018 (summer solstice) I asked individuals from across the UK, and globally, to collect samples of their local air by placing adhesive films, sticky side up, on their ground floor windowsills for 6–10 hours, before posting them back to me with details of their location. I then cultured *A. fumigatus* spores present on the air samples and preserved the colonies ready for susceptibility testing to the agricultural fungicide tebuconazole, resistance to which infers resistance to medical azoles. Of the 550 sampling packs I sent out, I received back 425 – a phenomenal 77% response rate! This equated to 864 air samples, which grew an incredible 1,431 *A. fumigatus* colonies.

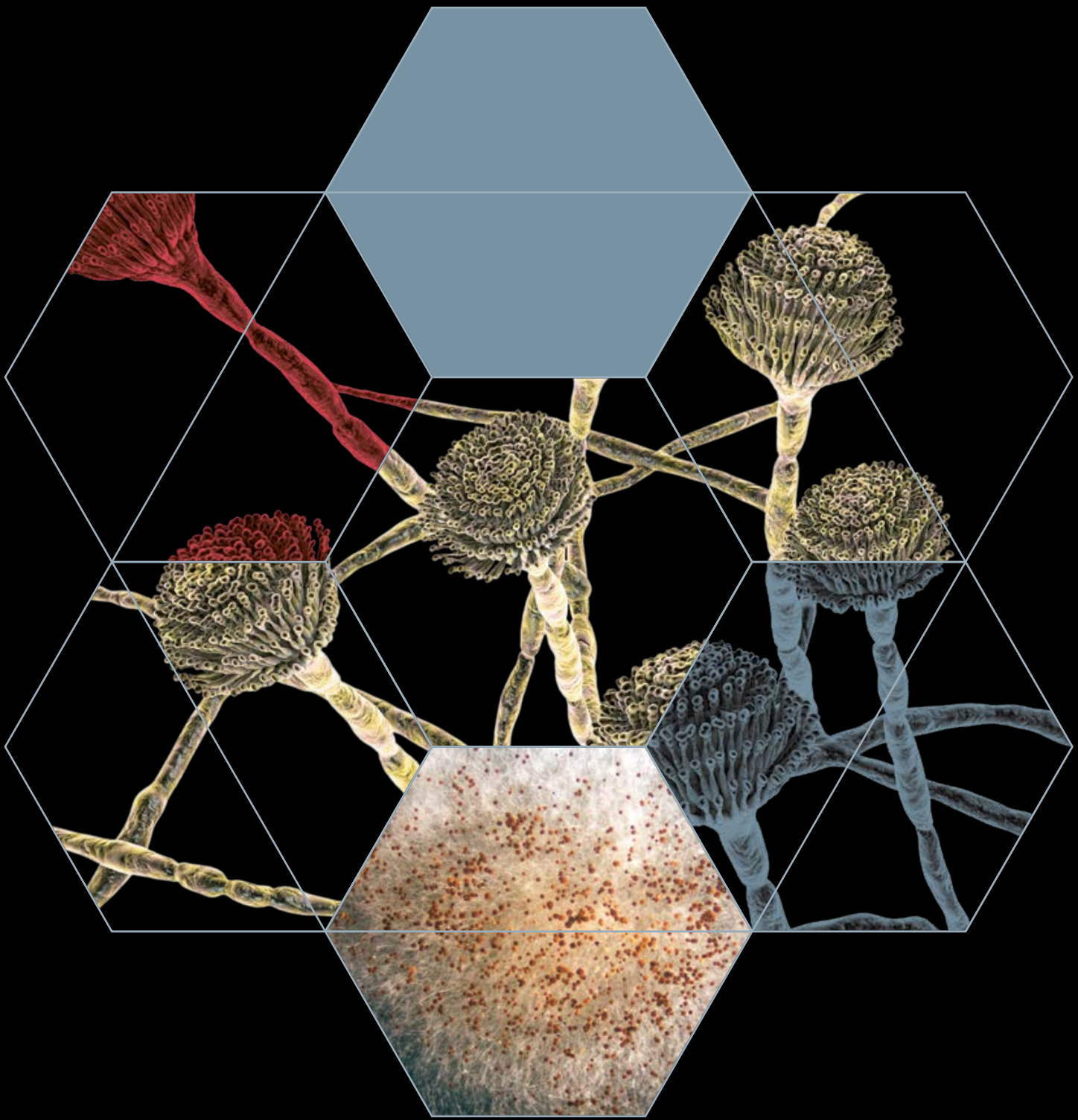
Due to the success of the project I asked participants if they'd be willing to repeat the sampling a further three times – in autumn, winter and spring – to investigate whether season has an effect on numbers of spores and levels of resistance. The autumn sampling round took place on 24 September 2018 (autumn equinox +1) and again garnered huge support, with 306 sampling packs sent out and an impressive 254 returned (83% response rate). This equated to 490 air samples, which grew a further 600 *A. fumigatus* colonies.

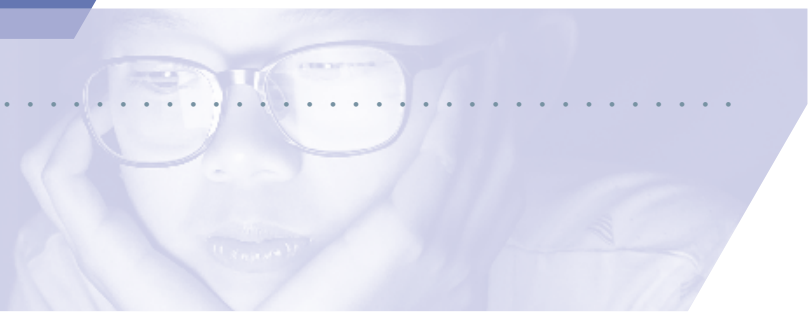
It is not yet known whether there will be resistant spores in the air, but if there are I would like to know the proportion that are resistant and whether this proportion

is consistent across the UK or clustered in certain locations. If there is spatial clustering I will use land-use maps of the UK to determine whether the clusters are in agricultural areas, or particular crop types are associated with high applications of azole fungicides. This information could be used to identify 'hot spots' of resistance in the UK that individuals at highest risk of contracting IA could be advised to avoid.

This project highlights the powerful role citizen science can play in monitoring for antifungal resistance in the environment as I alone, or even my research group together, could not have achieved such widespread sampling coverage at a single time point. I would like to thank all 550 participants for providing me with such a valuable dataset and for their enthusiasm, their continued engagement in the project and their genuine interest in my research.

If you would like to be involved in future sampling rounds please contact Jenny Shelton at ***j.shelton@imperial.ac.uk*** *or, if you are interested in project updates, follow the Twitter handle* ***#ScienceSolstice****.*





Bacteria Builder: a game of survival

Mel Lacey Jake Habgood
Sheffield Hallam University, UK

Many good ideas are born of drink or whilst walking the dog; some others come in the middle of the night or during a morning shower. But this good idea – and I am boldly claiming it to be a good idea – was born of cycling. In fact, I can still vividly remember where in my cycle home from Sheffield Hallam University the idea of *Bacteria Builder* was born: a computer game to teach structure and function of bacteria with a focus on the interplay between the two.

The topic of 'bacterial structure and function' is somewhat unique, as it is rarely taught to biology students through school and further education. Everything, from the very basics, needs to be taught to undergraduates on relevant degree programmes, and due to its relative simplicity it is often taught early on in the first year. Now I feel the need to justify the words 'relative simplicity'. The idea that some bacteria have tail-like flagella to allow them to swim is an easy concept to grasp; we have legs to walk, fish have tails to swim, so of course bacteria would have some kind of a structure to allow movement. However, 'bacterial structure and function' is also the gateway to understanding many key bacterial topics such as infection, antibiotic resistance and environmental microbiology, which amplify in complexity the more you understand about them. For example, without understanding that efflux pumps can pump out antibiotics, students are unable to understand a key mechanism for resistance. These same elements (little or no prior knowledge, simple initial principles and a big impact) are also what makes 'bacterial structure and function' a go-to outreach topic for many microbiologists.

Back to cycling; it was by the River Don that two experiences came together and led to the idea of the game. Firstly, in the previous weeks we had hosted our annual public engagement event where I ran a 'build your bacterium' stand. Using templates of bacterial shapes and craft supplies for various structures, I spoke to children from a wide age range about what structures they could put on their bacteria to give them specific functions. Whilst many children understood the idea of a flagellum (swimming) and efflux pumps (spitting), capsules and

Everything, from the very basics, needs to be taught to undergraduates on relevant degree programmes

fimbriae were somewhat more challenging concepts to convey. Many children opted out of any microbiology learning and just wanted to play imaginatively with the craft supplies. A personal favourite was a small boy who made his rod-shape bacterium a parachute from flagella (string) and a capsule (bubble wrap) and then proceeded to test the parachute by standing on a chair and throwing it. Secondly, I was marking the first-year exam papers and, just as at the outreach event, students (in the most part) could dutifully tell me that fimbriae allow bacteria to adhere to surfaces; they had clearly not progressed their understanding to include function. One student, for example, wrote that '*Staphylococcus aureus* is a non-motile cocci' then, to illustrate, drew a rod with every conceivable structure attached.

So I pondered, as I cycled, how to teach both the public and undergraduate students about bacterial structures in an interesting way, but encourage that depth of understanding of how the structures affect function. A game! A game in which you can be creative and build

Luke sat in on microbiology lectures to gain an understanding of the underlying science and the target audiences

your bacteria, and then see how the structures affect their ability to survive in environments relevant to both medical and environmental microbiology.

STEP 1: Have idea. Check.

STEP 2: Find funding. As I'd applied for small outreach grants before I was already aware of the SfAM educational resources grant which awards up to £10,000. Check.

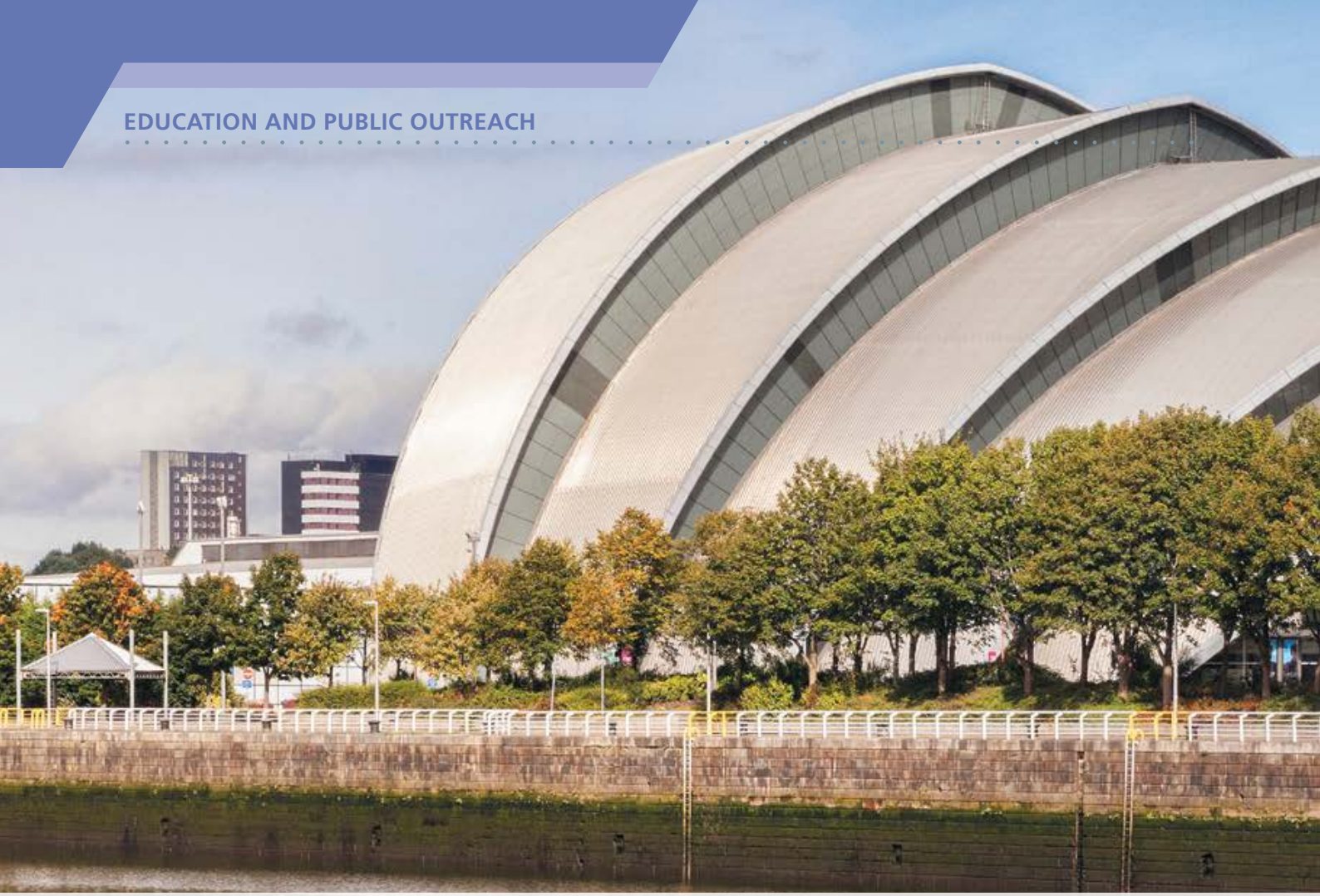
STEP 3: Find someone to make a computer game with me. After a bit of googling and a couple of emails I found that Sheffield Hallam University has a Computer Science for Games BSc as well as a game studio called Steel Minions. So I emailed Jake Habgood, who runs Steel Minions and teaches the game-programming students. After an initial meeting, in which we discussed the game design, he was happy to help. Check.

Once we had submitted and been successful in the grant application (steps 4 and 5) we named the game and purchased the website domain name. We also recruited Luke Melville, a placement student in the Steel Minions game studio on the MComp Computer Science for Games sandwich degree, to make the game. The game started as storyboard-like documents and Jake and Luke sat in on microbiology structure and function lectures to gain an understanding of the underlying science and the target audiences. Then Luke got to work on building the *Bacteria Builder* web game and after 3 months, and regular meetings, a first draft of the game was ready for testing. We held focus groups at the university to inform the design as well as taking it into local schools and outreach events for regular feedback. After another three months the game was pretty much complete and we then employed Patrick Loxley, a computer game artist, to make all the visual elements of the game.

I don't think I can accurately describe how much fun I had making *Bacteria Builder* and being able to claim it as working. It has definitely been one of the most enjoyable projects I've undertaken during my time at Sheffield Hallam, even though I'm pretty sure that Jake and Luke think I'm weird for liking bacteria so much. It was also a very enlightening experience to work so closely with people that have a completely different skill set; for example, Luke and Jake can both type code, without looking at their keyboard or screen, whilst having a conversion – witchcraft?

And the final question to answer is: does it work? Does *Bacteria Builder* help students bridge the gap between knowing about basic structures and understanding their effects on function? Well, to find out we undertook a study with first-year undergraduate nursing students and compared their learning during a 2-hour lecture between those who played Bacteria Builder for 15 min and those who did not, and yes, it does!

The game is now available to the public and you can play online at **www.bacteriabuilder.co.uk** or download it from the Google app store.



FEMS 2019

Save the date 7–11 July 2019

SfAM for the first time is partnering with the Federation of European Microbiology Societies (FEMS) for the 8th Congress of European Microbiologists in Glasgow, Scotland. The FEMS2019 Congress has a global reputation for bringing together leading scientists spanning different microbiological fields to celebrate the best of microbiology. FEMS2019 is an opportunity for the microbiology community to address some of the global challenges faced by humanity, such as antimicrobial resistance, environmental pollution and the emergence of pathogenic disease.

IN ASSOCIATION WITH

sfam society for applied microbiology

8th Congress of European Microbiologists

7–11 July 2019 | Glasgow, Scotland | www.fems2019.org

SfAM will be maintaining a strong presence at FEMS2019, with a number of presentations, symposiums and workshops. We will also be chairing '**Poster Lightning Talks**'. Could you explain your poster in under eight minutes? That's the challenge for the delegates this year and is bound to be a fun and informative venture.

A workshop for early-career scientists is planned and symposiums on wastewater treatment and vaccines are highlights. Recipients of the New Lecturer Research Grant and WH Pierce Prize Award will also be presenting their work. The SfAM Annual General Meeting (AGM) and the ECS AGM will also give SfAM members an opportunity to listen to our achievements of the past year and hopes for the future.

The FEMS2019 programme includes:

- 6 KEYNOTE SPEAKERS
- 32 SYMPOSIA
- 23 WORKSHOPS
- SPEAKERS FROM 23 COUNTRIES
- 11 MAIN CONGRESS TOPICS
- 8 PARALLEL SESSIONS FROM MONDAY TO THURSDAY.

Members of SfAM can take advantage of heavily reduced registration rates for FEMS2019 and can apply for multiple grants, including a new SfAM & FEMS Congress Accommodation Grant, worth up to £300.

The early registration deadline is 15 April 2019.

In addition to being at the nucleus of the latest microbiology research, FEMS2019 offers delegates the chance to enjoy Glasgow with its striking architecture, contemporary art galleries and museums. Glasgow city centre is one of the best shopping destinations in the UK, and when it comes to nightlife, Glasgow can party most cities under the table. With a diverse culinary scene, abundance of pubs and bars as well as some of the UK's best music venues, this is bound to be a conference to remember. Don't forget to check our website for details and get your tickets before 15 April!

Getting to Glasgow couldn't be easier – the city is served by three international airports, it's well connected by train from across the UK and it's easily accessible by Scotland's extensive road network.

The latest news, views and microbiological developments

Rapid, clear identification of *Salmonella*, *Shigella*, *E. coli*, *Yersinia*

Clean, clear agglutination is what all microbiologists want from antisera used to confirm the identity of a pathogen.

UK customer testimonial

Both Salmonella & Shigella reactions were noticeably stronger and easier to read with the Sifin antisera. We also observed that weak non-specific reactions with our existing antisera, caused by Hafnia alvei and E. coli (which would normally require further identification tests) were virtually eliminated with the Sifin antisera.

50% discount on your first order.

Start a conversation with us today.

Further information

Visit: **www.bioconnections.net/antisera-346119**
Tel: **+44 (0)1782 516010**
Email: **welcome@bioconnections.co.uk**

Microbiological media and cleanroom solutions

For over 45 years, Cherwell Laboratories has produced pre-prepared microbiological media for customers under the Redipor® brand name. Customers range from multi-national pharmaceutical manufacturers to small laboratories with their own individual requirements. The head office and manufacturing facility in Bicester, Oxfordshire can produce up to 7,000 plates per batch and as few as 20 depending on the order size.

The core of the Redipor® range consists of irradiated contact plates, 90mm and 140mm petri dishes, used in the environmental monitoring of cleanrooms in aseptic manufacturing and related industries. Those media types are available with a number of combinations of neutralisers or enzymes depending on your needs.

Cherwell also produce, as standard, a range of media compliant with the harmonized pharmacopoeia methods. For media and buffers not specified on the main price list please contact Cherwell to discuss your requirements.

For more information about Cherwell's Redipor® range of media, SAS air sampler product range and environmental monitoring accessories, visit Cherwell's website at www.cherwell-labs.co.uk.

Further information

Visit: **www.cherwell-labs.co.uk**
Tel: **+44 (0)1869 355500**
Email: **sales@cherwell-labs.co.uk**

Small, compact workstation launched

Don Whitley Scientific is proud to launch one of their most compact workstations, the Whitley A25 Workstation. The A25 is equipped with many unique features to ensure easy and efficient use and to guarantee that the very best anaerobic condtions are maintained. It has a capacity of 200 Petri dishes whilst leaving more than adquate space to process samples in a strictly controlled anaerobic environment.

This workstation is equipped with instant access ports and has a built-in, rapid airlock that can accommodate 20 x 90mm Ø Petri dishes or 3 x 500ml Duran bottles. The airlock allows items to be transferred into the workstation atmosphere in less than 20 seconds and the doors are interlocked so cannot be opened simultaneously. Two letterbox entry systems are available, providing a straightforward way to quickly introduce individual samples into the chamber. The A25 is fitted with a touch screen providing the user with an intuitive interface to control and operate the workstation.

The Whitley A25 Workstation

Previously unavailable on a workstation of this size, the A25 can provide automatic early warnings about the status of the anaerobic atmosphere and catalyst function.

Further information

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

One-day food testing

Detection of food pathogens in a single day
Control in IV Range

GPS™ (**genetic PCR solutions™,** a brand of Genetic Analysis Strategies SL.) has developed a protocol for foodborne pathogen control that produces results in a single working day. Time of each step has been reduced and the procedure has been simplified and optimized. The method is easy, safe and fast.

- **Minimum enrichment times**. Validations with different kind of food samples by spiking <10 cells. *Salmonella enterica* 8 hours, *Escherichia coli* 8 hours, *Listeria monocytogene*s 12 hours.
- **FastExt®**. GPS™ rapid DNA extraction (<20 min) from Peptone Broth and Fraser media pre-enrichments, eliminates PCR inhibitors, and validated in different matrices (vegetables, meat, dairy, cereals, and fruits).
- **Pathogen panel**. All qPCRs run with the same protocol (temperature and time), allowing all pathogens to be tested simultaneously in single-plex at very low cost. Avoid false negatives!
- **MONODOSE**, GPS™ Innovation. Ready-to-use PCR tubes contains all the reagents needed to perform the detection test for each specific pathogen. Just add the sample!
- **Fast-Cycling, qPCR in 35 min***. GPS™ has optimized its reagents to use a thermo-cycling protocol with very short reaction times (8 min). *, qPCR total time depends on your thermocycler ramp rates.

Further information

Visit: **www.geneticpcr.com**
Tel: **+44 (0)965 429 901**
Email: **info@geneticpcr.com**

NCIMB's next-generation sequencing and bioinformatics service

NCIMB has launched a next-generation sequencing (NGS) and bioinformatics service. Our capabilities include whole genome sequencing of bacteria and fungi, genome annotation, screening for antimicrobial resistance and virulence factors, phylogenetics, prediction of secondary metabolites, microbial community analysis (metagenomics), comparative genomics, strain differentiation and bespoke bioinformatics analysis.

At NCIMB, we have the microbiological expertise, combined with the cutting-edge bioinformatics capability required to get the most from your NGS data, no matter what your research or commercial aim. We can take you from experimental design to results interpretation, delivering clearly presented, actionable findings within detailed reports.

You can submit DNA or pure cultures for NGS projects. If you don't have the time or facilities to pre-prepare samples, we can also accept mixed cultures, lyophilised end products, and other sample types such as water, slimes or contaminated products for DNA extraction prior to sequencing.

NCIMB manages the UK's National Collection of Industrial Food and Marine Bacteria, and provides specialist microbiology, analytical and biomaterial storage products and services. We support clients in their quality control procedures, R&D projects, intellectual property protection and compliance with environmental regulations.

Further information

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

BioFocus: Shaping the future of the Royal Society of Biology beyond 2019

Like most learned societies, the Royal Society of Biology (RSB) strives to ensure the work we do is impactful long-term; a high priority for us is to provide structure and aid for the next generation of biologists to flourish, alongside working to ensure the community voice feeds into future decisions that will affect them.

Plan S, the initiative for open access science publishing, was launched by Science Europe in September of last year. Plan S looks to have all research from publicly funded organisations published in open access journals by 2020, with publication fees covered by the institutions themselves and standardised and possibly capped across the sector. Perhaps most critically, the option to publish most publicly funded research in hybrid journals will disappear.

Our Bioscience Careers Day saw more than 300 undergraduates sign up

In the run up to this change, the RSB has already held a meeting with representatives of several of our Member Organisations, including SfAM, to better understand the impact across our community. We are now coordinating views and feeding into other collective science publishing networks and groups to ensure the bioscience voice is heard, engaging with funding councils and the government as this initiative develops.

Towards the end of last year, we were also busy providing opportunities for our younger members: we were at Manchester Metropolitan University for the annual Bioscience Careers Day in October, and at the University of Birmingham for our first ever Biosciences Outreach and Engagement Symposium in November.

Our Bioscience Careers Day saw more than 300 undergraduates sign up to hear from biologists working in various fields including law, policy and communications, improve their CV writing and interview skills, and network. Meanwhile, more than 100 early career researchers came together at the symposium to take part in discussions, workshops and seminars and share their thoughts and ideas.

Mark Downs CSci FRSB
Chief Executive of the Royal Society of Biology

Both these days resonated positively with our younger members, and helped them build their own skill sets and connections that will no doubt prove to be fruitful in the future.

We kicked off 2019 with the parliamentary launch of the *Growing the Future* report, published by the UK Plant Sciences Federation, an RSB special advisory group. The report pinpoints the key requirements for plant sciences to mitigate the formidable challenges that face the global population, including food nutritional value, plant adaptation to climate change and ensuring we preserve our diverse ecosystems.

One of the bigger challenges for ourselves as an organisation, as indeed it is for most UK-based organisations, is Brexit; and it is too soon to say for sure what the situation may be when you read this column come March.

Regardless of the outcome, we will of course continue to represent the views of the biosciences community, and facilitate the networking and collaborative efforts of all biologists, from people at the beginning of their career through to those well established in their chosen roles. A voice and seat at the high-level ministerial working group on science and Brexit remains an important route to achieve that alongside our wider direct routes for engaging the UK parliaments.

Science thrives when people come together and share their ideas and expertise, and we are committed to ensuring this will remain the case regardless of our membership position within the EU.

This year we are also gearing up for our 10-year anniversary celebrations. The Royal Society of Biology initially was launched as the Society of Biology on 9 October 2009, after the merging of the Biosciences Federation and the Institute of Biologists.

We'll be celebrating the anniversary with a whole host of exciting events, activities, competitions, grants and more, and we will of course be inviting SfAM and its members to help us celebrate this significant milestone.

Since its inception, the society has grown immensely in both reach and influence. Such growth has been made possible by our members and Member Organisations. We thank you for your continued support and ask you to join us as we expand and grow further in the coming years.

A simple target with a complex solution

It is rare that a consensus is reached across the benches of the House of Commons. At a time of division, tensions and contrasting visions for the future of prosperity for the UK, a commonality arose for the science community to hang its hat on. In the Conservative, Labour and Liberal Democrat manifestos for the 2017 election were pledges to increase the UK's expenditure on research and development (R&D).

The UK is already considered a bastion of scientific excellence, accounting for 4.1% of the global population of researchers yet producing 15.2% of the world's most highly cited articles. Despite this, levels of investment in R&D in the UK have lagged well behind its competitors. In 2016, the UK invested the equivalent of 1.67% of its gross domestic product (GDP) on R&D, compared to the Organisation for Economic Co-operation and Development (OECD) average of 2.4%. In their manifesto, the Conservatives made a commitment to increase R&D expenditure to 2.4% of GDP by 2027, a pledge that has received continued support from the Conservative government.

Ambitious R&D spending targets are nothing new; yet previous attempts have fallen flat due to a combination of issues both inside and outside of government control. Reaching the target is not entirely the government's gift to give; a combination of public and private investment will be required to yield a successful outcome. However, a gear change in government commitments to funding R&D will be vital in delivering on the target. CaSE has projected that in 2027 the public sector must spend £20 billion on R&D to fulfil its commitments to reaching the target, £9 billion more than it is projected to spend in 2021. And crucially, the government must endeavour to create an environment in which businesses want to invest in the UK.

Private enterprise will be expected to contribute just over two-thirds of the total investment required to meet the government's R&D target. Our projections suggest this will need to be £42 billion in 2027 alone. CaSE has been drilling down into the reasons why private enterprise has chosen to invest in R&D in the UK in the past, what could make the UK a more attractive destination for investment and what the UK can learn from international competitors. We have held events and interviews with our Member Organisations across all nations of the UK over the last year. Large multinational businesses and small and medium-sized enterprises (SMEs) alike have cited the strength of the research base as a key factor in choosing the UK, both in terms of world-class workforce and the access to world-leading facilities. Other factors that made the UK attractive were the ease of access to collaborations

James Tooze
Campaign for Science and Engineering (CaSE), UK

and capable staff, a strong R&D tax credits regime and a strong legal system.

In our conversations with R&D-intensive organisations, it became apparent that in order to encourage businesses to stump up so much cash, the whole of government must be aligned and in tune with the agenda of creating a country that supports investment in R&D. Alongside a world-leading funding regime set by UK Research and Innovation (UKRI) in collaboration with the Department for Business, Energy & Industrial Strategy (BEIS) and HM Treasury, the Home Office must create an immigration system that supports the needs of science. Her Majesty's Revenue and Customs (HMRC) must make attractive proposals for business relief to incentivise R&D activities. The Department for Trade must support growing businesses to expand their networks and customers across the globe. Also, other departments must protect and use their own research budgets to not only support R&D but to help meet their departmental aims.

Despite setting an output goal, the government's interest in reaching the 2.4% target is to benefit the lives and livelihoods of the UK's residents. A central consideration of CaSE's upcoming work is developing a narrative that highlights the ways in which increased support for R&D will bring benefits to improve quality of life and healthcare provision, tackle climate change and bring high-quality jobs and opportunities up and down the UK. Communicating this message will be vital in capturing public interest in the target and ultimately help in holding the government to account.

The environment that enables R&D to thrive is in danger of being affected should the government not consider wider implications of all its policies. This would be a real shame, given what is an ambitious and admirable target set by the government. CaSE will continue to represent the sector to ensure the government does not kill its ambitions before real progress can be made.

The Home Office must create an immigration system that supports the needs of science

SAVE THE DATE

FEMS 2019

8th Congress of European Microbiologists

7–11 July 2019 | Glasgow, Scotland | www.fems2019.org

IN ASSOCIATION WITH

sfam society for applied microbiology

Society for Applied Microbiology
Charles Darwin House
12 Roger Street
WC1N 2JU
UK

+44 (0)207 685 2596
communications@sfam.org.uk

www.sfam.org.uk