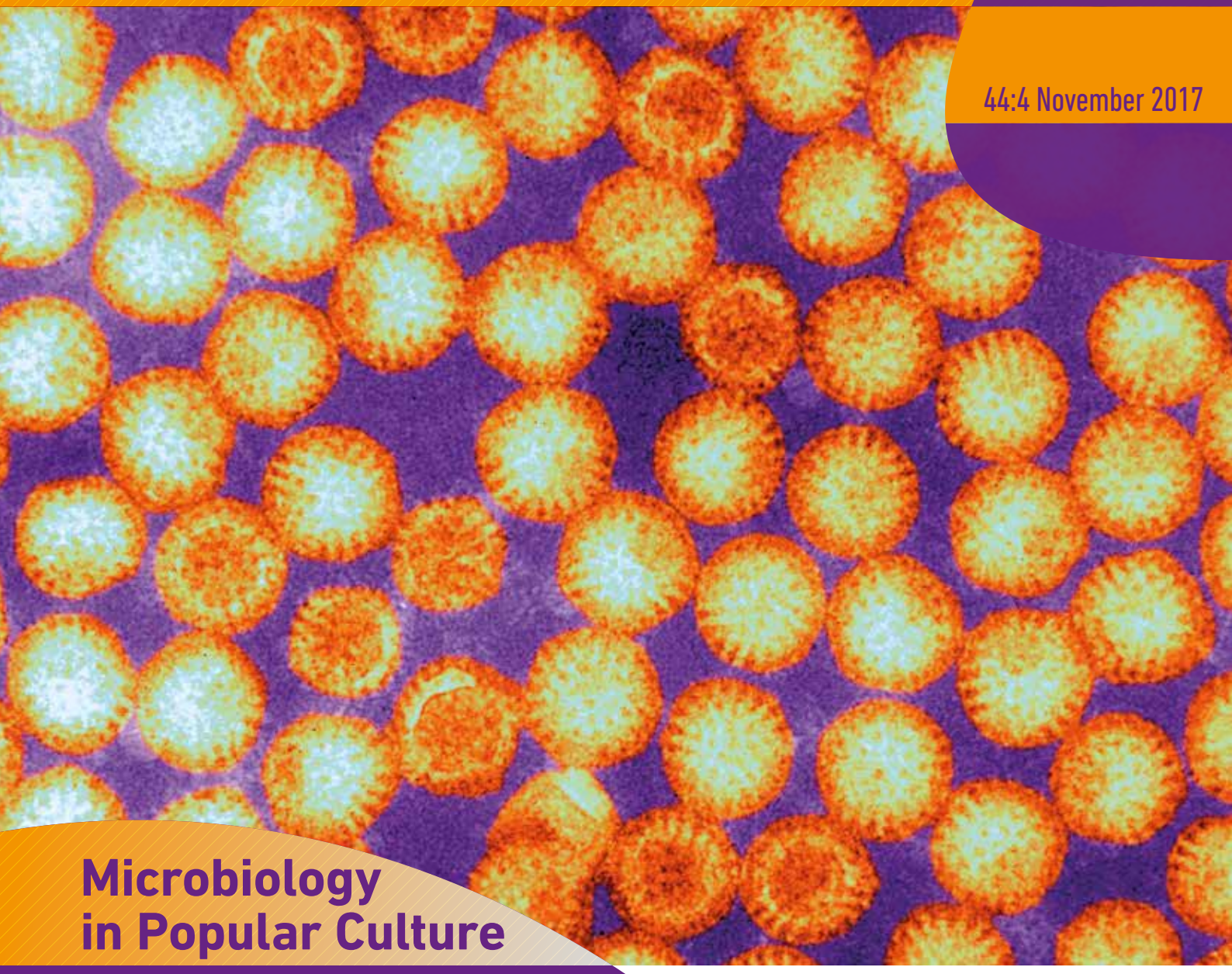
Microbiology TODAY

44:4 November 2017



Microbiology in Popular Culture

Genome editing and the cultural imagination
Managing the myths – the *CSI* effect in forensic science
Killer microbes in movies
Fungal disease and the end of the world as we know it?
Terra Firma II: terraforming Earth's sequel

MICROBIOLOGY SOCIETY

CHLORAMPHENICOL

CAPSULES

Widely distributed throughout the body, including CSF[1]

Oral levels comparable to i.v. levels[2]

Rarely implicated with *C.difficile*[3,4]

Effective against serious infections including:

- *H. influenzae*[1,5]
- Typhoid[1,5]
- MRSA[2]
- VRSA[6]
- Neisseria[1,5]
- Legionella[1,5]
- Rickettsia[1,5]
- *C.difficile*[7-10]
- *E. coli*[1]

Abbreviated Prescribing Information
Chloramphenicol Capsules BP 250mg

Presentation: Hard Gelatin Capsules.
Indications: Typhoid fever and life-threatening infections, particularly those caused by *Haemophilus Influenzae*, where other antibiotics will not suffice.
Posology: For oral administration.
Adults and elderly: 50 mg/kg body weight daily in 4 divided doses. For severe infections (meningitis, septicaemia), this dose may be doubled initially, but must be reduced as soon as clinically possible. Children: Not recommended.
Contra-indications: Known hypersensitivity or toxic reaction to chloramphenicol or to any of the excipients. Should not be used for the prophylaxis or treatment of minor infections; during active immunisation; in porphyria patients; in patients taking drugs liable to depress bone marrow function; during pregnancy, labour or by breast-feeding mothers.
Special warnings and precautions for use: Use only if other treatments are ineffective. Use should be carefully monitored. Reduce dose and monitor plasma levels in hepatic or renal impairment; in the elderly; and in patients concurrently treated with interacting drugs.
Interactions: Chloramphenicol prolongs the elimination, increasing the blood levels of drugs including warfarin, phenytoin, sulphonylureas, tolbutamide. Doses of anticonvulsants and anticoagulants may need to be adjusted if given concurrently. Complex effects (increased/decreased plasma levels) requiring monitoring of chloramphenicol plasma levels have been reported with co-administration of penicillins and rifampicin. Paracetamol prolongs chloramphenicol half-life and concurrent administration should be avoided. Chloramphenicol may increase the plasma levels of calcineurin inhibitors e.g. ciclosporin and tacrolimus. Barbiturates such as phenobarbitone increase the metabolism of chloramphenicol, resulting in reduced plasma chloramphenicol concentrations. In addition, there may be a decrease in the metabolism of phenobarbitone with concomitant chloramphenicol use. There is a small risk that chloramphenicol may reduce the contraceptive effect of oestrogens. Chloramphenicol reduces the response to hydroxocobalamin. Chloramphenicol is contra-indicated in patients taking drugs liable to suppress bone marrow function e.g. carbamazepine, sulphonamides, phenylbutazone, penicillamine, cytotoxic agents, some antipsychotics including clozapine and particularly depot antipsychotics, procainamide, nucleoside reverse transcriptase inhibitors, propylthiouracil.
Pregnancy and Lactation: The use of chloramphenicol is contra-indicated as the drug crosses the placenta and is excreted in breast milk.
Effects on ability to drive and use machines: No significant effect on driving ability.
Undesirable Effects: Reversible dose related bone marrow depression, irreversible aplastic anaemia, increased bleeding time, hypersensitivity reactions including allergic skin reactions, optic neuritis leading to blindness, ototoxicity, acidotic cardiovascular collapse, nausea, vomiting, glossitis, stomatitis, diarrhoea, enterocolitis, Gray Baby Syndrome particularly in the newborn, which consists of abdominal distension, pallid cyanosis, vomiting, progressing to vasomotor collapse, irregular respiration and death within a few hours of the onset of symptoms.
Overdose: Stop chloramphenicol immediately if signs of adverse events develop. Treatment is mainly supportive. If an allergy develops, oral antihistamines may be used. In severe overdosage e.g. Gray Baby Syndrome, reduce plasma levels of chloramphenicol rapidly. Resin haemoperfusion (XAD-4) has been reported to substantially increase chloramphenicol clearance.
Pack size and Price: 60 capsules £377.00
Legal Category: POM.
Market Authorisation Number: PL17736/0075.
Market Authorisation Holder: Chemidex Pharma Limited, 7 Egham Business Village, Crabtree Road, Egham, Surrey TW20 8RB, UK.
Date of preparation: January 2016.
See Chloramphenicol Capsules Summary of Product Characteristics for full prescribing information.

Adverse events should be reported. Reporting forms and information can be found at www.mhra.gov.uk/yellowcard. Adverse events should also be reported to Essential Generics on 01784 477167.

References:
1. Martindale: The Complete Drug Reference. Chloramphenicol. [Online]. Available from: http://www.medicinescomplete.com [22nd of November 2016]. **2.** Fluit, A.C., Wielders, C.L.C., Verhoef, J., and Schmitz, F.J. Epidemiology and susceptibility of 3,051 Staphylococcus aureus isolates from 25 university hospitals participating in the European SENTRY Study. Journal of Clinical Microbiology. 2001; 39(10): 3727-3732. **3.** Kelly, C., LaMont. Patient information: Antibiotic-associated diarrhea caused by Clostridium difficile (Beyond the Basics).June 2015. **4.** Bartlett J.G. Antimicrobial agents implicated in Clostridium difficile toxin-associated diarrhea of colitis. Johns Hopkins Med J. 1981; 149(1): 6-9. **5.** Feder. H, Chloramphenicol: What we have learned in the last decade. Southern Medical Journal. 1986; (79)9: 1129-34. **6.** Weigel LM *et al.* High-Level Vancomycin-Resistant Staphylococcus aureus Isolates Associated with a Polymicrobial Biofilm. Antimicrob Agents Chemother. 2007 Jan; 51(1): 231–238. **7.** Ensminger, P., Counter, F., Thomas, L., Lebbehuse, P. Susceptibility, resistance development, and synergy of antimicrobial combinations against Clostridium difficile. Current Microbiology. 1982; 7: 59-62. **8.** Poilane, I., Bert, F., Cruaud, P., Nicolas-Chanoine, MH., Collignon, A. Interest of the disk diffusion method for screening Clostridium difficile isolates with decreased susceptibility to antibiotics. Pathologie Biologie (Paris). 2007; 55(8-9): 429-33. **9.** Cattoir, V., Ould-Hocine, ZF., Legrand, P. Antimicrobial susceptibility of Clostridium difficile clinical isolates collected from 2001 to 2007 in a French university hospital. Pathologie Biologie (Paris). 2008; 56(7-8): 407-11. **10.** Brazier, JS., Levett, PN., Stannard, AJ., Phillips, KD., Willis, AT. Antibiotic susceptibility of clinical isolates of clostridia. Journal of Antimicrobial Chemotherapy. 1985; 15(2): 181-5.

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Editorial

Welcome to the November edition of *Microbiology Today* and one in which we discuss 'Microbiology in Popular Culture'. Now, I'm sure everyone reading this can think of a favourite book, TV show or film. I'm particularly partial to a good murder mystery, which, if on TV, is all neatly wrapped up in two hours; but how often do we consider the science that has gone into making the programme? In this edition our authors provide some insight into how popular culture portrays microbiology, whether it is in a carefully investigated crime scene or in a sci-fi classic portraying alien life on a planet far, far away.

Whole Picture

To start us off, Sandy Starr and Jennifer Willows look at how the many works of fiction that touch on gene editing might influence opinion on this subject. Whether considering old classics like *Frankenstein* or futuristic worlds with controlled populations, these fictions can bring genome editing to the forefront of public discussion. The topic of genome editing is a complex, fast-moving field of science that can raise concern about the ethical implications among the general population. Touching on their research into public understanding of this topic, Sandy and Jennifer share their findings about the kind of information people want to be provided with when having to make decisions about genome editing.

We then delve into crime dramas, particularly those showing the scene of a crime such as *CSI*. This example of an increasingly popular TV format showcases microbiology on screen, often depicting perfect sample matches to criminals and rapidly solved cases. How important is it for people to understand that part of what they are seeing in these shows is pure fiction? The writers of our second article, Lorna Dawson and Chris Gannicliffe, highlight the realities of forensic science, the range of complementary forensic services needed, and where the science ends and the fiction begins.

Following on from this, Andrew Burns and David Bhella address disease outbreaks and how the film version of events, while based on real microbiology, can rapidly diverge into something completely unexpected. Focusing on likely candidates of viral origin, they reflect on various outbreak films and suggest the possible inspiration for the contagions in question. This piece highlights how terrifying film scenarios can be rooted in very familiar science before they perhaps become a little more fantastical.

Our fourth piece takes a look at fungal disease and how it fits into popular culture. While fungal agents have been used as the causal agent of both a cannibalistic human race and zombie apocalypses for computer games, books and TV, it is perhaps less likely to considered to be a serious problem than its bacterial or viral counterparts. Lewis White describes how the fictional portrayal of fungal disease in mainstream media helps raise the profile of fungal disease, which increasingly shows resistance to treatments.

In the fifth piece by Arwyn Edwards, we leave Earth behind and look at the potential for reproducing Earth-like conditions on previously lifeless planets. In fiction, terraforming whole planets can be rapidly successful, resulting in new ecosystems that can support human life. While this rapid transformation is currently unrealistic, could it hint at something that will eventually be possible? Some of the planets depicted in sci-fi programmes mirror planets in our solar system. Could these be potential candidates for supporting life off Earth, even if that life might initially be microbial?

Our Comment piece has been written by Amy Chambers, focusing on the use of science in film, how films can influence public perception and their expectations of what science can deliver. Could it be that films which research the facts and utilise expert scientific advisors make for more entertaining films? Amy outlines how interdisciplinary collaborations between film-makers and scientific advisors can help deliver a better package for everyone watching at home or in the cinema.

Rowena Jenkins
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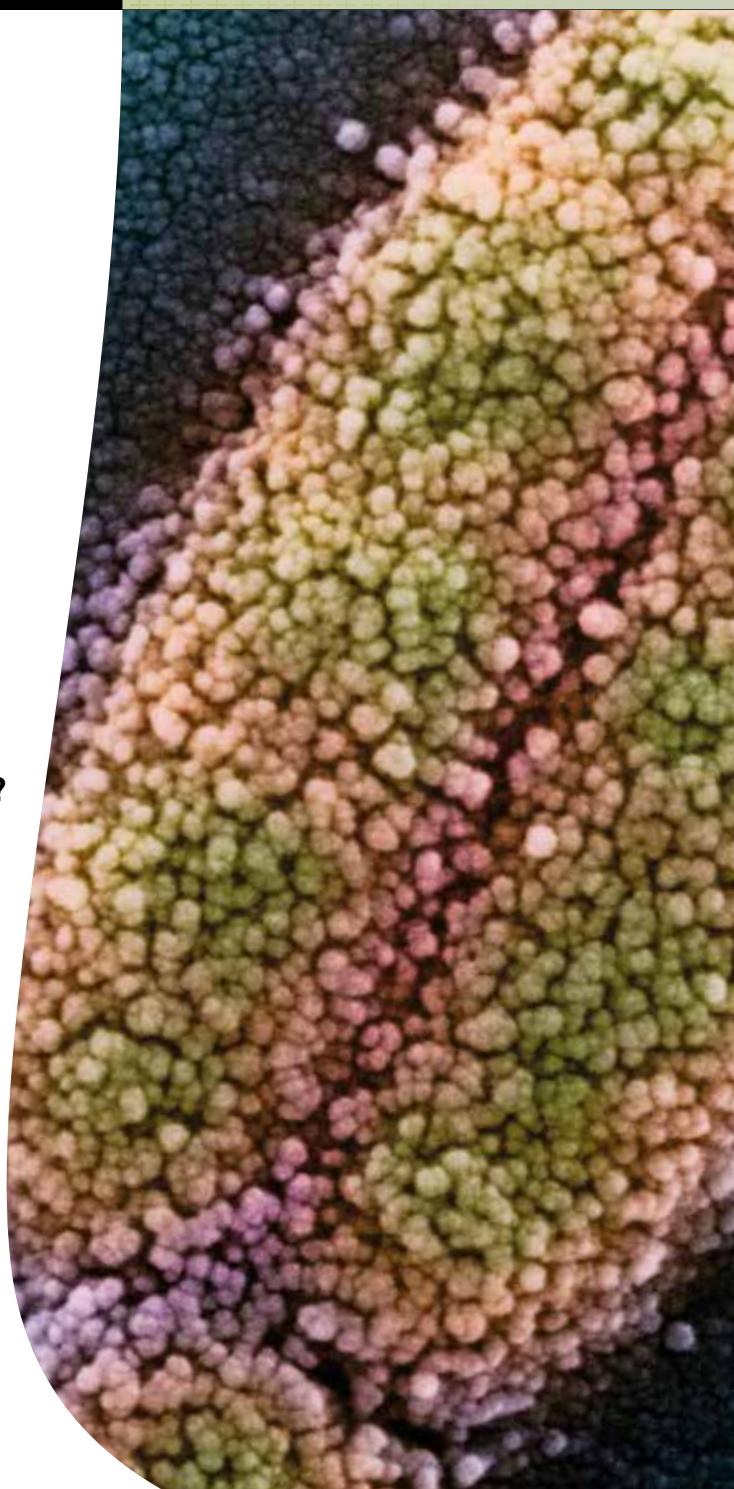

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Features

Regulars

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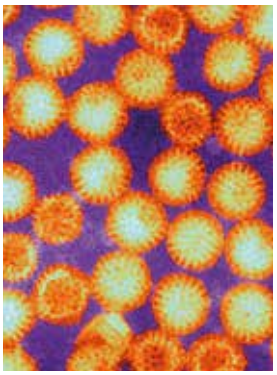

FSC Logo

Colour-enhanced transmission electron micrograph of simian rotavirus SA11, negatively stained with phosphotungstic acid.
ASM/Science Source/Science Photo Library

MICROBIOLOGY SOCIETY

Council 2017

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From the President

I like the double-entendre in the title of the topic of this issue of *Microbiology Today* – 'Microbiology and Popular *Culture*'. Culturing microbes has always been an important and popular activity, and a huge set of industries depend on their microbiological cultures. Indeed, life on planet Earth is really the outcome of its underpinning popular (microbiological) cultures!

However, this issue is really looking at the interface between science and science fiction. Recent popular culture films, such as the recent summer movie, *Life*, have toyed with the idea of exomicrobiology (microbes outside planet Earth). Recent scientific advances in astronomy and space science suggests that this idea may not be so far fetched after all. We have heard that ancient Mars may once have had oceans and therefore (possibly) Martian microbes. Potentially, some of the icy moons of Saturn and Jupiter may have conditions that would permit microbiological life to exist. Statistically it is almost certain that life exists outside the Earth and if it does you can be fairly sure that the first life forms anywhere will be microbial in nature. In the movies, from *The Andromeda Strain* to *Life*, science fiction has preyed on our fear of pestilence and microbial diseases rather than the beneficial and essential nature of microbes. Indeed, as humankind starts to contemplate space missions that travel far from the Earth we will certainly have to take with us a Noah's ark of microbial cultures to ensure that our microbiomes and other microbial partners on which we depend accompany us on that journey.

In terms of popular culture, I am working on the Society's behalf to try to push for greater exposure of the world of microbes in the popular media and on the television. This project is only at an early stage and we may or may not convey our vision of an 'invisible planet' of micro-organisms – but if we do I will report back to you and seek your help.

As President, you may feel that I would say this, but it really is a genuine pleasure working with people who share the same passion for microbiology. Our staff at Charles Darwin House are professionals that bring together a wide range of professional skills. They work as a team and make the role for those of us in Council as easy and pleasurable as it can be. I've also enjoyed the company of a large number of practising microbiologists who generously give their time to the Society as Council members, Editors, programme organisers and in other key roles. Discussions at Council have been dynamic, wide-ranging, yet focused and effective. I like team working and this Society is a very good team indeed.

When I started, our Chief Executive Peter Cotgreave asked me what would be my most important objectives during my tenure. I listed three for the record. Firstly, I wanted the Society to grow physically and in influence, but to retain its personality and reputation as a friendly, engaged and nurturing community. Our conference in Edinburgh smashed all records – but it was also a lot of fun. Secondly, I wanted our early career microbiologists to be drawn much closer into the core administrative activities of the Society. Our Early Career Microbiologists' (ECM) Forum is now going great guns and injecting tremendous energy and vitality into the Society (thank you to Helen Brown, Rebecca Hall and all of the ECM Forum). Lastly, I wanted to maximise our impact in the public arena. We are doing more and more impactful policy work than ever before – and there are more ideas and initiatives brewing. Therefore if I look back on how the first half of my term of office has gone I think we are on track to meet those objectives – but there is still important work to be done.

Neil Gow
President
president@microbiologysociety.org

From the Chief Executive

At the Microbiology Society's Annual General Meeting in September, Council set out its plans for the next five years. While the new strategy builds on recent successes, it recognises that if microbiology is to bring maximum benefit to the public, we will need an ever-greater level of ambition. The unique depth and breadth of knowledge and experience of the members is a massive resource, and the Society's role is to help unlock and harness the potential of that knowledge.

The strategy has been developed in wide consultation with members, Committees, staff and a range of other friends and partners. One of the most important and fascinating parts was defining the Microbiology Society's values – the ways in which we behave that make the Society special. All of us have different ways of expressing how we feel about an organisation, and the consultation threw up literally hundreds of words to describe the Society! But in the end, they came down to three key features – we are welcoming, transparent and dedicated. In practice, the first of these means that our reputation as a friendly, nurturing and approachable community is extremely important. Being transparent means, among other things, that we value evidence and expertise, both when Council, Committees or staff are making decisions about the Society's own activities and also in the wider world of policy and public life. The third value expresses a commitment to our charitable aim of advancing microbiology, and ensuring that all our resources are applied to that end.

In terms of what the Society will try to achieve over the next five years, the key feature of the new strategy is to put the members at the centre of everything we do. It is your knowledge and experience that gives the Society its legitimacy and authority, and it is the networks and connections that are fostered within the membership that help us to unlock the potential of that knowledge.

There are three objectives in the new plan. The first is about enabling members to strengthen existing networks and develop new ones. The second concentrates on championing the contribution made by members in addressing the world's challenges. The third objective emphasises the need to guarantee sustainability so that the Society can continue to play an important role into the future.

Collapsed into a single sentence, the new strategy document says:

> ***In the five years between 2018 and 2022, the Society's principal goal is to develop, expand and strengthen the networks available to our members so that they can generate new knowledge about microbes and ensure that it is shared with other communities.***

Of course, we will achieve this in part through the same traditional activities that the Society has pursued effectively for seven decades, such as organising world-class conferences and publishing the highest quality scientific papers. But having spent the past few years improving the mechanisms by which members drive the Society's direction, we are now able both to make these long-standing programmes more responsive to your needs, and to develop new ways of helping you to advance your careers.

The strategy expresses the reason the Microbiology Society exists in a simple statement:

> *When the discipline of microbiology is strong and intellectually vibrant, we have a better chance of finding solutions to these problems, and building a healthier, more sustainable and more prosperous future.*

To play our fullest part in making this happen, two sets of people need to be engaged in our success – the staff and the members. We are lucky to have a fantastic group of energetic and professional staff to complement the skills and knowledge of the membership. Together, by focusing on our own unique strengths, we can make a real difference. So please let me know how you want to see the Society develop over the coming years, the opportunities that you see ahead, and how you think we can work together to grasp them.

Peter Cotgreave
Chief Executive
p.cotgreave@microbiologysociety.org

The strategy can be found on the Microbiology Society website: **www.microbiologysociety.org/strategy**.

News

The new five-year strategy

The Society's new five-year strategy was launched at our recent AGM and Society members are at the heart of everything we aim to do. The new strategy will help empower our members to take their knowledge further, and to shape and help the future of microbiology. The Society's core values – being welcoming, transparent and dedicated to our charitable aims – are central. Our key objectives, outlining our commitment to our membership, and to long-term sustainability, will allow the Society to continue supporting microbiologists for years to come.

The strategy will be fully implemented from January 2018, but we have already established some initiatives to achieve these objectives – the Early Career Microbiologists' Forum, and the Council Shadowing Scheme, for example. Look out for many more in the near future.

You can read more about the five-year strategy on our website **www.microbiologysociety.org/strategy**.

Dr Linda Stannard, UCT/Science Photo Library

Focused Meetings

The Society would like to thank all those who took part and contributed to this year's Annual Conference and Focused Meeting programmes, particularly those in our Divisions and Scientific Conferences Committee who will be stepping down at the end of this year. These members ensure our scientific content and topics are current and relevant to our microbiology community, and ensure those accessing our conferences programme get the opportunity to hear from some of the top microbiologists worldwide.

We have now confirmed our programme of Focused Meetings for 2018, and you can read more about these events on page 176. Don't forget, these topics came from suggestions from Society members and you can find out more about how to suggest a topic for our 2019 events by visiting our website: **www.microbiologysociety.org/events**.

Multicoloured Microbiomes – a colouring book

The Microbiology Society has recently published *Multicoloured Microbiomes*, our microbiome-themed colouring book, priced at £5. Copies are available to order, to be delivered in time for Christmas – please see the insert inside this issue and the article on page 182, or email **books@microbiologysociety.org**.

Congratulations to our 2018 Prize Lecture winners

The Society is pleased to announce the Prize Lecture winners for 2018. These Prizes are awarded in recognition of significant contributions to the field of microbiology, and each winner will present a Prize Lecture at the Microbiology Society's Annual Conference 2018, taking place from 10 to 13 April in Birmingham. Please see **www.microbiologysociety.org** for more information.

Young Microbiologist of the Year

Daniel Hurdiss (University of Leeds) was presented with the Young Microbiologist of the Year award for 2017. Daniel gave his talk, entitled 'High-resolution cryo-EM as a tool to study virion assembly and cellular entry of BK polyomavirus, a major cause of kidney transplant rejection', at the Annual General Meeting this September. **Andrew O'Connor** (University College Dublin) won second place, with **Rebecca Hall** (University of York) taking third place in the competition. Congratulations to all participants for their excellent presentations.

IJSEM welcomes new Editor-in-Chief

International Journal of Systematic and Evolutionary Microbiology (IJSEM) is excited to welcome **Professor Martha Trujillo** (Universidad de Salamanca, Spain) as its new Editor-in-Chief. Martha is a leading expert in microbial ecology and systematics with over 120 publications to her name. She has been an Associate Editor for the journal since 2009 and is the current President of the Bergey's International Society for Microbial Systematics. Find out more on page 185.

All those involved with IJSEM would also like to say a huge thank you to **Professor Aharon Oren** for all his hard work and sincere dedication to the role during his tenure as Editor-in-Chief. We are immensely pleased to be retaining his experience and expertise as Nomenclature Reviewer and List Editor for IJSEM.

Grant deadlines

Date	Grant
1 December 2017	Travel Grants – to support members presenting their work at a conference between 1 January and 31 March 2018.
30 January 2018	Society Conference Grants – to support members attending the Annual Conference 2018.
10 February 2018	Harry Smith Vacation Studentships – to support members to host an undergraduate student for a summer project in 2018.

Please note: Further eligibility criteria apply. Please see **microbiologysociety.org/grants** for details.

Great news: we've won an award!

Earlier this year the Association of British Science Writers jointly awarded **Ben** and **Anand** the Dr Katharine Giles award for their writing on the Society's *Microbe Post* blog, ahead of a packed field of competitors. Needless to say we're absolutely delighted and want to thank all of our members for taking the time to read our posts or pick up the phone to answer our questions.

Society members attend parliamentary events

Over the summer, members and staff attended several science policy events supported by the Society. Parliamentary Links Day 2017, organised by the Royal Society of Biology, brought the STEM community and policy-makers to the Houses of Parliament to discuss 'UK Science and Global Opportunities'. Speakers included Science Minister Jo Johnson MP and Sir John Kingman, Chair of UK Research and Innovation. During panel discussions, Society members raised issues about Brexit and science. Afterwards, members attended a House of Lords luncheon with parliamentarians and speakers.

In July, Society members Professor Carol Munro and Dr Rebecca Hall attended a Parliamentary and Scientific Committee meeting on human fungal diseases. Parliamentarians and experts discussed the burden of fungal disease on public health, challenges of diagnosis and antifungal stewardship.

The Society also supported Science and the Assembly 2017. The STEM community and policy-makers at the National Assembly for Wales met at this event, organised by the Royal Society of Chemistry, to discuss antimicrobial resistance (AMR). Several members of the Society spoke at the event. Society Policy Officer Jonathan Hamston also attended a debate on this issue at the European Parliament ahead of the launch of the *European One Health Plan Against AMR*.

You can read more about Parliamentary Links Day 2017 and Science and the Assembly 2017 on our blog: **microbepost.org/category/policy**.

Annual Conference 2018

Registration and abstract submission is now open for our 2018 Annual Conference, which takes place 10–13 April at the ICC in Birmingham, UK. The abstract submission deadline is **Monday 11 December 2017**, so make sure you submit before this to be in with a chance of presenting your work. Read more on page 175 and visit our website (**microbiologysociety.org/annualconference**) for more information about session topics and the social programme.

FIS 2017

The Federation of Infection Societies (FIS) meeting will take place this year at the ICC in Birmingham from 30 November to 2 December. Find out more about what's on offer by visiting the event's website: **event.federationinfectionsocieties.com**.

ECM Forum Division Representatives

We are delighted to announce our new Division Representatives for the Early Career Microbiologists' (ECM) Forum:

Virology Division	**Dr Leah Fitzsimmons**
Prokaryotic Division	**Megan Booth**
Irish Division	**Dr Justine Rudkin**

We are still looking for a Eukaryotic Division Representative, so please contact **ecm@microbiologysociety.org** if you are interested.

These representatives will be vital in bringing the ECM viewpoint to our Annual Conference and Focused Meeting planning, as well as being key organisers of the new ECM Summer Conference next year.

Antibiotics Unearthed in Glasgow

The final pop-up event for Antibiotics Unearthed was held at the Glasgow Botanic Gardens in September.

Ethan Drury, the Society's match-funded PhD student, took part and was collecting interview data as well, as part of his project.

This concludes the series of pop-up events for Antibiotics Unearthed. To find out how the School Partnership programme has been going, visit the Schoolzone section (page 186) or visit **microbiologysociety.org/antibioticsunearthed**.

Deaths

The Society is sad to announce the passing of **Dr J. R. Dickinson**. His obituary can be read on the Cardiff University website: **http://microb.io/2y3iTM7**.

Contributions and feedback

The Society welcomes contributions and feedback from members. Please contact **mtoday@microbiologysociety.org** with your ideas.

Get the latest updates, follow the Microbiology Society on:

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Genome editing and the cultural imagination

Sandy Starr & Jennifer Willows

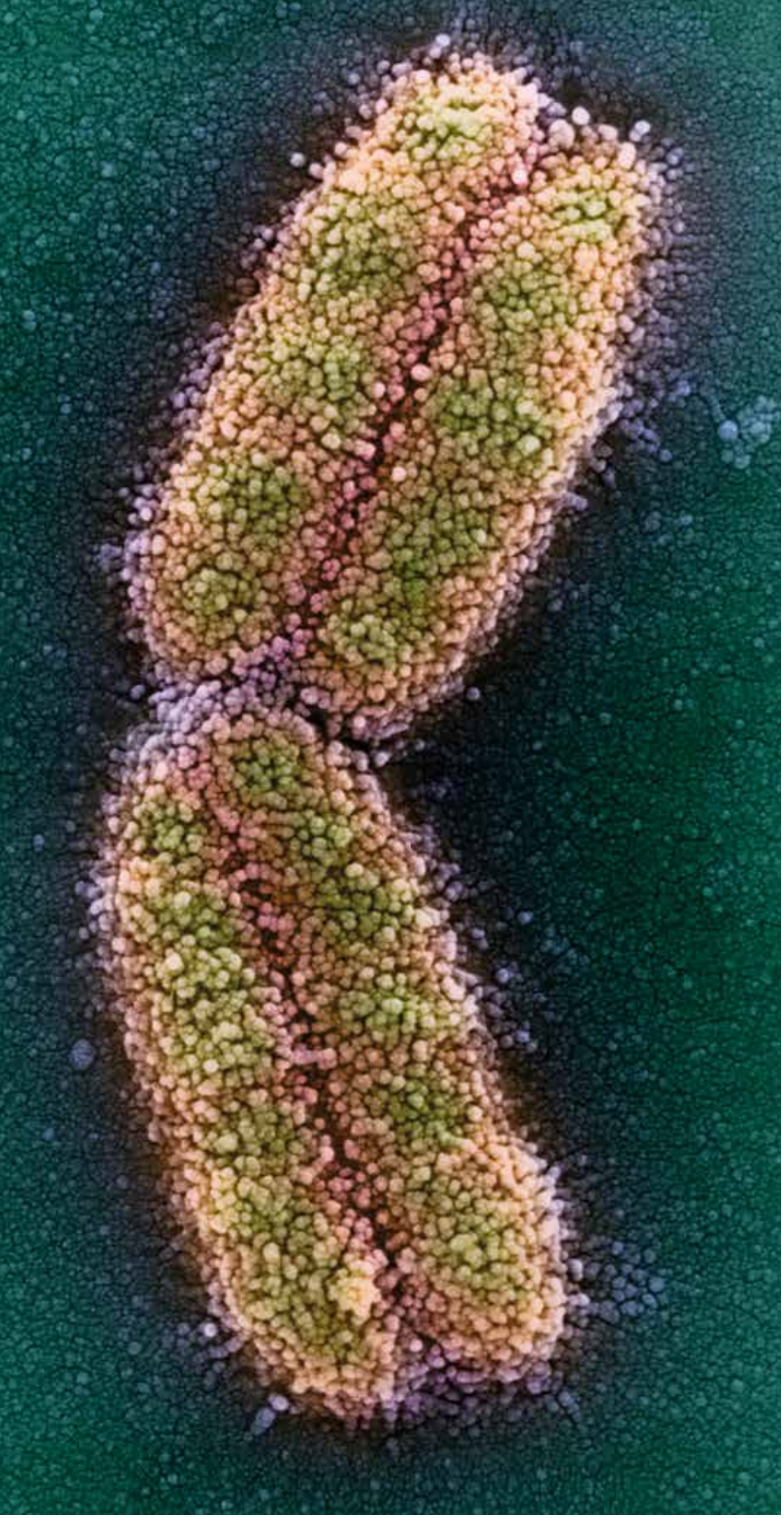
Genome editing – the deliberate alteration of selected DNA sequences in living cells – is increasingly at the forefront of scientific and public discussion, and has enormous potential to help us treat or avoid disease.

Alongside the benefits of this technology, mainstream discussion often raises fears of its misuse with reference to *Brave New World*, *Frankenstein*, or other dystopian fiction and science fiction. Are such cultural landmarks a good springboard for discussion, or do they result in unhelpful scaremongering?

Two charities – the Progress Educational Trust (where we work) and Genetic Alliance UK – recently collaborated to explore these sorts of questions in a series of workshops and online engagement activities, funded by the Wellcome Trust under the heading 'Basic Understanding of Genome Editing'. We sought to find out what patients and laypeople think and know about genome editing, and what language and metaphors they find most helpful.

We could hardly ignore Mary Shelley's *Frankenstein*, the famous gothic novel and pioneering work of science fiction, which celebrates its 200th anniversary next year and is still used as metaphorical shorthand for the perils of playing God. A more recent work which has had a significant impact, and which marks its 20th anniversary this year, is the film *Gattaca*.

The film depicts a dystopian future, with genetic haves and have-nots living in an apartheid-type society. In this world, a naturally conceived 'in-valid' cannot hope to get a good job – no matter how



Coloured scanning electron micrograph of human chromosome 1. Humans have 23 pairs of chromosomes, this is the largest. It accounts for 10% of the human genome. Adrian T. Sumner/ Science Photo Library

able or determined they are – if their genes aren't thought to be up-to-scratch.

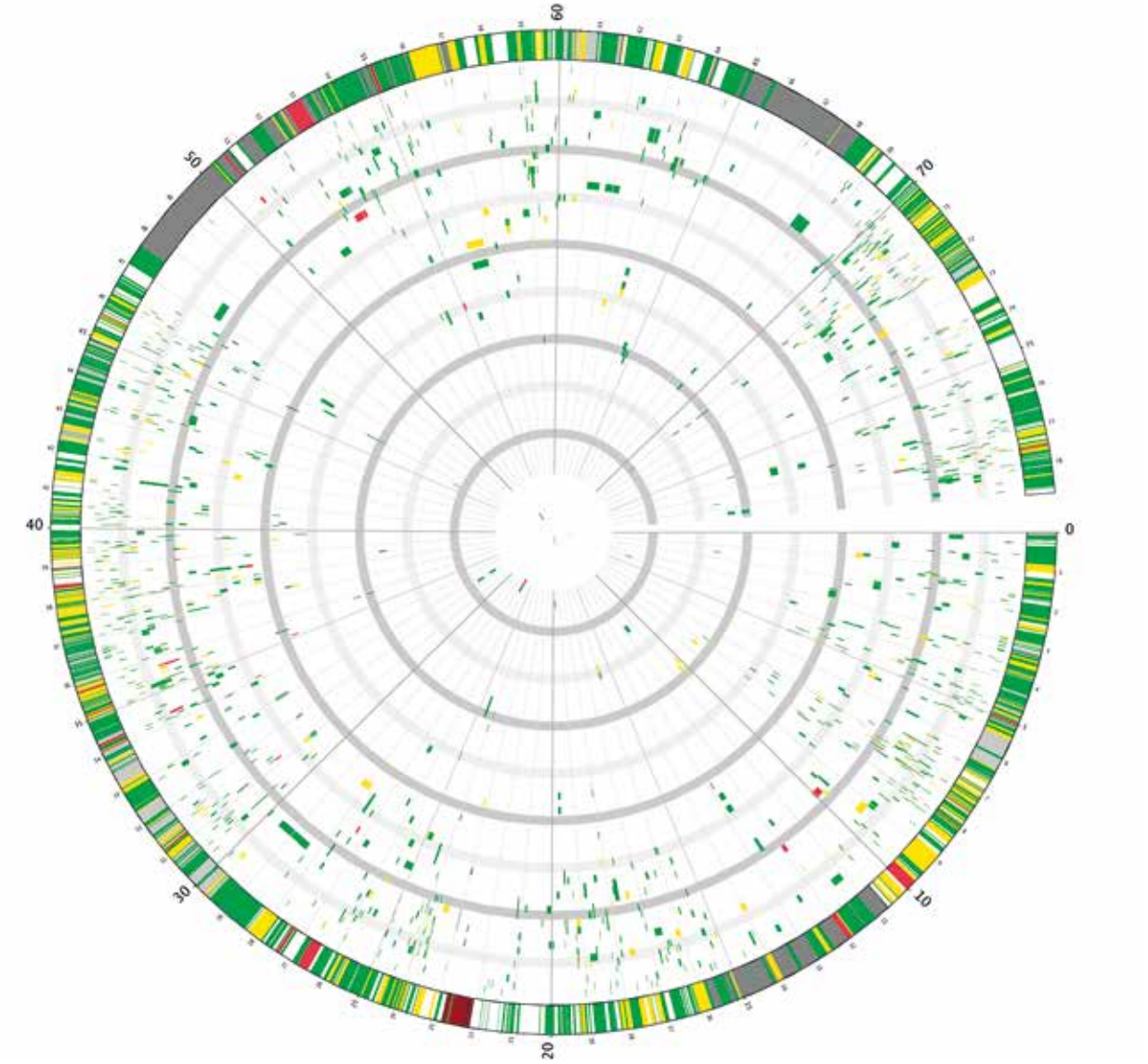
In recent years, the CRISPR approach to genome editing – which was adapted from a naturally occurring mechanism used by bacteria as a defence against invading viruses – has brought us closer to being able to edit the human genome in the way depicted in *Gattaca*. Nonetheless, it remains far beyond our technical capabilities (to say nothing of our laws) to tailor a bespoke genome from the genetic material of two parents.

Gattaca presents an overly determinist view of genetics – or at least, its characters do. A geneticist in the film says: *'We want to give your child the best possible start. Believe me, we have enough imperfection built in already. Your child doesn't need any more additional burdens. Keep in mind, this child is still you – simply, the best of you. You could conceive naturally a thousand times and never get such a result.'*

In fact, the more we learn about our genomes, the more we discover complex patterns of interdependence between our genes, our environment, epigenetic factors and the vagaries of chance. In other words, a society with advanced technology could create a child *artificially* a thousand times and still get very different results each time.

The parts of *Gattaca* that have perhaps weathered best are those that relate to genome *sequencing*, rather than genome editing. The film's characters constantly undergo genetic tests and checks of their genetic identity. Meanwhile, in the real world, this year's *Generation Genome* report from the UK's Chief Medical Officer looks at the prospective benefits of expanding the role of genome sequencing throughout the NHS.

Generation Genome, which concludes with a weighty chapter on ethical considerations, is hardly a blueprint for the world of *Gattaca*. But looking at the Chief Medical Officer's report alongside the dystopian drama does highlight the importance of our society making conscious decisions, about what it



Circular genetic map, showing human chromosome 17. The chromosome (outer ring) is based on a standard idiogram and arranged in a circle. The coloured bands represent genes (green), cancer genes (red) and other disease genes (orange). The graph within the circle shows reference sequence genes, a standard for gene identification, and exons, which are parts of the genes that encode for proteins. Martin Krzywinski/Science Photo Library

Ultimately, it isn't the knowledge and achievements of scientists which will either bring about or avert scenarios such those depicted in *Frankenstein* or *Gattaca*. Rather, it is the understanding and opinions of the public.

deems to be proper – and improper – uses of genomics.

One of the discoveries we made during the 'Basic Understanding of Genome Editing' project is that people don't like being presented with a ready-made set of assumptions about which uses of genomics are acceptable. If we want to have meaningful public discussion about the best use of science, then members of the public need to be given the latitude to come to their own moral conclusions.

Where does this leave organisations like ours, which want to promote more thoroughgoing public debate about genome editing? For one thing, we have a useful role to play in relation to the *Frankenstein*s and *Gattaca*s of the cultural imagination – not in seeking churlishly to correct these enduring and thought-provoking stories, but simply in explaining whether and how they converge with, or diverge from, what is scientifically possible and legally permitted at present.

For another thing, we can identify and remove impediments to understanding. The following recommendations – drawn from our experience with workshop participants – clear the ground for a more informed discussion of genome editing, while still giving people the freedom to decide for themselves whether particular applications of this technology deserve their support.

Say 'genome editing'

Consistency of language is essential. 'Genome editing' is an accurate term in most situations – even if you only change only one gene in an organism, that still constitutes a change to its genome. The current proliferation of synonyms for genome editing – 'gene editing', 'genomic editing', 'genome engineering', and so on – just creates needless confusion.

Likewise, 'CRISPR' shouldn't be used as a synonym for genome editing. Of course CRISPR has become a buzzword and has captured the public imagination, but it wasn't the first approach to genome editing and it may not be the last. One of the most celebrated uses of genome editing in the UK – to reverse advanced leukaemia in a one-year-old baby in 2015 – didn't actually involve CRISPR at all (an earlier approach called TALENs was used).

Say who or what is having their genome edited

Genome editing can be used on anything with a genome – in other words, just about any living thing. It's vital to distinguish between humans, animals, plants and micro-organisms that are having their genomes edited, rather than lumping all these things into one.

Say whether genomes are being edited for research or for treatment

There's a big difference between genome editing in the lab and in the clinic. Both are carefully regulated, but the latter involves a plethora of additional ethical and safety considerations.

Furthermore, genome editing in the lab isn't always a prelude to genome editing in the clinic. Not all researchers who edit human genomes do so with an eye to developing a genome editing therapy – their aim may be to improve our understanding of biology and disease, in order to develop and refine more traditional therapeutic approaches.

Say whether changes made to the genome will be inherited by the next generation

There's a very important difference between our soma (the part of our biology which *isn't* inherited by the next generation) and our germline (the part of our biology which *is* inherited by the next generation).

This distinction is biological, and it is also legal. In the UK, the difference between editing a somatic genome and editing a germline genome can be the deciding factor in whether or not you've committed a crime!

Of course, laws can be changed if a persuasive case is made for changing them. New possibilities in genome editing may present us with reasons to revise the laws which govern use of this technology. This revision could be permissive, or restrictive, or a subtle combination of the two.

Ultimately, it isn't the knowledge and achievements of scientists which will either bring about or avert scenarios such those depicted in *Frankenstein* or *Gattaca*. Rather, it is the understanding and opinions of the public.

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The findings of the Progress Educational Trust's 'Basic Understanding of Genome Editing' project can be found online at ***www.progress.org.uk/genomeediting***.

The tall, athletic man arrives at the crime scene with his beautiful, intelligent female lab assistant. Her hair flows and her heels are precarious. She waves a magic fluorescent stick and hey presto, it's a complete match! The DNA found on the victim's neck is a 100% match with that of the prime suspect, the victim's husband. They immediately interview the suspect at the scene and manage to get a confession, not only to that bloody murder, but to ten others... "So you want to find another victim?" They drive off in their black, 'top-of-the-range' off-roader, with the suspect in the back seat, to visit the next gory scene.

Managing the myths – the CSI effect in forensic science

Lorna Dawson & Chris Gannicliffe

The fiction

A scene from the TV series *CSI: NY*. Lindsay Monroe-Messer (Anna Belknap) talks to Danny Messer (Carmine Giovinazzo) while investigating the remains of a food truck explosion. Getty Images

Get the picture? Yes, far removed from anything we have ever experienced as forensic scientists at home or abroad. Unlike the *CSI* portrayal of scientists examining crime scenes in designer top, jeans and shades, personal protective equipment must always be worn at a scene. In the real world, disposable coveralls, gloves, mask, mob cap or hood, and booties are worn. Not glamorous, but they minimise contamination by the scientist (who might otherwise inadvertently deposit their own DNA and trace evidence), and protect the scientist from the risks of infected body fluids and other hazardous materials at the scene. However, such misrepresentations are perhaps relatively trivial when one considers the other ways in which televised crime dramas can influence public perception of forensic science.

With a rapid rise of interest in crime dramas all across the world, there runs the risk of false expectation amongst the general population as to what forensic science can actually deliver. In adversarial systems such as in the USA and the UK, where juries are key to the process of deciding guilt, it is vitally important that when an expert witness presents his/her evidence in court, that there is an understanding of what is truly meant by the data presented and what is meant by the expert opinions conveyed.

Scientific evidence and law

Forensic science is the application of science to both criminal and civil law. In the context of criminal investigation, it is governed by the legal standards of admissible evidence and criminal procedure.

Forensic scientists assist the investigator by recovering, preserving and analysing samples during the course of an investigation. Just as importantly, the forensic scientist then has to interpret the significance of their findings in the context of the case circumstances. Some forensic scientists attend the scene of the crime to collect the evidence themselves, while others solely work in the laboratory and analyse exhibits and samples brought to them by other members of the team. Very seldom does the same person attend the scene and also analyse the samples in the lab, and the forensic scientist never ever interviews the suspects, unlike in the storyline in many crime dramas.

In addition to the on-the-scene and lab roles, forensic scientists also testify as expert witnesses in both criminal and civil cases and can work for either the prosecution or the defence. Theoretically, any subject can be 'forensic', although the main evidence types used are: biology (identification and attribution of body fluids and blood pattern analysis); chemistry (analysis and comparison of trace material such as glass and paint, and comparison of footwear marks); fibre and hair identification and comparison; analysis of illicit drugs of abuse; toxicology (the detection and analysis of toxic substances in body fluids and tissues); and fingerprints. The investigation of serious crimes, such as murders and rapes, can also involve the wider complementary forensic 'ologies' such as pedology (study of soil science), geology (study of the Earth's structure and surface), taphonomy (study of decay and fossilisation), palynology (study of pollen grains and spores), and entomology (study of insects). Bacteriology and virology can also have their increasingly important part to play. Forensic microbiology has recently emerged as a separate discipline, using a range of tools from specific culture methodology to whole genome sequencing (molecular techniques used

The reality

At a crime scene recovering evidence in full personal protective equipment.

Lorna Dawson

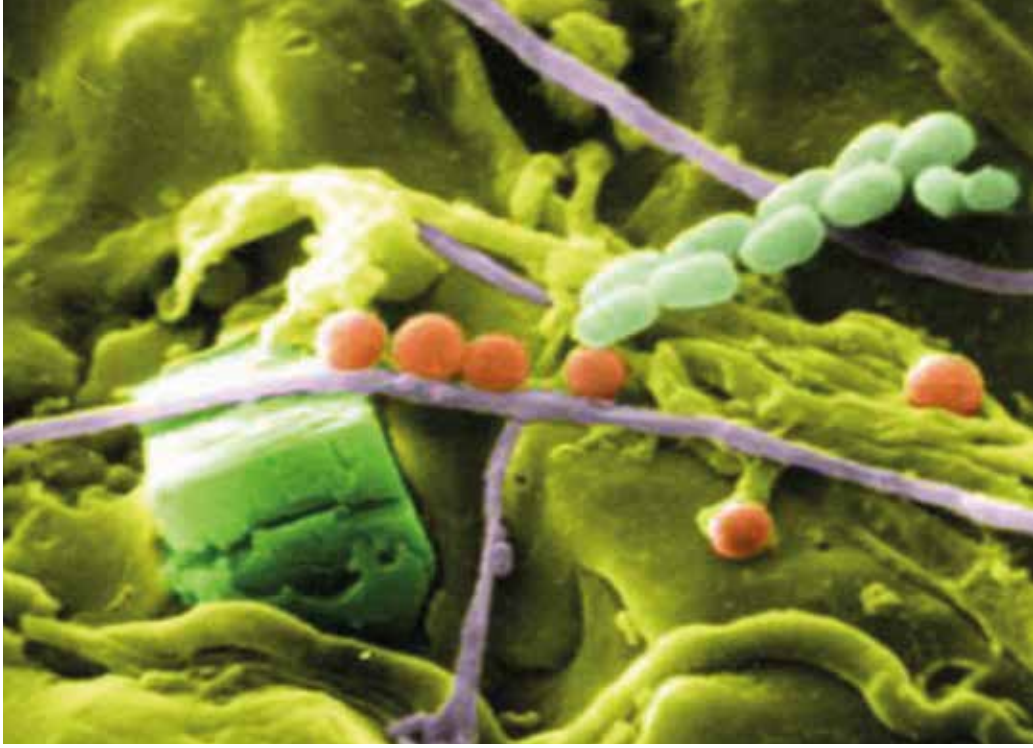
for detecting the microbes' genetic material).

Just a few centuries ago, the very idea that living matter, invisible to the naked eye, even existed was almost science fiction. Today, microbiology is at the forefront of human health and counter-terrorism. Forensic microbiologists study genes, pathogens and contagions in a never-ending fight to keep people safe and to track-down those who could bring harm. Forensic microbiology is the study of micro-organisms in a forensic context and can be used in order to determine the path of an outbreak, the identity of a criminal, or the origin of a particular strain of biological weapon or contagion. Forensic microbiologists also work below the visible world to find biological markers hidden in the DNA of all living matter. These markers, known as 'microsatellites', identify patterns in DNA that help in many ways, from establishing the person responsible for a sexual offence to establishing the direct link between two seemingly dissimilar outbreaks of food poisoning in different parts of the world.

Analysis, uncertainty and source

Very little scientific evidence is categorical, and only very rarely can forensic science identify evidential material with absolute certainty, or can compare and 'match' two samples to the exclusion of all other possibilities. Unless a particular object splits apart at the scene, with one half remaining behind and the other half transferred to the perpetrator, there will be uncertainty associated with any comparison and inference about the source of the item.

Whilst CSI programmes typically focus on evidence recovery at the crime scene and the subsequent analytical identification and unique 'match' to a comparison sample, in the real forensic world the evidential material is frequently minute, decomposed or damaged. All of which limit the capacity to undertake unlimited analyses, consequently the information gleaned from analysis is frequently incomplete, or the 'match' to the comparison reference sample from the suspect is limited because only a few attributes or characteristics are available for comparison. In turn, this requires a subsequent interpretation phase rarely featured in the television programmes, addressing the question 'how likely is it that I would see these characteristics if this sample was not X?', or 'how likely is it that these samples would correspond in these specific attributes by chance if the samples in fact originate from *different* source materials?'

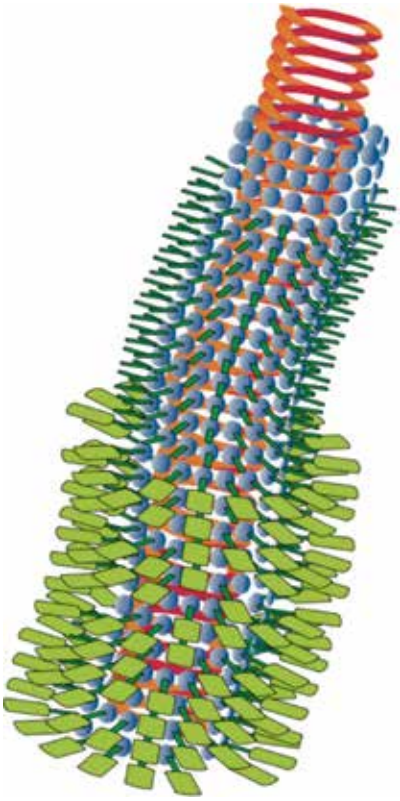


False-colour SEM image of a soil showing clays, bacteria and fungi spatially located from a soil smear.
James Hutton Institute

When trace evidence appears to have been transferred between a suspect and a victim, the forensic scientist has to consider the possibility that the trace evidence was in fact transferred *indirectly*, via an intermediary surface ('secondary transfer'), or even via multiple indirect transfers (for example, 'tertiary' transfer). This can have significant implications – for example, the presence of a suspect's DNA on the underwear of a victim of indecent assault may sound incriminating. However, a plausible explanation may be that it originated from DNA transferred legitimately when the suspect shook hands with the victim earlier in the evening at a social event. This DNA may have then been later transferred from the victim's hands to her underwear when she visited the bathroom. After trace evidence has been transferred, there is the issue of persistence. For example, it is unusual for the clothing of a suspect, or their vehicle, to be seized immediately after a crime has been committed. In that time, at least some of the fibres transferred to the suspect's clothing from the victim will have been lost during wear. The vehicle will have visited multiple places since the crime, during which some of the soil from the crime scene may have been lost from the wheel arches, for example, and additional biological debris from subsequent journeys will have been deposited on top of any remaining material of interest. Additionally, the impacts of rainfall, heat, freeze–thaw, degradation by organisms, amongst other factors, can all affect the material trace evidence that had originally come from the crime scene.

Process and structure

Not many of the CSI programmes feature court, as that is usually a long, slow process, and not generally exciting viewing for the general public. As a result, the exposure of the public to forensic science is mainly from the dramatic crime scene reconstruction, often using a TV studio's replica crime lab, where results are obtained instantly. However, in reality, all methods usually take a long time to carry out carefully according to structured protocols. Results are rarely unequivocal, and the evaluation of those findings in the context of the case circumstances is frequently open to multiple interpretations, all of which should be appropriately assessed and communicated effectively by the expert witness at court.



Computer-generated image of a virus from a berry, which could be used to infer contact with a particular plant. James Hutton Institute

In adversarial legal systems such as in the UK and US this requires the forensic scientist to present their findings, and their interpretation of those findings, to a jury of members of the public. In countries with an inquisitorial legal system, for example Germany, criminal evidence is presented to a judge or panel of judges. However, presenting scientific evidence in court to a jury of laypersons brings its own array of challenges. Take, for example, the use of microbiology in the investigation of crime. If the object of interest is far smaller than can be seen by the naked eye, it is even more difficult for the layperson to visualise than a blood spot or a mud stain. The forensic scientist must therefore first explain to a jury of diverse educational backgrounds the fundamental nature of the microscopic evidence type, at a level that the jury understands, before moving on to more abstract issues such as transfer and persistence of the particular evidence type. In explaining the significance of the forensic evidence, the forensic scientist is often required to try to convey concepts such as frequency and probability to a lay jury – perhaps no wonder the CSI programmes steer clear of the court arena!

Presentation of forensic evidence to juries in court is now frequently an exercise in expectation management; juries expect an array of forensic techniques to have been utilised in every case, regardless of cost to the public purse, and their expectations of forensic outcomes are informed (or frequently misinformed…) by CSI programmes.

The forensic scientist might explain to the jury that he/she would not have expected to find blood spatter on an offender's clothing given the alleged case circumstances, however, nowadays the manner in which that interpretation is presented has to be sufficiently persuasive to counter the jury members' pre-conceived views on what blood spatter would have been produced, influenced by what they have seen on their favourite CSI programme!

Care, caution and clarity

So, while new forensic tools are becoming progressively available, we need to exercise caution in their use and in communication of their outcomes to both the investigator in the intelligence phase of an operation and to the lawyers and juries in court. Care, caution and clarity are key rules of a forensic scientist whether at the crime scene, lab or court, while our fictional counterparts seem to take speed, style and certainty as their mantra.

If forensic scientists can work more closely with crime authors and TV production companies, providing clear plausible science, while still allowing for artistic licence, then the people who serve on juries and judges would be better placed to make the judgments required at activity level in court, thus improving the outcome of our criminal justice systems. Thankfully, responsible crime writers are already striving to make this happen.

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Killer microbes in movies

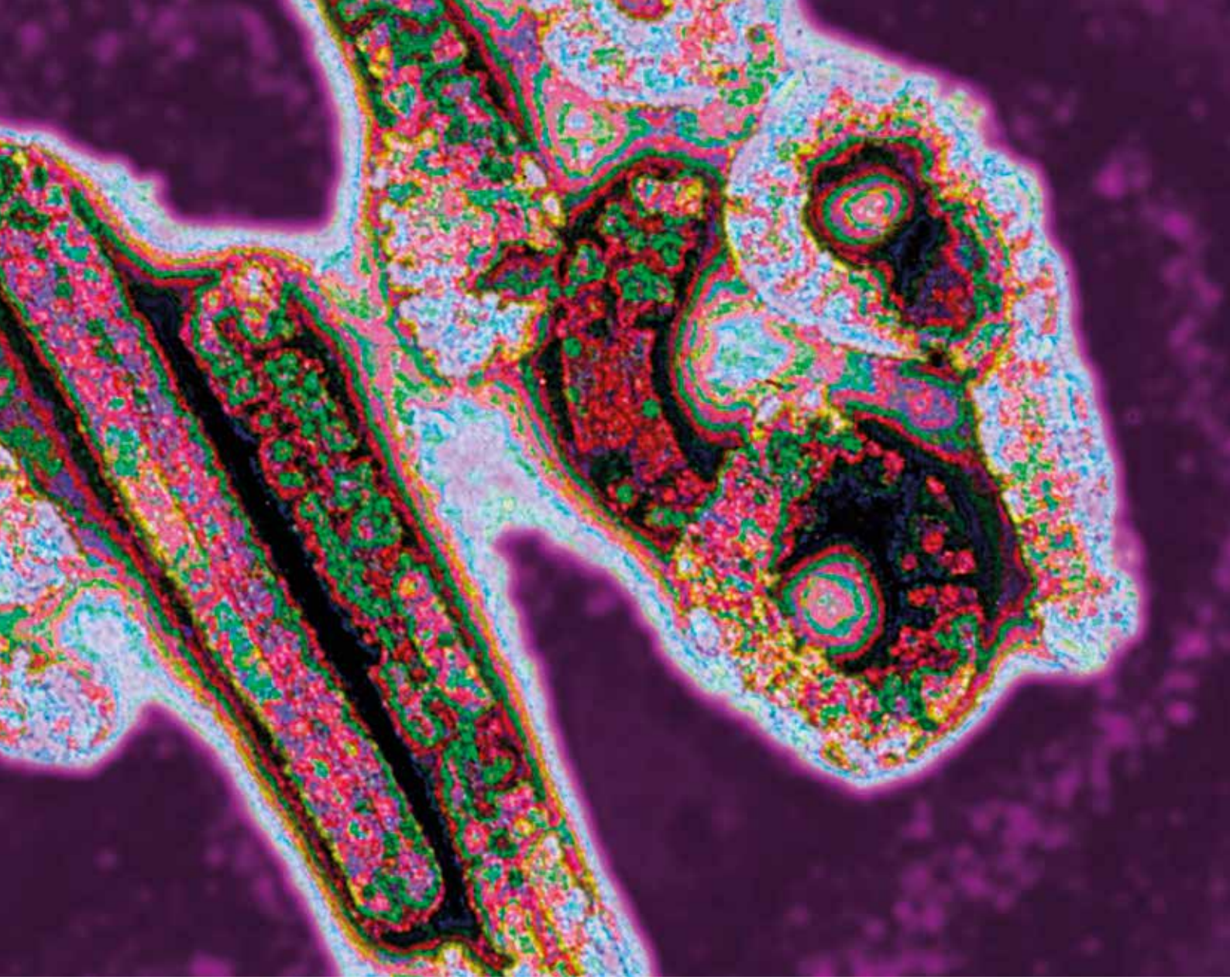
Andrew M. Burns & David Bhella

Killer microbes that cause doomsday scenarios are popular topics for film plotlines. With the public generally scared of infectious disease epidemics and the biological agents responsible for them, these films must strike a balance between delivering gripping, action-packed cinematography and accurate science to be believable and realistic.

There are a variety of infectious disease epidemics represented in film. These differ in how much science is portrayed, how accurate the science is, and which aspects of the science the director feels is important to convey to the viewer to appreciate how deadly epidemics can be caused by deadly micro-organisms.

Viruses are popular!

Viruses seem to be the most favoured infectious agent chosen for films based on mass deaths from infectious disease. This is for good reason as virus outbreaks occur often – such as the recent Ebola outbreak in West Africa,



Coloured transmission electron micrograph of a number of Ebola viruses. CDC/Science Photo Library

or the Zika virus outbreak in the Americas. Additionally, virus outbreaks are known for causing large numbers of deaths. For example, the 'Spanish Flu' outbreak of 1918 killed more people than the entirety of World War I. The AIDS crisis of the 1980s in the USA was also caused by a virus, the human immunodeficiency virus, which led to almost 1 million people being infected by 1990.

Although responsible for large outbreaks, viruses themselves are the smallest microbes known. They consist of simple genetic material (DNA or RNA) surrounded by a protective protein coat. Sometimes viruses also have a lipid bilayer on top of the protein shell, in which more viral proteins are embedded. Viruses cause disease essentially by 'hijacking' infected host cell machinery, taking over cellular processes to replicate themselves and, in doing so, cause disease and even death. We suspect their potential for huge outbreaks combined with their relative simplicity have made them popular infectious agents for film plotlines.

Outbreak and airborne transmission of viruses

The film *Outbreak* centres on the transmission of the fictional 'Motaba' virus in the fictional Cedar Creek – a small town in California, USA. Symptoms of the Motaba virus included haemorrhagic fever with organs liquefying and blood streaming from sores on the skin and the eyes, with death a few days later. Key to this story is a monkey, which was illegally smuggled into the USA from a Zaire (now Democratic Republic of the Congo) jungle without going through any quarantine or testing. The monkey was infected with a mutated strain of the Motaba virus, which changed transmission route from blood-borne to airborne compared with the original Motaba strain. This allowed for the spread of disease to humans in

Cedar Creek, which then rapidly spread throughout the town.

There are some similarities between Motaba virus and influenza viruses in that influenza viruses are airborne and have also crossed species via mutation events, but from asymptomatic aquatic birds into mammals such as humans, pigs and horses. This was seen during the recent H5N1 and H7N9 'bird flu' outbreaks. The influenza viruses can mutate further, as happened during the H1N1 'swine flu' outbreak in the 2000s, where a swine influenza virus mutated to allow transmission to humans. The mutation event that changed host susceptibility to Motaba was quite clear in *Outbreak*, even if the change in transmission route was not. The use of biosafety containment level 4 laboratories was useful to show the viewer how experiments on dangerous viruses are carried out in the laboratory with regards to the high level of protection required.

The rate at which the viral epidemic was cured, however, was flabbergasting. Within a few days of discovering the infection in Cedar Creek the virus had been imaged, with a structure similar to Ebola virus. Shortly after, an antiserum was made available to the infected individuals that was very effective. This is a very unlikely situation. The chance that the entire virus outbreak would be cured by an experimental treatment against a different viral strain is very low. This would require extensive stockpiling of experimental treatments against predicted infectious disease outbreaks, which would be very costly. Were a global outbreak such as Ebola or Marburg virus to occur, we would not find ourselves in the same 'lucky' situation that the residents of Cedar Creek were in.

Contagion and surface transmission

The fictional 'meningoencephalitis virus one (MEV-1)' virus outbreak in *Contagion* caused severe fever, leading to death a few days later. Within one month the MEV-1 virus had killed over 26 million people due to ease of spread throughout densely populated cities. The MEV-1 virus in the film was found to originate in bats. Bats are thought to be reservoirs for many viruses in the wild, including Ebola virus and Nipah virus. MEV-1 was transmitted around the world very easily from initial transfer to humans as it could be transmitted solely from contact with infected surfaces. Well-used surfaces, such as door handles, are covered in micro-organisms and so transmission rates can be high.

We found it entertaining to see the scientists in the film had solved the structure of the MEV-1 envelope protein within six days. Six days! Solving the structure of viral proteins normally takes many years, though recently the Zika virus structure was solved in a few months. The following day MEV-1 was sequenced and virus entry had been modelled. This amount of work would be more than enough to create an excellent PhD thesis. When a vaccine then became available within a month of the initial infection, and was in mass production and deployment within another few months, the believability was non-existent.

Image of a bat from a research trip to the Amazon.
Daniel Streicker (MRC-University of Glasgow Centre for Virus Research)

Microbiologist using a lightbox to count viral plaques within fixed monolayers of cells.
CDC/Science Photo Library

Although sometimes the science portrayed isn't fully realistic, it introduces enough science to the casual viewer to understand how outbreaks occur and how disease manifests after infection. As microbiologists, it is exciting to see microbiology represented in films and provide a basic introduction to microbiology to the audience during watching, even if not entirely (or at all) accurate.

28 Days Later and bodily fluid transmission

Bodily fluids have long been known to be reservoirs of viruses ready to infect a new host, such as HIV and hepatitis C. However, while HIV and hepatitis C cause chronic, long-lasting infections, the incurable 'rage'-inducing virus in *28 Days Later* is much faster acting. The virus spread rapidly as the rage-inducing virus took control of the brain, causing infected individuals to become aggressive – attacking uninfected people, infecting them by biting and body fluid contact.

There are some similarities to rabies, which also induces aggressive behaviour to enhance transmission. However, rabies is not transmitted nearly as fast, but is very deadly and contagious if one is not vaccinated. The portrayal of rapid transmission is a fear of many in the context of newly emerging viruses. This was seen in the recent Zika virus outbreak where microcephaly symptoms appeared in newborn babies in Brazil, but could not be treated and it was unclear what caused it.

Infectious disease outbreaks remain popular plotlines for films, particularly those with a worst-case, wiping-out-of-the-human-population scenario. Although sometimes the science portrayed isn't fully realistic, it introduces enough science to the casual viewer to understand how outbreaks occur and how disease manifests after infection. As microbiologists, it is exciting to see microbiology represented in films and provide a basic introduction to microbiology to the audience during watching, even if not entirely (or at all) accurate. If anything, we could hope it encourages more people to become microbiologists like us!

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Not such a fungi – fungal disease and the end of the world as we know it?

P. Lewis White

The natural world can be stranger than fiction. Scientists observe things that are astounding and amazing but also disconcerting and sometimes horrifying, and all of which can inspire and be appropriated into popular culture.

A sign of things to come?

The entomopathogenic fungus *Ophiocordyceps unilateralis* is infamous for causing lethal fungal disease (FD) in ants. The fascinating infection caused by *Ophiocordyceps* has the ability to change the behaviour of the ant, so called 'zombification'. This process forces the ant to relocate to environmental conditions that favour fungal proliferation. The ant fixes itself to the underside of a leaf using its mandibles, where it remains until death. This is followed by the production of a fruiting body that protrudes out of the ant's head and ruptures to release hundreds/thousands of spores capable of infecting other ants in the vicinity, even destroying entire colonies.

This process of infection has been exploited in the sci-fi horror genre, where cerebral infection in humans by *O. unilateralis* was the cause of the 'zombie apocalypse'. In the popular 2013 video game *The Last of Us*, and more recently the 2016 film *The Girl with all the Gifts* (based on the 2014 book of the same name), the fungus was deemed responsible for an infectious disease spread by transfer of bodily fluid or fungal exposure. Through infection of the brain, humans were transformed into cannibalistic beings that unknowingly spread the infection through primal instincts, ending society as we know it. In

both, the only hope for a cure lay with two children, who either showed immunity to infection or were born to an infected mother and bore cannibalistic traits while retaining human intellect. While it is accepted that *O. unilateralis* infection does alter behaviour in ants, it is far from making them cannibals and simply represents the fungi ensuring its further propagation. Nevertheless, it does bring FD to the fore, and for a manifestation that is often considered of low incidence or mainly superficial in presentation, this can only be a good thing.

Scratch below the surface

FD is far more than hair/nail infections (Fig. 1), ringworm or candidal thrush – medical conditions often encountered by the general public and representing a significant burden that is almost impossible to determine but often associated with social stigma. An ever-increasing population of immuno-suppressed patients (e.g. haematological malignancy, HIV infection, solid organ transplantation and genetic conditions) are surviving longer periods of severe immuno-suppression, increasing the opportunity for invasive FD, and patients with underlying respiratory conditions (e.g. cystic fibrosis or chronic obstructive pulmonary disorder) are increasingly diagnosed with allergic or chronic forms of fungal infection requiring long-term treatment. A major marker of the 1980s HIV epidemic was the increased incidence of *Pneumocystis* pneumonia and cryptococcal meningitis. Traumatic implantation of fungi have resulted in FD in soldiers post-exposure to improvised explosive devices in Afghanistan and Iraq, and in civilians engulfed by large scale natural disasters such as the 2011 EF-5 rated tornado that devastated Joplin, Missouri. In

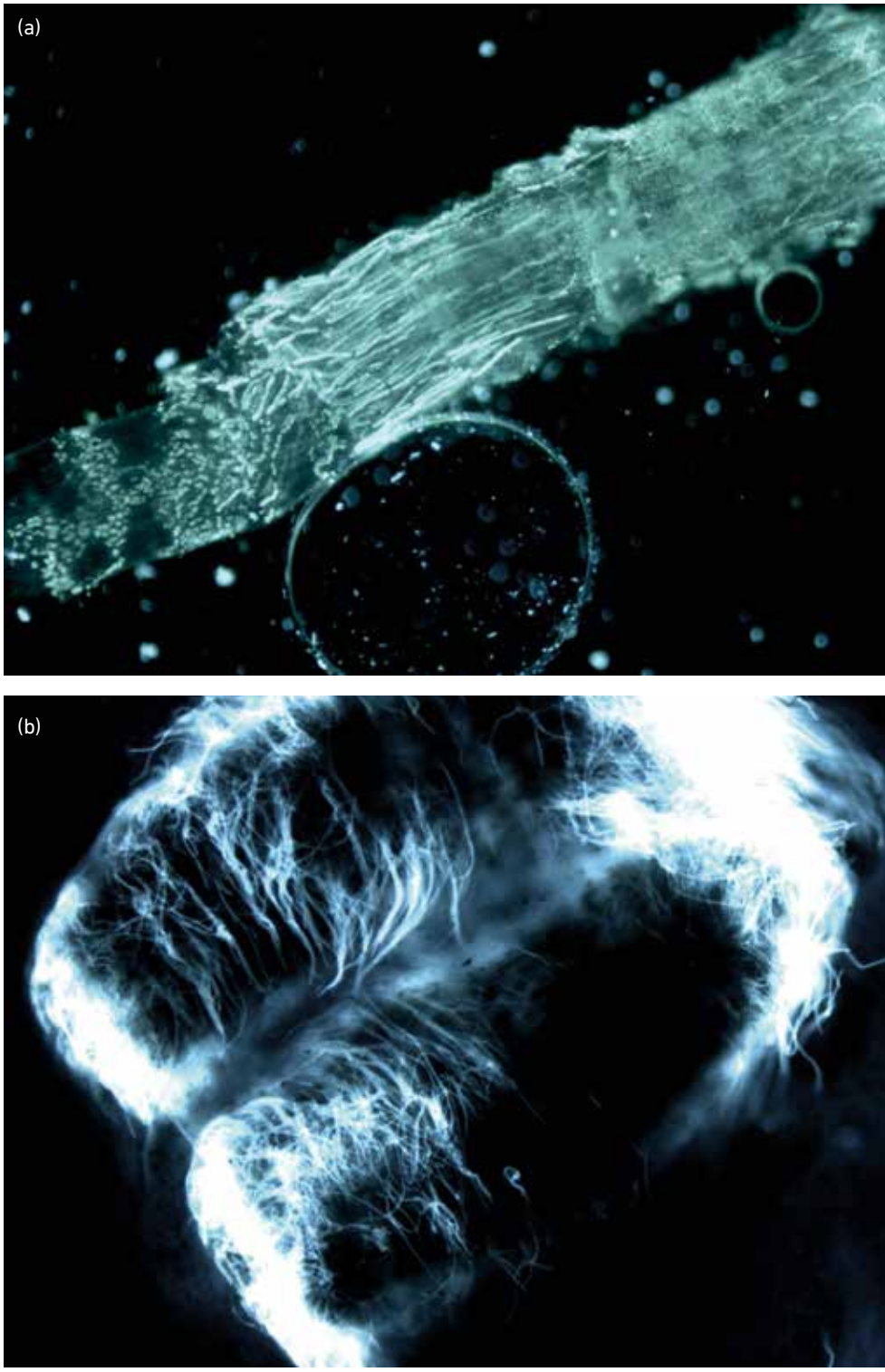

Fig. 1. **Dermatophyte infection of a hair follicle, showing (a) internal hyphae and spores (endothrix), and (b) external fungal hyphae (ectothrix).** P. Lewis White

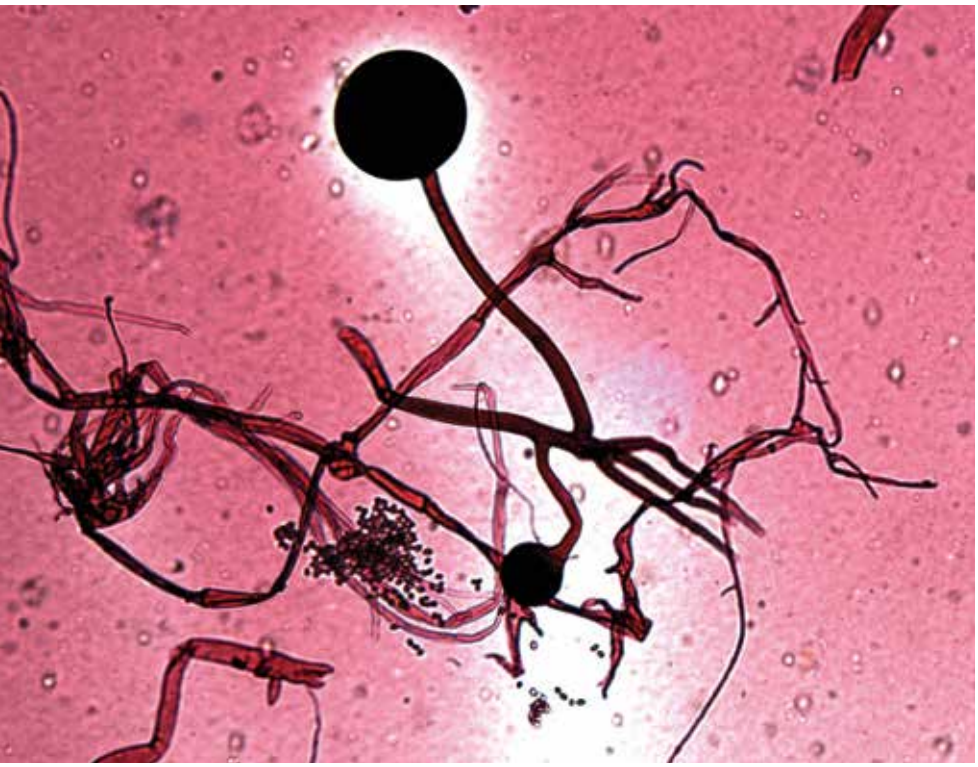

Fig. 2. **Microscopic image of a Mucorales species.** P. Lewis White

both situations tissue was penetrated with shrapnel contaminated with soil/detritus containing environmental fungi (Mucorales species, Fig. 2) that became opportunistic pathogens. Insertion into the tissue resulted in complicated FD in severely traumatised, but immuno-competent patients. Cases of FD can also occur in immuno-competent patients after a simple garden injury, such as severe prick with a thorn. If the fungus involved is broadly resistant to antifungal therapy (e.g. *Scedosporium* species, Fig. 3) then management can be dependent on extensive surgical debridement. Unfortunately, large-scale outbreaks of FD have also been associated with the healthcare setting. In 2012/13, a US multistate outbreak of fungal meningitis was caused by the use of methylprednisolone acetate drugs contaminated with fungi at a New England compounding centre. Epidural injection of this contaminated steroid resulted in 751 cases of meningitis and 64 deaths. Fungal keratitis associated with the inability of contact lens disinfectant to inactivate fungi, including resistant species such as *Fusarium*, remains a global concern.

As our ability to manage critically ill and severely immuno-compromised patients improves, the opportunity for FD increases and it is almost inevitable that the incidence will increase.

The current state of play

It is estimated that globally almost 15 million individuals will be infected with allergic, chronic or invasive FD, and of these approximately 2 million will die. More people die from FD than malaria and tuberculosis; while the latter two are accepted as global clinical concerns FD is somewhat ignored. Lack of access to state-of-the-art diagnostics and therapy hamper care in low-income countries, and it is proposed that 80% of cases could be saved if the best tests and treatment were available.

The 2016 UK Government review into antimicrobial resistance touched on antifungal resistance, describing the overuse of antifungals in agriculture.

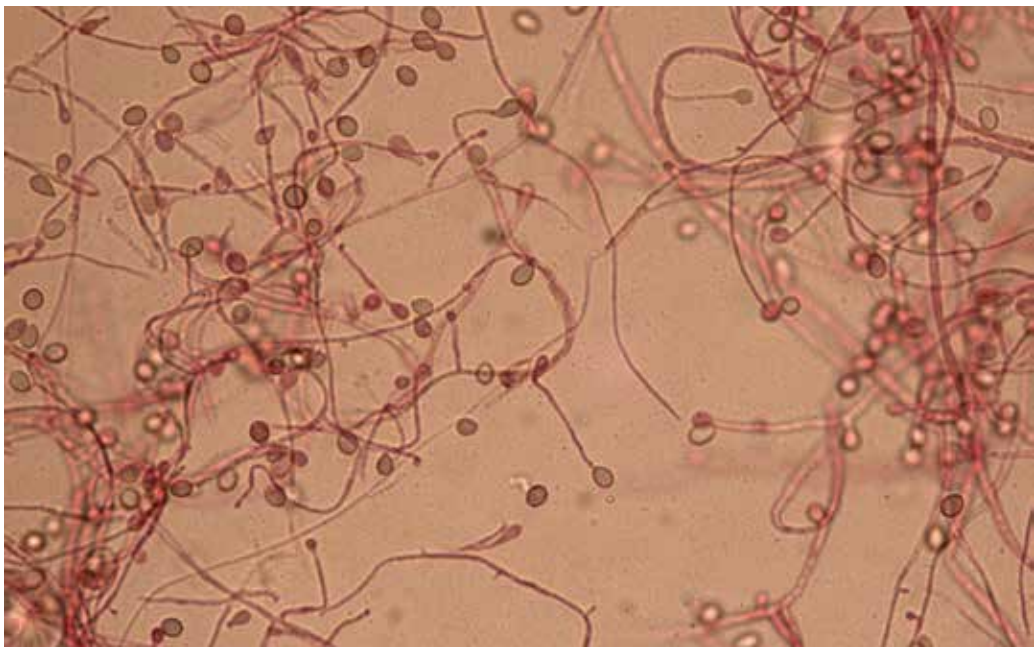

Fig. 3. **Microscopic appearance of a *Scedosporium* species.** P. Lewis White

It emphasised the need for regulation, but in agriculture this will always be countered by the need to produce food crops. It highlights the ethical dilemma of restricting antifungal use to protect the limited number of clinical antifungal drug classes currently available, against the ever-growing need to produce more and more food for the expanding population. Paradoxically, an issue which would be propagated further should more individuals be successfully treated for FD.

Ominously, fungi have the ability to reproduce asexually, whether through budding in yeasts or spore production in filamentous fungi, the offspring will be exact clones of the parent. If resistant mechanisms are apparent these will be passed on, in the case of filamentous fungi, to potentially millions of spores that can travel hundreds to thousands of miles on air currents. Being environmental organisms fungi do not require a host, and if agricultural antifungal use continues natural selection will favour resistant fungi in antifungal-treated areas. The most ubiquitous fungus with airborne spores, *Aspergillus fumigatus*, is already showing significant increases in resistance to azole therapy due to agricultural use (Fig. 4). Hundreds of spores from this organism are inhaled by humans on a daily basis, and globally over 10 million people are estimated to suffer from one form of the clinical manifestations. Mortality rates of invasive aspergillosis are already high (≥40%), but delayed appropriate therapy will increase this significantly!

Not to be outdone the yeasts are also cashing in, with the recent emergence of *Candida auris*, which is almost inherently resistant to fluconazole, and rapidly develops resistance to other classes of antifungal therapy. Amazingly, different

Fig. 4. ***Aspergillus fumigatus*** **isolate 302w1, demonstrating resistance to azole antifungal therapy: (1) itraconazole, (2) voriconazole, (3) posaconazole and (4) no antifungal control.** P. Lewis White

yet resistant, strains of this organism have emerged across the globe and it is not yet clear what activated their appearance. It has been associated with several outbreaks in healthcare settings and is readily resistant to disinfectant treatments, and colonisation of patients is difficult to eradicate, even in those successfully treated for infection.

In conclusion

It is unlikely that the sci-fi depiction of fungi in converting humans into mindless zombies will occur. It is true that FD can alter/control the behaviour of insects, but this is less concerning than the emergence of antifungal resistance in the main fungal pathogens, *Aspergillus* and *Candida*. It is well known that the only cure for zombification is to sever the central nervous system, usually by decapitation; this would not fit well in our current clinical algorithms for managing FD! However, we must avoid a situation where we are only able to offer palliative care due to the lack of therapeutic options or a delayed diagnosis of resistant FD.

An eminent mycologist has proposed that fungi played a role in the extinction of the dinosaurs, and we must prevent this happening to us. Remember, every single mushroom is edible, at least once!

P. Lewis White

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Further reading

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The *Pale Blue Dot* of our solar system taken at a distance of 4 billion miles by the Voyager I space probe. This first snapshot of our solar system conceals both our own inhabited planet and potential candidates for habitable worlds. NASA/JPL

Terra Firma II: terraforming Earth's sequel

Arwyn Edwards

As E. O. Wilson wrote, we have just "one planet, one experiment" in the form of life on Earth. Implicit in his statement hides perhaps the grandest challenge to a creatively minded biologist: To build replicate biospheres on lifeless planets, populating each with a functional ecology. Rather than merely satisfying the need for experimental reproducibility at the biosphere scale, such biospheres could serve usefully as interstellar outstations of humanity.

Such notions are certainly far-fetched, but not inconceivable. This article explores the frontiers between science fiction and fact in the habitability of planetary systems. Science fiction has long imagined engineered alien biospheres within the plots of countless films and novels, arriving at the term *terraforming* to denote the process of developing a habitable planet, with *paraterraforming* describing smaller, enclosed habitable zones. As with the mobile telephone, the tablet or organ transplants, might science fiction once again presage science fact?

Lessons from science fiction

There are arguments for terraforming. These range from the innate human tendency to explore new frontiers to the lucrative prospects of mining other planets for rare elements. Such endeavours must support human life for prolonged periods off Earth. Moreover, we are presently tied to our one planet, and should our one experiment fail, it would not auger well for the future of our species. So, with the future of humanity at stake, could a terraforming microbiologist learn from science fiction?

Most immediately we are in the era of a new, synthetic biology where microbiologists and their colleagues re-design and repurpose biological systems. While the targets of present-day endeavours are predominantly genes, genomes and cells it is likely ambitions could grow in their scale and complexity, culminating in the engineering of ecosystems, biomes and indeed even biospheres. Could a synthetic biology toolkit for colonising a planet be a realistic proposition?

Shooting for the stars

Such a kit would surely draw inspiration from *Star Trek*'s Genesis Device, a torpedo used to transform lifeless planets into habitable environments for humanoids. However, while the Genesis Device's mechanism for terraforming entailed reworking the planet from its subatomic particles, the synthetic biologist's toolkit would need to install a functional suite of biogeochemical cycles to support sustainable ecosystems.

This tall order may not be impossible. Indeed, Earth's biosphere supports complex ecosystems of extremely diverse and abundant microbes and a side-order of fauna and flora. While we currently lack a complete understanding of the intricate and intertwined nature of Earth's biogeochemical cycles, we know that these cycles are regulated by a tiny core of conserved gene families within the inestimable diversity of Earth's microbial genomes. Functional biogeochemical cycles exist in Earth's most extreme environments, and these offer a ready source of enzymes and host cells evolved to withstand extremes which might be encountered on an alien planet. From these, harnessing a tightly-packed toolkit of the genes to install carbon and nutrient cycles on a lifeless planet would be relatively straightforward. With a nod to *Star Trek*'s Prime Directive, namely not to interfere with the inner workings of another civilisation, building in genetic circuits designed to kill the toolkit could prevent "forward contamination" of other planets. The harder part of this enterprise would simply be the waiting. For example, humans have a fairly stubborn addiction to oxygen. Around 2.45 billion years ago, thanks to oxygenic photosynthesis, oxygen became abundant in Earth's atmosphere. To oxygenate Earth's atmosphere took millions of years to saturate terrestrial oxygen sinks, so installing biogeochemical cycles would take rather longer than even the most epic sci-fi film franchise.

Life on another planet

But favourable climates and geochemistry on some planets might

offer the terraforming microbiologist a head start. Life has four basic needs: liquid water, essential elements, catalytic surfaces and an energy source. Our metabolism and evolutionary history prejudices us towards certain forms of these ingredients, leading us to overlook potentially habitable planets and moons. As plant carbon fed dwellers of Earth's surface we are accustomed to the generous supply of solar radiation as a foundation for life. However, beneath our feet, lithotrophic microbes breathe elements leached from the rock to grow biomass from carbon dioxide. Similarly, we may not think of the polar regions as biodiverse or productive biomes, but microbial life actually thrives upon, within and beneath the coldest glaciers on Earth, with laboratory evidence for bacterial protein synthesis even in liquid nitrogen (–196 °C).

Here, the freedom of imagination afforded by science fiction again helps us recognise potentially habitable worlds. Consider *Star Wars'* Planet Hoth, an icy world synonymous with the hostile conditions inherent in unrelenting cold. As *The Empire Strikes Back* reveals, Hoth is home to just a few animal species in a conceptually challenging food web. Nevertheless, Planet Hoth is an excellent fictional analogue for the most likely candidates for habitable worlds elsewhere in our solar system. Six of the planets within our solar system are permanently cold, and the two best candidates for harbouring life elsewhere in our solar

Computer artwork of Mars before (left) and after (right) terraformation. Detlev van Ravenswaay/Science Photo Library

> **If our aspiring terraforming microbiologist learns anything from sci-fi it is that to terraform another planet may not be impossible, just exceedingly difficult.**

system are exceedingly Hoth-like. These are the ice-covered moons of Jupiter (Europa) and Saturn (Enceladus). Both possess temperature ranges warmer than liquid nitrogen and the elements required for organic carbon-based biochemistry. Thick ice surfaces would protect life within their briny subsurface oceans from radiation. Life within these Hoth-like icy moons could well be nourished near hydrothermal vents, with conditions akin to those which could have supported the origin of life on Earth. Moreover, we already know life survived for millions of years on Earth during the intensely Hoth-like conditions of "Snowball Earth" glaciations.

Human survival

Considering the likely motivations for terraforming, a fundamental challenge posed to the terraforming microbiologist is to sustain human life. This need not entail colonising an entire planet, and as many sci-fi disaster films reveal, when our survival is threatened, our innovative nature comes to the fore. Perhaps our terraforming microbiologist could learn something from a fellow biologist, Mars's first botanist, Dr Mark Watney. The hero of *The Martian* may have a PhD in plant biology, but it is his microbes that help save him. Trapped on Mars, Watney is forced to supplement his rations by growing potatoes within the shelter of his "Hab" station. To achieve this feat of para-terraforming requires improvisational genius, explosive rocket fuel and no small amount of duct tape. But Watney's key challenge is to provision the Martian soil with organic matter, nutrients and viable microbes to sustain his potato crop. In stark contrast to a high-tech synthetic biology Genesis Device, he can only use his own freeze-dried faeces as fertiliser, a practice which has supported agriculture for millennia in the form of nightsoil. In a sci-fi film at pains to retain credibility, Watney's struggle for survival and his emaciated condition highlight just how much of a challenge staying alive would be for just one human terraforming less than a hundred square metres of Mars.

So, if our aspiring terraforming microbiologist learns anything from sci-fi it is that to terraform another planet may not be impossible, just exceedingly difficult. Success would require life to survive challenging conditions, some very innovative thinking, and the capability to understand and sustain complex biogeochemical cycles to promote life. In other words, a shortlist of talents which coincidentally starts to resemble the essentials for making a success of our one planet, our one experiment!

Arwyn Edwards

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Further reading

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1,850
delegates and guests

31
exhibitors and sponsors

212
hosted speakers

Annual Conference **2017** – Edinburgh

The programme covered 28 topics, including flash posters, professional development sessions, and plenty of networking opportunities and social activities. Below are some comments taken from our delegate survey:

> The conference allowed me to network with a variety of scientists at different stages of their career and I learned about some innovative and exciting analytical techniques that I might be able to adapt for my research.

> Excellent networking opportunities, great speakers including a good number of offered orals. Poster sessions, especially the flash posters, were great.

> This is a very organised and considerate conference, with programmes ranging from basic microbiology to those more pro-applied disciplines, such as plant pathology, and the programmes associated with paper writing and career development, which I think suited the various needs of faculties, postdocs and students. In addition, speakers from different countries may open a window of new thinking and new approaches.

> It was my first time attending the Annual Conference. My general view about this meeting is greater than I thought before my attendance. I could really expand my scientific knowledge about cutting edge topics in my direct and indirect fields. Also, I met new colleagues who are interested in establishing new collaborations with us and develop new projects together. I am very grateful to the Microbiology Society for awarding me with a Society Conference Grant to attend this Annual Conference, making it possible for me to present my work and to improve my career.

The Society would like to thank everyone who took part in Annual Conference 2017, including all of the session organisers, sponsors, exhibitors and delegates who came and made it a great success.

Get involved and help shape future Annual Conferences

Every year our Annual Conference programme is developed and driven by the members of our Divisions who represent the three key areas of microbiology – virology, eukaryotic and prokaryotic. Each year we seek ideas from the wider membership for topics we could cover at our flagship event. If you have any ideas for a topic for Annual Conference 2019 then please let us know by completing the suggestions form online. Planning takes place in January of each year so make sure you send in your ideas by **15 December 2017** for consideration for 2019. The form and further information can be found online: **www.microbiologysociety.org/events**.


ICC Birmingham

Keep up-to-date with events, follow the Society on Twitter: **@MicrobioSoc**

Annual Conference **2018** #Microbio18

Our 2018 Annual Conference takes place between 10 and 13 April at the ICC in Birmingham. Due to venue availability we have had to move the conference to run from the Tuesday to the Friday so make sure you mark these dates correctly in your calendars!

Register

Register online today. Take advantage of the early bird rate and don't forget to secure your place at the conference before making your travel arrangements as we have a maximum capacity for each day at our Annual Conference to avoid overcrowding.

Accommodation

Secure your room through the accommodation booking service provider for the Annual Conference, Reservation Highway: **www.reservation-highway.co.uk/micro18**.

Abstract submission

You can now submit your abstract online for consideration by our session organisers. The submission deadline is: **Monday 11 December 2017**. When logging on to the abstracts system, Oxford Abstracts, you should select the most appropriate and relevant session for your research to feature.

Please identify your preference to present i.e. oral, poster or both. The session organisers have the final say about allocations and will accommodate as many offered talks as possible. We cannot guarantee that your preferred choice will be offered.

Please remember that by submitting an abstract to this conference, you are indicating to the session organisers your commitment to attend the event if selected.

Presenting your best material...

The abstract is the only information for session organisers to go on when deciding whether to accept your work for presentation as an offered oral or poster. If accepted, it will also be published in the abstract book for the conference – so think carefully about what needs to be included. Read more about how best to submit your abstract and some hints and tips on how to present your work when accepted on our website (**www.microbiologysociety.org/annualconference**).

Annual Conference Social Programme 2018

We are happy to shortly be launching our social programme for our Annual Conference 2018 too.

Places are limited and sold out quickly for our 2017 event so make sure you book your place to avoid disappointment.

Conference Networking Event

Monday 9 April 2018

18:00–20:00

Join us for this pre-conference workshop. This will be a chance to meet people, take part in interactive games and to brush up on your networking skills with senior members of the Society ahead of the main event. Ticket purchase required per person, includes dinner and refreshments.

Annual Quiz Night

Tuesday 10 April 2018

20:00–23:00

The Society Quiz returns for a second year! Get your thinking caps on and join us for an evening of fun, laughter and intrigue! Ticket purchase required per person, includes welcome drink and dinner. Cash bar on site.

End of Conference Party

Thursday 12 April 2018

20:00–00:00

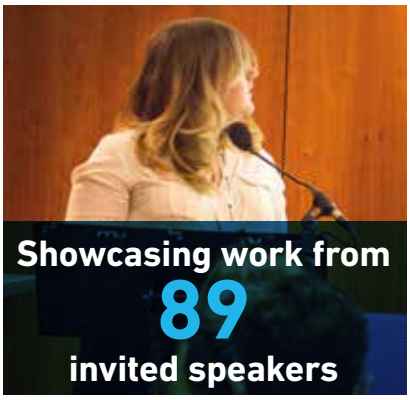
Celebrate the end of the conference in style with live entertainment and music to dance the night away. Places are limited. Ticket purchase required per person, includes welcome drink and dinner. Cash bar on site.

Visit our website for information about Annual Conference, including booking and submitting your abstract: **www.microbiologysociety.org/annualconference**.

Focused Meetings and Events update

The Microbiology Society Focused Meetings are going from strength to strength in the microbiology community, with delegates and speakers appreciating the dedicated time given to their field of research. Not only do these events ensure those attending can network with relevant contacts, they allow for closer discussion on ideas and the latest developments to enable insightful conversations while enjoying the social aspects that these events offer.

2017 Focused Meetings



Microbial Resources for Agricultural and Food Security

21–23 June 2017
Metropolitan Arts Centre, Belfast

ISSY33 – Exploring and Engineering Yeasts for Industrial Application

25–29 June 2017
University College Cork

Antimicrobial Resistance and One Health

29–30 August 2017
Maynooth University, Co. Kildare

16th International Conference on Pseudomonas

5–9 September 2017
St George's Hall, Liverpool

2nd International Meeting on Arboviruses and their Vectors (IMAV)

7–8 September 2017
University of Glasgow

British Yeast Group (BYG) – The Versatility of Yeasts

11–13 September 2017
University of Kent

The Society would like to thank all those who took part in these events during 2017, including all of the session organisers, sponsors, exhibitors and delegates who came together to make these events such enjoyable experiences.

Keep up-to-date with events, follow the Society on Twitter: **@MicrobioSoc**

2018 Focused Meetings

We are pleased to announce our programme of Focused Meetings for 2018.

#MMS18

Microbes and Mucosal Surfaces

21–22 June 2018, University College Dublin

microb.io/MMS2018

#EZAMR18

Emerging Zoonoses and AMR: A Global Threat

2 July 2018, University of Surrey

microb.io/EZAMR18

#AVIAN18

Molecular Biology and Pathogenesis of Avian Viruses

3–4 September 2018, University of Oxford

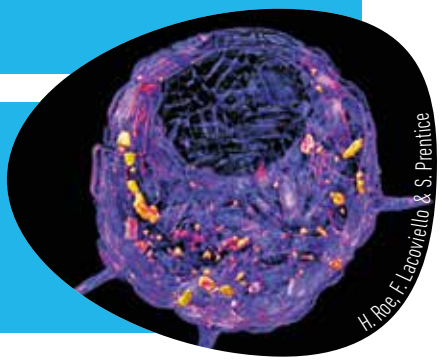
microb.io/avian18

#ISTA9

9th International Symposium on Testate Amoebae (ISTA9)

10–15 September 2018, Riddel Hall, Belfast

microb.io/ISTA2018



#MUA18

Microbiomes Underpinning Agriculture

1–2 October 2018, The Kingsley Hotel, Cork

microb.io/MUA18

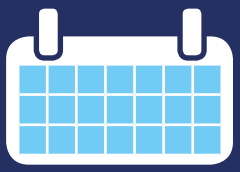
Please visit our webpages **www.microbiologysociety.org/events** for more information and follow the Microbiology Society on social media for updates.

Grants & Events

Society-Supported Conferences 2017

These events are delivered by our members within their networks and institutions, and supported via our Society-Supported Conference Grants. The sponsorship ensured the Society could share information on the variety of events taking place in the microbiology community as well as providing a presence at the event.

Sponsorship of **15** events



40 days of science

Over **1,700** attendees

Below is a summary of the successful applications we sponsored this year:

The 2nd International Symposium on Stress-Associated RNA Granules in Human Disease and Viral Infection
Young Microbiologists' Conference (YMC) 2017 Beyond Petri dishes: Capacity Building for Applied Research
24th International HIV Dynamics and Evolution Workshop
Seventh Advanced Lecture Course on Human Fungal Pathogens: Molecular Mechanisms of Host–Pathogen Interactions and Virulence
***Staphylococcus* Great Britain and Ireland 2017**
The Annual Irish Fungal Society Conference 2017
London Microbiome Meeting
15th UK Meeting on the Biology and Pathology of hepatitis C virus
EMBO Conference – Anaerobic protists: Integrating parasitology with mucosal microbiota and immunology
Exploiting Algae and marine biomass for Industrial Biotechnology and Bioenergy
The Inaugural Glasgow Microbiology Collective
The International Cancer Microbiome Consortium meeting 2017
Fungal Cell Wall 2017 Conference
6th International Conference on Cell to Cell Communication in Bacteria
Out of the Ordinary; Above Ordinary

For further information on our society supported conference grants visit our events pages on our website: **www.microbiologysociety.org/events**.

Our next Society Supported Conference Grants deadline is **15 December 2017** for consideration in January 2018.

Conference Grants

The Society offers a number of grants to support members presenting their research at our Annual Conference, Focused Meetings.

Society Conference Grants

Open to technicians, postdoctoral researchers or PhD students. This grant can also support those attending their first Society meeting, whether or not they are presenting.

Inclusion Grants

These grants support those who wish to attend any Society meeting but find that the costs of caring arrangements are getting in the way.

Travel Grants

To support eligible members to present at any Society Conference, but who are not eligible for Society Conference Grants.

For further information, including full eligibility criteria, please visit: **www.microbiologysociety.org/grants**.

Federation of Infection Societies Meeting (FIS) 2017

As a member of the Federation of Infection Societies (FIS) the Microbiology Society will be hosting a session at the event titled 'The conundrum of polymicrobial infection diagnosis: if it's on the pitch, is it interfering with play?' We will also be exhibiting during the meeting to promote the work of the Society so make sure you visit us at our stand to say hello. The meeting this year will take place at the ICC in Birmingham between the 30 November and 2 December 2017, and you can register and find out more by visiting: **http://event.federationinfectionsocieties.com**.

Membership is changing

Over the past few months we have been quietly implementing the outcomes of the recent member research project and preparing for the introduction of a new membership database. These are two very significant pieces of work for us internally and should make their impact felt across the membership, by making it easier for non-members to join and for existing members to have a more fulfilling and rewarding membership experience.

Here are some of the key changes:

- Fewer membership grades – we're reducing the number of membership grades from nine to three (Full Members, Student Members and Affiliate Members).
- These grades will be more international – all grades are now available in all countries.
- Multi-year memberships are being introduced.
- Members will be able to have more control over the communications they wish to receive from us.
- The Member Directory is coming back, enabling members to build their presence in our community.
- There will be more support for professional development and more opportunities to engage with others across the Society.

These changes have been introduced in response to member feedback and our wish to see the Society continue to thrive and grow. If you have any comments or questions relating to the changes please feel free to contact the membership team at **members@microbiologysociety.org**.

One thing you can do for us...

Most new members come into the Society on the recommendation of a colleague, tutor or friend. If you have contact with students, collaborators and others who may benefit from membership of the Society, please encourage them to join. The changes above will make being a part of our Society an even more attractive proposition.

Paul Easton
Head of Membership Services
p.easton@microbiologysociety.org

2017 Society Showcase and AGM

Each year the Society hosts a Showcase event before our Annual General Meeting for members of our Early Career Microbiologists' Forum Executive Committee, Society Champions, Young Microbiologist of the Year finalists and Annual Conference poster prize winners. The event provides an opportunity for the Society to acknowledge the excellent work of our early career members and aid their professional development.

This year the Showcase presented a speed networking session which gave our guests the opportunity to network with exceptional professionals from a wide variety of backgrounds, who started their career with an undergraduate degree in microbiology.

The opportunity to network is a key benefit of membership of the Society. The speed networking session gave our early career members the chance to delve into the career paths of other microbiologists who have gone on to work in a number of industries. These guests were: Reagan Blyth, Director of Service Modelling, Research and Innovation, Pennine Care NHS Foundation Trust; Ariel Blocker, Reader in Microbiology, University of Bristol; David Grainger, Professor at the University of Birmingham; Jo Marchant, award-winning freelance journalist; and Peter Cotgreave, Chief Executive at the Microbiology Society.

The Sir Howard Dalton Young Microbiologist of the Year Competition finalists.

Guests were then invited to view posters from the Annual Conference poster prize winners during lunch before proceeding to the Sir Howard Dalton Young Microbiologist of the Year (YMOY) Competition finals.

From over 600 abstracts at the Annual Conference alone, the finalists were narrowed down to seven outstanding early career microbiologists who presented their research to members and a judging panel made up of representatives from our four Divisions. The quality of all seven presentations was outstanding, and the winners were announced at a reception at the Royal College of General Practitioners that night. Congratulations to **Daniel Hurdiss**, from the University of Leeds, for his first prize presentation 'High-resolution cryo-EM as a tool to study virion assembly and cellular entry of BK polyomavirus, a major cause

of kidney transplant rejection', and to second and third prize winners **Andrew O'Connor**, University College Dublin, and **Rebecca Hall**, University of York.

On winning first place, Daniel said: 'I feel honoured to have been chosen as the winner of this year's YMOY competition, especially given the calibre of the other finalists. It's a nice feeling to present your work to an audience with such a broad scientific background and receive this kind of recognition in return. I'd like to thank the Microbiology Society, not only for this prestigious award but for their support to present at the Annual Conferences over the last few years. Without these opportunities, I wouldn't be the confident public speaker I am today.'

Rachel Asiedu
Professional Development Officer
r.asiedu@microbiologysociety.org

Brexit debate

Brexit is perhaps the most important political event to affect the UK science community in living memory. But while Brexit is big for science, science is only one small element of Brexit, which is set to be a massive, unwieldy and uncharted long-term process. At the AGM we included a debate on the topic to provide a forum for attendees.

What has been clear from discussions with members is that the Microbiology Society cannot just ignore Brexit. Our job is to support your careers in microbiology by connecting and empowering communities, and if this process will have an impact on your working lives, the Society must find constructive ways of helping.

So at the Annual General Meeting, Maggie Smith, the General Secretary, chaired a discussion about the process of Brexit and how it might affect the lives of microbiologists. Importantly, this does not just mean in the UK but also members in Ireland, where the Society has a strong and vibrant membership who may be affected by Brexit in different ways from their British colleagues. We were joined for the discussion by two people intimately involved in influencing how the Brexit process will affect science. Professor Graeme Reid, Chair of the Campaign for Science & Engineering, is a member of the Government's High Level Forum on Science and Brexit. Professor Nick Talbot, a mycologist from the University of Exeter, sits on the Russell Group's Europe Advisory Group, which is in direct contact with the Brexit negotiators both from the UK side and the EU side.

What emerged from the discussion is that while there is no doubt that the scientific community did not want Brexit, we have to find the most constructive ways to get the best possible outcome for UK research and development now that it is happening. And there is some hope in the fact that the UK Government has published a paper expressing a desire for "an ambitious science and innovation agreement with the EU". While the document may seem a little thin and vague to scientists used to hard evidence and detailed argument, our guests reminded us that we are not the main audience. In a wide and sometimes acrimonious political process, the mere existence of a document saying these positive words is reason to hope and to engage.

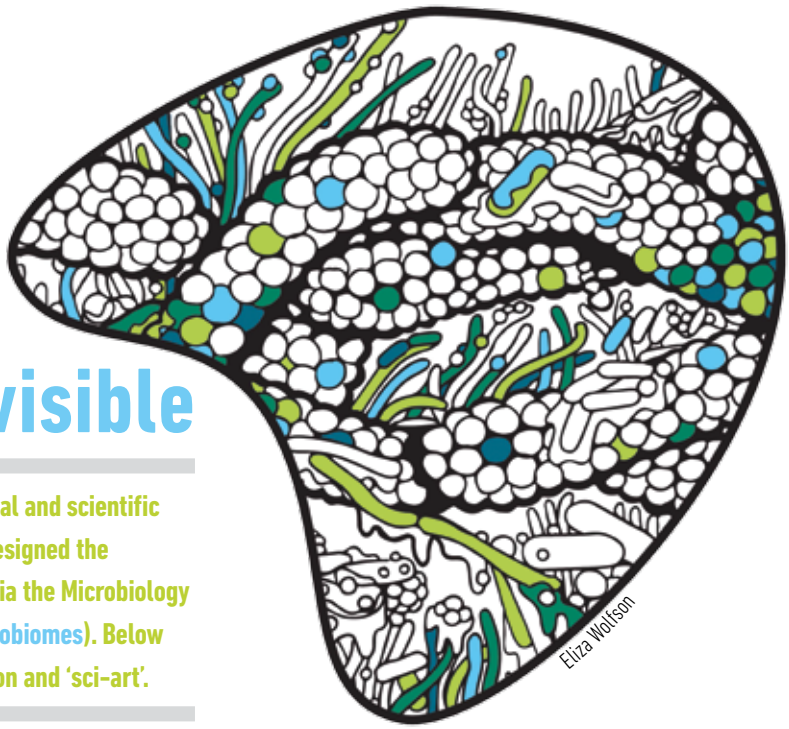
There was a strong sense from the discussion that we will have the biggest impact where we make common cause with other communities who have common interests, not just the British research community. Examples include the City of London, the veterinary community, and importantly our colleagues in other EU countries. When the House of Lords surveyed what the other 27 EU member states were saying about Brexit, only one – Ireland – said it was worried about research collaboration. But we know that our collaborators in many European countries are nervous about the impact of the UK being left out of future projects. One thing we can do is ask them to make sure their own politicians know this.

The Society's Policy Committee will now build on the discussion and work out what the Society can do in a practical way to maximise the chances of the most positive outcomes for the membership. One part of that process will be to identify those groups and communities with whom we might make common cause. It would be enormously helpful if members could let us know of areas where your work intersects with other communities who might want to join forces and work together to help get the best Brexit deal for science and for microbiology.

Policy Team
policy@microbiologysociety.org

Outreach

Making the invisible visible



Microbiology Society member Dr Eliza Wolfson illustrates biological and scientific concepts for a variety of different audiences. Eliza has recently designed the *Multicoloured Microbiomes* colouring book which is on sale now via the Microbiology Society website (www.microbiologysociety.org/MulticolouredMicrobiomes). Below are some of her experiences with the world of scientific illustration and 'sci-art'.

I've been torn between the lab bench and sketchpad for as long as I have been initiated into the dark arts of plate pouring, colony counting and polymerase chain reaction (PCR) optimisation. Between experiments and cartooning, I've always followed the Nikon Small World and Wellcome Images Awards with interest. It wasn't until I embarked upon a freelance career of scientific illustration that I realised these images and my science-inspired doodling had a name: 'Sci-art'.

Sci-art is art derived from science. It's a rather loose concept that can involve anything from art inspired by scientific observation, as with traditional anatomical drawings, to art illustrating or exploring scientific processes and ideas. It can be focused on one principle or far-reaching in scientific scope. It can be made by artists alone, in collaboration with scientists (for example, **www.ascus.org.uk**), or by scientists with an artistic bent.

The sci-art pieces themselves can be explanatory, investigatory, abstract or multi-dimensional. Sometimes they're as simple as post-processing some micrographs for artistic effect (**www.micronaut.ch**). Alternatively, they can be quite complex like Mellissa Fisher's Microbial Michael (**www.mellissafisher.com**), where entire microbial ecosystems are replicated onto complex agar shapes.

Sci-art is gaining momentum in popular culture. During a given week, #sciart gets nearly 3,000 mentions and reaches 1.3 million people on Twitter and Instagram alone. Then there are special events, like the sci-art tweetstorm last year, which involved more than 6,000 contributors and reached 13 million people in just one day. The buzzing from social media may be faintly irritating, but it's a good indication of a curious audience out there.

Lucky for us microbiologists, sci-art is so well suited to the subject. Even the media used to make it lends itself to microbiological analogies; lino printing is easily likened to bacterial clonal reproduction, right down to the small differences or mutations with each print or generation. Yet, the main reason sci-art works so well with microbiology is because very little of what we study is seen directly. Indirect measurement – some magnification here, some sample preparation there – is necessary for us to study many microbiological phenomena, which can make it difficult to talk to people about what you do. I've found that sci-art is a great way of starting that conversation. Getting people to pay attention and see what's inside your head is half the battle to any dialogue, whether these people are family, students, Joe public or a funding body. Sci-art can kickstart this process, making invisible ideas visible, allowing everyone to start on the same page.

The appeal of sci-art about microbiology doesn't stop at simply looking at it. Sci-art can be used as an engagement activity to explore and understand microbiological concepts. This is one of the reasons behind the Microbiology Society developing the *Multicoloured Microbiomes* colouring book. Creation of art from scientific ideas also feeds back into further scientific ideas. How many times have you realised how little you know about something when trying to construct a model figure for a paper? Sometimes placing your ideas into a physical space allows you to realise there are elements you hadn't even considered. So, the next time you find yourself doodling in a lab meeting, maybe ask yourself how sci-art might be able to help...

Eliza Wolfson

Eliza Wolfson is a microbiologist and scientific illustrator based in Bristol, UK. You can follow her on Twitter and Instagram as **@eliza_coli** or visit **http://lizawolfson.co.uk**.

For further information about the colouring book please contact **books@microbiologysociety.org** or see the flyer included in the print issue of the magazine.

Making the most of the Member Directory – find a mentor!

You will have noticed that the Society will soon be re-launching our Member Directory online, making it easier to find out who is in your area – both geographic and scientific.

With contact details of so many experienced fellow members of the Society, we're creating a series of resources to help you find a mentor and sustain a mentoring relationship. We know how important it is to find someone who can help steer you through some of the complex challenges you will face in your career in microbiology, so we want to help you as best we can.

The resources, produced in collaboration with the Early Career Microbiologists' Forum and the Professional Development Committee, will be available to members, and will not only help you decide how best to approach a mentor using our Directory, but will also include resources for members who are ready to help others in their careers. Mentors aren't just those at the top of their fields; we all have had valuable experiences when encountering challenges during our careers that could help others progress.

If you can share how you have progressed in your career, or even just give hints on particularly tricky techniques, other members could greatly benefit from your experience so please consider indicating your expertise in the Member Directory.

The new incarnation of the Member Directory will help members make the most of our ever-growing community, and support the evolution of our network worldwide.

Maria Fernandes
Professional Development Manager

Journals update

Microbiology Society Journals Prize Winners

This year we have seen an amazing amount of interest in journal-sponsored poster prizes. We would like to thank all of our Editors who have taken part and presented prizes. The winners received a cash award and a year's complimentary membership to the Microbiology Society. Some of our winners are listed below.

Microbiology

- **Keenan Lacey** Investigating the role of cell wall-anchored proteins in *Staphylococcus aureus* skin infection. *Dublin Academy of Pathogenomics and Infection Biology Annual Meeting*
- **Dara Niketic** Secretion-Substrate Targeting By the Flagellar Type Three Secretion System (T3S). *Bacterial Locomotion and Signal Transduction Conference*
- **Christian Schwall** Single cell sigma factor dynamics in *Bacillus subtilis*. *19th International Conference on Bacilli & Gram-Positive Bacteria*
- **Geoffrey Gourinchas** Designer Biology: From proteins and cells to scaffolds and materials. *Designer Biology Conference*
- **Fabio Amadei** The MoCo Riboswitch. *Molybdenum and Tungsten Enzymes Conference*
- **Kourtney Cousser** Bacterial secreted factors regulate mucormycete germination. *7th Advanced Lecture Course Human Fungal Pathogens: molecular mechanisms of host-pathogen interactions and virulence*

Journal of General Virology

- **Rachid Tahzima** New developments in the epidemiology of Little cherry virus 1 and its occurrence in European plum *Prunus domestica* L. in Belgium. *24th International Conference on Virus and other Graft Transmissible Diseases of Fruit Crops*
- **Ioanna Malandraki** Simultaneous detection of pome fruit-tree viruses by triplex quantitative RT-PCR. *24th International Conference on Virus and other Graft Transmissible Diseases of Fruit Crops*
- **Catherine Redmond** Characterization of HPV16 Integration Loci using Fiber-FISH. *DNA Tumour Virus 2017*

Journal of Medical Microbiology

- **Joshua Raji**, Graduate Oral Communication Prize, and **Brett Colbert**, Undergraduate Oral Communication Prize. *19th Annual Biomedical and Comparative Immunology Symposium*
- **Dearbhla Lenehan** Characterisation of *Escherichia coli* lipopolysaccharide adherence to platelet receptors. *Dublin Academy of Pathogenomics and Infection Biology Annual Meeting*

Microbial Genomics

- **Leah Roberts** Outbreak of carbapenem-resistant *Acinetobacter baumannii* (CRAB) in a Brisbane intensive care unit. *Conference on Applied Bioinformatics and Public Health Microbiology*
- **Wei Ding** panX: an interactive tool to construct and explore bacterial pan-genomes. *Conference on Applied Bioinformatics and Public Health Microbiology*
- **Nelly Sélem Mojica** CORASON: CORe analysis of syntenic orthologs to prioritize natural products biosynthetic gene clusters. *18th International Symposium on the Biology of Actinomycetes*

International Journal of Systematic and Evolutionary Microbiology

- **Yeonjung Lim** Isolation of two novel marine bacteria belonging to the 4-Org1-14 and OCS 116 clades of *Alphaproteobacteria* and their genomic characterisation. *2017 International Meeting of the Microbiology Society of Korea*

If you would like to hear more about our winners, be sure to check out our end-of-year round-up on our website: **www.microbiologyresearch.org**.

Journal of Medical Microbiology introduces new categories

Earlier this year we saw an introduction to Co-Editors-in-Chief Norman Fry, Public Health England, and Kalai Mathee, Florida International University, to the journal. With the aim of growing the journal for its readership, two new section categories have been introduced. The introduction of these categories will define the huge response in submissions within the Clinical Microbiology category.

Disease, Diagnosis and Diagnostics

Section Editor: Arunaloke Chakrabarti, Postgraduate Institute of Medical Education and Research (PGIMER), India.

Antimicrobial Resistance

Section Editor: Vincent Cattoir, University of Caen Normandy, France.

For more information on these categories as well as others please see our website: **http://jmm.microbiologyresearch.org**.

Journal links

Microbiology
http://mic.microbiologyresearch.org

Journal of General Virology
http://jgv.microbiologyresearch.org

Journal of Medical Microbiology
http://jmm.microbiologyresearch.org

Journal of Medical Microbiology Case Reports
http://jmmcr.microbiologyresearch.org

Microbial Genomics
http://mgen.microbiologyresearch.org

International Journal of Systematic and Evolutionary Microbiology
http://ijs.microbiologyresearch.org

IJSEM welcomes new Editor-in-Chief

We are delighted to announce the appointment of Associate Editor Martha Trujillo as the new Editor-in-Chief of *International Journal of Systematic and Evolutionary Microbiology* (IJSEM). An Editor for the journal since 2009, Martha has already contributed a wealth of experience and knowledge to IJSEM. President of the Bergey's International Society for Microbial Systematics and Editor for *Bergey's Manual of Archaea and Bacteria*, she is a leading expert in microbial ecology and systematics, with over 120 publications to her name.

After obtaining a PhD in Microbial Systematics from Newcastle University, Professor Trujillo completed a postdoc at Novartis International AG and then joined Instituto Biomar, S.A. as research group leader for the marine fungi screening programme laboratory, before moving to the University of Salamanca in Spain in 2002. Now Vice-Dean of the Faculty of Agriculture and Environmental Science, she leads the microbial ecology and biotechnology research group. Her main research areas are actinobacterial systematics and microbial ecology, with a special interest in plant–actinobacteria interactions, and bacterial communities that inhabit deteriorated stone monuments and arid environments.

We would also like to say a huge thank you to Aharon Oren for all his hard work and sincere dedication to the role during his tenure as Editor-in-Chief. We are immensely pleased to be retaining his experience and expertise as Nomenclature Reviewer and List Editor for the journal.

Antibiotics Unearthed: teacher experiences

Antibiotics Unearthed has been running successfully for over two years as part of an initiative to crowdsource antibiotic discovery from soil and inspire the next generation of students to consider microbiology or other STEM subjects. One part of the project that has been particularly successful is the Schools Partnership Programme. This programme has schools partner with local universities, allowing groups of students to do a real research project and inspire them to have a career in science.

School students carry out their own research experiment and are supported by the academic partner for the more complex microbiology experiments required to discover any antibiotic. The school teachers, technicians and academic partners attend summer school training in July each year to acquaint themselves with the techniques and processes used before working out the best way to implement the project with their students. The flexibility of Antibiotics Unearthed means that each partnership was slightly different from the next.

During the course of running Antibiotics Unearthed, 17 schools – from Cork to Oxford – have taken part, with many continuing to run it again each academic year. Below are two accounts from teachers who have participated in the Antibiotics Unearthed Schools Partnership.

UTC Oxfordshire – Sue Lea

UTC Oxfordshire is a new school specialising in science and engineering. The school has an extended day with built-in curriculum time for learning real world employability skills, so the Microbiology Society's Antibiotics Unearthed research programme was an ideal challenge for our sixth form biologists. Thirteen students applied to join this challenging project, a mixture of Year 12 and 13 students studying A-level Biology and the BTEC Extended Diploma in Applied Science.

Our academic partner, Dr Hee-Jeon Hong, Lecturer in Microbiology at Oxford Brookes University, and her PhD student, Sam Connelly, helped us deliver the 14-week project along with enormous support from the Microbiology Society and Oxford Brookes University. Hee-Jeon and Sam led six of our Wednesday morning sessions, when the students were off timetable for two hours each week. The initial sessions developed practical skills and allowed students to experiment with selective media, as well as learning more about the problems of antibiotic resistance. Conventional culturing methods of local soils showed that several antimicrobial producing species could be found using serial dilution. Oxford Brookes University worked with the students on more complex techniques such as bioassays, testing for antibiotic production and testing for any antibiotic resistance of purified bacteria.

After a few days the students realised that we had a huge fungal contamination problem – every plate was covered in fungi which out-competed most of the bacterial species and we think that our agar may have been contaminated in the production process.

This was somewhat frustrating but a realistic lesson in science research for the students. Interestingly, having stored these contaminated plates in the fridge for a week or so, there was evidence of additional bacterial growth but we had run out of time to investigate further. Harvey Williams, 17, summarised his experience: "Overall the microbiology project increased my knowledge of many different practical techniques and I developed many different skills that I will be able to use in the future, such as project planning, poster creation, presentation and group work. The project was a really enjoyable experience and also gave me a better understanding of antibiotic resistance and working with university staff."

The students worked in pairs or threes to create scientific posters summarising their research and presented their findings to Hee-Jeon and Sam at the end of the project. Students Rebekah Vaughan and Rui Manaia were selected to present their poster at the Microbiology Society's Annual Conference in Edinburgh. This was an incredible two days for the sixth formers – flying to a scientific conference, explaining their own research, listening to lectures, talking to researchers and getting to explore an amazing city. In July, the project finished with a celebratory lunch at Oxford Brookes University and a tour of the biosciences department with Hee-Jeon and Sam. It was a lovely surprise for the students to discover their posters on display at the university.

This experience has left a lasting legacy at UTC Oxfordshire. Not only has one student received an offer to study Microbiology at Reading University, but others are already planning ways to extend and improve their research next year. Those who took part will be mentors for our new Year 12 students. Oxford Brookes have agreed to support the school again and we are modifying our programme in light of the lessons learned. Rebekah Vaughan, 18, summarised her experience: "For me there were several major benefits of this project. Firstly it confirmed my decision to study microbiology at university and provided a topic for my extended project dissertation. Secondly the experience of working with university staff improved my practical and research skills. The creation of a scientific poster and presentation at the Microbiology Society's Annual Conference was a great learning experience."

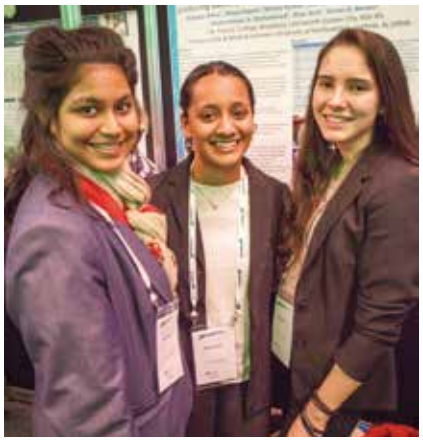
St. Francis' College – Christine Caine

During the academic year 2016–2017, St Francis' College were lucky enough to take part in the Microbiology Society's Antibiotics Unearthed project. Our college worked in collaboration with the University of Hertfordshire over a period of four months, with the aim of growing and isolating bacteria from soil samples collected from the local area and then analysing these bacteria to see if any of them produced antimicrobial substances. The aim of the project is to raise awareness of the current problem we are facing with antibiotic resistance and to see if we could maybe find the next new antibiotic!

Nine Year 12 students were involved and the project was carried out either after school or during lunchtime, with each session lasting approximately 45–60 minutes. The majority of the sessions, including serial dilutions and plating out of the dilute soil samples, took place at the college. Some of the more technical practical work, such as the DNA purification, was carried out at the university. Our students loved their day spent in the university labs, with one saying: "It was brilliant to work in a professional laboratory with all of our own sets of equipment."

This project was highly rewarding both from a teaching perspective and also for the students, giving them a unique opportunity to take part in some real, relevant science which was challenging, interesting and completely up-to-date. An additional bonus was that this particular year group will be able to include this on their personal statements for their university applications later this year.

The project culminated in a trip to the Microbiology Society's Annual Conference in Edinburgh with three of our girls presenting a poster of the work that they carried out (see picture). This was a fantastic experience with the girls having to answer some difficult questions posed by other delegates which they handled brilliantly.



Hannah Forrest
Public Engagement Officer
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Roland Remenyi

Early Career Microbiologists' Forum Update:

Insider tips on the academia career path

The ECM Forum Executive Committee are thinking a lot about careers and professional development at the moment. We are keen to use the Forum to develop skills and networks to help members as they progress through the different stages of their career.

The need for mentors and the support of people who understand what you are going through was something that came up repeatedly at the roadshows in summer. With this in mind, we have picked the brains of Dr Roland Remenyi from the University of Leeds to gain some insight in how to do just that.

Rebecca Hall: Thank you for giving a great talk at the ECM Forum Leeds Roadshow! When did you decide that you wanted to become a scientist?

Roland Remenyi: At age 17 I realised that the opportunity to make discoveries that impact human health was a powerful motivator. I was also attracted to Biology after my parents gave a copy of the Campbell Biology textbook, which, in addition to the wonderful illustrations, had short interview sections where scientists described their work.

RH: My Biology teacher told me to buy that book! There are always different opinions about whether doing a PhD or postdoc in a different country is an advantage. What challenges did you find with this?

RR: During the first year of my PhD, I lacked a support network and felt like I had to re-build my social connections from scratch. I had to be patient and realise that it takes time to establish a new circle of friends and find a community you feel comfortable in. Another challenge was not to become hung up on the things that you missed from home, like German food or drink, but instead appreciate new things you might now be able to experience.

RH: When did you decide to continue in academia and how easy was it for you to find the right position?

RR: After I had completed my PhD I dedicated my time to exploring postdoc job adverts in different sectors. I started to look fairly late, but needed that gap to re-focus and make sure I looked for the right position rather than settling. I interviewed for a few positions that didn't end up being the right fit. In a way you are interviewing the lab as well, and if it doesn't feel right then there's nothing wrong with moving on and look for the next opportunity. In the end, my fourth interview got me a position that was right for me.

RH: What do you wish you could tell your 20-year-old self?

RR: Learn to code. I feel I could save a lot of time in my research if I was able to write programs that would help me analyse data instead of having to fish for programs others have written.

RH: And finally, what is your career back-up plan?

RR: I like to think if the route towards being a professor doesn't turn out to be right for me, I will still be grateful that I had the opportunity to work in such an exciting field for as long as I have, but would have no qualms about moving forward on another parallel path.

We'd love to hear what your career back-up plan is! Chair Helen Brown quite fancies teaching crochet. Let us know: tweet using **#altcareer** and we will feature some of the best in the next edition of *Microbiology Today*.

Rebecca Hall
Communications Representative,
ECM Forum Executive Committee

Membership Q&A

This is a regular column to introduce our members. In this issue, we're pleased to introduce Mayri (Ale) Diaz De Rienzo.

M. Diaz Re Rienzo

Where are you currently based?

Liverpool John Moores University as a Lecturer in Biotechnology.

What is your area of specialism?

Applied microbiology and biotechnology. The production of biosurfactants to use as antimicrobial agents.

And more specifically?

Fermentation and downstream processing of biosurfactants, and their use in the disruption/killing of biofilms as well as planktonic cells.

Tell us about your education to date.

I obtained my BSc in Cell Biology from the Central University of Venezuela in Caracas, Venezuela. After that I worked as a researcher assistant in a fermentative process lab at the same university until March 2006, when I started my PhD (funded by FONACYT) in Cell Biology at the Central University of Venezuela. After two years there I did a placement in 2008 at the National Autonomous University of Mexico at the Biomedicas Institute, followed by a second placement at the Complutense University of Madrid (2009) in the bio-hydrometallurgy department with the aim of finishing there. By 2010 I got the degree certified by both universities: Central University of Venezuela and Complutense University of Madrid. In early 2011 I started my first postdoc position at Professor Ibrahim Banat's lab at the University of Ulster in Northern Ireland, and then, in early 2014, I moved to the University of Manchester to do my second postdoc in the lab of Dr Peter Martin until August 2017. I am now at Liverpool John Moores University.

Where did your interest in microbiology come from?

Venezuela is one of the main oil producers in the world. From when I started my degree in biology I knew I would like to work in a field where I could integrate oil production and microbiology from a bioremediation point of view. I did my final dissertation in the characterisation of metabolites that could be used in petrochemical processes, and from there I have been working with biosurfactants in a wide range of applications.

What are the professional challenges that present themselves, and how do you try to overcome them?

I'd say that the main challenge is keeping up with science, as everything changes so fast. The best ways to overcome this is establishing wide and strong collaborations where contributions can happen more quickly and effectively.

What is the best part about 'doing science'?

Going out there and talking passionately about what I do! And no less important is the networking; I have made amazing friends at each event I have attended.

Who is your role model?

I admire George O'Toole for all his contributions to the biofilm world! But there is no bigger role model than my mother.

What do you do to relax?

I'm not sure if relax is the right word, but in my spare time I go to the gym regularly, and I run, swim, and hike! In 2015, I took part in the Manchester Sport Awards and the Great Manchester Sports Awards in the Life Change Category.

What one record and luxury item would you take to a desert island?

This is a hard one! A record I think would be *Let Her Go* by Passenger, and the item would be a very thick duvet that I could use in different ways!

Tell us one thing that your work colleagues won't know about you.

In June 2013 I injured my spine and, as a result, I had two surgical operations on my back and couldn't move my legs for over six months. I went from lying down for 24 hours a day in a bed to a wheelchair, then crutches, and now I feel it is mandatory to run 10K in each new city that I visit!

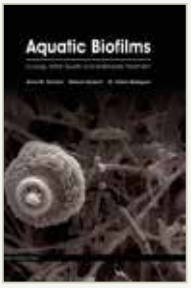
If you weren't a scientist, what would you be?

A doctor. I'd be a cardiologist.

If you would like to be featured in this section or know someone who may, contact Paul Easton, Head of Membership Services, at **p.easton@microbiologysociety.org**

Reviews

Aquatic Biofilms: Ecology, Water Quality and Wastewater Treatment



Edited by A. M. Romaní, H. Guasch & M. D. Balaguer
Caister Academic Press (2016)
£159.00 ISBN 978-1910190173

Aquatic Biofilms is an excellent reference book for students, researchers or scientists who are working or interested in the topic. Various facets of biofilms in the aquatic environment are discussed, focusing on history, definition, type, structure, diversity, mechanisms, biogeochemistry, methodology and applications.

The book has been divided into three broad sections: 'Biofilms Mode of Life', 'Biofilms and Pollution' and 'New Technologies using Biofilms'. The first section begins with what constitutes an aquatic biofilm, based on biotic and abiotic factors, followed by laser confocal microscopy techniques to study 3D architecture of biofilms. The role of cell–cell signalling – particularly quorum sensing in biofilm development and how such pathways can be used for development of novel targets – are discussed. An overview of microbial biodiversity in natural biofilms is presented next, and biogeochemical processes that occur in biofilms are explored. The second section concentrates on how biofilms can be used to monitor environmental pollution. Specifically, in what way the tolerance or sensitivity to diatoms present in biofilms is used to evaluate ecological aspects of aquatic sources is elucidated. Furthermore, the role of biofilms in detection of freshwater community ecotoxicology is also described. Reactions and physicochemical processes that occur in sewer biofilms are also covered in depth. The third and final section concludes with the newer role of biofilms in biodegradation of persistent organic pollutants and that of electroactive biofilms in removal of pollutants from water and air.

Aquatic Biofilms provides a unique perspective to biofilms in the aquatic environment with several illustrations and photographs to engage the readers. It offers a balanced view of aquatic biofilms, spanning from theory to application and from ecology to engineering, ensuring a holistic insight of environmental biofilms.

Arindam Mitra
Adamas University

For more reviews, please visit the online issue of *Microbiology Today* at **microbiologysociety.org/microbiologytoday**

Comment

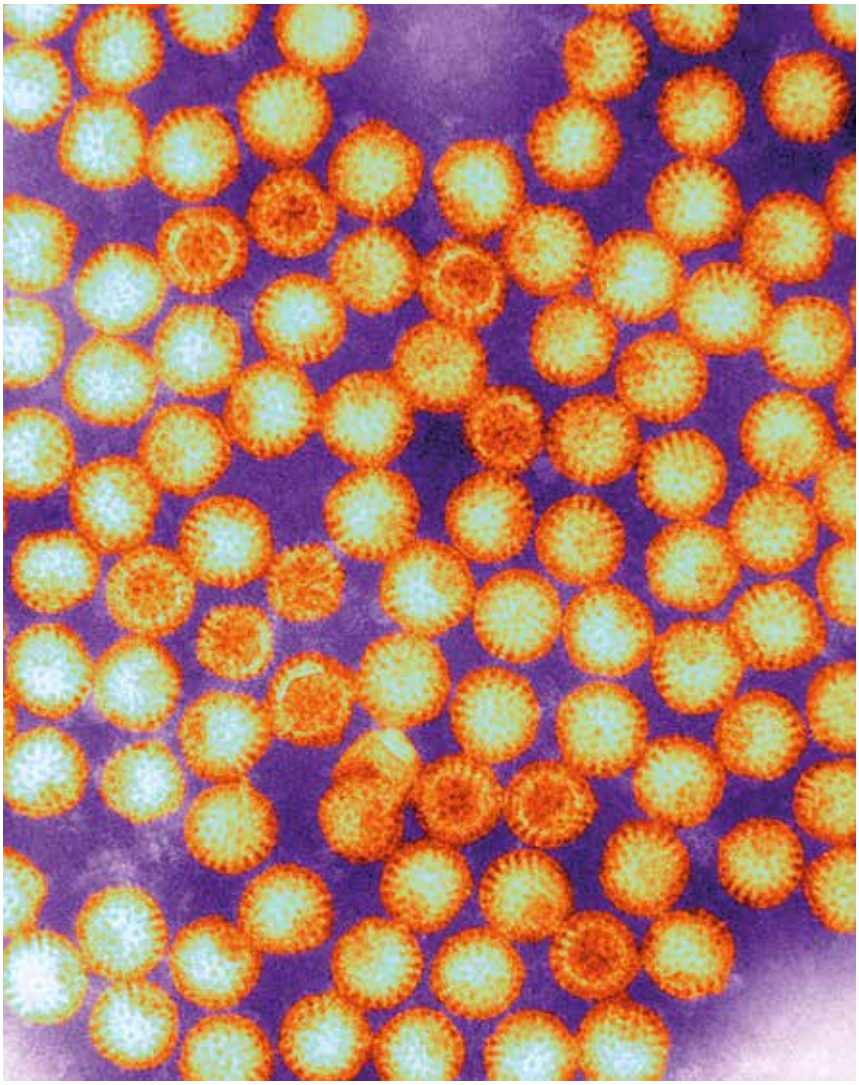
Movies and scientific accuracy

Amy C. Chambers

This is the way the world ends. Not with a bang but a virus.

In *Planet of the Apes* (1968) Charlton Heston faced a future of intelligent apes in the aftermath of a nuclear holocaust but in the 2011 re-launch of the franchise – *Rise of the Planet of the Apes* – the fall of humanity follows a global pandemic that kills 1 in 10 humans whilst heightening ape intelligence. Although *Rise of the Planet of the Apes* falters in accurately representing the processes of science it does have a striking visualisation of the spread of the 'Simian Flu' – an unintended side effect of an attempt to cure Alzheimer's disease. *Rise of the Planet of the Apes* is an example of recent film and TV that shows that lab-engineered outbreaks have replaced the nuclear holocaust on screens as the imagined and expected end of humanity. Science and scientists are central to causing and perhaps saving humanity from extinction.

Recent films like *World War Z* (2013), *28 Days Later* (2002), *Contagion* (2011), *[REC]* (2007), *I am Legend* (2007), *The Host* (2006), *Cabin Fever* (2002), *12 Monkeys* (1995), and *Outbreak* (1995) imagine the drama and consequences of a rapidly spreading contagion. Public understanding of how to deal with an outbreak might even come from movies, but they also heighten the expectation



Colour-enhanced transmission electron micrograph of simian rotavirus SA11, negatively stained with phosphotungstic acid. ASM/Science Source/Science Photo Library

that scientists will be able to produce and disseminate vaccines or cures. Science can now be found in narratives that would have previously been supernatural – vampires and zombies are creations of science not magic in shows like *iZombie* and *The Strain*, and the movies and games of the *Resident Evil* franchise. Popular culture can subtly and powerfully communicate ideas and stories about science in ways that other methods cannot. A science-based movie is more likely to inspire rather than (re)educate someone about science, and making a film that is both entertaining and accurate is a delicate balancing act!

From the implausibility of successfully locating and extracting dinosaur DNA in *Jurassic Park*, to the accelerated evolution of the mutants in *X-Men*, to Indiana Jones surviving a nuclear blast in a fridge in *Indiana Jones and the Kingdom of the Crystal Skull*, it is easy to locate and highlight the many mistakes film-makers have made in their representation of science. But, how important is scientific accuracy? Should film-makers be as obsessed with fact checking as we might want or expect them to be? What are the issues with producing a science-based creative work that also has to be entertaining and profitable?

Science in fiction will rarely be perfect, but believable if not entirely accurate science can make for a better story. Media producers want to create something that will entertain their audiences, and truly awful science not only annoys scientists but disrupts the viewing experience as audiences struggle to believe the science that creates or underpins the drama. It is in the best interests of filmmakers to collaborate with scientists during production to cut out silly errors and work through bigger scientific issues. Plausible, believable science is more achievable and perhaps important than a strict adherence to scientific fact. Film-makers have to negotiate scientific accuracy as they work within the limitations of the industry in terms of technology, cost, and audience and studio expectations and desires.

The reality of science is often more complicated and exciting than anything that can be made up. There is a changing culture of how science is viewed in fictional film and TV and how it can be seen to genuinely enhance a story and make it more entertaining.

Science advisors are now a common feature of the film industry and the majority of science-based films produced in Hollywood will have included consultation with a specialist. The Science & Entertainment Exchange, which is a programme of the US National Academy of Sciences, facilitates connection between filmmakers and research scientists across the STEMM subjects. The Exchange recognises the importance of finding a meeting point between scientific accuracy and entertaining and engaging movies. Film-makers can contact The Exchange to access experts for fact checking but also for consultations on creatively imagining plausible alternative, and even future, science. Films including *Contagion* and *Prometheus* (2012), and even superhero movies like *Ant-Man* (2015) and *Doctor Strange* (2016), have been supported by The Exchange and the opportunity it offers to film-makers who are pursuing feasible onscreen science!

Scientists have expertise in their field of research, and film-makers have expertise in creating entertainment media with all of its technological and artistic complexities. By working with scientists, film-makers can produce movies that are entertaining *because* they include science. The reality of science is often more complicated and exciting than anything that can be made up. There is a changing culture of how science is viewed in fictional film and TV and how it can be seen to genuinely enhance a story and make it more entertaining. Accurate science can create restrictions, but the process of working around and creatively through these problems can potentially lead to new and exciting stories and act as inspiration for new science too!

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