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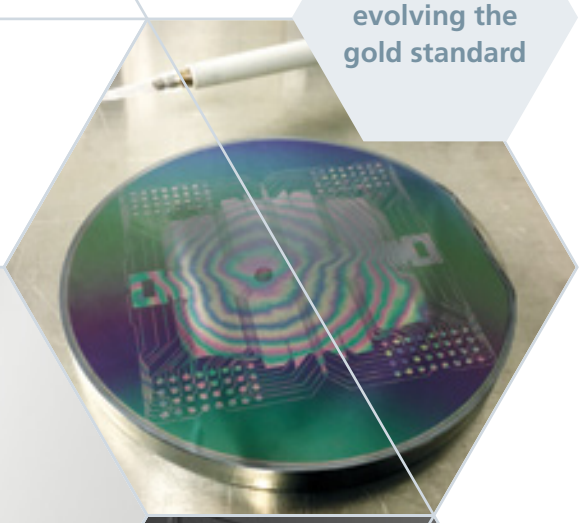
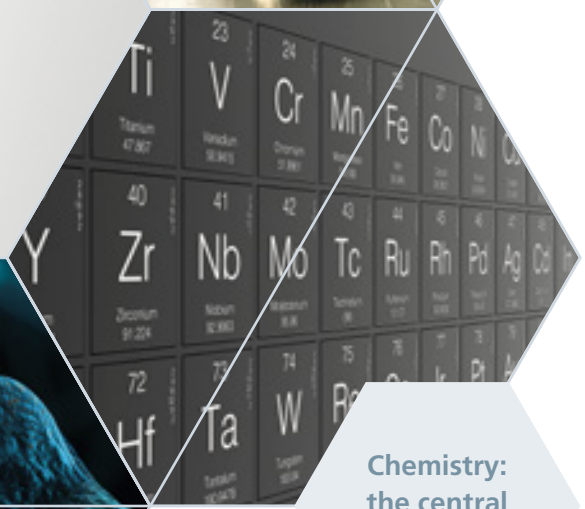
microbiologist

An historical reflection on **Patricia Clarke's** bacteriology

Engineering: evolving the gold standard





Chemistry: the central science

Neurobiology: a nematode's perspective

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Together we make the difference

It is hard to imagine, as a microbiologist, what it is like to be illiterate in microbiology. Microbial literacy does not just give us access to the knowledge needed to be effective in the laboratory, but gives us the facts and skills to make informed choices about our own health, the well-being of others and animal husbandry, and also an informed perspective on environmental stewardship.

In an incredible editorial for *Environmental Microbiology* (*EMI*), **'The urgent need for microbiology literacy in society'**, Professor Ken Timmis states:

'*An understanding of key microbial activities is as essential for transitioning from childhood to adulthood as some subjects currently taught at school and must therefore be acquired during general education. Microbiology literacy needs to become part of the world citizen job description*.'

Shocking numbers of people across the world still believe dangerous incorrect statements by the anti-vaccination movement. Even more believe that all bacteria are harmful and do not appreciate the links between biomes and protection, or digestion, or the myriad of other beneficial interactions with their hosts.

In the *EMI* editorial Ken Timmis urges microbiologists, microbiological learned societies and all microbially literate professionals to influence educators, politicians, business leaders, relevant governmental and non-governmental agencies, and others, to join forces in an international effort to convince facilitators of the crucial need to achieve microbiology literacy in society.

As we are all stakeholders in planetary and human health we have an opportunity to champion microbial literacy education in the wider society. Certainly, SfAM has a part to play here and will be helping the authors of **'The urgent need for microbiology literacy in society'** achieve this goal.

The SfAM Fellowship Evening on 18 June 2019 will see Professor Dame Sally Davies, an outstanding advocate and champion of microbial literacy, receive fellowship of the Society; and partnering with the Federation of European Microbiology Societies, for **FEMS2019** 7–11 July 2019, will give the Society an opportunity to help hundreds, possibly thousands of early career researchers communicate their science to a wider audience.

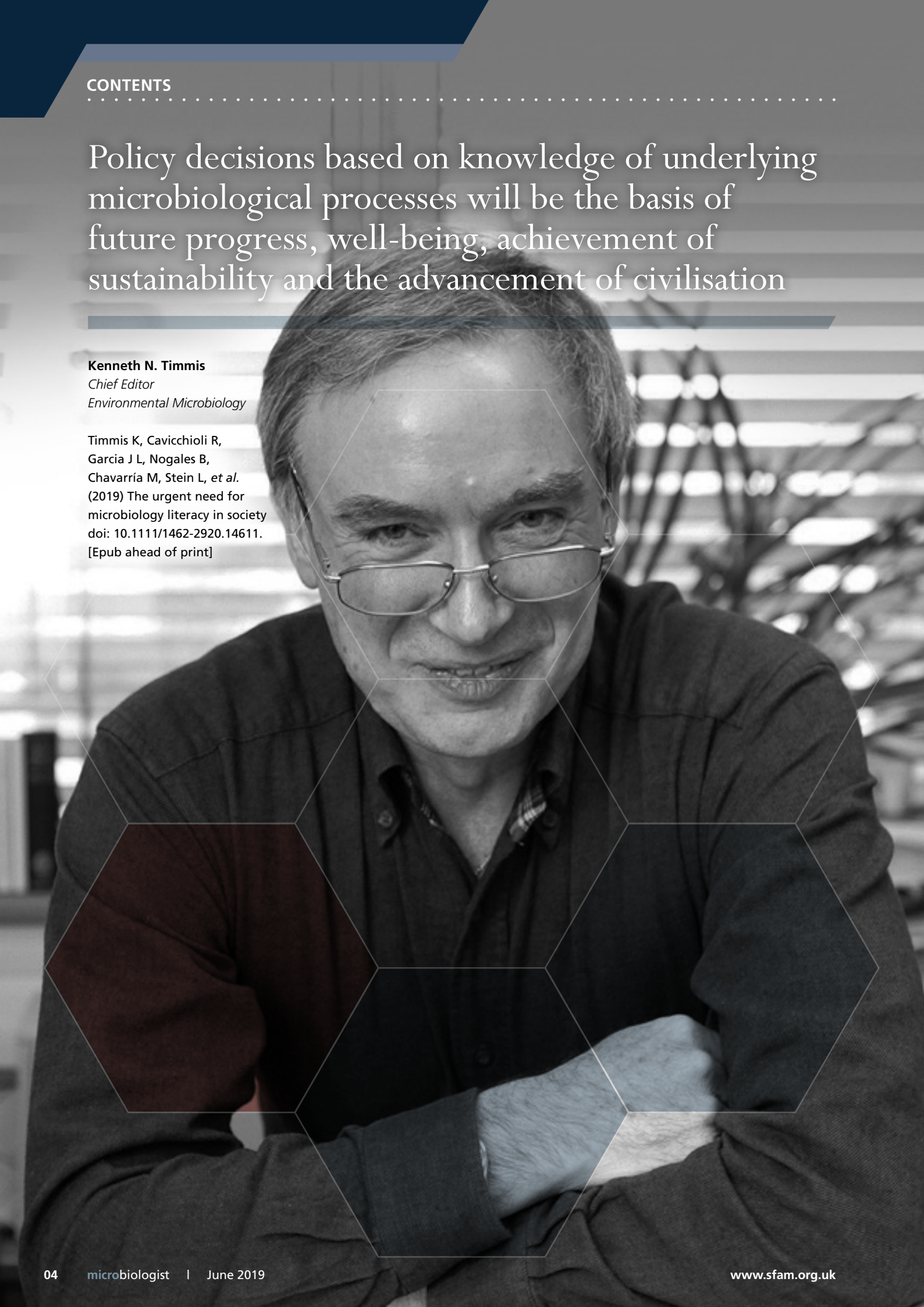
In this issue of *Microbiologist*, we hear from chemists, engineers, mathematicians, artists and neurobiologists as they discuss the impact of microbiology on their subject areas. We even managed to squish in a hand-drawn comic. Enjoy!

Paul Sainsbury
Editor

Policy decisions based on knowledge of underlying microbiological processes will be the basis of future progress, well-being, achievement of sustainability and the advancement of civilisation

Kenneth N. Timmis
Chief Editor
Environmental Microbiology

Timmis K, Cavicchioli R, Garcia J L, Nogales B, Chavarría M, Stein L, *et al.* (2019) The urgent need for microbiology literacy in society doi: 10.1111/1462-2920.14611. [Epub ahead of print]



News

Features

Must-read Articles

People & Places

Education & Public Outreach

Policy & Public Affairs

Industry

Microbiology is a fascinating multidimensional science

You can pretty much apply our subject to almost any other branch of science with relatively little effort and, to be honest, the links are none too tenuous!

I was once challenged at an event at my university to make a meaningful link between microbiology and all the other subject areas under discussion at the event. Nutrition was first up. That link was of course quite easy, be it food protection, food spoilage, food production or nutritional enhancement; therefore we could apply microbiology with relative ease. Next up was cancer biology. Again we could talk about oncoviruses, care of immunosuppressed patients and so on. The worlds of biochemistry, molecular biology and immunology came to the fore. Again our subject fits with all, either as a tool or model system for the biochemists and molecular biologists, or as the microbiological 'ying' to the immunological 'yang', so to speak. The final two subject areas to present a challenge were the pharmacy group and the optics group. The pharmacists already recognised the challenge of infection, treatment and of course antimicrobial resistance – so here there was no resistance – you could even say #resistanceisfutile! Finally, the optics group issued me with the challenge of explaining how microbiology interacts with their discipline. I reeled off a few conditions such as bacterial or viral conjunctivitis, naming organisms including *Staphylococcus aureus*, *Haemophilus influenzae*, *Streptococcus pneumoniae*, herpes simplex virus, varicella-zoster virus, adenovirus and so on. There is also bacterial keratitis, which can be caused by organisms including *S. aureus*, coagulase-negative staphylococci and *Pseudomonas aeruginosa*. Some of the effects of this condition can have a direct effect on the physics of light passage into and through the eye. We must not forget the effects of certain parasites and the chlamydiae on eyesight and optics too! So once more the way in which our subject can be applied to more than one discipline, directly or indirectly, is clear. I admit some of these examples may not fully stand up to the closest scrutiny but it does serve to help demonstrate how versatile and far-reaching microbiology can be!

This perspective is being recognised in the wider community too and improving what might well be termed 'microbiological literacy' should be important to us as individuals and as a learned society. The general public have never had greater access to information than they do today. However, we all know that some of that information is accurate and of use, whilst other parts are, at best, fake news. A very pertinent example of this is the false mythology whipped up by the anti-vaccination lobby. Ill-informed views are not helpful and have repeatedly placed public health in potential danger.

It is without doubt that we need to improve microbiological literacy and this doesn't have to be staid lectures in town halls, but can make use of all aspects of public engagement. This includes comedy events, plays, musicals, interactive microbiology detective role plays, Café Scientifique events and engaging with schoolchildren. We are talented people; we have the ability to be skilled communicators so let's take every aspect of our treasured subject to the masses, improve subject literacy and let people know just how important the microbe is to our existence!

Mark Fielder
President of the Society for Applied Microbiology

Plan S: scholarly publishing and open access

On 4 September 2018, a consortium of international research funders known as cOAlition S, including UK Research and Innovation (UKRI), Wellcome and the Bill & Melinda Gates Foundation announced 'Plan S'.

You may have heard of this initiative that requires scientific publications that result from research funded by public grants must be published in compliant open access journals or platforms.'

As members of the Society, you will be aware of one of the benefits of membership: access to the five journals in our portfolio. Four of our five journals (*Journal of Applied Microbiology*, *Letters in Applied Microbiology*, *Environmental Microbiology and Environmental Microbiology Reports*) operate using a hybrid model. This means that authors are given the choice of publishing articles through either:

- a subscription model – where readers pay to access content, or institutional libraries pay to make journal content available to members of the institution, or
- open access – where authors pay to make their work accessible to all readers immediately upon publication.

Our fifth journal, *Microbial Biotechnology*, is fully open access.

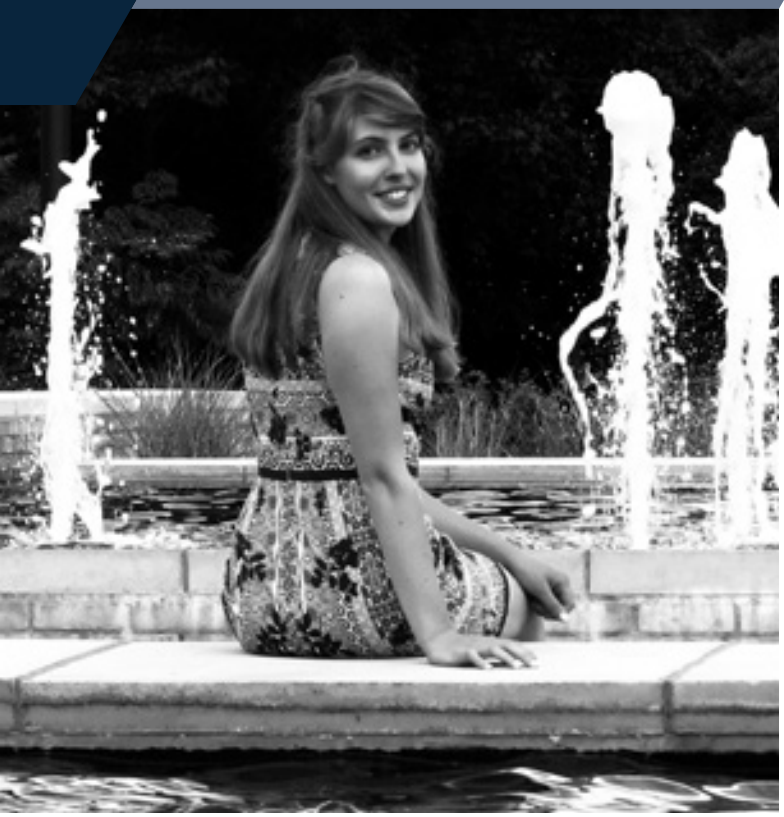
The majority of the Society's income is from subscription revenue, and as you know, this income is returned to the scientific community to provide valued support to applied microbiologists globally. This support takes the form of grant funding, scientific meetings, networking opportunities and career development. In 2018, 93% of this income funded activities to achieve the Society's charitable goals, such as public engagement, science policy work and supporting our membership. I think you'll agree that this revenue is vitally important to the sustainability of the Society.

One of the ten principles of Plan S, states that: 'The "hybrid" model of publishing is not compliant with the above principles' (of Plan S). This means that from January 2020, those scientists funded by members of cOALition S, could be prevented from publishing in the majority of the Society's journals. This is a significant development and a situation shared by many other learned societies.

A group of such societies, the **Scholarly Publisher's Coalition**, have been sharing information and contributing significantly to discussions on the implementation of Plan S. SfAM are part of this group whose aim is 'to see an orderly and sustainable transition to open scholarship and to improve the efficiency of the scholarly communication ecosystem for the benefit of researchers and society at large in a fair and sustainable way.' This group has been meeting regularly and following developments closely, with one output being the response to the call for feedback on the Guidance on the Implementation of Plan S.

In parallel to this, the Society's Trustees, Chief Editors and Wiley have been working hard to develop a new strategy for our journals to enable the Society's and our journals' sustainability in a more open-access world.

Lucy Harper
Chief Executive of the Society for Applied Microbiology



Sexually transmitted infections and symposium highs

At this year's Early Career Scientist (ECS) Symposium there was a lot of talk about sexually transmitted infections (STIs) and the challenges they pose to humans.

What would you expect to see at a conference about STIs? Up-to-date talks on super-gonorrhoea, hepatitis and sexual attitudes? An STI charity offering support and advice while giving away glow-in-the-dark sperm keyrings? A panel discussion with four experts in the field? That's exactly what the delegates at this year's ECS Symposium got.

Five brilliant young scientists talked about their work. Third-year undergraduate, Viktorija Asmolovaite from Coventry University, talked to us about her summer placement where she isolated antibiotic-resistant Gram-negative bacteria from fish and shrimp in the UK. Kate Bamford from the University of Warwick discussed 'Matrix-assisted laser desorption/ionisation-time-of-flight (MALDI-ToF) mass spectrometry for epidemiological analysis of mastitis-associated pathogens in sheep flocks'. Sophie Coulter from Queen's University Belfast introduced the potential for self-assembled peptide-mimetic hydrogels being used as long-acting delivery platforms for HIV prevention. Charlotte Litten, from the University of Nottingham, took us through her talk entitled 'Dissemination of an ESBL *bla*$_{CTX-M-15}$ determinant associated with the mobile element IS*Ecp1* within *Escherichia coli* isolated from a dairy farm.' Liisa Veerus from the University of Oxford explained how she explored microbial communities across the female reproductive tract of the red junglefowl. To conclude the ECS presentations, a pre-recorded presentation from international member Mary Neupane was played. Her talk focused on the isolation and identification of *Acinetobacter* from various clinical specimens and the determination of their antibiotic susceptibility pattern. This is something that the ECS would like to include in future symposiums to give members from different countries a chance to present their work at the event.

After lunch it was time for the keynote speakers to take the spotlight. To introduce us to the problems that STIs pose, Harriet Wallace talked about the re-emergence of syphilis and the new issue of *Mycoplasma genitalium*. Her talk was followed by that of Michelle Cole who spoke about the rise of super-gonorrhoea, its comical media attention and the various resistance mechanisms it uses. Pam Sonnenburg followed with a talk about the National Surveys of Sexual Attitudes and Lifestyles (NatSAL) and Andrew Lee presented an honest discussion about hepatitis A, which he likened to the iconic 'Death Star' in the *Star Wars* film series, punctuating with the memorable phrase 'wash it now or eat it later'.

In the final hours of the day, Andrew, Michelle and Pam sat on a panel (chaired by yours truly) to discuss STIs with the delegates and expertly answered questions posed to them by the intrigued audience. It was a thought-provoking day and hopefully many of the delegates will feel more comfortable discussing STIs with their peers.

Jennie French
SfAM Early Career Scientist Committee Vice-chair

We would like to warmly welcome the following

New members of the Society

Australia
L. Jebeli

Bangladesh
M. A. Rahman

Brazil
L. Miranda Marques
G. Barreto Campos
R. de Souza Bittencourt
A. Brito
D. Cruz dos Santos
I. Rezende

Canada
S. Saleh

Chile
R. Santibáñez

Finland
A. Karkman
H. Li
J. Hultman

France
R. Datar
M. Goyal

Gambia
A. Bojang

Germany
B. Braun
O. Igbalajobi

Ghana
K. Duedu

Grenada
A. Khalil

India
R. Debnath
K. Sengupta
N. Joshi

Iraq
R. Abdulrahamn

Ireland
C. Kroeger
A. Angelopoulou
Y. Cao
A. Finnegan
Y. Cortese

Japan
M. D. Hoang
P. Thi Vinh

Korea, Republic of
J. Lee
J. An
S. Cho
S. Mun

Malaysia
S. Rahman

Mexico
J. Guadalupe

Nepal
S. Humagain
G. Dhungana
L. Neupane

Nigeria
T. Oresanya
O. Aniche
O. Owolo
V. Ezebuiro
S. Fapohunda
B. Olayinka
T. Obuotor
A. Adefiranye
S. Ojo
E. Afocha
C. Ogugbue
J. O. Ogunrinade
O. Lanlokun
B. Atobatele
C. Ekwealor
N. O. Oloso
K. Adediran
I. Ekwealor

Pakistan
N. Ahmad

Romania
E. Alexa

Spain
S. Wettstadt
Y. Moreno
J. Garcia-Hernandez
N. Baeza

Sweden
M. Hoetzinger
Y. Bezabhe

Switzerland
C. Rezzoagli

Thailand
C. Chaiwut
T. Chitov

United Kingdom
J. Scadden
O. Donnachie
S. Coulter
C. Neath
M. J. Minnell-Gault
R. O. Dascalescu
H. Hatton
C. Padua
E. Faull
M. Barnett
C. Stevens
A. Bankole
S. Miles
A. Berepiki
K. Doughty
P. Stevens
L. Gibson
C. Chilton
A. Hughes
J. Morris-Cottell
D. Green
A. Kostrytsia
H. Fisher
J. Chin
M. McDonald
T. Cornell
Z. Assil
O. Okafor
C. Chang
R. Hough
P. Neaves
H. Hogg
C. Sargent
P. Livingstone
C. Waite
L. Blake
C. Kousser
A. Pritchard
J. Munnoch
A. Stratakos
P. Adamou
L. Hobley
C. Ludden
R. Aljalamdeh
R. Gilbertson
E. Erskine
M. Hale
C. Aston
C. Karyal
M. Bryan
R. Poria
S. Kalathil
J. Edwards
M. Pandey
A. Haag
V. R. Ibarra Chavez
C. Green
N. Quiles-Puchalt
T. Curtis
J. Roche
A. Dafis-Sagarmendi
F. Gamble
G. McCallum
W. van Schaik
J. Rodrigues
M. Knight
J. Ashworth
J. Personal
S. Darwish
K. Stewart
M. C. Garcia-Pelayo
R. Garbero
A. Bosworth

United States
A. Guss
M. Konopka

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

From early career researcher to editorial manager

I have been the managing editor of the *Journal of Antimicrobial Chemotherapy* (*JAC*) since 1999. A small staff (about three full-time equivalents) and I are responsible for producing all published articles.

What do I do?

My work mainly involves managing the online submission system, where authors submit their research articles, liaising with the team of editors, who obtain peer reviews of these articles and make decisions on them. Once articles are accepted for publication we are involved in the early stages of copy-editing them before they are handed to our publisher, Oxford University Press, for proof production. Once the proofs are ready, we read them in parallel with the authors and are responsible for collating our corrections with the author corrections and resolving any questions that may have arisen regarding the content. *JAC* publishes around 500 articles annually and is among the leading journals in this field.

What's the job like?

There is quite a lot of structure to the job, with deadlines (such as the compilation of monthly issues) and apparently repetitive tasks, such as proofreading, or preparing accepted articles for release to the publisher taking up the bulk of most working days. However, there is a great degree of variety within the individual articles and that is where the satisfaction lies (for me at least).

How did I get where I am?

I always had a fascination with observing the natural world and science in general; perhaps if I had been more courageous I would have taken up the study of animal behaviour as a career path! I was influenced by reading Dawkins' *The Selfish Gene* when I was about 16. I was impressed by the elegance of the DNA-to-RNA-to-protein process and the insights genetics had provided. Around this time there was also quite a bit of excitement about the potential for genetic engineering of microorganisms to make them do useful things (biotechnology). This seemed to me to be interesting and probably have some employment prospects so I applied for courses and was an undergraduate at the University of Warwick studying microbiology and microbial technology. After a year we could opt to switch between several closely related courses and I moved to microbiology and virology, having discovered I was more interested in molecular genetics and disease than the (to me) rather complex-looking mathematics of running fermenters.

I thoroughly enjoyed my course, which was very well run and taught, and I graduated in 1989. Having enjoyed the third-year research project, I decided to sign up to do research at the University of Oxford. Unfortunately, this proved not to have been a good choice and at the end I was quite clear that an academic career was not for me.

Colin Drummond
Editorial Manager, Journal of Antimicrobial Chemotherapy

Early jobs in journal publishing

While writing up my research I applied for a staff editor position on the *Journal of General Microbiology* (now just *Microbiology*). I was not invited to interview but when a similar position on the *Journal of General Virology* (*JGV*) came up, they contacted me and asked if I was interested (stroke of luck number 1).

I spent 3 years working on *JGV* and I am very grateful for the solid grounding and training I received. This is one piece of advice I would give: if you are starting a new career path, do everything you can to ensure your first job is a good place to learn. When I started, all copy-editing was still being done on paper but by the time I left we had moved to doing it on-screen.

I was keen to move on and gain experience so I applied for and got a job as an editorial manager with a medical communications company in London. The company had a small journal publishing wing, specialising in virology (and specifically antiviral) journals. I spent another 3 years working on these journals and also learning about the medical communications industry before a position as editorial manager arose on *JAC* in Birmingham. I had been alerted about the job by an ex-colleague from the medical communications agency who had moved to work for the journal's publisher (stroke of luck number 2). Although the focus of *JAC* was mainly bacteria, the editor-in-chief had a particular interest in antivirals and was keen to expand this aspect, which probably assisted my cause and I was appointed as editorial manager in October 1999. I have been with *JAC* ever since, working as part of and managing a small but expanding team looking after the online peer-review system, preparing articles for release to the publisher and proofreading.

Job satisfaction

Working on a science journal brings with it a constant stream of deadlines of various types, which is ideal if you like having some external structure imposed on you. It does mean that you have to be able to cope with some pressure from time to time. One part of the job that brings me particular satisfaction is being able to keep up to date with the developments in the field. Having worked in this area for over 20 years it is interesting to reflect on the changes that have taken place. Another aspect that is very satisfying is being able to interact with many of the scientists and clinicians who are editors, authors or referees. The enterprise of publishing a science journal is an effort by a whole community, many of whom are contributing as a goodwill gesture; it is very gratifying to take part in this endeavour, which ultimately aims to improve human health and well-being.

The future

There have been large technological changes in publishing over the last few decades. We haven't yet seen how these will ultimately play out and alter the current models of scientific journal publishing, but changes are happening.

One aspect that is reassuring is that I think it will be some time before artificial intelligence (AI) can take on the task of reading and understanding scientific papers; there will be jobs for humans in this area for some time to come.

As a final thought, I suspect that most people's careers take a few unexpected twists and turns. It can feel like you have turned up a dead end and it may take a lot of courage to admit this and take a new path. However, if you are committed and resourceful you will be able to exploit any good fortune that comes your way, as it certainly has in my case.

Working on a science journal brings with it a constant stream of deadlines of various types, which is ideal if you like having some external structure imposed on you

Microbiology and…
Genomics: *Staphylococcus aureus*, a select bunch

Matthew Holden
School of Medicine, University of St Andrews, UK

The story of *Staphylococcus aureus* is one of overwhelming success, evident in its broad host range, its ability to cause disease and its transmissibility. Arguably however, the most successful trait of *S. aureus* that has emerged in recent years has been its ability to develop resistance to antibiotics. The increased burden of resistance in bacterial pathogens is well documented and is a direct result of the widespread use of antibiotics and the selective pressures that this has created. *S. aureus* has proven itself to be one of the most versatile and adaptable species in the face of this challenge, with a track record of resistance variants emerging shortly after the introduction of new antibiotics into clinical practice, and the epidemic spread of drug-resistant clones that survive and thrive in healthcare environments. Perhaps the most notorious of these are methicillin-resistant *S. aureus* (MRSA) strains, which have emerged on multiple occasions in the species population, spread globally and have had a major impact on human health.

Genomic insights

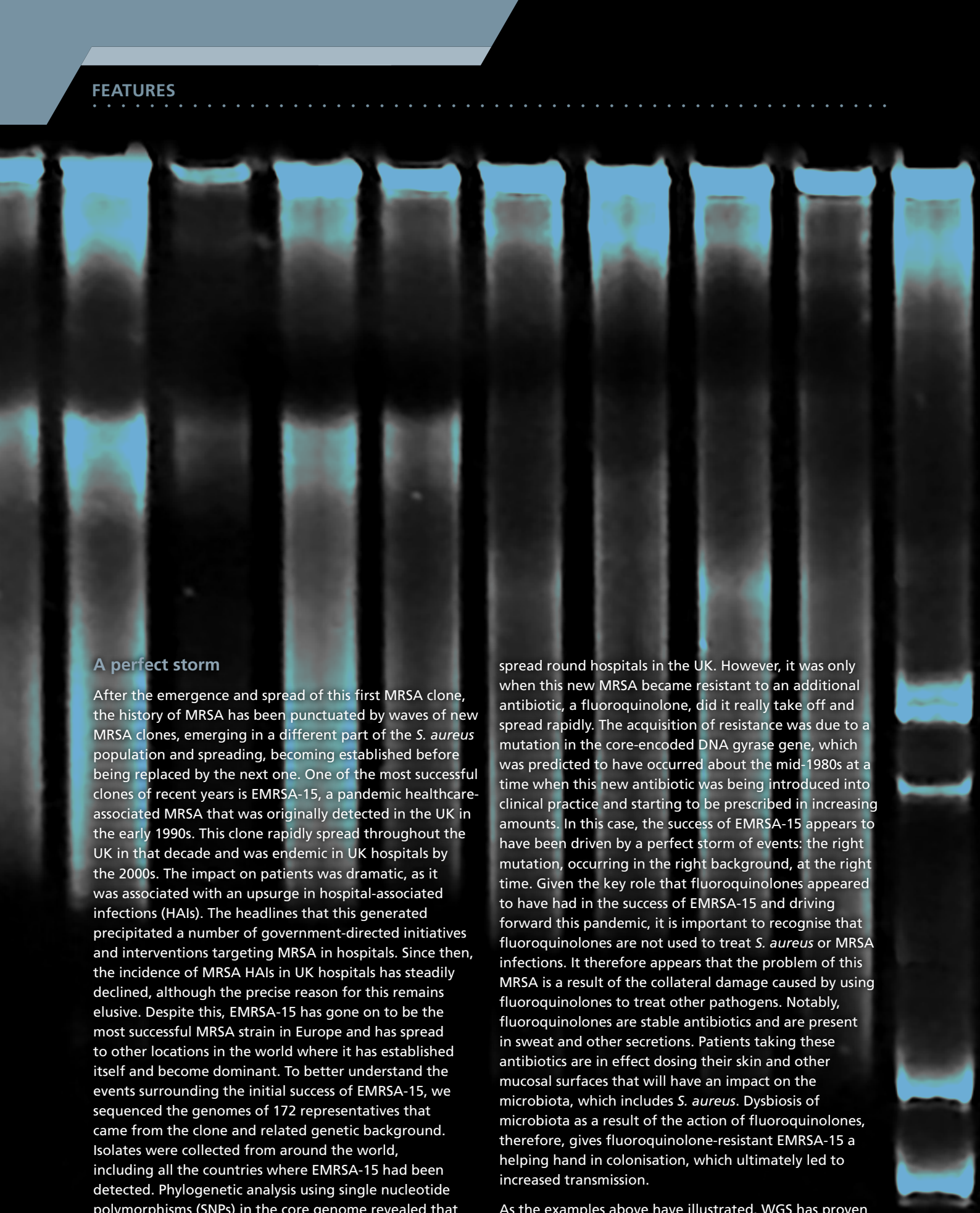
An effective tool to study the success of MRSA has been genomics. Whole-genome sequencing (WGS) captures the genetic inventory of a cell and provides a blueprint that can be used to explore the biology of the organism. The genome is also an historical record and contains information shaped by the ancestry of the organism. By comparing genome sequences alongside the epidemiological information about the strains, it has been possible to piece together evolutionary histories and identify the genetic events that have shaped populations.

The genesis of MRSA

The β-lactam antibiotic penicillin works by binding with cell wall transpeptidase enzymes involved in peptidoglycan biosynthesis, which is vital for cell wall formation. *S. aureus* rapidly developed resistance to penicillin shortly after the introduction of this new wonder drug in the 1940s. Over the years that followed, penicillin-resistant isolates of *S. aureus* carrying a β-lactamase enzyme, BlaZ, spread in hospitals and in the community, blunting the effectiveness of this first-generation β-lactam antibiotic. As a result, semi-synthetic second-generation β-lactam antibiotics, such as methicillin, were developed that were not targeted by β-lactamases. In 1959, methicillin was introduced into clinical practice in the UK and within a year the first MRSA strains were detected. The widely held belief has been that resistance developed in the *S. aureus* population shortly after the very first exposure to this new antibiotic and as a result of the selection it provided. Using a collection of historic MRSA isolates, including some of the originally described MRSA isolates, we were able to show that the methicillin resistance determinant, *mecA*, was carried on a mobile genetic element, which was acquired by a sensitive strain approximately 14 years before methicillin was introduced into clinical practice. The resistance gene in this case encodes an alternative penicillin-binding protein, MecA, that is insensitive to β-lactam antibiotics, and replaces the function of the core version targeted by methicillin. This surprising result demonstrated that the introduction of methicillin was not the selective pressure that drove the emergence of resistance. The dating of the acquisition of resistance was far closer to the introduction

of penicillin into clinical practice, suggesting that the widespread use of first-generation β-lactams was responsible for the original MRSA. In addition to BlaZ, MecA also provided *S. aureus* with an alternative mode of resistance to penicillin. Therefore, it was the earlier use of penicillin that created the selective environment leading to the acquisition of *mecA*. When methicillin was introduced, a pre-existing variant that conferred resistance was already present in the population and the wide spread of this new drug drove the spread of this variant.

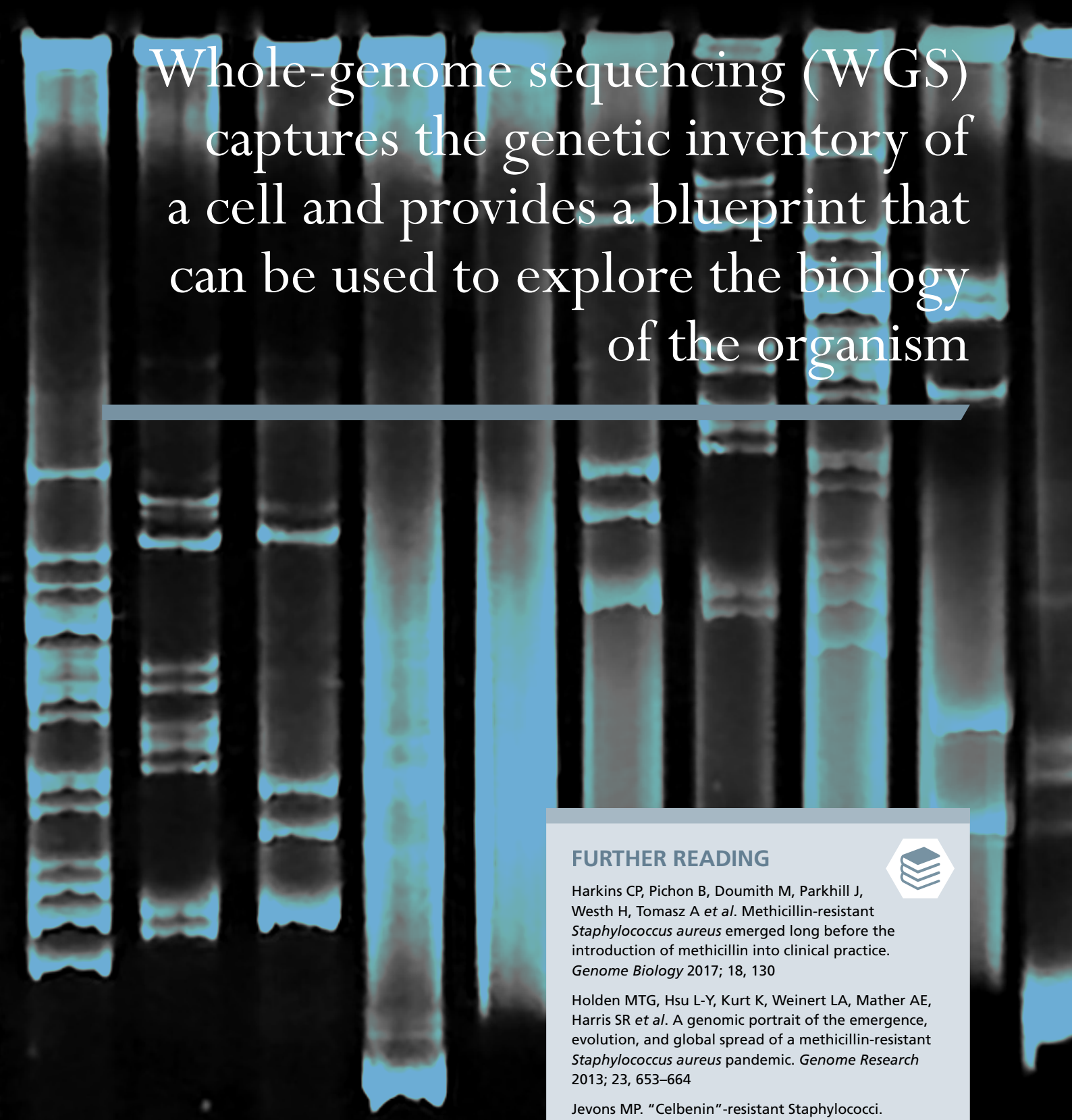
The message that emerged from this study was how the previous selective landscape of old antibiotics can drive the emergence of resistance to new antibiotics, even before they have been developed. This has important implications for the future introduction of new antibiotics into clinical use and highlights the importance of establishing effective surveillance mechanisms to horizon scan for any emerging resistance before it becomes a problem.



A perfect storm

After the emergence and spread of this first MRSA clone, the history of MRSA has been punctuated by waves of new MRSA clones, emerging in a different part of the *S. aureus* population and spreading, becoming established before being replaced by the next one. One of the most successful clones of recent years is EMRSA-15, a pandemic healthcare-associated MRSA that was originally detected in the UK in the early 1990s. This clone rapidly spread throughout the UK in that decade and was endemic in UK hospitals by the 2000s. The impact on patients was dramatic, as it was associated with an upsurge in hospital-associated infections (HAIs). The headlines that this generated precipitated a number of government-directed initiatives and interventions targeting MRSA in hospitals. Since then, the incidence of MRSA HAIs in UK hospitals has steadily declined, although the precise reason for this remains elusive. Despite this, EMRSA-15 has gone on to be the most successful MRSA strain in Europe and has spread to other locations in the world where it has established itself and become dominant. To better understand the events surrounding the initial success of EMRSA-15, we sequenced the genomes of 172 representatives that came from the clone and related genetic background. Isolates were collected from around the world, including all the countries where EMRSA-15 had been detected. Phylogenetic analysis using single nucleotide polymorphisms (SNPs) in the core genome revealed that a progenitor EMRSA-15 clone emerged from an already globally successful methicillin-susceptible *S. aureus* (MSSA) clone around the middle of the 1970s when it acquired the *mecA* methicillin resistance gene. This clone then started to spread round hospitals in the UK. However, it was only when this new MRSA became resistant to an additional antibiotic, a fluoroquinolone, did it really take off and spread rapidly. The acquisition of resistance was due to a mutation in the core-encoded DNA gyrase gene, which was predicted to have occurred about the mid-1980s at a time when this new antibiotic was being introduced into clinical practice and starting to be prescribed in increasing amounts. In this case, the success of EMRSA-15 appears to have been driven by a perfect storm of events: the right mutation, occurring in the right background, at the right time. Given the key role that fluoroquinolones appeared to have had in the success of EMRSA-15 and driving forward this pandemic, it is important to recognise that fluoroquinolones are not used to treat *S. aureus* or MRSA infections. It therefore appears that the problem of this MRSA is a result of the collateral damage caused by using fluoroquinolones to treat other pathogens. Notably, fluoroquinolones are stable antibiotics and are present in sweat and other secretions. Patients taking these antibiotics are in effect dosing their skin and other mucosal surfaces that will have an impact on the microbiota, which includes *S. aureus*. Dysbiosis of microbiota as a result of the action of fluoroquinolones, therefore, gives fluoroquinolone-resistant EMRSA-15 a helping hand in colonisation, which ultimately led to increased transmission.

As the examples above have illustrated, WGS has proven to be an effective tool to unravel stories behind the success of MRSA and highlight some of the unintentional consequences of antibiotic usage, which select and shape the problem pathogens we face.



Whole-genome sequencing (WGS) captures the genetic inventory of a cell and provides a blueprint that can be used to explore the biology of the organism

FURTHER READING

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Microbiology and…
Chemistry: the central science

Peter Harrison
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Chemistry is often referred to as 'the central science', bridging the physical sciences with biological sciences. Indeed, it is easy to see why. Biological systems are, fundamentally, built from molecules, which are the domain of chemists. However, it is an interesting quirk that biology, with the aid of evolution, can often outperform the traditional chemist. Biological systems are able to catalyse an unimaginable range of different chemical reactions, at neutral pH and at 37°C, via the use of enzymes. This is the 'Holy Grail' for any synthetic chemist, who must often use harsh conditions (temperature, pH and pressure) to perform identical reactions in a round-bottomed flask. As such, no longer do chemists and biologists work in isolation, but increasingly together. At first glance, the fields of chemistry and microbiology may seem strange bedfellows, but in fact microbiology has a strong influence on the field of chemistry.

We have been using microbes to perform chemical reactions for thousands of years – perhaps, most notably, the conversion of sugar to alcohol to make beer. As such, due to nature's proficiency at catalysing chemical reactions with exquisite regio- and stereo-specificity, chemists are turning to nature, searching microbial organisms for enzymes to catalyse transformations that are challenging for the synthetic chemist. These enzymes are referred to as biocatalysts and are increasingly being used in industrial processes as an environmentally friendly alternative to established harsh synthetic protocols. Frequently, extremophiles are used as a source of these enzymes as these organisms are adapted to live in extreme conditions (temperature, salinity and pH). As such, enzymes from these microbes have undergone selective evolutionary pressure to work in certain conditions, which may be advantageous. For example, Taq DNA polymerase, used by scientists worldwide, was originally isolated from *Thermus aquaticus* – a bacterium which lives in hot springs at temperatures around 70°C, making it ideal for use in PCRs.

Unfortunately, oftentimes nature has not yet created exactly the right enzyme for the desired process. In these instances, chemists use directed evolution to engineer an enzyme capable of performing the desired chemistry. This process of generating novel biocatalysts is so important that, in 2018, one half of the Nobel Prize in Chemistry was awarded to Professor Frances Arnold for 'the directed evolution of enzymes'. The beauty of this process is well illustrated with the drug sitagliptin, which is the active ingredient in the type 2 diabetes treatment Januvia™ from Merck. A key step in the chemical synthesis of sitagliptin is a high-pressure, rhodium-catalysed asymmetric hydrogenation. Although catalytically efficient, the process was not 'green'. To this end, Merck worked with Codexis to replace the rhodium-catalysed step with an enzyme-catalysed one instead. An (*R*)-selective aminotransferase from an *Arthrobacter* sp. was chosen and, via directed evolution, an *in silico* design was evolved to perform the same reaction with almost complete enantioselectivity and in high yield. The evolved enzyme had 27 mutations across the entirety of the enzyme structure and was able to work under 'industrial conditions', namely at 40°C and in organic solvents. Given how effectively a biocatalyst has been used in the synthesis of sitagliptin, many in industry are looking to microbes as a source of enzymes to catalyse costly, inefficient and environmentally unfriendly processes in their synthetic routes.

The importance of microbiology to chemistry is not limited to just enzymes, but also the compounds produced by microbes: secondary metabolites. As highlighted in the December 2018 issue of *Microbiologist*, we face the increasing threat of antimicrobial resistance (AMR). One of the tools in our arsenal against this threat is the microbes themselves, which produce compounds known as secondary metabolites. These are natural products that help the microbes survive in their environment. Secondary metabolites have uses not just as antimicrobials, but also as agrochemicals and in cancer treatments. The enzymes that produce these secondary metabolites are often grouped together on the microbial genome in gene clusters. Next generation sequencing has given us the genetic information of over 30,000 different bacterial genomes and bioinformatics has allowed us to identify thousands of different gene clusters, many of which are orphan as we do not know what the metabolite produced is. An additional problem is that many of these gene clusters are silent – that is to say, the metabolite is not produced by the microbe under laboratory conditions.

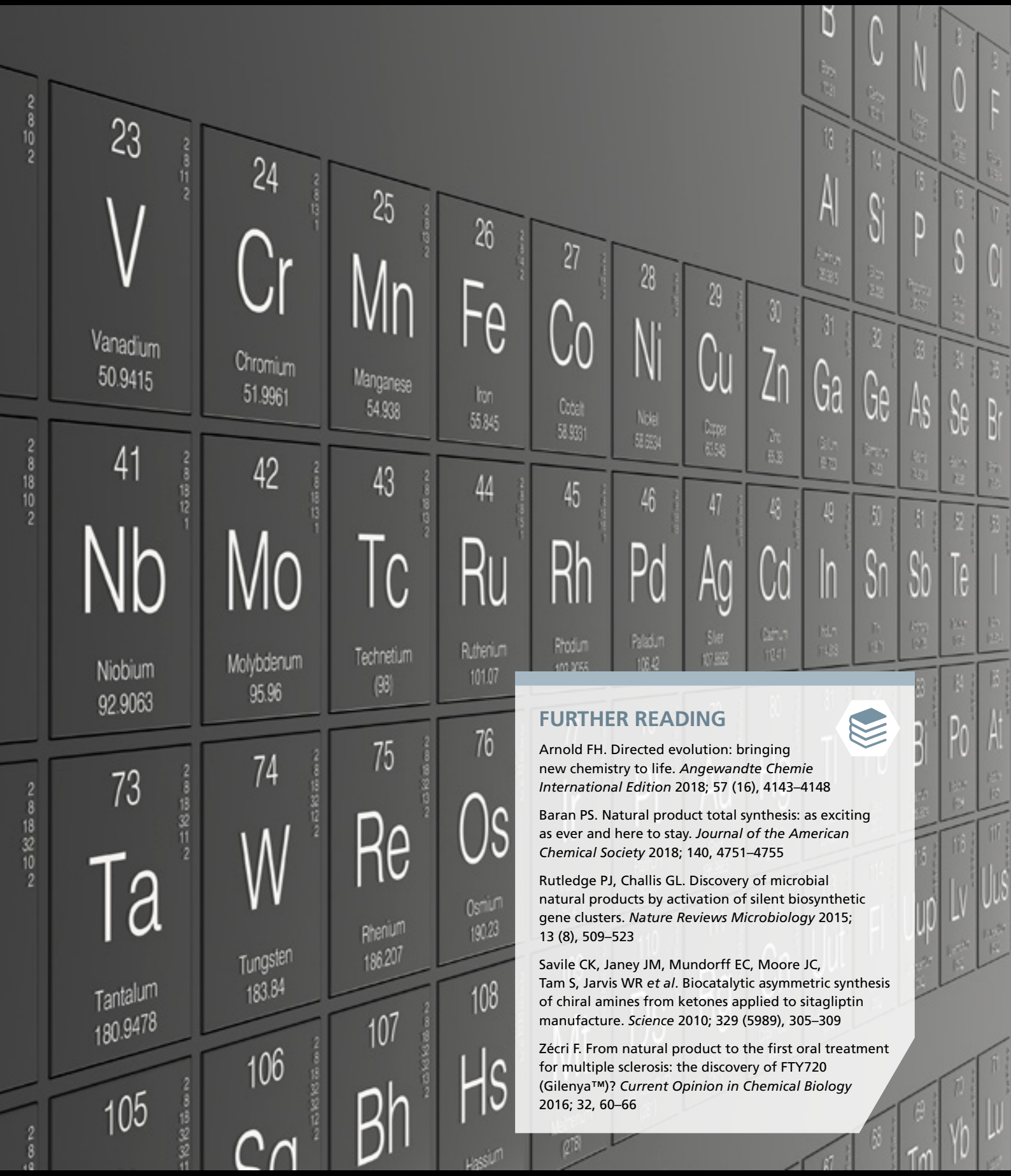
Professor Frances Arnold *bottom right*
2018 Nobel Prize Winner

Awakening these 'cryptic' clusters to produce their chemical output is a current research area. A process known as 'genome mining' is used to identify the gene clusters and to discover the secondary metabolites they produce. Once a gene cluster has been identified, a variety of different methods can be used to activate it (if it is not so already), including (but not limited to) altering growth conditions, manipulating pathway-specific regulators, epigenetic perturbation and transferring the whole cluster to a more efficient microbial host. Once activated, analytical chemistry techniques (high-resolution mass spectrometry, high-performance liquid chromatography and nuclear magnetic resonance) can be used to elucidate the structure of the compound(s) produced by a specific gene cluster and identify key intermediates along the pathway. This leads to the annotation of the enzymes involved in every step of the pathway and helps find close functional homologues in other clusters that may have had no ascribed function. Natural products are often used as the starting point for medicinal chemists who explore their mode of action and engineer them to become even more effective interventions. A good example of this is the natural product myriocin, an inhibitor of the enzyme serine palmitoyltransferase (the first enzyme in sphingolipid biosynthesis) from the ascomycete *Isaria sinclairii*. A medicinal chemistry programme led to the development of FTY720, which is in fact not a serine palmitoyltransferase inhibitor, but a sphingosine 1-phosphate receptor (a GPCR) modulator. FTY720 is sold as Gilenya™ and is used as a treatment for multiple sclerosis. What is more, studying these cryptic gene clusters often leads to the discovery of interesting new enzymes with potential biocatalytic applications.

Many pages in the scientific literature are devoted to the total synthesis of natural products from microorganisms. These endeavours are not only interesting from an academic point of view (biology can make a compound in significantly fewer steps than a synthetic chemist), but they also allow the development of new synthetic techniques. Possibly most famous for this is the chemist Robert Burns Woodward, who won the Nobel Prize in 1965 for the synthesis of complex organic molecules. Woodward reported the first total synthesis of many different natural products, including vitamin B12, erythromycin A and cephalosporin C. Many synthetic techniques now routinely used in synthetic chemistry labs were first developed for the total synthesis of natural products.

Here, I have highlighted only three areas where microbiology has impacted upon chemistry. However, the impact is not limited solely to natural products or biocatalysts. Bioremediation for example, the process of using microorganisms for the detoxification of the environment, is very much in the domain of chemists, especially if this involves the engineering of enzymes to detoxify a specific chemical. It is often said that 'imitation is the greatest form of flattery' and chemists are frequently trying to copy and build upon nature. Chemistry is not a rigid subject, but in fact a broad subject area, and so it is likely that microbiology will continue to influence chemistry for the foreseeable future.

Microbiology will continue to influence chemistry for the foreseeable future



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Microbiology and…
Engineering: evolving the gold standard

Daniel McCluskey and **Ian Johnston**
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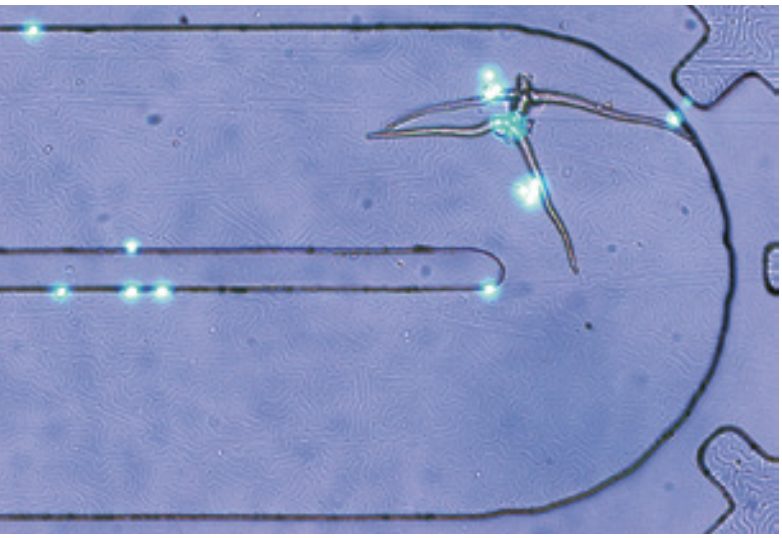
Real-time *in situ* biological analysis has long been the ambition of many industries, from airport security to environmental monitoring. Advances in laboratory biological instrumentation have hinted at the potential for robust, high-sensitivity fieldable systems. However, the successful deployment of rapid response chemical detection techniques has far outpaced their biological cousins within challenging environments, such as airport security, highlighting the limitations of existing biological detection hardware. Clearly, this is only one deployment scenario, yet the expectations set by the existing technology, such as advanced body scanning and liquid/powder residue screening hardware, point to the primary obstacle for biological detection systems, namely processing time.

***Magnetic beads**, the interloping ballerina. The unintended consequences of prefiltration failure in microfluid bioanalysis*



Regardless of the biological process, the desire to deliver near-instantaneous information to the operator is beset by challenges associated with the time required to capture, process and assess biological targets. The more challenging the environment, the more complex the protocol and processing stages required for bioanalysis. Such is the difficulty of achieving this biodetection aim that many institutions continue to rely on the gold standard – namely strategic placement of agar-loaded Petri dishes, varying incubation times from 6 to 72 h and a big dollop of luck. This well-established approach is perfectly adequate for routine monitoring. However, for high-risk scenarios requiring early warning, such as biowarfare detection, endemic disease monitoring and hospital infection control, this approach is slowly giving way to more advanced systems. Despite these advances, evolving the gold standard remains a challenge, where the development of complex multidisciplinary engineering methodologies may well be the approach to bring recent advances in microbiology into alignment with chemical detection techniques.

Spread plating to molecular diagnostics

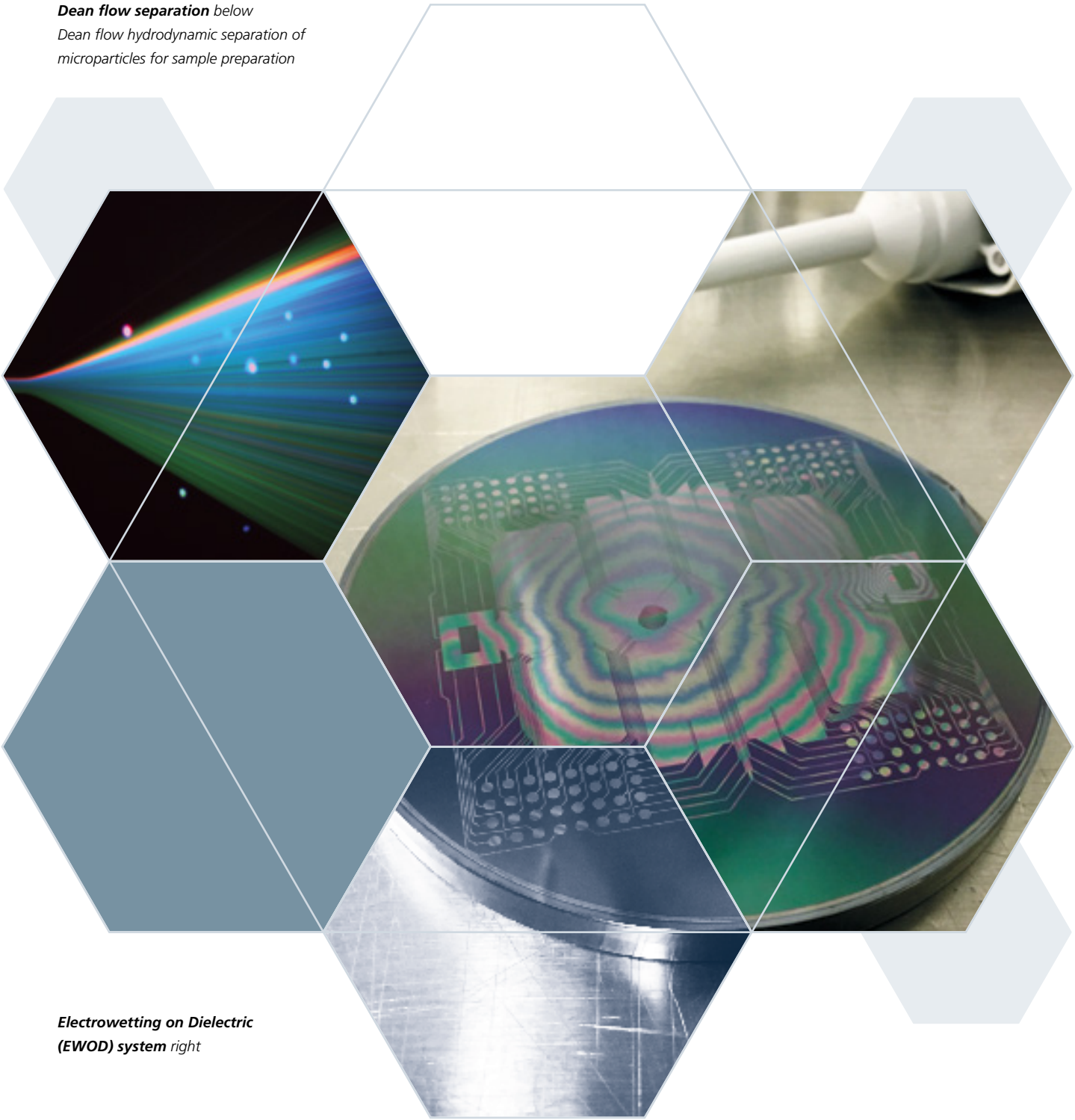
Engineering approaches thrive on a deterministic, specification-led approach to develop technologies fit for purpose. Laboratory instrumentation relies on a myriad of sample preparation techniques to minimise variability and uncertainty, optimising sample purification wherever possible. Technical challenges are not the only obstacle to overcome. The application of new technologies for medical applications requires a high degree of reliability and repeatability to be accredited under medical device regulations. Nonetheless, complex molecular diagnostic techniques have been developed for multiple areas of microbiology, for example, monitoring of cancer biomarkers for the identification of infectious diseases in

animals, plants and humans alike. In all cases there is a common aim: to develop engineered hardware capable of providing repeatable, reliable and rapid biological identification.

Engineering cannot solve problems in isolation. Instead, appropriately used engineering can provide the bridge between existing and emerging bioprocessing methods and the means to propagate the fundamental microbiological principles.

One standout exemplar is Dr Kary Mullis' PCR method for molecular diagnostics. This practice has proven to be one of the most disruptive technologies in microbiology and biochemistry, earning Mullis the Nobel Prize in Chemistry in 1993. Clearly the PCR technique has been groundbreaking; however, it was the engineering innovations that provided the stability and reliability that led to the first commercialised systems in the late 1980s. The development of engineered instruments to exploit the technique allowed mass propagation of PCR. While the success of PCR undoubtedly stands on its own, the

Dean flow separation *below*
Dean flow hydrodynamic separation of microparticles for sample preparation



Electrowetting on Dielectric (EWOD) system *right*

simultaneous commercial release of the AmpliTaq DNA Polymerase alongside the availability of the PCR-1000 Thermal Cycler helped propagate both research into PCR and its worldwide practical implementation in laboratories and clinical settings.

From the lab to the field

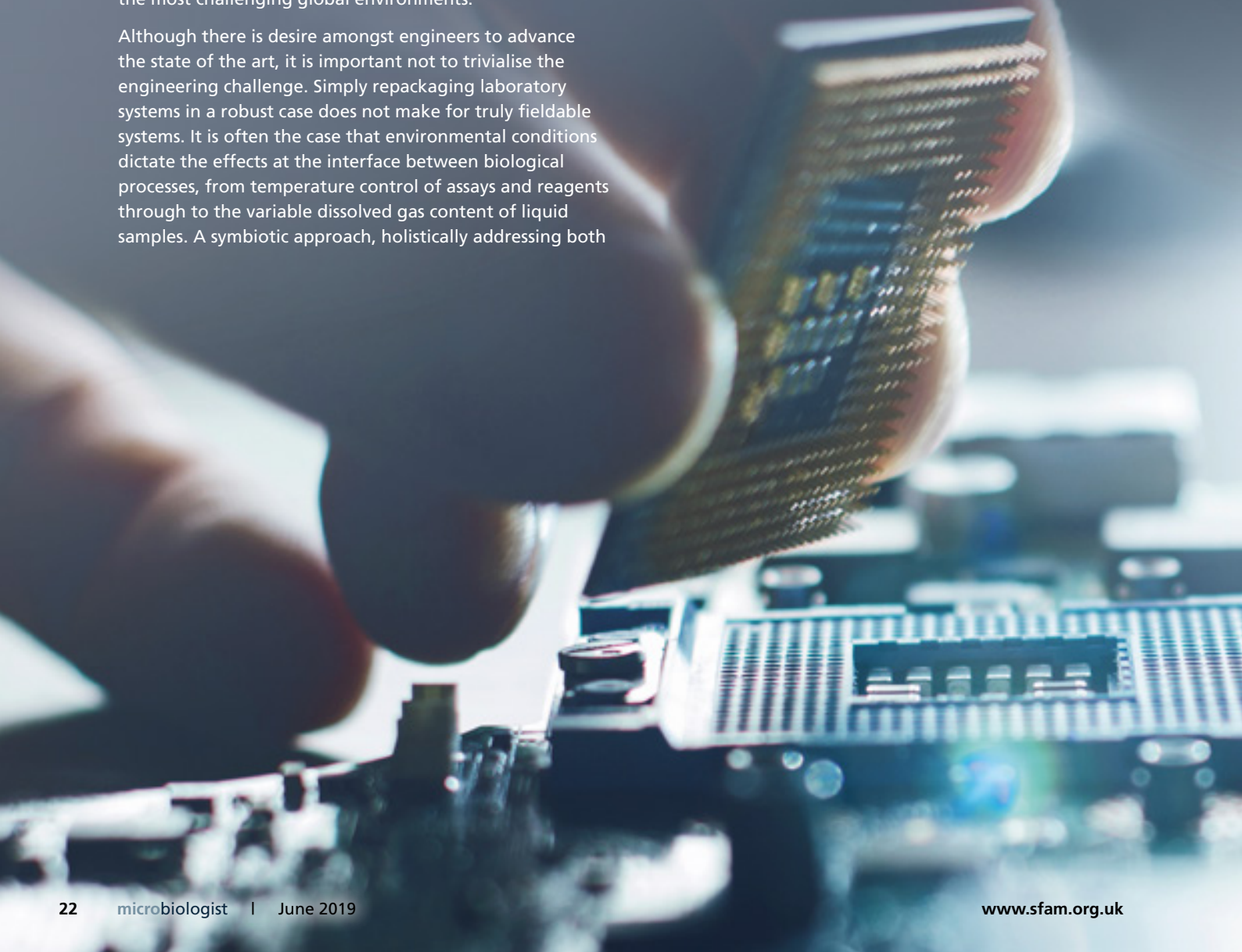
The co-development of microbiological techniques and processes alongside engineering progress in instrumentation capability has continued to advance microbiology. The supporting instruments are ubiquitous across microbiology laboratories worldwide. Microscopes, colony counters, incubators, plate readers, washers, thermal cyclers, the list is endless. Through engineering development, laboratory instrumentation has become more complex, more accurate, user friendly and, perhaps most significantly, cheaper. Price reduction has led to more exposure and a better understanding of the techniques themselves, giving rise to the next wave of engineering development, taking the instruments out of the laboratory and into the field. This is a current focus for engineers and microbiologists alike, with the development of portable systems potentially leading to deployment into some of the most challenging global environments.

Although there is desire amongst engineers to advance the state of the art, it is important not to trivialise the engineering challenge. Simply repackaging laboratory systems in a robust case does not make for truly fieldable systems. It is often the case that environmental conditions dictate the effects at the interface between biological processes, from temperature control of assays and reagents through to the variable dissolved gas content of liquid samples. A symbiotic approach, holistically addressing both microbiological and engineering concerns, ascertaining the constraints and operating environment, is a much better approach to system development, even when compromises may be required on the ultimate detection threshold or sample size.

New technologies for microbiology

This cooperative approach between engineering and microbiology can be seen in a number of new technologies coming onto the market. These include application-independent tools, such as the product portfolio from Oxford Nanopore Technologies, to the application-specific integrated SporeSentry detection system from OptiSense. Similarly, evolving emerging research tools such as the Electrowetting on Dielectric (EWOD) platforms for on-chip biochemistry are coming out of both my own microfluidic and microengineering group at the University of Hertfordshire, UK, and Aaron Wheeler's highly successful group at the University of Toronto, Canada.

The Oxford Nanopore Technologies sequencing systems not only innovate in compact gene sequencing capability but the form factors have been developed to maximise



uptake, adopting mobile computational power through laptops, smartphones and tablets to enable true portability. Alongside the engineering innovation, Oxford Nanopore Technologies' support community is pivotal in driving rapid advances in the technology, drawing upon a large cohort of real users to influence the subsequent development of their products.

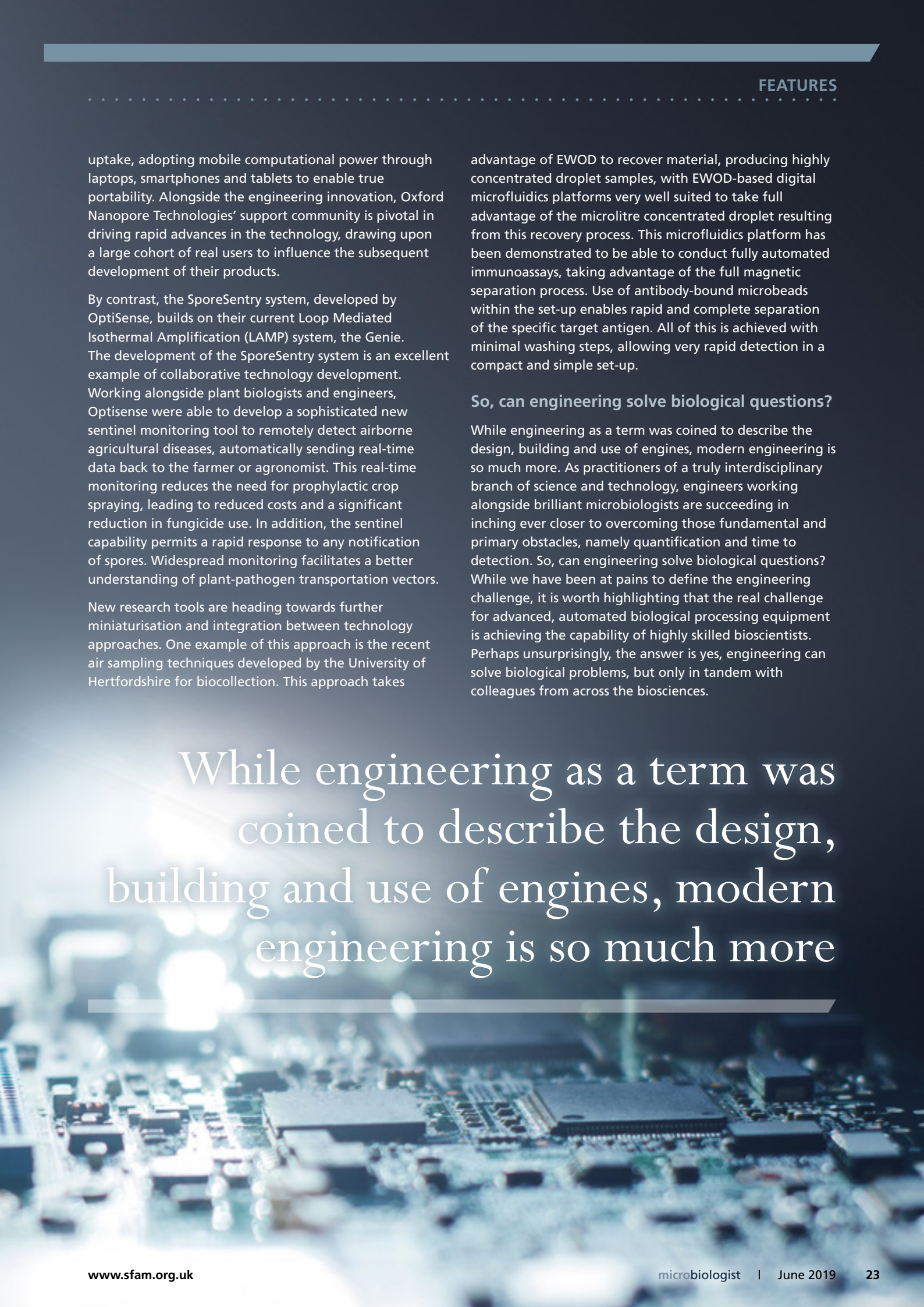
By contrast, the SporeSentry system, developed by OptiSense, builds on their current Loop Mediated Isothermal Amplification (LAMP) system, the Genie. The development of the SporeSentry system is an excellent example of collaborative technology development. Working alongside plant biologists and engineers, Optisense were able to develop a sophisticated new sentinel monitoring tool to remotely detect airborne agricultural diseases, automatically sending real-time data back to the farmer or agronomist. This real-time monitoring reduces the need for prophylactic crop spraying, leading to reduced costs and a significant reduction in fungicide use. In addition, the sentinel capability permits a rapid response to any notification of spores. Widespread monitoring facilitates a better understanding of plant-pathogen transportation vectors.

New research tools are heading towards further miniaturisation and integration between technology approaches. One example of this approach is the recent air sampling techniques developed by the University of Hertfordshire for biocollection. This approach takes advantage of EWOD to recover material, producing highly concentrated droplet samples, with EWOD-based digital microfluidics platforms very well suited to take full advantage of the microlitre concentrated droplet resulting from this recovery process. This microfluidics platform has been demonstrated to be able to conduct fully automated immunoassays, taking advantage of the full magnetic separation process. Use of antibody-bound microbeads within the set-up enables rapid and complete separation of the specific target antigen. All of this is achieved with minimal washing steps, allowing very rapid detection in a compact and simple set-up.

So, can engineering solve biological questions?

While engineering as a term was coined to describe the design, building and use of engines, modern engineering is so much more. As practitioners of a truly interdisciplinary branch of science and technology, engineers working alongside brilliant microbiologists are succeeding in inching ever closer to overcoming those fundamental and primary obstacles, namely quantification and time to detection. So, can engineering solve biological questions? While we have been at pains to define the engineering challenge, it is worth highlighting that the real challenge for advanced, automated biological processing equipment is achieving the capability of highly skilled bioscientists. Perhaps unsurprisingly, the answer is yes, engineering can solve biological problems, but only in tandem with colleagues from across the biosciences.

While engineering as a term was coined to describe the design, building and use of engines, modern engineering is so much more



Microbiology and…
Mathematics: microbiological meaning from mathematical models

Jan-Ulrich Kreft [1] and **Gamze Gülez** [2]

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[2] *Istanbul, Turkey*

Mathematical modelling has traditionally been a normal part of microbiological research. It was not considered to warrant any special mention in the title and abstract and then required burying in the supplementary material. Models were simply used when useful and researchers had the skills to use them. Describing the growth and death of populations is probably the first area where models were used as a matter of course; then came the molecular biology revolution. While pioneered by scientists with strong theoretical skills and mindset, experiments soon trumped theory in the elucidation of the genetic code. Moreover, molecular biology had been enormously successful in revealing the function of myriads of genes without any theory, not even statistics. This side-lined modelling and the skills it required although quantitative reasoning survived in some areas of microbial sciences such as predicting bacterial growth in foodstuffs. The effects of the molecular revolution are still felt today despite the increasing recognition that mere qualitative understanding of the interactions of genes and gene products and products of gene products cannot deal with the complexity and dynamic nature of these interactions, giving rise to systems biology and the need for biologists to have quantitative skills. As Schnell, Grima and Maini put it in 2007, 'Molecular biology took Humpty Dumpty apart; mathematical modelling is required to put him back together again'.

What is this thing called a mathematical model?

When reading papers including mathematical models, it is empowering to understand the nature of such models, even when technical details may be beyond us non-mathematicians. In the words of Gunawardena in 2014, 'a mathematical model is a logical machine for converting assumptions into conclusions' (Figure 1). From this nature of models, everything follows:

(i) Scrutinise assumptions. Since the biology is in the assumptions, they should be scrutinised by us microbiologists and indeed that is what we are best placed to do. Developing models helps to bring such assumptions to light so they can be scrutinised more easily (Figure 1).

(ii) Assumptions simplify reality. The purpose of a model is to simplify reality, otherwise, reality would be the best model of itself. The same actually holds for experimental

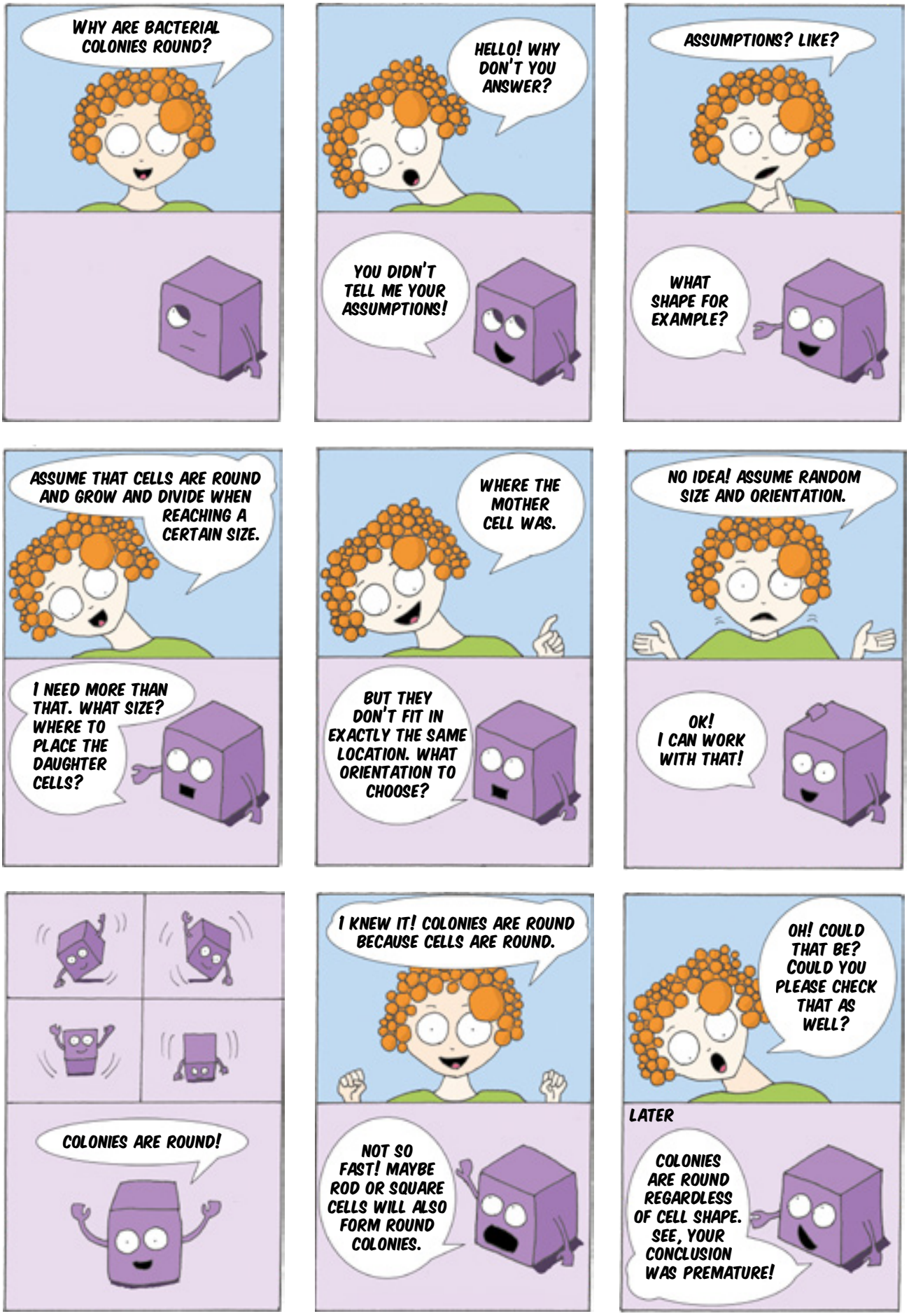

Figure 1 *Logic machine and microbiologist*

MICRO-C-OMICS by Gamze Gülez

Mathematical models are not useful because they are wrong, but they are useful due to the extent to which they are not wrong

models; for example, laboratory models, insect models or mouse models of the human gut simplify reality to various degrees like different mathematical models do. Although assumptions should simplify reality, they should not distort reality. It is here that modelling of any kind is more an art than a science. As Sober and Wilson put it in 1999, 'simplifying assumptions are both the soul and Achilles' heel of mathematical models' (Figure 2).

(iii) Predictions are predictions. Even when predictions follow from empirically supported assumptions, predictions should never be given the same status as empirical truth. Since a model will predict what would happen if the assumptions were true, we can merely rule out sets of assumptions that are wrong (Figure 2). However, there might be alternative assumptions that generate similar predictions so one should test various assumptions with a family of related models (Figure 1).

(iv) A model can give the right answer for the wrong reasons (Figure 1). Even if the predictions of a model match experimental data, it can still be wrong if its assumptions are wrong. Claudius Ptolemy's geocentric astronomical model predicted the planets' positions but it is wrong because its geocentric assumptions are wrong.

A tale of neglect

The importance of scrutinising assumptions as well as predictions can be illustrated by mathematical models of ageing in unicellular organisms. Neglecting processes of damage repair and cellular growth led to the prediction that damage segregation is beneficial but not damage repair, despite the fact that all known organisms evolved to repair damage (Figure 2).

Chance behaviours

We evolved to recognise patterns and find regularities in natural events and predict future events. Thus, we find it hard to imagine and accept that chance, the unavoidable and uncontrollable, plays an important role in many fundamental life processes. For example, (i) chance is necessary for the formation of spatial patterns from initially uniform conditions (Turing patterns or biofilm formation), (ii) stochastic gene expression generates individual differences and (iii) evolution arises from natural selection of random mutations. Stochastic processes on a microscopic level can make systems behave predictably on a macroscopic level.

Feedback

Logical machines have also been essential in understanding the role of positive and negative feedback in a wide range of biological processes. In quorum sensing, positive feedback in signal production amplifies the response to the signal, particularly in clusters of cells, so quorum sensing is also the sensing of clustering rather than just cell density. The positive feedback also leads to hysteresis, where down-regulation of cells occurs at an autoinducer level much below the level required for up-regulation. Such hysteresis is hard to understand without a model demonstrating how it can emerge from known non-linearities in signal production and response.

Bistability

Another example of feedback leading to the emergence of surprising macroscale behaviour is bistability, where a cell can switch between two different but stable states, such as growing or persister states or other types of cellular differentiation. The difficulty is understanding that both states are stable to a degree but switching between them is possible. Again, logical machines help by showing that double-negative feedback or positive feedback can turn a stochastic perturbation in a molecular process into a switch on the macroscopic scale of the cell. Similarly, switching between multiple stable states on the level of microbial communities may explain the existence of enterotypes, which are stable associations of microbial populations in the gut that can differ between individuals.

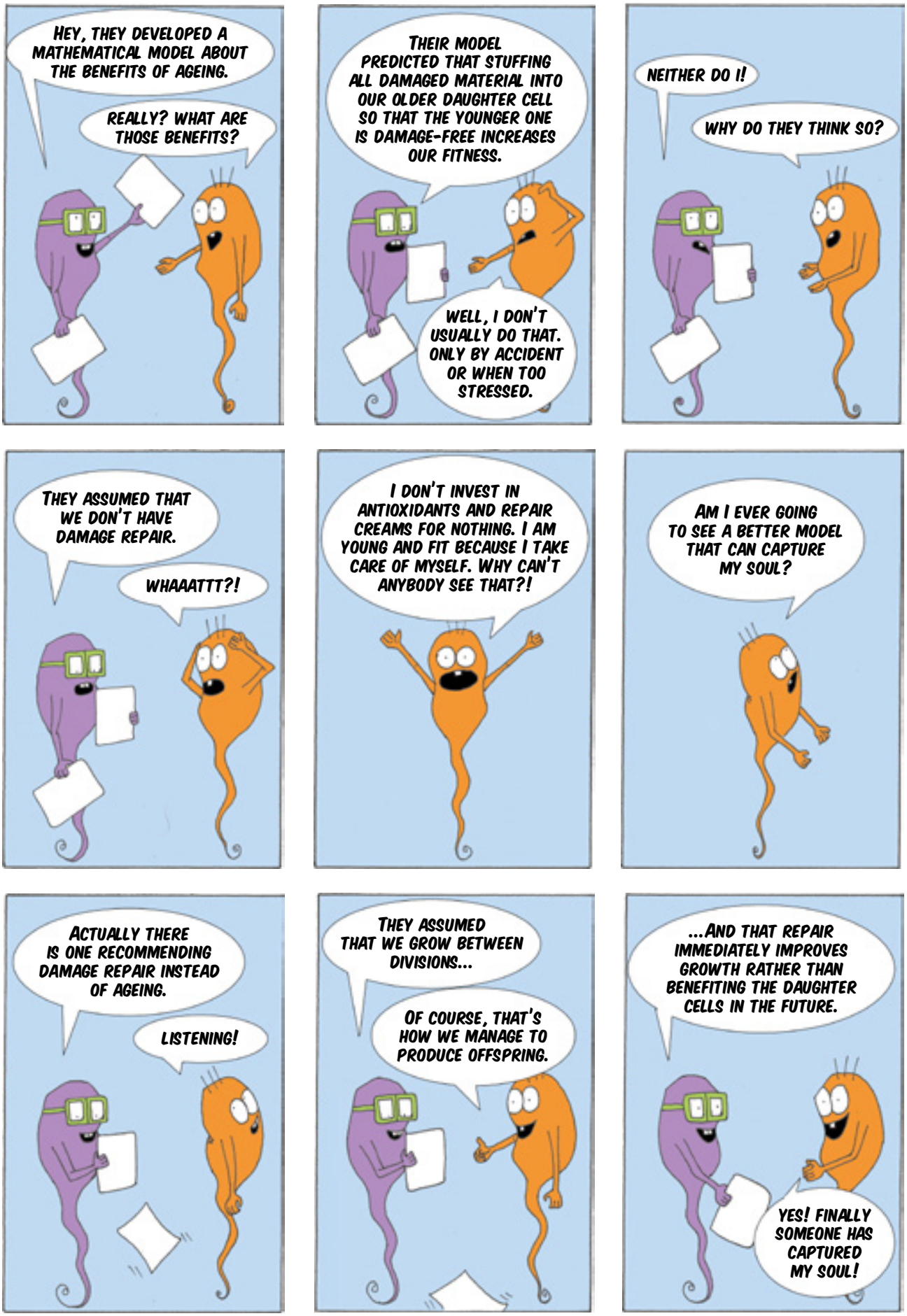

Figure 2 *Assumptions simplify or distort reality*

MICRO-C-OMICS by Gamze Gülez

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Feedback, trade-offs and biofilms

An example of spatial pattern formation driven by positive feedback is the fingering instability in biofilms that explains how finger-like structures can emerge from initially flat biofilms. Similar positive feedback can arise in biofilms if individual cells cooperate by refraining from competition for limiting resources. Cells with a higher growth yield, producing more biomass per substrate consumed, use these resources more economically. Due to a trade-off, they have a lower growth rate (maximum specific growth rate) as a disadvantage. Surprisingly, a cluster of such economical cells with a lower growth rate grows faster in a biofilm than a cluster of cells with a higher growth rate. This is because a cluster of economical cells, consuming less substrate, benefit from the locally higher substrate concentration boosting their growth. As the cluster grows larger, the benefit increases, leading to positive feedback. Recognising the benefits of a higher yield when living in biofilms where growth is limited by the diffusion of substrate into the biofilm led us, in 2006, to predict that complete ammonia oxidation (comammox) should have fitness benefits in biofilms. By oxidising ammonia completely to nitrate rather than nitrite, the growth yield was predicted to be higher but the growth rate was lower according to the kinetic theory of optimal pathway length (Figure 3). Comammox was discovered in 2015.

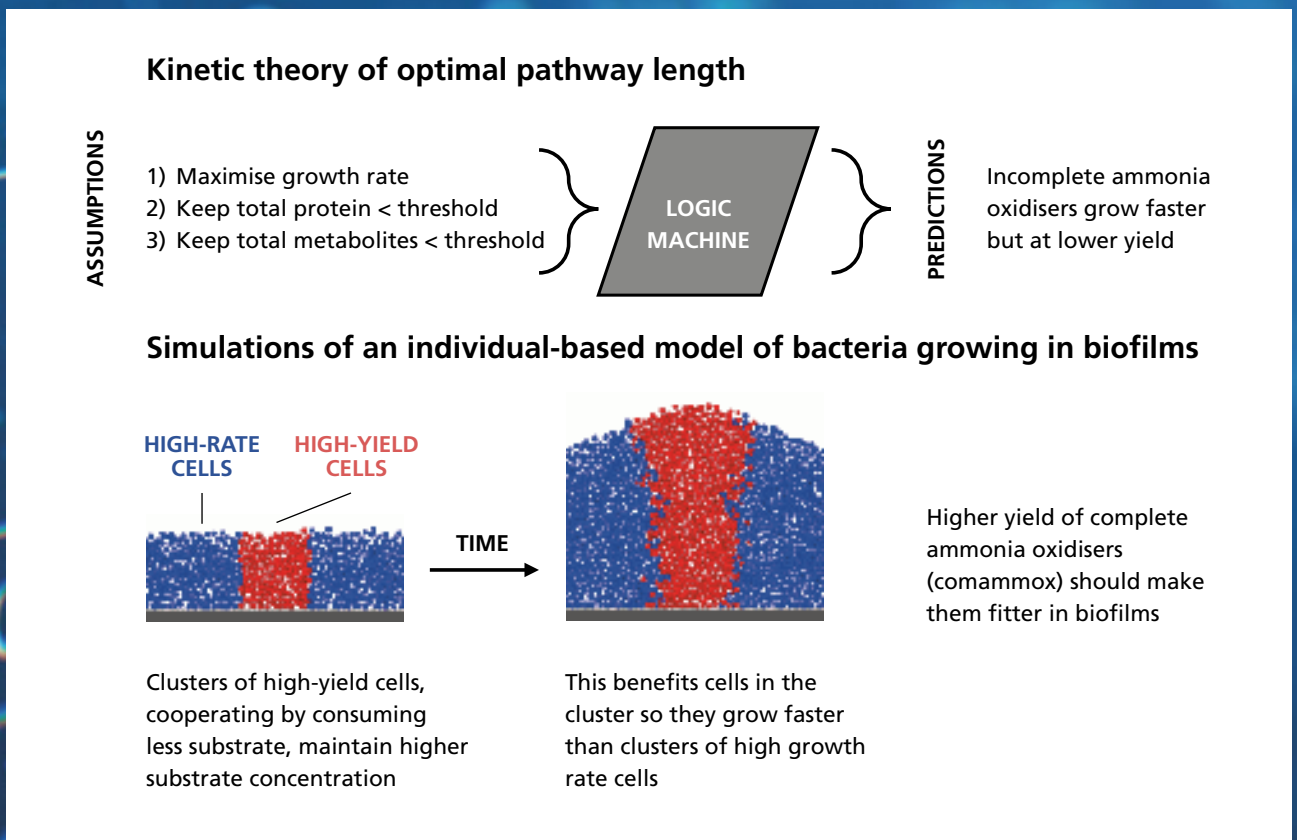
What we learned from mathematical modelling

From a personal perspective, using mathematical models helped us to gain a deeper understanding of the role of stochastic processes, positive and negative feedback and the emergence of complex macroscopic behaviour from simple microscopic rules or vice versa. We have learned to consider different time and spatial scales and recognised that models are our only chance to cope with the complexity that makes biology unique and fascinating.

True or false?

Returning to our logical machine perspective for our conclusions, mathematical models are not true or false by virtue of being models but they are 'truer' if their assumptions and predictions have stronger empirical support and if alternative models have been tested and found to be less adequate. To recast George EP Box's famous yet misleading quip 'all models are wrong but some are useful', where he had statistical models in mind, mathematical models are not useful because they are wrong, but they are useful due to the extent to which they are not wrong. The truer the model, the more useful it is.

Figure 3 *below: From studies of growth rate versus yield trade-off in biofilms and kinetic theory to the prediction of complete ammonia oxidation (comammox)*



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Microbiology and…
Neurobiology: a nematode's perspective

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Over 50 years ago, Sydney Brenner introduced the use of the bacterivorous nematode *Caenorhabditis elegans* as a model to genetically address biological questions. With its small size (1 mm long), 3-day generation time and transparent body, *C. elegans* has proven to be a powerful model organism that has contributed seminal insights into neurobiology, ageing, physiology and cell biology, worthy of three Nobel Prizes so far.

In the wild, *C. elegans* feeds on bacteria growing on decaying organic matter and has a microbiota consisting of a few dozen bacterial species. In the laboratory, *C. elegans* has been bred for decades monoxenically (on a single bacterial species), typically on a non-pathogenic form of *Escherichia coli*. Recently, researchers have been using the strengths of the worm to investigate the interactions of gut microbes with their host, as exemplified below.

One axis of research has explored how gut bacteria affect lifespan. Worms live for only 3 weeks, which makes them very convenient for longevity studies. Bacterial diets directly impact the worm's lifespan: *C. elegans* lives longer when fed on *Bacillus* species, found in its natural environment, than when fed on *E. coli*. *Bacillus subtilis* specifically increases *C. elegans* longevity, as well as strengthening thermotolerance, stress resistance and resistance to pathogens. Some of the beneficial effects of a *B. subtilis* diet depend on the formation of a bacterial biofilm in the gut of the worms and the production of nitric oxide, a short-lived signalling molecule that nematodes are unable to synthesise on their own.

The ease of experimentation with *C. elegans* makes it feasible to tease apart effects of individual microbiota species and to discover the precise bacterial genes responsible for interactions with the host. Using *E. coli* single-gene deletion libraries and feeding each deletion strain to the worms, researchers were able to pinpoint pro-longevity bacterial metabolites. For example, bacterial mutations that increase the secretion of colonic acid, a polysaccharide normally produced by bacteria under environmental stress conditions, extend lifespan by tuning the host's mitochondrial homeostasis. Thus, animals like *C. elegans* may have developed ways to sense stress-associated information directly from their gut microbiota and respond by improving organismal fitness.

Another exciting area of research explores the intersection of drug metabolism, host and microbiota. Gut microbiota can alter drug toxicity or efficacy and *C. elegans* studies are uncovering some of the underlying mechanisms. Metformin, a drug widely prescribed to treat type 2 diabetes, differentially affects the lifespan of worms depending on the presence or absence of *E. coli* bacteria in the gut. The drug changes microbial metabolism, namely folate and methionine synthesis, which in turn limits nutrient availability to the host, resulting in lifespan extension. However, in the absence of metabolically active *E. coli*, metformin has toxic effects and shortens lifespan, highlighting how gut microbiota can alter drug toxicity.

Further *C. elegans* studies have explored the efficacy of chemotherapy drugs in the presence of different

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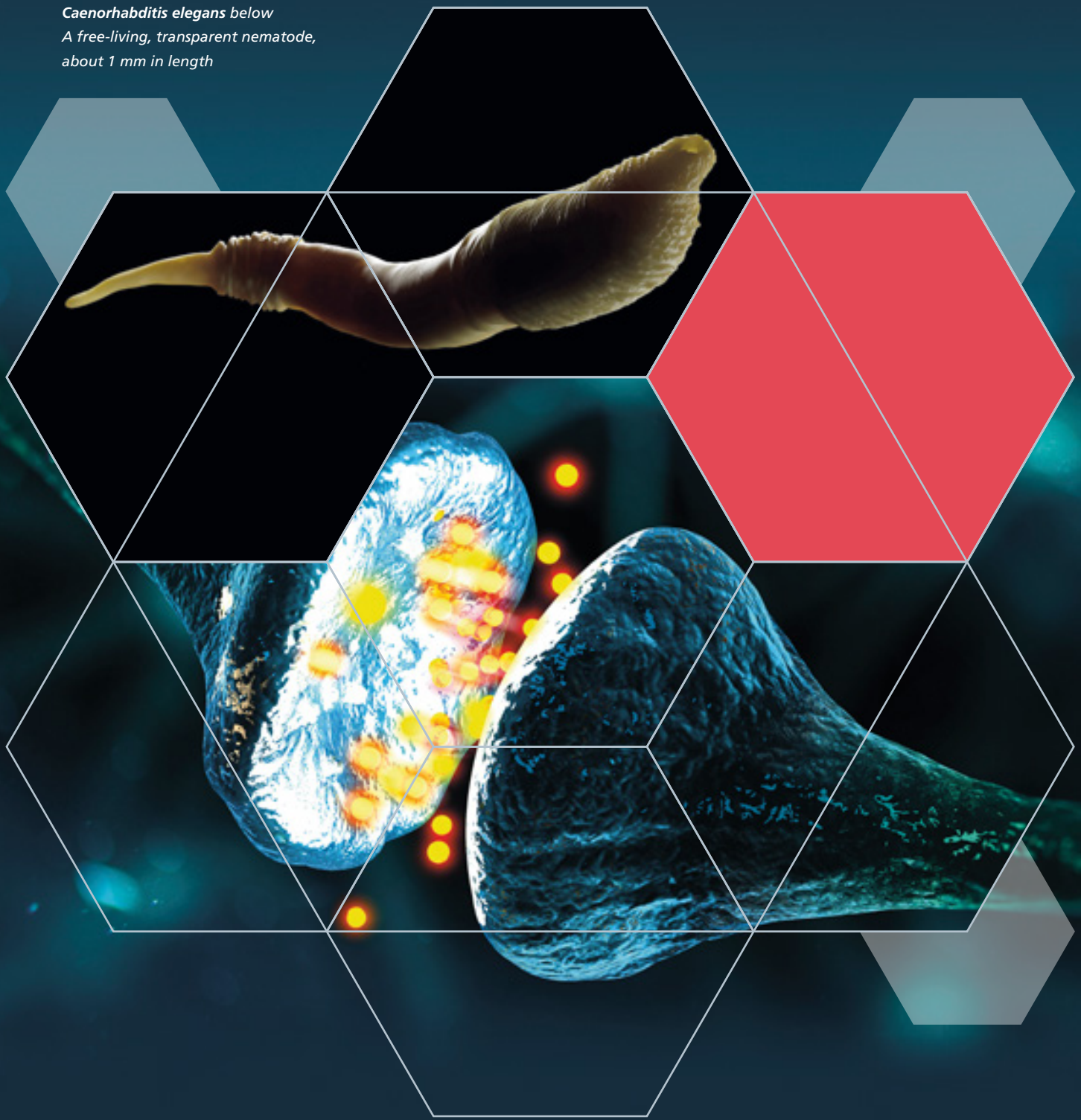
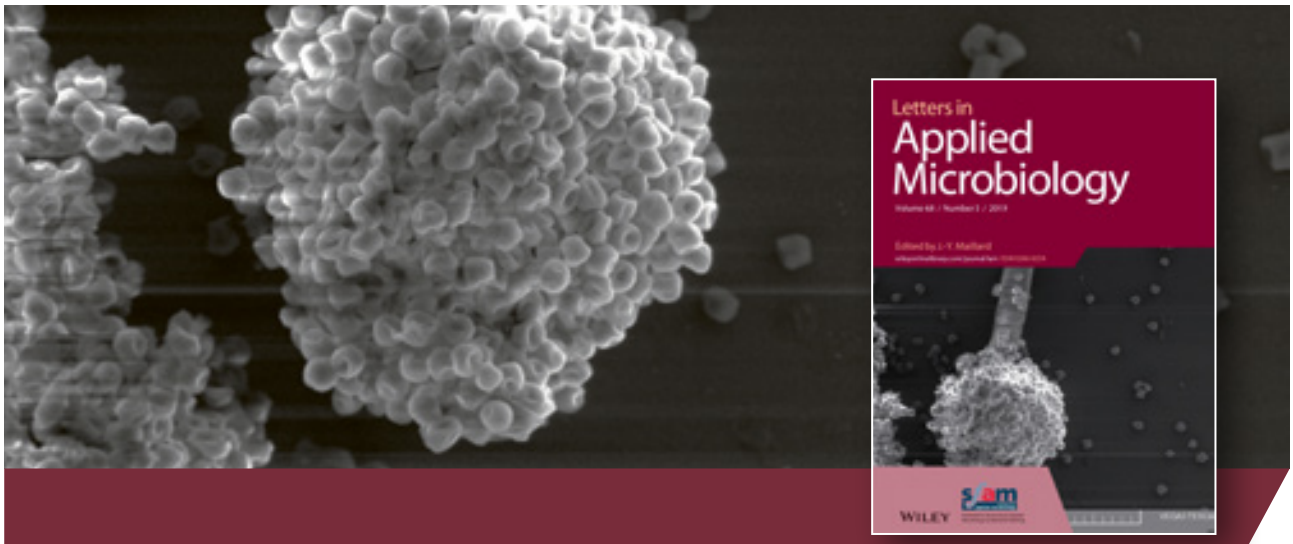
microbiotas. Fluoropyrimidine-based compounds, often used in cancer treatment, change their efficiency several-fold, depending on the type of bacteria present in the worm gut. Microbial RNA metabolism and vitamins B6 and B9 are key contributors to converting the chemotherapeutic drug to its active form; therefore the drug's efficacy depends on the metabolic properties of the microbiota species. Pharmacomicrobiomics, a new frontier in pharmacology that investigates the interplay between drugs, microbiota and host genotype, is opening new prospects in personalised medicine.

These sorts of studies are difficult to perform in mammalian systems because of the time-consuming experimentation and the complexity of their microbiota. Thus, *C. elegans* offers a unique opportunity to investigate complex phenomena at a single-species/single-gene resolution. Over two-thirds of *C. elegans* genes have human orthologues with evolutionarily conserved functions; therefore, discoveries made with the worm open exciting possibilities in humans, such as diet-based interventions to target ageing and microbiota manipulations for optimal drug treatments.

Caenorhabditis elegans *below*
A free-living, transparent nematode, about 1 mm in length





Letters in
Applied Microbiology

Antagonistic effects of *Streptococcus* and *Lactobacillus* probiotics in pharyngeal biofilms.

Humphreys GJ, McBain AJ. Antagonistic effects of *Streptococcus* and *Lactobacillus* probiotics in pharyngeal biofilms. *Letters in Applied Microbiology* 2019; 68, 303–312.

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https://onlinelibrary.wiley.com/doi/pdf/10.1111/lam.13133

Probiotics are now a multimillion-pound industry and are ingested with a view to promoting host health. Historically, most of the work in this field has been aimed at the gut, although some probiotic strains have shown promise when targeted to the upper respiratory tract, such as in the treatment of bacterial pharyngitis.

The human pharynx harbours a complex bacterial population, which probably plays a role in colonisation resistance against pathogens that attempt to establish themselves within the upper respiratory tract. By ingesting probiotics, we are in effect exposing our commensal microbiota to large quantities of potentially antagonistic bacteria. The consequences of such interactions are unclear, but in a worst-case scenario, probiotic-mediated antagonism could lead to a disruption in microbial homeostasis at this site and subsequent impairment of some innate host defences.

To begin to address this gap in knowledge, we used a previously validated continuous culture model to mimic the bacterial communities present in the human pharynx. As well as direct inhibition of pharyngeal pathogens, this allowed us to determine changes in population composition following their exposure to probiotic species of streptococci and lactobacilli.

Longitudinal changes in bacterial communities were observed following viable counting and were generally limited to the staphylococci and streptococci. However, upon investigation with deep sequencing, these effects were shown to be comparatively limited. Similarly, significant effects on bacterial diversity and total observable taxa were not associated with probiotic dosing.

This work demonstrates the potential utility of using *in vitro* models in the preclinical testing of the safety and efficacy of candidate pharyngeal probiotics.

Gavin Humphreys and **Andrew McBain**
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Environmental Microbiology

The urgent need for microbiology literacy in society.

Timmis K, Cavicchioli R, Garcia JL, Nogales B, Chavarría M, Stein L *et al*. The urgent need for microbiology literacy in society. *Environmental Microbiology* 2019 [Epub ahead of print].

Available from

https://onlinelibrary.wiley.com/doi/full/10.1111/1462-2920.14611

Microbes and their activities have pervasive, remarkably profound and generally positive effects on the functioning, and thus health and well-being, of human beings, the whole of the biological world, and indeed the entire surface of the planet and its atmosphere. Collectively, and to a significant extent in partnership with the sun, microbes are the life-support system of the biosphere. This necessitates their due consideration in decisions that are taken by individuals and families in everyday life, as well as by individuals and responsible bodies at all levels and stages of community, national and planetary health assessment, planning and the formulation of pertinent policies.

However, unlike other subjects having a pervasive impact upon humankind, such as financial affairs, health and transportation, of which there is a widespread understanding, knowledge of relevant microbial activities, how they impact our lives and how they may be harnessed for the benefit of humankind – microbiology literacy – is lacking in the general population, and in the subsets thereof that constitute the decision makers. Choices involving microbial activity implications are often opaque, and the information available is sometimes biased and usually incomplete, and hence creates considerable uncertainty. As a consequence, even evidence-based 'best' decisions not infrequently lead to unpredicted, unintended and sometimes undesired outcomes.

We therefore contend that microbiology literacy in society is indispensable for informed personal decisions, as well as for policy development in government and business, and for knowledgeable input of societal stakeholders in such policymaking.

Ken Timmis
Chief Editor of Environmental Microbiology

An interview with Nicola Baldwin

Nicola Baldwin

Playwright and script writer
SfAM Public Engagement Grant recipient

Stewart Cumiskey

Society for Applied Microbiology

In our latest interview, Nicola Baldwin (one of the creators behind *Nosocomial*) gives an insight into the early stages of making the show, visiting the labs in Great Ormond Street Hospital and how the ideas were brought to life.

What made you choose performance rather than other forms of media to get the message across?

I met Elaine Cloutman-Green while I was researching another play, commissioned by a theatre company. Elaine attended (as a member of the public) a participatory workshop. We had a shared interest in theatre but what struck me, on visiting Elaine's own lab, was how 'performative' healthcare science is – how utterly dependent on performing the correct actions in the correct order and sharing an understanding among teams that everyone will perform their role, in order to save lives.

It's made me rethink healthcare, and in fact health, as a series of correct actions.

What did you learn about healthcare scientists that you didn't know previously?

That healthcare scientists are people too! On two levels; firstly that prior to working on *Nosocomial*, I didn't appreciate that healthcare scientists existed as a professional group. This was also felt by all the actors and creative team. It seems obvious now that when a doctor talks about 'doing some tests' it's like a waitress in a restaurant taking your order; there has to be a whole kitchen out of sight that prepares and cooks and organises what comes back to you.

On the other level, I learned that when you, as a healthcare scientist, discover that a person has cancer, or that a patient you have been treating all their life is improving, you feel this in the same way anyone else would but, because of your job, there's no place for you to express that emotion. Because that would make you less effective at your job…

I learned that healthcare scientists are aware that their work is out of view, and most of the time they just get on with it because the science is what matters to them, but once in a while, you know, it would be quite nice if someone else in the restaurant said… 'by the way, we do have an excellent kitchen and chefs. Their work is enormously high-pressured because the buck stops with them.'

I also learned that there are aspects to their job which make all this worthwhile, as the place they really work is the wild and wonderful theatre of human microbiology.

What was the biggest challenge in bringing Nosocomial to the stage?

The original idea was for the science fiction element to be uppermost, with research to support that. In fact, when we applied to SfAM for funding, the pitch was for a fact-based, science fiction drama. But as soon as we started, the personal testimonies of the healthcare scientists took over and it became about them.

So, then I realised that the biggest challenge was to do these precious stories justice.

What was the most consistent message that came from the workshops with healthcare professionals – was there one?

If I were to sum this up on their behalf, I would say that these are engaged, highly qualified professionals who are committed to their work and their patients, but who are underappreciated.

But they love science. No matter if she started at 05:30 for a 07:00 meeting before a long day… Elaine's eyes still light up talking about bugs!

Did you find it a challenge to find a balance between entertainment/narrative and facts/message?

Because of the way we worked, as a collaboration between a theatre-loving scientist and a science-curious playwright, I think it was more about trying to find a language in the play that did everything. Our shows last September were R&D and we listened to what everyone said afterwards. The play is still developing and I like to think that the final version of any successful drama finds its balance in the audience thinking about it afterwards.

Was there an overriding educational aspect to the play or a theme that you particularly wanted audiences to absorb?

It's not like theatre and TV are awash with representations of healthcare science, so we had pretty much an open playing area by just bringing the world into the light.

I think by showing the world, taking us into the world in the words of the people who work there, it educated people about healthcare science and microbiology. I actually think about my own health differently now, from understanding the science behind it. I'm much more receptive to messages on TV news about antimicrobial resistance (AMR) because I've got a better grasp of the microbiology.

We're trying to reflect the drama of healthcare science, which exists because – and this was an early message/theme Elaine and I discussed – microbiology is not linear. Like any narrative, it can have twists and dead ends.

We thought the drama would be mainly about the narrative of the central character, Jo, trying to work out what's happening, but in fact it's also about Kitty, Helena and Paul working through their diagnostic protocols in the lab, dealing with uncertainty and how to approach differential diagnoses.

So, if the educational aspect is an understanding of healthcare science, the theme is an understanding of how to approach uncertainty in a logical way. I love that.

Casualty, ER, Holby City – audiences LIKE a hospital drama – what's your favourite medical drama?

Quincy MD. Since being a kid I loved that show, which is of course about pathology!

In *Silent Witness*, the team seem to be habitually puzzled by the basic science, such that they need to explain everything to each other. *Quincy* (once you've got past the wide lapels and 'professional women = air stewardesses' side of it) seems to capture the energy and boundless curiosity of medical science, in my opinion.

Following the work-in-progress performance, did you get any critical feedback that led to any aspects being reconsidered?

We didn't have any hugely negative feedback, but of course that can be hard to gauge if people hate it and leave. Our R&D draft was 50 minutes long and it will expand into a 70 minute or so version during this year, so we had a lot of feedback on what people would like to see more of.

We had a reading on 8 March 2019 and an NHS event on 13 March 2019, and we're planning to continue evaluation with other audiences as the final draft develops.

Ideally, where would you like to see Nosocomial in a year or two?

Still playing. I'd like to see *Nosocomial* touring and also published so it can be done more widely.

We'd like to do a film version so it can reach audiences where a full production wouldn't be feasible.

Ideally, it would spark a wider conversation about healthcare science and individually taking responsibility for understanding and managing our health.

Oddly, we had a few couples come up after performances where one partner worked in theatre or the arts, and the other in healthcare, as a scientist, paramedic or healthcare professional, who were (a) delighted to find a play they both liked, and (b) really excited to be able to share each other's worlds and talk about their work.

If *Nosocomial* can carry on – zipping the 'opposing' worlds of arts and science together – that would be a continuation of the original conversation between Elaine and me which sparked the play, and if that conversation continues rippling outwards over the next couple of years, that would be an amazing legacy.

***Nosocomial* was funded by an SfAM Public Engagement Grant.**

‘Directed evolution’ as narrative science: a historical reflection on Patricia Clarke’s bacteriology

Dominic J. Berry
London School of Economics, UK

Engineers and scientists have lots of different reasons to consider the history of their fields. My motivations are to see how current assumptions, ideas and expectations can be changed or challenged by giving attention to the past. As part of a larger international collaborative project, I am particularly concerned with asking how, and in what ways, narrative has mattered for the biological sciences. At the outset, therefore, I assume that there are all sorts of ways in which narrative works for scientists and in sciences: that narratives and the process of narrative making are made up of lots of different tools for thinking. In addition, in some areas, narrative will be an inescapable feature: think of what it takes to give an account of rock formations in geology, or case histories of patients in psychology, or the differentiation of zebrafish form in developmental biology or indeed the speciating lineages of mutating organisms in microbiology. For these purposes I will be subjecting ‘directed evolution’ to narrative scrutiny. It is true that what directed evolution actually boils down to in any given case always depends on the materials at hand. Leaving this diversity to one side, I want to focus only on bacteriology and, more specifically, the work of Patricia Clarke (1919–2010).

Directed evolution earns our attention as an important and interesting collection of ideas, practices, people and goals; ones that occupy a place all of their own in the microbiologists’ toolkit. Clarke deserves our attention not only thanks to her being among the first to develop methods of directed evolution, but for eventually making a highly successful career at the intersections of university and industrial life, one that followed a number of twists and turns through biochemistry, taxonomy and munitions. Once at University College London (UCL), where she was appointed assistant lecturer in 1953, Clarke helped to build a world of biological technologies long before biotechnology, affording us a different perspective on topics of contemporary interest, such as synthetic biology, industrial biotechnology and biological engineering. Rarely, however, does Clarke make an appearance in our histories of such things. What I draw out of her case is not only the longer history of industrial microbiology, following in the footsteps of Robert Bud’s excellent *Uses of Life*, which I am sure will be very familiar to readers of *Microbiologist*, but also the surprising extent to which ‘narrative knowing’ featured in her work and understanding. My hope is that in learning to recognise narrative knowledge when we see it, we may well find it operating elsewhere in microbiology and beyond.

We learn from her Royal Society biographical memoir that Clarke was born in Pontypridd, Wales, and after winning a scholarship to attend Howell’s School in Llandaff she eventually went on to Girton College at the University of Cambridge to study natural sciences. We can learn much more though by reviewing a 3-hour video-recorded interview with Clarke in 1994, organised by the Biochemical Society. Some obvious kinds of narrative in science here begin to write themselves. For instance, Clarke made clear that as a young girl in South Wales she was only able to get where she got to thanks to the attention of some dedicated schoolteachers who encouraged her across science subjects and the arts. Gallery visits to the National Museum of Wales taught her a love of visual practices and an appreciation of changes in artistic method over time, while attendance at the public lectures organised at the University of Wales likewise stoked her imagination: ‘One of the things I can still remember is being absolutely enthralled by Patrick Blackett talking about artificial isotopes. This seemed to me amazing!’ Clarke also emphasised the availability of a well-stocked local library, one which distinguished between ‘fiction’ and ‘non-fiction’ according to the ‘suitability’ of a text, rather than whether it was written as more or less fictional or

factual (Clarke was only allowed to dip into the adult section of 'non-fiction', which included Dickens, JB Priestley and lots of Greek mythology). Lastly, she recalled her enjoyment of putting on plays: 'I really enjoyed writing plays and acting in them, that was probably quite a good preparation for being a university lecturer later in life I suppose.'

From these snippets we can start to build a narrative of a life and mind that had little need for the categories of fiction and non-fiction, one thoroughly committed to acquiring new knowledge, to investigation and to achievement. As a starting point, this only suggests that the humanities and sciences need not be, and most often have not been, a million miles from one another, a conclusion that by now is surely uninteresting. Many shelves of history, and the biographical experiences of scientists like Clarke, attest to the close historical relations between the humanities and Science, Technology, Engineering and Mathematics (STEM) subjects in terms of motivation, interpretation, method and meaning-making. To show why 'narrative science' has been worth your time

Patricia Clarke (1919–2010) *above*

Girton College at the University of Cambridge *right*

then, I need to take you deeper. This I can do through Clarke's own explanation for part of her method as she embarked on directed evolution, or 'selective evolution' as it was then sometimes called.

To demonstrate that directed evolution was taking place, Clarke needed to choose a suitable change in conditions for her microbes, which they could then be shown to have adapted to, either by producing a new enzyme or by producing an existing one in greater or lesser amounts. She would also have to demonstrate that the supposed adaptation was regular and stable, as would be shown through the assaying of microbial extracts, checking these assays against alterations in the chemistry of the overall growth media, and also comparing them between different strains of the same species. The pre-established experimental approach was to begin by growing a given species on a substrate on which it was known to grow poorly and then, at a later time, show that it had begun to grow well on that substrate. Knowing what kind of enzymatic change to try and induce, and with what organism, is not obvious! For Clarke, the organism question was pretty straightforward, as among her most important successes by this time was establishing pseudomonads as an experimental system. So how to choose a substrate? Midway through the 1994 interview, Gareth Morris asked Clarke precisely why she ended up trying to induce the production of amidase enzymes in her microbes:

'It was quite logical. What had impressed me with Monod's work was the way in which he had been able to use analogues of lactose in looking at the synthesis of β-galactosidase, and this seemed to me a very sensible way of doing it. And I wanted a substrate that was very easy to modify, and I also wanted an enzyme that was easy to assay, so I wanted to make things easy you see... so I turned back to Marjory Stephenson's great book on bacterial metabolism, and looked again at the table of den Dooren de Jong, who had looked at what bacteria would grow on all sorts of improbable compounds. Amongst the things that Pseudomonas aeruginosa would grow on, and some

Think of what it takes to give an account of rock formations in geology

strains of Pseudomonas putida for that matter, was acetamide. Since this could be used as a carbon and a nitrogen source for growth, it seemed to me a promising way to begin. den Dooren de Jong's table is fascinating and I often went back to re-read it. It's thought by many that this was unknown to English readers in microbiology until the Stanier, Doudoroff and Palleroni paper of 1966, but of course it's been available since the 1930s in Marjory Stephenson's book.'

Narrative science resides here in at least three ways. First, Clarke thinks analogically from Monod's approach to her own case. The making of analogies and metaphors isn't always understood as doing epistemic work, and is perhaps more commonly associated with rhetoric or poetry, but here analogy-making is justifying new directions in experimentation. When we claim that 'so-and-so was inspired by X', we can always ask how? Analogy-making is one of the most common ways in which researchers relate to one another, and I am interested in exploring these interactions as building research narratives (the latter being a term coined by my colleague Robert Meunier). Second, she pulls together different goals (easy to modify, easy to assay, a substrate that offers a range of metabolic contributions) in order to imagine an ideal experimental substrate, which she could then go and look for in the world. Scientists asking themselves 'what kind of thing *could* I want?', in order to establish a good experimental design, are making themselves answer short speculative stories, clearly with productive results. Third, and last, she had a long-standing relationship with a text, Stephenson's, that she could clearly recall decades after first encountering it, presumably thanks to many close readings, a text which opened up provocations and implications (such as den Dooren de Jong's table of strange substrates that microbes can grow on), which she could draw on time and again. Good narratives build a variety of

implications that the reader can't help but want to work out. I would argue that one of the main reasons that Clarke returned to Stephenson's book at the times she did was because it helped set up implications that Clarke had become invested in. There is no need to interpret this kind of reading experience and subsequent recall as being fundamentally different from the reading and recalling of an engaging novel; we do not need to understand it as somehow 'scientific' reading in order to appreciate the epistemic role it plays. The collecting together and arrangement of Stephenson's text therefore instilled another kind of narrative knowledge and the importance of building inviting implications.

Each of these forms of narrative science are quite different from one another and relate to very different parts of research life, from interpreting results to designing experiments and strategising. Beyond this short list, there are a great many more ways in which narrative is implicated in the sciences, either as a way to know or as a tool for thinking with. My hope is that thanks to this three-course taster menu, you might now be interested in exploring at least some of the possibilities for yourself. Regardless, by turning to Patricia Clarke, I have put into the spotlight someone that the history of microbiology can learn much from. Her archive of papers is now available in the special collections department of UCL library and promises to reveal a great deal more about how we arrived at the present moment and the important, surprising and forgotten means by which we reached it.

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London's microbiota: beer of revenge

Martin Adams
SfAM President 2011–2014

As far as I am aware, no member of SfAM has ever been honoured by having a beer named after them; something I find quite surprising in view of the heroic contribution many have made in support of the brewing industry over the years. Louis Pasteur, however, was more fortunate, with 100 bottles of Louis Pasteur Ale produced by the Whitbread brewery in 1995 to mark the centenary of his death. The brewery in Chiswell Street, adjoining the Barbican, had particular reason to commemorate his passing as, to quote their head of R&D speaking in 1967, 'We like to think that our scientific tradition stems from the time when Pasteur was here and persuaded the company to buy a microscope'.

Pasteur had started studying the brewing process, prompted by the humbling defeat of France in the Franco-Prussian War of 1870–1871. An ardent patriot, he felt that defeat had been due, in part, to Prussian technical superiority. One aspect of this, he recognised, was in brewing; a problem that had been further aggravated by the loss of Alsace and Lorraine (France's major hop-growing and brewing region) as a result of the war. To assist in his nation's recovery, Pasteur began a programme of research at the Kuhn brewery in Chamalières, near Clermont-Ferrand, and in June 1871 he patented an improved method of brewing based largely on the exclusion of atmospheric contamination. Beers produced following his precepts were to be described as *bières de la revanche nationale* – beers of national revenge. The Kuhn brewery was very small and Pasteur wanted to visit some of the large concerns in England to see their practices and how they related to his work. To this end he travelled to London with his son in September 1871, staying at the Grosvenor Hotel at Victoria Station. On 9 September, they ventured out to the Whitbread brewery in Chiswell Street – the only brewery visit there seems to be a record of.

At the time, London was a major brewing centre and Whitbread, founded by Samuel Whitbread in 1742, had been one of its largest concerns for more than a century. The Chiswell Street brewery was built in 1750, specifically designed for the production of Porter – the first industrial beer, benefiting from production on a very large scale. Porter has already been described in this column in connection with the Great Beer Flood of 1814, caused by the bursting of huge vats used to store the beer during its maturation. Whitbread used similar vats but he also spent considerable time and energy converting underground vaults, previously used to store casks, into large cisterns for Porter maturation. Conversion did not prove entirely straightforward, taking nearly 10 years to make the vaults effectively watertight. The first attempts employed Robert Mylne, the architect of Blackfriars Bridge, who, despite confidently declaring that he was prepared to stand under the vaults when first filled, was 'let go' when they leaked like a sieve. He was followed by John Smeaton, the world-renowned civil engineer responsible for, among other things, the design of the third Eddystone Lighthouse. He suggested York stone slabs and a resistant cement of rosin, beeswax and sand, which unfortunately was found to have little resistance to the corrosive powers of Porter. Whitbread wrote to the potter Wedgwood enquiring about the use of glazed tiles, ship's caulkers were employed to make the joints watertight, tinned copper plates were put over angles and iron ties and buttresses were installed to resist the pressure on the walls. It wasn't until 1784 that he finally succeeded. The completed cisterns could hold 12,000 barrels (nearly 2 million litres) and Whitbread named two of them the King's Vault and the Queen's Vault following a Royal visit in 1787, commemorated by a wall plaque surviving to this day. Despite the numerous setbacks, the exercise was declared a success since the ability to mature Porter in even larger volumes achieved a greater uniformity and improved the quality of the beer produced. Whitbread was a noted technical innovator in other ways, being the second brewer in London to install a Boulton and Watt steam engine in 1784, only 2 years after the introduction of rotative steam power.

During his visit, Pasteur toured the brewery and examined samples of yeast using a microscope he had brought with him. It appears that he did not like beer very much and was not a good judge of its sensory properties. However, looking at a sample of Porter yeast, he recognised and

drew an infecting organism, declaring that surely this Porter must leave much to be desired and that the presence of the contaminant must have betrayed itself by some sensory defect. It was admitted that this was the case and that fresh yeast had been bought in from another brewery. On examination he declared the fresh yeast to be much better, unlike other samples he examined of yeast from ale fermentations and finings used to clear the beer. Though some other breweries in the UK were using microscopes at this time, Whitbread was not. When Pasteur returned a week later, he found that a binocular microscope had been bought, costing £27 15s (£27.75).

Brewing at Chiswell Street ceased in 1976 and Whitbread sold its pubs and breweries in 2001. Several brewery buildings remain as part of the Montcalm Hotel and, across the street and below ground, the cisterns are still in use, now as 'event spaces'. Whitbread plc is now a 'hospitality' company operating hotels and restaurants. Its website declares its vision 'to grow its brands by building a strong customer heartbeat'. One can speculate whether it was concerns about 'customer heartbeat' that prompted their 2018 sale of the Costa Coffee chain to Coca-Cola.

***Boulton and Watt steam engine** below*

Chiswell Street brewery

Working with lively material

Louise Mackenzie
Visual artist, Newcastle, UK

In 2017, I was invited by ASCUS Art & Science, a public-access research laboratory for artists and scientists based in Edinburgh, to become artist-in-residence at the Society for Applied Microbiology (SfAM) Annual Conference at BALTIC Centre for Contemporary Art, Gateshead, as part of the ASCUS Artists are Present programme. The aim of the residency was to research the work of SfAM through the conference, leading to the development of a commissioned work for SfAM's headquarters in London.

I am a visual artist and in recent years I have worked with what I describe as lively material (microbiological material such as cells and DNA) as my medium. Before training in fine art, I practised psychology so, conceptually, I'm fascinated by our potential as human beings, both positive and negative: what we will do next – our progress – and the waste that we leave behind in our wake.

Whereas earlier my conceptual focus was on consumerism and waste, around 2013 I started to explore human technological progress and scientific research. My first encounter with microbiology arose when I was experimenting in the studio with the cyanotype print process. The deep scientific blue of the cyanotype and their use as blueprints in the 19th century echoed the genetics that I was researching. By happy accident my practical and theoretical research collided as I came across cyanobacteria.

I approached Gary Caldwell and Chelsea Brain at Newcastle University's School of Marine Science and Technology and when I first saw cyanobacteria in the lab I was humbled. An initially unremarkable as a glass jar of green liquid, under the microscope these single-celled organisms came to life, moving and swimming before my eyes. Cyanobacteria are some of the earliest forms of life on earth.

Coming from the ocean 3.5 billion years ago, cyanobacteria were the first species to photosynthesise, producing oxygen via chloroplasts that exist within them. The chloroplasts evolved into chlorophyll within plants, allowing the development of plant life and ultimately all land-based species. From my privileged position, where I could compact this 3.5 billion-year history into a single moment under the microscope, these almost magical, hybrid organisms – moving like animals yet producing oxygen like plants – appeared to have breathed life into our planet like tiny gods. In cyanobacteria, I saw something that was arguably responsible for humanity's existence on earth.

This led to the development of a series of works based on our symbiotic (or otherwise) relationship with cyanobacteria and other similar microalgae. The sculpture *Life Support* (2013), draws upon our fundamental connection to the natural world through photosynthesis and respiration. *Life Support* mimics the intravenous fluid stands on wheels commonly found in hospitals, but in place of medically defined fluid nutrients, there is a set of glass lungs – repurposed scientific glassware – filled with cyanobacteria. Attached to the lungs is a mask that provides us with oxygen and enables us to give back CO_2 to the microalgae within the lungs.

When I attended the SfAM Annual Meeting in 2017, I learned many things – some a reminder of statistics I had heard before, others entirely new. I learned that bacterial cells in and on the human body outnumber our own cells by a factor of 10; that, like Heinz, we have 57 varieties of core microbiota and that we excrete our own body weight in faecal bacteria each year.

Moments that stuck in my mind were discussions of the destructive power of *Cronobacter*, named after the Greek titan Cronus who ate his own children, of the hope inherent in uncovering archaea found deep within ancient salt mines as a potential new source of antimicrobial resistance and the potency of hi-tech plasma deployed to eradicate microbes from food and from wounds.

What struck me most, however, was the deep sense of entanglement between us and our microbial relations. Whether we are ingesting them along with a ripe juicy tomato or whether our bodies actively nurture their growth, they are inextricably a part of us. This is surely never clearer than in our use and abuse of antibiotics.

I began to wonder whether, as a society, we are destined to struggle like Sisyphus, or if we could attempt to develop a different form of relationship with microbial life altogether. My recent PhD research, *Evolution of the Subject*, where I divided my time between the studio and a genetics laboratory, began to question whether we can perceive ourselves as a more-than-human community-being of cells (microbial and human) rather than as simply 'human'.

Deep Time Sisyphus *at SfAM, Charles Darwin House (detail) Rock salt, xenon gas, glass, high-voltage transformer, midi-sprout, Raspberry Pi, plywood, audio*

I feel it is a valid perception of our bodies and one that I imagine many microbiologists can get on board with. During my research I developed a strong sense of microbial life existing across deep time in a way that it is difficult for humans to perceive. The crisis of antimicrobial resistance suggests this. We work within our human time frame to develop ways in which to combat disease and as fast as we do this, bacteria evolve to outwit us.

It is as if we are determined to halt the process of evolution itself. Perhaps we are destined to forever push the ball up the hill only to watch it roll back down again. Generally, it is of course the aim of the scientist to find solutions, to break free of the Sisyphean struggle. As an artist, I am fortunate to be allowed to dwell in the poetics of the process itself.

I chose to find a way to combine the work undertaken to unearth new potential sources of antibiotics from the salt mines of Kilroot, Carrickfergus in Northern Ireland, with the latest plasma technologies being deployed to eradicate microbes from our food and wounds. Combining the two represented for me a Sisyphean struggle across deep time: unearthing ancient microbes only to destroy them with futuristic technology.

I visited Brendan Gilmore at Queen's University Belfast, where I witnessed the glowing energy force of a plasma beam and we went down into the ancient salt mines at Kilroot where I was able to retrieve two large samples of rough-hewn rock salt from miles underground. This salt would become the hill upon which Sisyphus would toil. I had learned from Brendan that the rock salt was potentially full of halophiles – microorganisms that once swam in ancient seas, now locked into crevasses within the crystallised ocean remains.

To gain a sense of the presence of microbes in the rock salt, I turned to sound. As organic material, the rock salt has an inherent level of electrical conductivity that can be converted into sound. I drew from the work of the author Joseph Sansonese, who suggested that the origins of myths are rooted in cultural re-tellings of the physical bodily experience of archaic ritual trance states. Sansonese postulates that the onomatopoeic 'siss' and 'phus' sounds of nasal breathing, the cyclic rhythm of life itself, are the premise for the myth of Sisyphus.

Using a DIY device that reads electrical conductivity in the rock and converts it into midi-signals, I recorded and programmed in 64 different versions of the word 'siss' and 64 versions of the word 'phus', 128 sounds in total. When switched on, the rock appears to babble, 'siss...phus', or variations of, over and over.

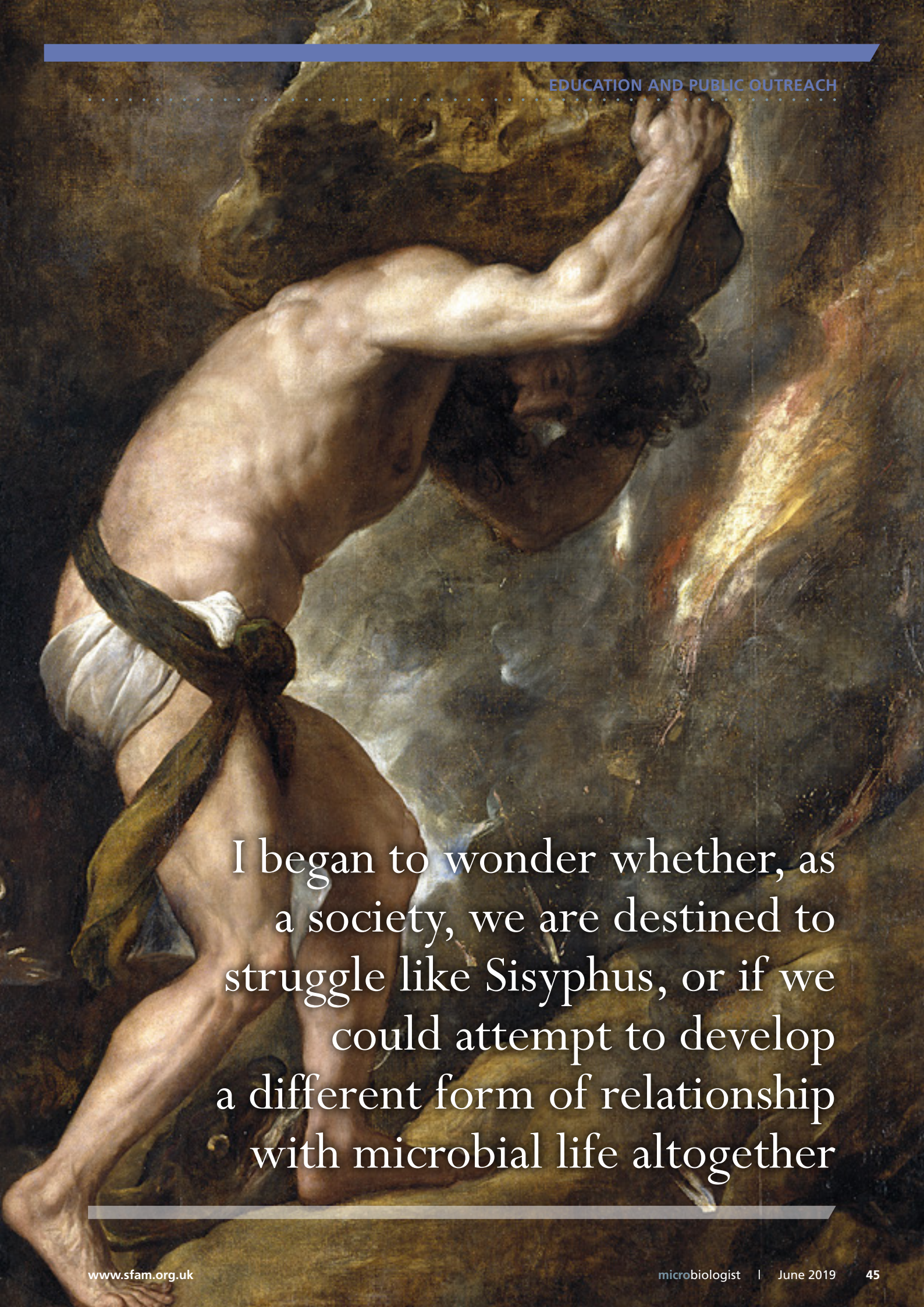
When switched on, the rock appears to babble, 'siss…phus'

Plasma serves as Sisyphus' endeavours. At the conference I had learned how plasma, described as the fourth state of matter, is ionised gas, researched for its potential to eradicate microbial life from within food packaging and used with pinpoint accuracy to sterilise wounds in surgery. I was drawn to the inevitable circularity of our actions to uncover new microbes on the one hand whilst destroying existing microbes with the other.

With help from Neon Workshops in Wakefield and the National Glass Centre in Sunderland, I was able to develop a custom plasma sphere that would sit atop the rock salt 'hill'. The final element in the work was Sisyphus: our human interaction with the work. Hypothetically, in touching and activating the plasma sphere, any microbial matter slowly leaching from the salt would be rendered sterile. Thus the work encapsulates life in more-than-human forms and our Sisyphean struggle to control it.

The work I undertook with the support of SfAM has led me in new directions, considering the breadth of possibility of working with sound in relation to lively material and also the interactions between the unseen organism and distinct environmental conditions such as the presence of plasma. I am grateful for the generosity of SfAM in allowing me the freedom to experiment with new materials and ways of working in the making of *Deep Time Sisyphus* and look forward to bringing these new elements of my practice into the making of future works.

With thanks to Lucy Harper, SfAM; ASCUS Art & Science; Brendan Gilmore, Queen's University Belfast; Jason Hopps, Kilroot Salt Mine; Richard Wheater, Neon Workshops Wakefield; Jeff Sarmiento, National Glass Centre and Brian Jones, Wearside Glass Sculptures.



I began to wonder whether, as a society, we are destined to struggle like Sisyphus, or if we could attempt to develop a different form of relationship with microbial life altogether

Microbiology in Mekelle, Ethiopia

Chris Megson
Microbiology Biomedical Scientist
Sheffield Teaching Hospitals NHS Foundation Trust

Over the past 3 years I have become involved with the charity Sheffield Health Action Resource for Ethiopia (SHARE). This charity acts as an international health link between Sheffield Teaching Hospitals, in the UK, and Mekelle in the Tigray region of Ethiopia. Working alongside organisations such as the Tigray Regional Health Bureau and local hospitals, the primary aim of SHARE is to improve the healthcare system in Tigray.

Back in 2014, two scientists visited Mekelle to perform a feasibility study to determine areas where microbiology education and training were needed. In 2016, I applied for an SfAM International Capacity Building Fund Grant so that we could help to deliver this training, and in November that year I travelled to Mekelle with several other members of the SHARE team to put our plan into action. This was my first visit to Africa and exposed me to many new sights, sounds, smells and experiences. Life in Mekelle is a pleasant combination of easy-going and frenetic; folk relax on the street, enjoying their coffee or juice, while numerous blue 'Bajaj' tuk-tuks zoom around delivering people to their destinations. The people here are some of the friendliest you could meet.

Our first visit was based primarily in the microbiology department at the Ayder Referral Hospital. The lab lacks equipment, has limited resources and has an intermittent supply of water and electricity. Staff here must collect and process specimens and interpret microscopy and culture results. Their dedication is humbling and admirable; everybody remains stress-free and happy despite the daily challenges. All culture media is prepared on-site and several sheep are housed on campus to provide the essential ingredient for blood agar. Shepherding skills were not something I thought I would ever need as a biomedical scientist! Spending an hour of our time to round up sheep was met with laughter and a shrug of the shoulders. Working with these people has made me appreciate the privileges that we have back at home, yet I cannot help feeling saddened at how the increased efficiency of lab diagnostics in the UK has forced us to become more 'factory-like' and impersonal.

There are clear obstacles to overcome when working in a lab that is under-resourced. Most of the training we delivered centred on bacterial identification and susceptibility testing. In Sheffield we've been using matrix-assisted laser desorption/ionisation-time-of-flight (MALDI-ToF) for so long that I needed a refresher of the basics of traditional methods! Organism identification is very difficult when some tests are not available, so alternative approaches are needed to solve these problems. For example, penicillin susceptibility is not usually considered to be an identification test but can help confirm the identification of β-haemolytic streptococci.

The lab had recently begun using a PCR platform for TB diagnosis and rifampicin resistance testing that we, in Sheffield, had considered too expensive to procure! TB, alongside malaria and HIV, is considered one of the 'big three' infectious diseases of major global concern. This instrument was provided as part of a WHO-funded strategy aiming to end the global TB epidemic. It was interesting to observe this combination of old 'outdated'

technology juxtaposed with the most modern diagnostic tools available.

The University of Mekelle shares a campus with the Ayder Hospital and we spent time there delivering lectures to staff and students. Fortunately, most Ethiopians speak very good English and could understand me despite my Yorkshire accent. The university has a need for international research collaboration – they have the fertile ground for research but lack funds to bring this to fruition. There are many areas here where microbiology research could be performed and every resident appears thirsty to learn, grow and be engaged in new experiences. It is a shame to see this passion for research underutilised.

In 2017, the project evolved from training and education at the Ayder Hospital to helping set up a lab at a rural health centre in the remote Gera region. This health centre serves a population of approximately 250,000 and did not perform any lab testing before our involvement. The first diagnosis from the lab was of syphilis in a pregnant woman – it was incredibly rewarding to see that this new lab potentially contributed to saving the life of her baby and will continue to have a positive impact on the health

of the community. At the end of the 2017 visit, we ran the Great Ethiopian Run and amazingly managed to raise over £2,000 in sponsorship money, which we used to fund the Gera lab project.

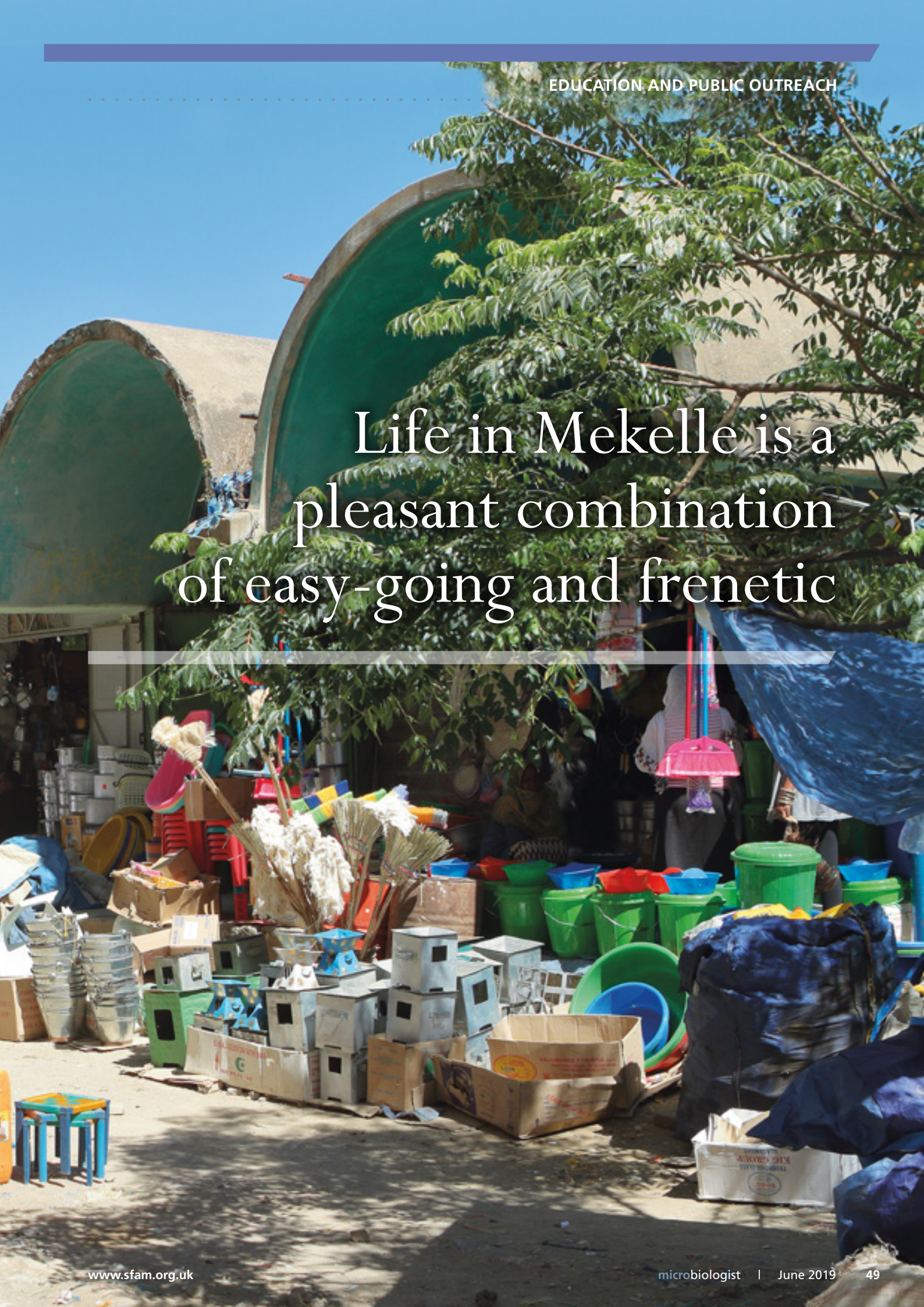
We last visited Mekelle in November 2018. The Gera lab has proved to be a success and is functioning well. We also spent time visiting other health centres to look at the potential of repeating what we had done for Gera. There is a significant lack of trained lab staff, especially in the more remote areas of the country. For the majority of Ethiopians, it is more desirable to live in a city so it can be difficult for smaller rural health centres to retain trained lab technicians. One region of Tigray has recognised this issue and has begun a 'task-shift' training programme to move performance of some of the simpler lab diagnostic tests onto other resident staff members, such as nurses or midwives. This training project has shown extreme promise and SHARE has committed to supporting it in any way it can.

I have found my visits to Ethiopia to be enjoyable and rewarding and feel that my perspective of lab diagnostics has consequently changed dramatically. The work performed by SHARE has undoubtedly had a positive effect on the people of Tigray and needs to be developed further in future visits. We are grateful to SfAM for their financial support – schemes such as the International Capacity Building Fund are essential for charities such as SHARE to deliver the work we do. I am hopeful that I can return to Mekelle in the future to help continue this work.

FURTHER READING

SHARE. *Sheffield Health Action Resource for Ethiopia*.
https://www.sharesheffield.org.uk/

Facebook. *Sheffield Health Action Resource for Ethiopia*.
https://www.facebook.com/ShareSheffield/



Life in Mekelle is a pleasant combination of easy-going and frenetic

BioFocus: driving change through strong and valued partnerships

The past few months have been threaded with uncertainty regarding the UK's future relationship with the European Union and science funding, networks and collaborations continue to remain at risk.

RSB staff and members alike have been actively engaging with policymakers and parliamentarians, but there are bigger issues for government which still dominate the agenda and the situation may have changed again by the time this column goes to print. Nonetheless, it is critical that the science voice is heard and RSB continues to support this sector-wide endeavour.

Earlier in the year, alongside a number of other sector leaders we wrote a joint letter, published in *The Independent*, warning (not for the first time) of the dangers of a no-deal Brexit. Many believe that risk has diminished but we will, of course, continue to monitor developments carefully, and ensure the voice of the biosciences community remains audible in the wider 'science and Brexit' conversation.

> Supporting the development of the biosciences in collaboration with our key partners is still a top RSB priority

Regardless of external political stresses, supporting the development of the biosciences in collaboration with our key partners is still a top RSB priority. One of our special advisory committees, the UK Plant Sciences Federation (UKPSF), has had a particularly active few months. The UKPSF is a key network of collaborators, with representatives from 21 member organisations creating a coordinated approach to research, industry, funding, education and outreach in this vital sector of the biosciences, very much in the RSB vision.

Earlier this year the UKPSF published a flagship report, *Growing the Future*, which highlighted to policymakers and other stakeholders the excellence, impact and importance of plant sciences in the UK.

In April, UKPSF launched their plant health studentships, supported by DEFRA, BSPP, N8 AgriFood and the David Colegrave Foundation. This initiative allows researchers to apply for funding for summer studentships, which are then undertaken by undergraduates looking to expand their experience in plant health.

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

Also in April, we held our annual Degree Accreditation Awards ceremony, and a Degree Accreditation conference. The RSB Accreditation programme looks to recognise academic excellence of degree streams that drive up the standards of Higher Education biosciences education and equip students with skillsets desired by employers.

This year we were pleased to award 85 more degree programmes with RSB Accreditation, ranging from undergraduate degrees through to doctoral programmes, across a number of UK and overseas universities. This programme is enabled by the collaborative efforts of the Accreditation committee, the assessors and member organisations that are involved with the process.

In May, we saw the return of the Natural Capital Initiative's (NCI) summit – Valuing our Life Support Systems. The summit, the third of its kind since the launch of the NCI in 2009, offers an independent platform for people in science, policy, NGOs, businesses and society to discuss and debate innovative natural capital solutions that enhance the environment and strengthen society.

A wide variety of invested stakeholders came together over two days to share their thoughts, ideas, research and projects that are looking to help and enhance the collective benefits provided by the natural environment.

NCI is a special interest group comprising RSB, the Centre for Ecology and Hydrology, the British Ecological Society and the James Hutton Institute.

We are now only months away from marking 10 years since the formation of the Society of Biology (now RSB), with celebrations taking place between this year's Biology Week and Biology Week 2020. We will reflect on our role and impact as a membership organisation, celebrate our progress so far and start planning what we hope to achieve in the next decade.

Despite moving home, away from Charles Darwin House, we will continue to work closely with SfAM and further develop all the collaborative relationships we have nurtured over the years. These partnerships are vital in delivering so much for the biosciences, and we hope to increase collaboration efforts as we move in to the second decade of the RSB.

Celebration of our progress embraces our partners and is as much SfAM's success as ours, and we invite SfAM members to join us in looking forward to the next decade of supporting the biosciences.

Science policy and you: meet our subcommittee members

There are many facets to science policy. These include the development of policies that govern how science and research is conducted to pursue technological goals in the national (or global) interest, or can include the application of scientific knowledge and evidence to the development of policies that benefit society.

Our mission is to boost the impact of microbiology in its application to the critical issues facing society and the world around us, today and in the future. One of the key ways we can achieve this is by supporting our members to engage with science policy: getting the best quality evidence and expertise to policymakers at the right time.

We rely on the vision and expertise of our members to direct the Society's science policy work. Earlier in 2019 we appointed three new members to the SfAM Policy Subcommittee, broadening the expertise we draw upon. We recently asked some of our subcommittee members what they thought about science policy engagement and what it meant for them.

Chris Brown
Policy & Public Affairs Manager of the Society for Applied Microbiology

Q: ***What interested you about joining SfAM's Policy Subcommittee?***
Joey Shepherd *Policy Subcommittee Member (July 2017–present)*

A: I'm a microbiology lecturer at Sheffield, a member of SfAM (of course!) and a STEM ambassador. My research interests lie primarily in novel approaches to detecting and treating bacterial infections without traditional use of antibiotics. I first became aware of the SfAM Policy Subcommittee after seeing an advert in the SfAM newsletter back in 2016. My interests very much aligned with SfAM's position statement on antibiotic resistance with respect to global collaboration; my colleagues in India and I are attempting to reduce indiscriminate antibiotic use in rural India. Without global collaborative initiatives our work would be much harder. This is where I find being part of the Policy Subcommittee really interesting; the fact that we as researchers can proactively influence policy by having open lines of communication with government policymakers is fantastic. I have learned much about the inner workings of scientific policymaking, as well as the importance of areas outside my own interests, and it is gratifying to see that our work, both scientific and political, really can make a difference.

Q: ***As a new subcommittee member, what focus would you like to bring to our policy engagement?***
Diane Purchase *Policy Subcommittee Member (March 2019–present)*

A: As a member of the Policy Subcommittee, I am keen to leverage my experience of science communication and policymaking to raise awareness of microorganisms and the environment. Climate change and explosion in population growth are two of the most pressing issues facing the 21st century. There is an urgent need to ensure sustainable practices are used to meet population demands, such as food and energy security, without compromising the health of the environment. I believe microorganisms can provide sustainable solutions to safeguard and improve the environment. I wish to apply my expertise to champion the application of environmental biotechnology and to inform and bring together different stakeholders for the betterment of humanity.

Q: ***What would you like to gain from your time on the subcommittee?***
Suzy Moody *Policy Subcommittee Member (March 2019–present)*

A: I would say that I'm most looking forward to contributing to policies that put science at the heart of government decision-making. I love working in academia, but for me the real societal value of microbiology is when we apply it to inform policymakers and suggest thoughtful ways to meet current challenges. I feel a great responsibility to draw on accurate and robust scientific knowledge so that we are making the best contribution possible. By working with more experienced members of the subcommittee I hope to gain an understanding of how to construct policy documents and learn from their diverse and extensive experience.

Q: ***How has your experience on the Policy Subcommittee had an impact on your work?***
Sarah Maddocks *Policy Subcommittee Member (July 2017–present)*

A: My experience of being part of the SfAM Policy Subcommittee has enabled me to understand how the work I do can make a difference beyond just the scope of my field, and how to begin to take steps to make that happen. It's encouraged me to participate in networking events that bring together scientists and members of the Welsh Assembly, something which I otherwise wouldn't have attended or kept an eye out for. Having greater knowledge about the way in which microbiological research can inform science policy has also helped me to gain a better understanding of impactful research.

Q: ***How do you think the Society can further support its members to engage with science policy?***
Jacob Hamilton *Policy Subcommittee Member (March 2019–present)*

A: I think the best thing the Society can do is produce a few guides on how to interact with politicians. It can be quite unnerving the first time you sit in front of your MP to talk about science, so helping people understand how to talk to politicians and how to pitch it, like all the guides on public engagement, can help people know what they need to do and improve the outcomes at the same time.

Q: ***What key piece of advice would you give to our members who are interested in science policy?***
Clare Taylor *SfAM General Secretary and Policy Subcommittee Chair (July 2017–present)*

A: Many of us conduct our science with the belief that our outcomes will benefit society; for example, developing alternatives to antibiotics, or understanding how pathogens are transmitted in the environment. But in order for these outcomes to be useful to policymakers, they must be able to understand the issues and translate scientific findings. Scientists play a key role in bridging the gap between science outcomes and policymakers by getting involved directly, but this may seem like a daunting prospect. So the easiest way to take your first steps is probably through a learned society (like SfAM) or campaigning organisations such as CaSE (**http://www.sciencecampaign.org.uk/**) or Sense about Science (**https://senseaboutscience.org/**). SfAM regularly responds to parliamentary and government inquiries (**https://sfam.org.uk/about-us/our-work/promoting-microbiology/influence/science-policy-responses.html**) and we often seek evidence and views from our members to inform our responses. Thus, we need you to engage with us to ensure that we are promoting good practice and sound, robust evidence. More recently, SfAM has been taking a proactive approach to highlight key issues and we are always keen to hear from members about what we should be talking to policymakers about. So, my key piece of advice for members who want to get involved in science policy is simply to get in touch with us and we can help you find the right opportunities.

If you are interested in learning more about the Society's Policy Subcommittee and how you can get involved in our science policy engagement, come and visit our exhibition area at the FEMS 2019 Congress in Glasgow, UK. Alternatively, you can always get in touch with Chris, SfAM's Policy and Public Affairs Manager (**policy@sfam.org.uk**).

Don Whitley

The directors of Don Whitley Scientific Limited are very sad to announce that Dr Don Whitley, founder and chairman of Don Whitley Scientific Limited, died on Thursday 28 February 2019 after a short illness.

Over the past four decades, the company that Don founded has continued to grow and is now a leading international manufacturer and supplier of innovative equipment and services to the microbiology and tissue culture industries. Don Whitley Scientific Limited (DWS) now employs 89 staff, moved to new, larger premises in 2018, and owns the majority shareholding in subsidiaries in Germany and Australia.

Born in London in 1929, the family moved to Leeds in 1940 because Don's father was employed in the tea industry, which was dispersed throughout the country during the Second World War.

Don wanted to train as a doctor, but was dissuaded from doing so by his parents. He joined the staff of the Hospital for Women in Leeds as a student medical laboratory technician and for ten years worked at Leeds Maternity Hospital and Killingbeck Hospital.

In 1956, Don joined Oxoid Ltd as a technical representative, covering North East England and, later, the Republic of Ireland. Other sales and technical roles in several companies culminated in his appointment as Technical Director of the Bydand Group.

In 1973, Don and a Bydand Group colleague formed LIP (Equipment and Services) Ltd. Then, in 1976, with the proceeds of the sale of his minority shareholding in LIP, Don and his wife, Pam, started Don Whitley Scientific in the spare bedroom and basement of their home in Shipley.

Don possessed an ideal blend of scientific and engineering knowledge, natural curiosity and wide-ranging interests. He is named on 24 national and international patents. He 'retired' and became company chairman in 1992 when his son, Paul Walton, became managing director.

'*Don retained a strong interest in product development activities and was consulted frequently, although he was no longer involved in the day-to-day management of the business. He attended key conferences, scientific meetings and events – and was held in high regard by many influential individuals in our industry,*' commented Paul.

'*Within a few hours of my father's death, tributes began to arrive from all over the world. He was generous with his time, supported many scientists in the early years of their careers, was widely travelled and had many, many friends.*'

Ironically, had Don become a medical doctor he may not have contributed to improvements in public health and the understanding and treatment of cancer in anything like the same way as he did, all over the world, through the company he founded. In 2009, Don was awarded an Honorary Doctor of Science degree by the University of Bradford, acknowledging a lifetime of achievements in applied microbiology.

In accordance with Don's wishes there was not a funeral. He requested that his body be left to medical research at the University of Nottingham Medical School. A celebration of Don's life will take place in June.

Four generations

Pictured left to right: Don with son Paul, grandson Thomas and great-grandson Frank

The latest news, views and microbiological developments

APHA Scientific Biological Reagents – produced by experts for reliable laboratory testing

Animal and Plant Health Agency (APHA) specialise in diseases of livestock and plants, diagnosis of disease and surveillance of new and emerging disease. Our scientists have a unique breadth of veterinary and scientific expertise and a comprehensive knowledge of animal and zoonotic diseases.

APHA has achieved world reference laboratory (OIE) status for a number of animal diseases.

Over many years, we have developed specialist veterinary diagnostic reagents and test kits for effective, reliable laboratory testing. The reagents are manufactured in a dedicated Biological Reagent production unit certified to ISO 9001 quality standard and many of them are currently used by national and international reference laboratories.

With over 150 different reagents available for sale, and many more customised options, our wide range of products (antisera, antibodies and diagnostic kits) targets bacterial and viral pathogens found in common livestock.

- Avian Influenza
- Escherichia coli
- Infectious Bursal Disease
- Newcastle Disease
- Bovine Viral Diarrhoea
- Maedi-Visna
- Salmonella
- Brucella
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- Mycoplasma

An extensive collection of cell lines and control sera is available, as well as a culture collection.

As well as Biological Reagents, APHA Scientific also provides a range of services, including:

- Bacterial Identification and Characterisation
- Antimicrobial Testing
- Extensive Culture Collection

For more information, please see our website.

Order directly from APHA Scientific, or from our network of distributors available from our website.

Further information

Visit: **www.aphascientific.com**
Tel: **+44 (0)3000 600001**
Email: **salesdesk@apha.gov.uk**

A unique chromogenic medium for the isolation of both O157 and non-O157 STEC

An increasing and worrisome number of studies have lately shown that non-O157 Shiga-Toxin producing *E. coli* (STEC) have been responsible for foodborne poisoning outbreaks. The CDC has also reported warnings about this potential risk:

'60 STEC serotypes have been implicated in Diarrhoeal disease, and several non-O157:H7 serotypes have been implicated as the cause of foodborne outbreaks and HUS in the United States, Europe, and Australia. Studies from Canada, Europe, Argentina, and Australia suggest that non-O157:H7 STEC infections are as prevalent, or more so, than O157:H7 infection.'

In many cases, laboratories have limited their search for pathogenic *E. coli* to the common O157 serotype. This is due, among other reasons, to the fact that there were no available selective culture media for non-O157 *E. coli*. CHROMagar STEC is designed to fill this gap: detection, as mauve colonies, of not only the classical STEC O157, but also many other serotypes.

An outbreak of STEC O104:H4 was reported in Europe during 2011. This medium was used to screen large numbers of samples and successfully isolate the STEC that would not have been routinely identified. In addition CHROMagar developed a selective supplement for addition to this medium rendering it highly selective for the specific strain causing the outbreak.

CHROMagar manufacture a large range of chromogenic media that have applications in both clinical and industrial microbiology. These media are available in the UK through BioConnections.

Further information

Visit: **www.bioconnections.net**
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 harmonised 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**

GPS™, part of an H2020-project for the diagnostic of tuberculosis: ARREST-TB

The Spanish company **Genetic Analysis Strategies SL**, the owner of the **GPS™** brand dedicated to developing genetic diagnostics methods, participates in an H2020 European project called **ARREST-TB** (*Arrest, Rapid, Robust and Economical diagnostic Technologies for tuberculosis*). The project brings together a consortium of academics from the University of Edinburgh, the Heriot-Watt University (Edinburgh) and the University of Padua, together with the SME companies **GPS™**, DestiNA Genómica and Optoi (Italy), in collaboration with the Central Institute of Tuberculosis Research (Moscow, Russia), the National Institute for Tuberculosis Research (Chennai, India) and ShanMukha Innovations Pvt. Ltd. The new technologies based on molecular probes and optical devices for the diagnostics of *Mycobacterium tuberculosis* and its resistance to antibiotics will be evaluated in countries with a high TB prevalence.

Tuberculosis, costing 1.3 million human lives annually (2016 WHO report), is the ninth leading cause of mortality in the world, and participates in the global growth of resistance to multiple antibiotics that has been detected in many other pathogens. According to **Dr Antonio Martínez-Murcia**, Professor at the Miguel Hernández University (Alicante) and director of **GPS™**, 'as a result, drug resistance is considered to be the most accurate and imminent threat to the population'.

Further information

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

NCIMB's growing range of lactic acid bacteria is food for thought

NCIMB has recently added 47 strains of lactic acid bacteria to its reference culture collection. Forty-five of the strains were isolated from naturally fermented Chinese pickle, and two were isolated from naturally fermented yoghurt. The strains were all deposited by scientists from the College of Life Sciences, North East Agricultural University, Harbin, China.

The new additions include 41 strains of lactobacilli, five enterococci and one *Weissella* species – 46 of them are novel species.

NCIMB manages the National Collection of Industrial, Food and Marine Bacteria: the UK's biggest repository for reference strains of environmental and industrially useful bacteria, plasmids and bacteriophages. This collection includes an extensive selection of lactic acid bacteria, and is continuously expanding as a result of new accessions from the international research community.

The range of lactic acid bacteria in NCIMB's open collection includes strains isolated from a diverse range of sources in addition to pickles and yoghurt, such as silage, marinated fish, brewery yeast, fermented cassava and lettuce leaves.

NCIMB also offers a comprehensive range of services to assess the suitability of strains for use as feed additives or probiotics, including screening for antibiotic resistance and virulence factors.

Further information

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

SfAM Annual General Meeting Agenda

88th Annual General Meeting of the Society for Applied Microbiology

10 July 2019, SECC Centre, Glasgow, UK

1. **Apologies for absence.**
2. **Approval of minutes of the 87th Annual General Meeting held in Brighton, July 2018; published in the September 2018 issue of *Microbiologist*.**
3. **Matters arising from the previous minutes.**
4. **Report of the Trustees of the Society 2018:**
   - (i) *Objectives and Activities*
   - (ii) *Achievements and Performance*
   - (iii) *Financial Review*
   - (iv) *Plans for the Future*
5. **Adoption of the 2018 Annual Report.**
6. **New members, deaths and resignations.**
7. **Nomination and election of vice president.**
8. **Nomination and election of treasurer.**
9. **Nomination and election of new Executive Committee members.**
10. **Special resolution (company in general meeting) to alter Memorandum and Articles of Association.**
11. **Any other business*.**

* To ensure the meeting keeps to time, items of any other business must be raised with the General Secretary at least 24 hours before the start of the meeting.
Email: **communications@sfam.org.uk**

Join us at STAND A22 in the Exhibition Hall for:

- Thought-provoking discussions on what the microbiologist of the future looks like.
- Research promotion activities.
- Training, skills and funding-focused sessions.
- Policy campaign launch.
- Ask-the-speaker opportunities.
- Games, exhibition giveaways and competitions.

Join us at
STAND A22

www.sfam.org.uk

sfam society for applied microbiology

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