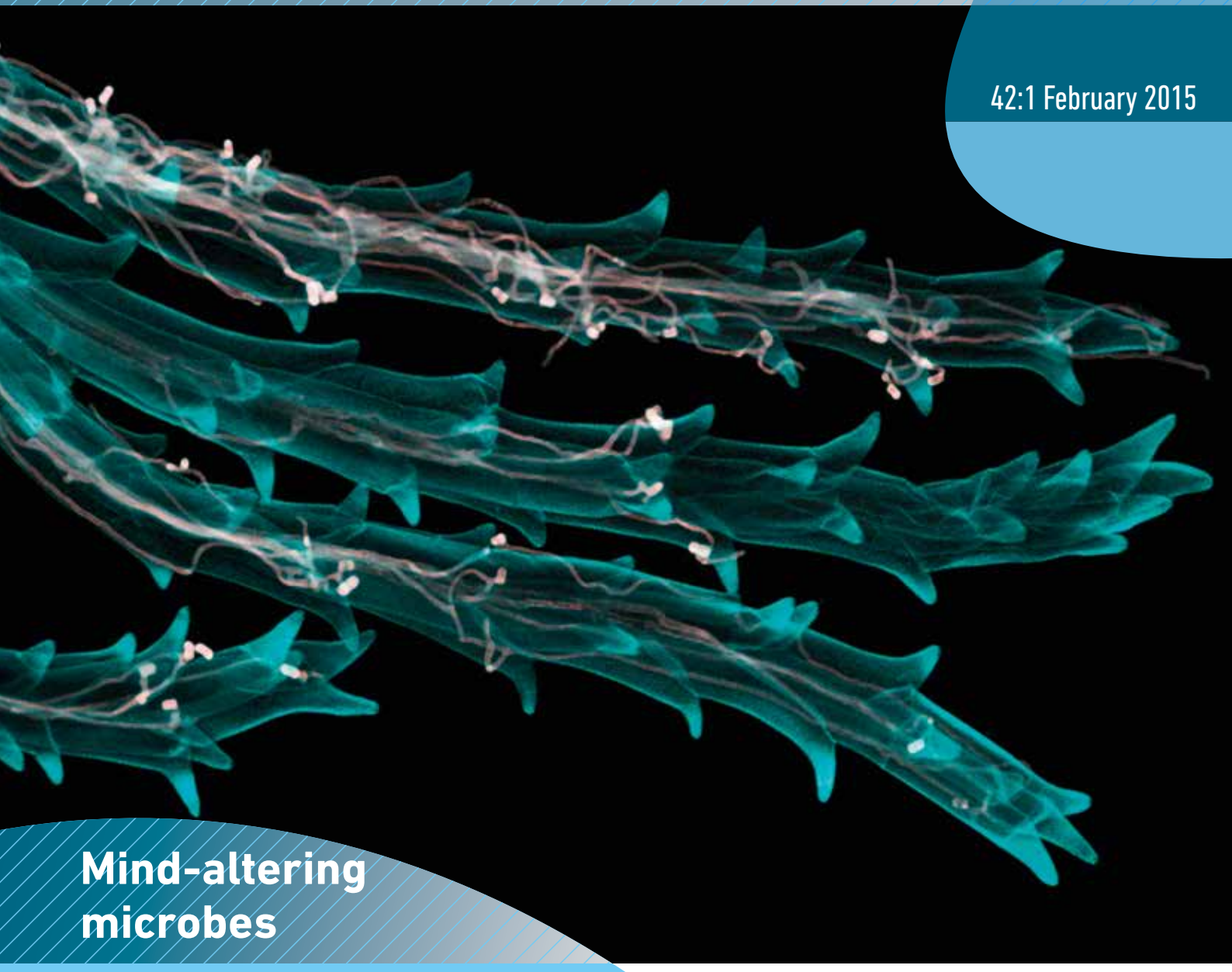
Microbiology TODAY

42:1 February 2015



Mind-altering microbes

Toxoplasma mind control
The highs and lows of ergot
Ant brains manipulated by a fungus
Viruses and eukaryote evolution
The impact of microbes on brain and behaviour

SOCIETY FOR GENERAL MICROBIOLOGY

CHLORAMPHENICOL

Widely distributed throughout the body, including CSF[1]

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

Rarely implicated with *C.difficile*[3]

Effective against serious infections including:

- *H. influenzae*[1,2]
- Typhoid[1,2]
- MRSA[4]
- VRSA[5]
- Neisseria[1,2]
- Legionella[1,2]
- Rickettsia[1,2]
- *C.difficile*[6-9]
- *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. 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: October 2014.
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 [Accessed 18th August 2014]. **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.** Weigel LM *et al.* High-level vancomycin-resistant Staphylococcus aureus (VRSA) associated with a polymicrobial biofilm. Antimicrobial Agents and Chemotherapy. Published online ahead of print on 30th October 2006. http://aac.asm.org/cgi/reprint/AAC.00576-06v1.pdf. (Accessed on 22nd August 2011). **4.** Kelly, C., LaMont, T. Patient information: Antibiotic-associated diarrhea (Clostridium difficile). www.uptodate.com. 2011. **5.** Feder. H, Chloramphenicol: What we have learned in the last decade. Southern Medical Journal. 1986; (79)9: 1129-34. **6.** 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. **7.** 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. **8.** 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. **9.** 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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CAPSULES

PIP: 106-5796
AAH: CHL600B
ALLIANCE: 065995
MOVIANTO: CHL25060

ESSENTIAL GENERICS

For further information, please contact: Essential Generics, 7 Egham Business Village, Crabtree Road, Egham, Surrey TW20 8RB, UK

Editorial

Mind-altering microbes as a concept has provided a wealth of dystopian imagery that has often been explored in science fiction. Richard Matheson's novel *I Am Legend* (1954) describes an epidemic of human vampires that emerge as a result of a mind-altering viral infection. The idea of mind-altering fictional microbes that can change human behaviour (often with negative consequences!) was often exploited in the network TV show *The X-Files* (1993–2002) and on the big screen in Danny Boyle's film *28 Days Later* (2002). As is often the case with science fiction, it offers us new and engaging perspectives on scientific facts.

This edition of *Microbiology Today* provides a fascinating overview of some of the factual microbes that demonstrate mind-altering properties. These microbes have not confined themselves to "altering" human minds but have demonstrated their prowess throughout the animal kingdom.

Dietmar Steverding and Kevin Tyler describe how the common protozoan parasite *Toxoplasma gondii*, which can infect any warm-blooded animal, resides silently in the brains of billions of humans worldwide. For a long time, *T. gondii* was considered to be harmless but recent evidence suggests that it modulates neurotransmitter levels, changing personality and behaviour to increase its opportunity for onward transmission.

Paul Nicholson describes how a small fungus, *Claviceps purpurea*, infects a large number of plant species, including many cereals. This fungus produces a wide range of chemical poisons called alkaloids to keep it safe during the winter period and it is the ingestion of this fungus and the chemical poisons that cause a disease called ergot in humans. This disease was a scourge throughout the centuries and is associated with migraines, manic dancing and convulsions, as well as massive loss of life.

The antics of "zombie ants" and their parasitic masters the *Cordyceps* fungi have also been the inspiration for Hollywood movies and video games, not only because of the bizarre actions the carpenter ants are made to perform, but due to the grotesque structures that grow out of them. These ants are also the inspiration for Hilary Hurd's article that outlines this parasitic relationship. Ants are not the only host for behaviour-changing parasites, tiny hymenoptera parasitic wasps are parasitoids that use viral particles to manipulate the behaviour of other species. Julien Varaldi details how these parasitoids inject their eggs into caterpillar hosts along with tiny circular viral particles. These viral particles are then actively transcribed and translated by the caterpillar cell machinery. The consequence of this phenomenon is that the parasitoid's eggs circumvent the caterpillar's immune system and the "viral" genes manipulate the caterpillar to create the newly hatched parasitic wasp.

Finally, we have an article written by Roman Stilling, Timothy Dinan and John Cryan who explore the recent advances in studying the effect of microbial colonisation on host physiology, metabolism and even host behaviour: are we as hosts not only dependent but also manipulated by our age-old microbial companions?

Richard Preston's 1994 non-fiction book *The Hot Zone*, escalated public fears of bizarre, highly contagious viruses such as Ebola. These fears were stocked by a further flurry of non-fiction books that detail the tragic outcomes of microbial infections. The film *Outbreak* (Wolfgang Petersen, 1995) also graphically illustrated human bodies bleeding out from a highly infectious Ebola-like virus. Without doubt, these vivid, frightening illustrations of viral infections have been in the background of public consciousness as the most recent Ebola outbreak has been reported in the media. Veena Rodrigues and Anne Swift have provided the Comment for this edition. It provides a factual account of the recent outbreak and its impact on the countries most affected by this deadly infection.

Let's hope that by the time this edition arrives and spring is round the corner the news from western Africa is more positive. We are exquisitely aware that this deadly virus has engendered a concerted, worldwide, humanitarian effort and an intense scientific will to focus research activity on beating this disease: Ebola, an example of a mind-altering microbe indeed!

Laura Bowater
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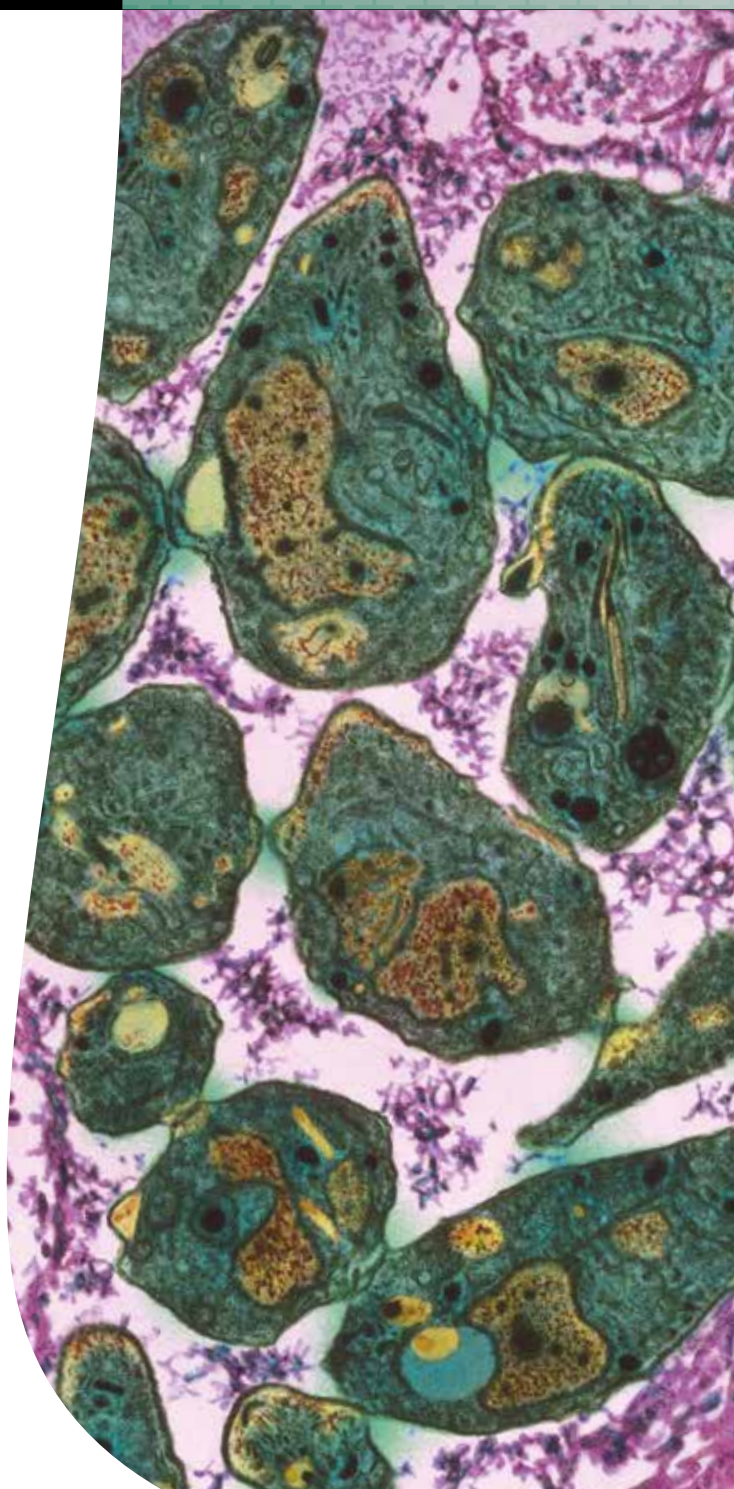
TODAY

Articles



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Features

Regulars

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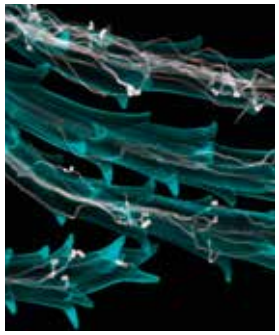

FSC Logo

Ergot fungus infection in wheat. Anna Gordon, Fernan Federici and Jim Haseloff, Wellcome Images

SOCIETY FOR GENERAL MICROBIOLOGY

Council 2015

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From the President

This year the Society for General Microbiology is 70 years old. We have reached the Psalmist's "three score years and ten", but we are still a vibrant and active organisation. The Society was founded as an offshoot of the Society of Agricultural Bacteriologists on 16 February 1945 to broaden the interests beyond agriculture and to embrace the different microbiological kingdoms. In those days the word "General" indicated the breadth of interest; sadly, it is now more likely to be interpreted to mean unfocused. However, as members know, we are focused on some of the major microbiological issues of today.

Photo Ian Atherton

Nevertheless, I sometimes facetiously describe us as the Society for Academic Cellular and Molecular Microbiologists, as this describes the roles and interests of the vast majority of our members. If we are truly to represent the aims and ambitions of our founders, we need to increase our membership among industrial, environmental, and clinical microbiologists, for example, by providing meetings and resources of greater interest to them.

Happily, the Annual Meeting in Birmingham next month should provide presentations and posters of interest to a wide variety of microbiologists. The programme is available on our website. As a former Birmingham resident, I can vouch for the excellence of the venue and the availability of a large number of local restaurants and pubs for those important scientific discussions. I look forward to seeing many of you at the Conference. I particularly encourage early-career members to engage with the more long-standing microbiologists there. You might be surprised by how interested they are in your research and what helpful advice they can offer.

As well as "talking to ourselves", as conferences are sometimes described, we are increasingly bringing microbiology to the attention of the wider public. Our Small World Initiative was launched on 18 November 2014 (European Antibiotic Awareness Day). This initiative engages schools and members of the public to help in the search for new antimicrobials. This citizen science activity is in collaboration with scientists in the USA. The Society and many others have brought to public attention the significant problems of antimicrobial resistance (AMR). At the Prime Minister's initiative the O'Neill Commission was formed in 2014 and published its first report in December. This indicated the potential cost in lives and losses to the economy if AMR is not brought under control, and was headline news on the day the report was launched. Over the next 18 months, or so, the Commission will seek information and advice from a wide range of interested parties. I am sure that the Society and its members will participate in this.

In 2014, the Society has been actively engaged with other learned societies in policy work. For example, we have held joint policy workshops with the Society for Applied Microbiology (SfAM – which also originated with the Society of Agricultural Bacteriologists!), and the results of these meetings will feed into the policy developments of both societies. The Learned Societies' Partnership on Antimicrobial Resistance (LeSPAR), of which the Society is a key member, has been working to bring together the range of disciplinary expertise to address AMR. We also interact with the AMR Funders' Forum, which seeks to finance research relevant to addressing the problem. In part, these interactions have been made easier by our move to London in early 2014. During 2015 we will continue to take forward our 2012–2017 Strategy and to develop this in light of the contributions made by members.

Although it is obvious that micro-organisms can affect the behaviour of societies – one has only to think of the recent over-reaction to Ebola in the US media – it is not immediately apparent that they can affect the behaviour of individuals. Other than the fact that micro-organisms can cause a person to become ill, and the more recent attention the beneficial effects of the gut microbiome on individual health has received, the effects on micro-organisms on individual behaviour have not been acknowledged. In this issue of *Microbiology Today* we explore the fascinating effects that micro-organisms and their products have on the behaviours of insects and people. Enjoy the articles!

Nigel Brown
President
president@sgm.ac.uk

From the Chief Executive

Microbes might be tiny, but they have a huge impact. One of the reasons for this is the sheer variety of different ways they affect our daily lives. Their direct medical impacts are starkly apparent to anyone who has been following the fight against the Ebola virus. Less well-known influences, such as the mind-altering properties of various viruses, bacteria and eukaryotes described in this issue of *Microbiology Today*, can be just as striking.

One of the core benefits of the Society for General Microbiology is that it allows specialised researchers easy access to a wide network of scientists and opportunities to understand their diverse interests.

I try hard to find time to learn more about this fascinating diversity; just by reading the short descriptions of the science done by this year's Prize Lecturers, I was struck by the serendipitous links that have fuelled some major advances. Both David Baulcombe and George Lomonossoff started out studying plants but their work now has an impact in human medicine. Robin Weiss is famous as a major figure in understanding HIV and his studies now relate to a completely different disease – cancer. Mike Brockhurst is an evolutionary biologist and yet his work is directly applicable to cystic fibrosis. And if any further proof were needed of the unfathomable variety of microbial patterns and processes, Simon Park is studying the microbiology of an antique copy of Ovid's epic poem, *Metamorphoses*.

It is important for the Society to reflect this range in its activities and that is one reason why we have an open call for your ideas on the subjects for Focused Meetings. The Focused Meeting last November, on using model systems to study microbial diseases, was a showcase for the diversity of microbes, models and maladies that members of the Society are working on. The participants are studying protozoa, fungi, bacteria and viruses using mice, insects, fish and little cubes of pig lung as their model systems, and all of them are revealing new and absorbing insights not just in their specialist interests but across a massive range of microbial impacts.

This almost overwhelming variety is one of the things that makes the Society's Annual Conference such a positive experience. You can guarantee that as well as exciting developments in your own field, there will be sessions on a wide assortment of captivating microbiological impacts you had not previously thought about. There will be talks on biofilm production, sensory perception in microbes, the microbiome in health and disease, the building blocks of microbial evolution, virus ecology, and antimicrobial resistance. The speakers will range from distinguished professors to early-career students, and they will come from all over the world. They study every kind of microbe you can think of, using laboratory experiments, field trials and mathematical modelling. There really will be something for everyone.

So I look forward to seeing you in Birmingham next month. It will be my first Annual Conference as Chief Executive of the Society and it will be a wonderful opportunity to meet members face-to-face and to find out directly what you think we are doing well and what you want the Society to do in the future. The Society exists to serve the needs of the microbiology community and it is important to my colleagues and me that we understand how we can best do that. So at the Annual Conference, come and find me at the Society's stand, collar me in one of the workshops or stop me while I'm reading the posters. I want to hear your views about the Society for General Microbiology and the scientific landscape in which you work. Equally importantly, I also want to know about the part you are playing in the scientific endeavour to understand the microbial world and its astonishing variety of influences on our lives.

Peter Cotgreave
Chief Executive
p.cotgreave@sgm.ac.uk

News

Small World Initiative – Call for universities and schools to get involved

The Society has launched the Small World Initiative in the UK and Ireland. It will give the general public, students and educators the opportunity to work with scientists as part of a global initiative to discover new antibiotics. We are currently looking for 10 universities and five school and university partnerships to take part in the Initiative. If you would like to apply please visit: **www.sgm.ac.uk/smallworld**

New Council Members

The following Council members took up office on **1 January 2015**:

Mike Skinner	Elected Member
David Whitworth	Chair of Professional Development
Charles Dorman	Chair of Publishing

Demitting Members of Council

The Society would like to say a special thank you to the following Council members, whose terms of office were completed at the end of 2014. They have contributed significantly to the work of the Society.

John Sinclair	Elected Member
Sara Burton	Chair of Professional Development
Colin Harwood	Chair of Publishing

Nominations to Council, Committees and Divisions

Nominations for elections to Council, Committees and Divisions will open in **March 2015**.

Participation offers an exceptional opportunity to develop personal leadership skills and gain experience not found through other means. Further information and nomination forms will be available on the Society's website shortly.

Upcoming grant deadlines

Date	Grant	Notes
1 March 2015	Travel Grants	For conferences and courses from **1 April** onwards
15 March 2015	Microbiology in Schools Fund	For activities from **1 May** onwards
1 April 2015	Research Visit Grants	For visits from **1 June** onwards
1 April 2015	International Development Fund	For visits from **1 June** onwards
1 April 2015	Education and Outreach Grants	For visits from **1 June** onwards

Rolling application

Local Microbiology Event Sponsorship

All members can apply for funds to support microbiology-related events, e.g. sponsored talks.

Leading journals in the fields of microbiology and virology from the Society for General Microbiology

Microbiology

Journal of General Virology

Journal of Medical Microbiology

International Journal of Systematic and Evolutionary Microbiology

JMM Case Reports

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SOCIETY FOR GENERAL MICROBIOLOGY

Prize Lectures call for nominations

Nominations for the 2016 Prize Lectures and the 2017 Prize Medal are now open. Full details on the criteria, process and the nomination form can be found on the website: **www.sgm.ac.uk/prizelectures**.

Please submit all nominations to **appointments@sgm.ac.uk** by **3 August 2015**.

Prize recipients are regarded as role models and leaders, so it is important that the nomination and award selection process is both inclusive and representative of our diverse membership and also reflects the wider microbiological community.

The Society encourages proposers to consider the widest talent pool available in submitting their nominations.

All winners will give a lecture on their work at our Annual Conference.

News of members

It is with great sadness that we report the death of the following members:

Professor G. E. (Ted) Mathison died on 26 October 2014 in Barbados, where for 20 years he was Head of Biology in the Cave Hill Campus of The University of the West Indies. Ted was in the first wave of graduates who left UK universities in the 1950s with BSc degrees in non-medical microbiology (only about four universities offered such degrees at that time). He graduated from Bristol and subsequently held lectureships in microbiology in the Universities of Nottingham and London (Queen Elizabeth College) before moving to Barbados. Members of the Society, particularly the older ones, will remember Ted with great affection.

Dr Sidney Donnelly Neill who recently passed away and had been a member since 1975.

Professor Dr Axel Rethwilm passed away on 29 July 2014 and had been a member since 1994.

Annual Conference Prize Lectures 2015

Congratulations go to the following microbiologists who have been awarded Society for General Microbiology Prizes. Their lectures will be given at the Society's Annual Conference 30 March–2 April, ICC, Birmingham.

Sir David Baulcombe.
Sir David Baulcombe

Sir David Baulcombe, Royal Society Research Professor and Regius Professor of Botany at the University of Cambridge has been awarded the 2015 Prize Medal.

Robin Weiss, Emeritus Professor of Viral Oncology at University College London has been awarded the 2015 Marjory Stephenson Prize Lecture.

Professor Mike Brockhurst, Professor of Evolutionary Biology at the University of York has been awarded the 2015 Fleming Prize Lecture.

Professor George Lomonossoff, from the John Innes Centre, Norwich, has been awarded the 2015 Colworth Prize.

Dr Simon Park from the University of Surrey has been awarded the 2015 Peter Wildy Prize.

Further information on our 2015 Prize Lecture Winners can be found on p. 30 or visit the Society's website: **http://microb.io/1yV0cio**

New Years Honours list

Congratulations to Society member **Professor Venugopal Nair** from the Pirbright Institute who was awarded an OBE for service to Science.

The Society celebrates its 70th Anniversary

The Society for General Microbiology was formally inaugurated on 16 February 1945 at a meeting at the London School of Hygiene and Tropical Medicine. At this meeting the Society's governing body was elected with Alexander Fleming becoming the first President. In July of the same year the first scientific meeting of the Society took place at Cambridge.

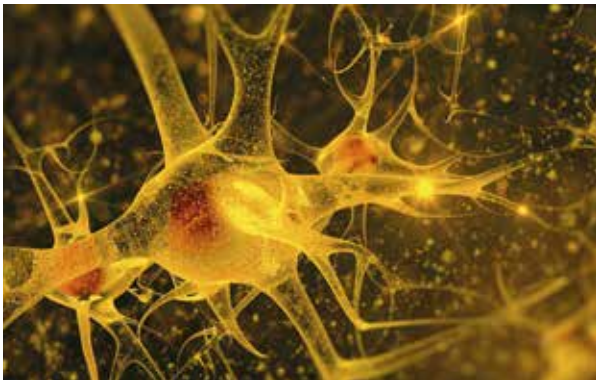
Over the last 70 years both the discipline of microbiology and the Society have gone from strength to strength, and it continues to be an exciting time to be working in the field of microbiology and also to be a member of the Society. To mark this auspicious occasion a series of initiatives will take place throughout the year. Details will be posted on the Society's website and in the newsletter.

A fuller account of our history is given in the book, *Society for General Microbiology - Fifty Years On* written by John Postgate (**http://microb.io/17KCFdP**). The book marked the Society's golden jubilee in 1995.

Contributions and feedback

The Society welcomes contributions and feedback from members. Please contact **mtoday@sgm.ac.uk** with ideas.

Dariel Burdass
Deputy Chief Executive and
Director of Strategy and Communications
d.burdass@sgm.ac.uk

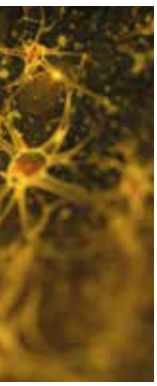


Nerve cells. Svisio / iStock / Thinkstock

Dietmar Steverding & Kevin M. Tyler

Of mice and men: are billions victim to *Toxoplasma* mind control?

Toxoplasma gondii **resides silently in the brains of billions of us worldwide. For a long time, infection with *T. gondii* was considered harmless but recent evidence suggests that it modulates neurotransmitter levels, changing personality and behaviour to increase its opportunity for onward transmission.**



Life cycle of *Toxoplasma gondii*

T. gondii is a protozoan parasite that can infect any warm-blooded animal, including humans. It is a very common parasite throughout the world and about one-third of the world's seven billion population is believed to be infected with this single-celled organism. The parasite lives and replicates intracellularly, and is capable of infecting any nucleated mammalian or bird cell. Cats are the only known definitive host, the host where the parasite reproduces sexually. All other mammals and birds are intermediate hosts where the organism replicates asexually. The natural life cycle of *T. gondii* is between cats and rodents. Infected cats shed oocysts with their faeces. Between one and five days in the environment, the oocysts sporulate forming two sporocysts each carrying four sporozoites.

Rodents become infected upon ingesting sporulated infectious oocysts. Sporozoites are released from the oocyst in the gut and infect intestinal epithelium cells. The sporozoites transform into tachyzoites, which then multiply inside specialised vacuoles within the epithelium cells. Eventually, the host cell dies and ruptures, and the newly produced tachyzoites are spread via the bloodstream to infect cells of all organs

Domestic cats are the only known definitive host of *T. gondii*. Seregraff / iStock / Thinkstock

and tissues, including the brain. Within their new host cell, the tachyzoites differentiate into bradyzoites to form tissue cysts. The bradyzoites reside dormant in the tissue cysts for the life of the host. Livestock may also become infected after ingesting sporulated oocysts present in the environment. Cats usually become infected when eating an intermediate host harbouring tissue cysts. Usually, humans get infected by eating undercooked meat harbouring tissue cysts. Other infection routes are consumption of food or water contaminated with oocysts or by handling soil samples and cat litter containing cat faeces. Blood transfusion and organ transplantation are also routes of transmission. During the first three months of pregnancy, a mother can infect her unborn child.

Pathology of toxoplasmosis

In humans, *T. gondii* causes the disease toxoplasmosis, which is usually a self-limiting disease with few symptoms. During acute toxoplasmosis, when there is a rapid reproduction of tachyzoites, the typical symptoms are malaise, fever, fatigue, headache and swelling of the lymph nodes in the neck. Clinical disease occurs only in immunocompromised patients (HIV/AIDS patients and immunosuppressed oncological and transplantation patients) where the disease can quickly turn into a new, severe acute phase causing encephalitis from which the patient will eventually die. When an expectant mother is infected immediately before or during the first trimester of pregnancy, the infection can be transmitted to the foetus resulting either in abortion or malformation (such as an abnormal enlargement or diminution of the head) of the unborn child.

Due to its manipulation of behaviour, *T. gondii* may be an important risk factor for traffic and workplace accidents and schizophrenia.

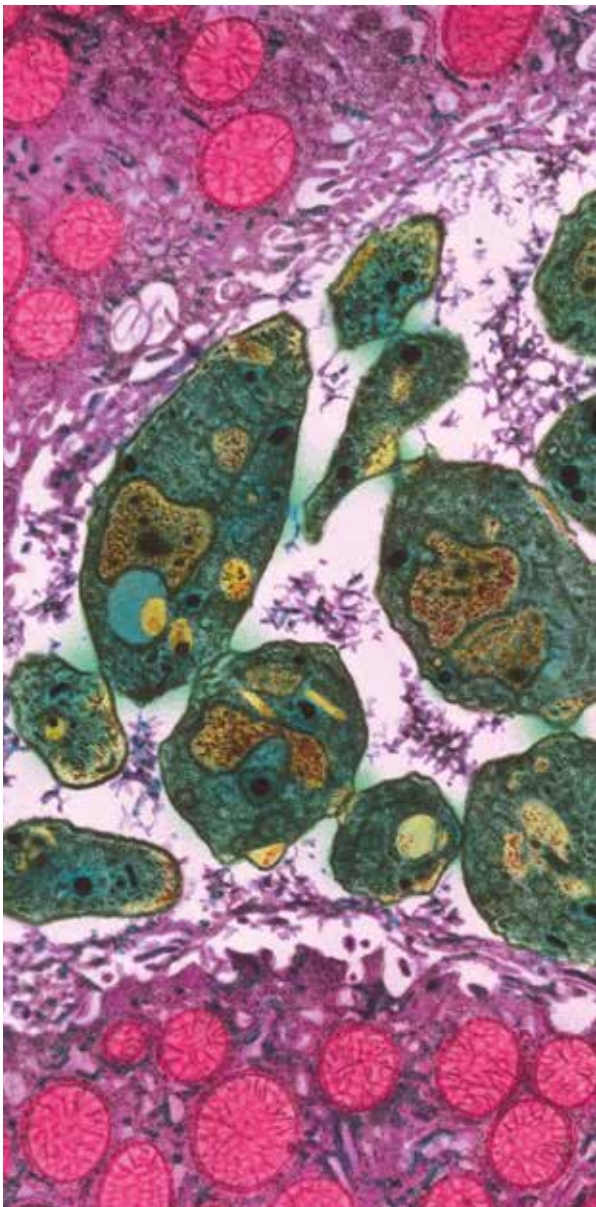
T. gondii induces behavioural changes in rodents

In its natural life cycle, *T. gondii* is transmitted by predation: when a cat catches and eats a rodent harbouring the protozoan, the cat will become infected with the parasite. Normally of course, rodents do their best to avoid getting caught by cats: rodents have an inborn fear of cat odour. To increase the likelihood for a rodent infected with *T. gondii* to get caught and eaten by a cat, the protozoan appears to be able to change the behaviour of prey animals. *T. gondii*-infected mice and rats stop fearing cat odour and instead they are attracted by this smell. As a result, infected rodents visit and spend more time in places smelling of cat urine. This is a very specific attraction, as infected rodents are not attracted by the urine smell of other species. In addition, it seems that *T. gondii* prolongs the reaction time and reduces the vigilance and alertness of infected mice and rats. This manipulation of mouse behaviour is associated with the presence of tissue cysts in certain parts of their brain such as the amygdaloid bodies, which play a crucial role in fear response. These changes make rodents easier prey for cats and thereby increase the probability of transmission of *T. gondii* to its feline definitive host.

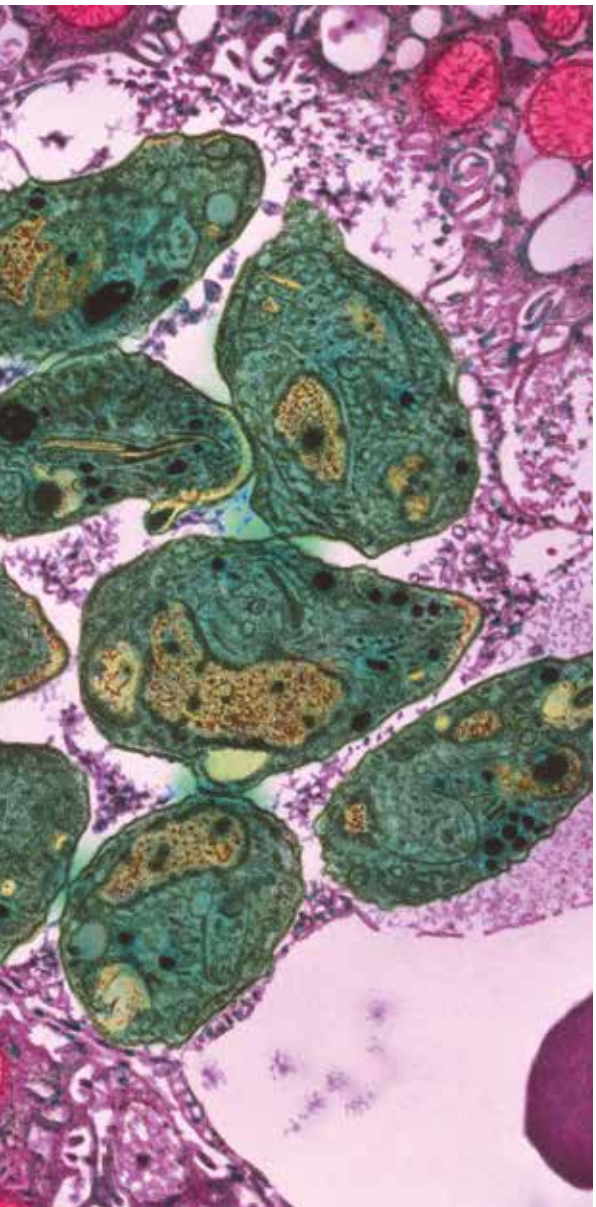
Effect of *T. gondii* infection on humans

As with rodents, *T. gondii* seems also to influence the behaviour of people. Like infected rodents, infected people show an increased attraction to cat odour. One study found that compared with parasite-free male students, their infected peers rated the smell of diluted cat urine as "more pleasant". More importantly, people infected with

Coloured transmission electron micrograph of *T. gondii* parasites (green). Moredun Scientific Ltd / Science Photo Library



the parasite have a longer general reaction time than uninfected individuals. This impaired psychomotor performance has been linked to a higher risk in traffic and workplace accidents for those infected with *T. gondii*. In addition, the parasite's presence can alter personality profiles. Infected men have a tendency to disregard rules and take risks and are more suspicious and jealous; whereas, infected women are more warm-hearted, open-minded and carefree than their uninfected counterparts who are more reserved, detached and critical. Infected men and women reported that they thought their instinctive reflex behaviour to imminent danger was rather slow and passive.



Surprisingly, the explanation for all this appears to lie not just with parasite positioning in the brain (which does show a biased distribution, but which is not tightly targeted) but with L-DOPA, a chemical endogenously manufactured by the brain and from which the neurotransmitter dopamine is produced. L-DOPA is both upregulated in *T. gondii*-infected tissue and actively manufactured by the parasite. It seems infected individuals also have a reduced novelty-seeking activity, i.e. they have a lower tendency to search for new stimuli, which correlates with the lower novelty-seeking activity which is characteristic for individuals with a raised concentration of dopamine in the brain. More dramatically, raised dopamine levels are associated with schizophrenia and *T. gondii* infection also increases the risk of schizophrenia. It has been found that the infection increases the risk for this psychiatric disorder by about 2.7 times. It has been known for some time that an unusually high percentage of schizophrenic patients are infected with *T. gondii*. Magnetic resonance imaging studies have shown that *T. gondii*-infected schizophrenics have decreased density of grey matter in certain parts of their brain, whereas such changes are absent in parasite-free schizophrenic patients. The symptom profiles of infected and uninfected schizophrenic patients differ too; parasite-harbouring schizophrenics experience more severe psychotic episodes. However, it seems that *T. gondii* can trigger schizophrenia only in individuals with particular predisposition for the disease.

Summary

Currently, the most important hosts for *T. gondii* are domestic cats as the definitive host and small rodents as intermediate hosts. Nevertheless, nearly all changes observed in *T. gondii*-harbouring rodents are also found in humans infected with the parasite and while modern man is not prey for domestic cats, our ancestor may have been prey for big cats. So while those of us who are infected with *T. gondii* are not seeking closer contact with lions or tigers, the next time you narrowly avoid colliding with someone undertaking a foolhardy manoeuvre on a public highway, pause and wonder if it is a microscopic brain parasite that is responsible for their actions.

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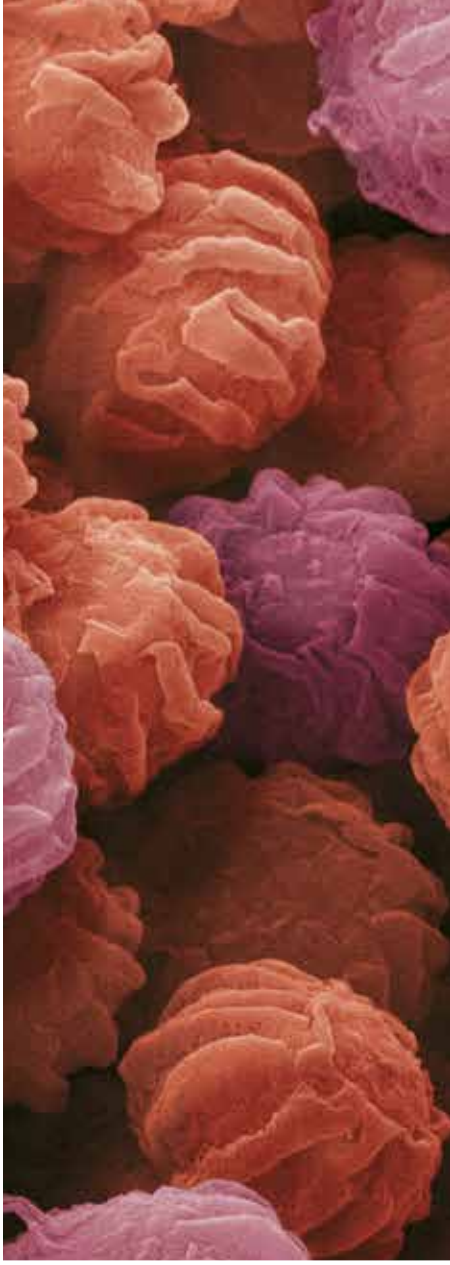
Further reading

Flegr, J. (2013). How and why *Toxoplasma* makes us crazy. *Trends Parasitol* **29**, 156–163.

Flegr, J. (2013). Influence of latent *Toxoplasma* infection on human personality, physiology and morphology: pros and cons of the *Toxoplasma*–human model in studying the manipulation hypothesis. *J Exp Biol* **216**, 127–133.

Ingram, W. (2013). Dr. Strangelove, or: how I stopped worrying and learned to love a brain parasite. **http://microb.io/1wFQHXp**

The highs and lows of ergot



Manic dancing, drug-crazed academics, migraines and massive loss of life are all connected by one small fungus – *Claviceps purpurea*. This is one of almost 50 species of the *Claviceps* genus and is the most common one found in Europe.

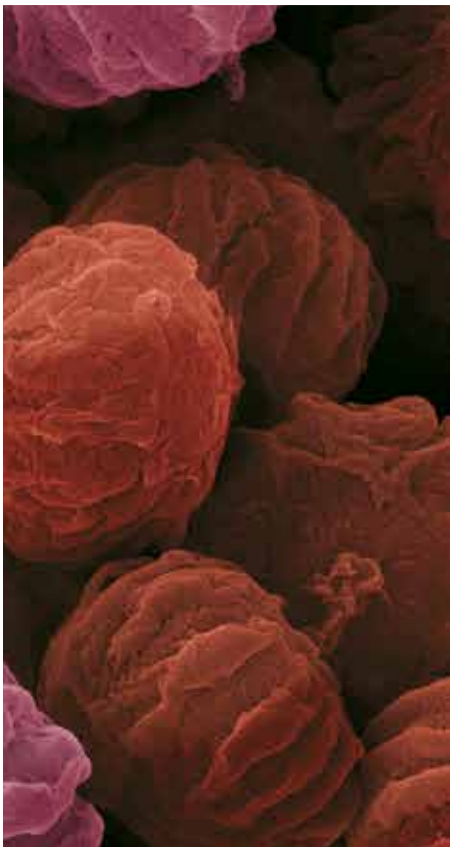
Paul Nicholson

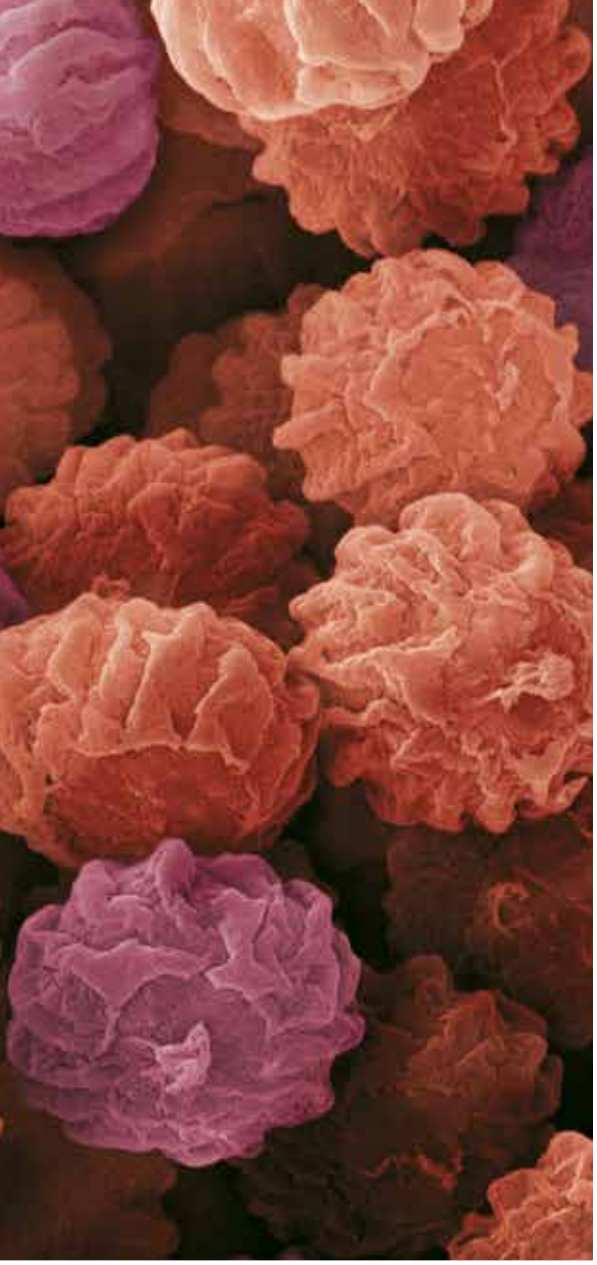
Unlike many of its relatives, *C. purpurea* can infect a large number of plant species including many cereals to cause a disease called ergot. The name comes from the French word *argot* which means spur. The ergot structures (technical term sclerotia) are produced by the fungus on cereal heads where the grain should form (see Fig. 1). The most important host is rye, which seems to be particularly susceptible and in which the fungus produces the largest ergot structures (see Fig. 1 to compare ergots on wheat, barley and rye).

The ergot sclerotia are produced by the fungus to protect it during the winter when the ergots lie on the soil. In spring, the fungus re-emerges and produces spores that can infect the next crop and so complete the lifecycle of the fungus. Within the sclerotia the fungus produces a wide range of chemical poisons called alkaloids to keep it safe during the winter period. These chemicals include ergotamine, ergosine and ergocristine that are potent vasoconstrictors (they cause blood vessels to constrict, preventing blood flow therefore starving tissues of oxygen).

Ergot – the lows

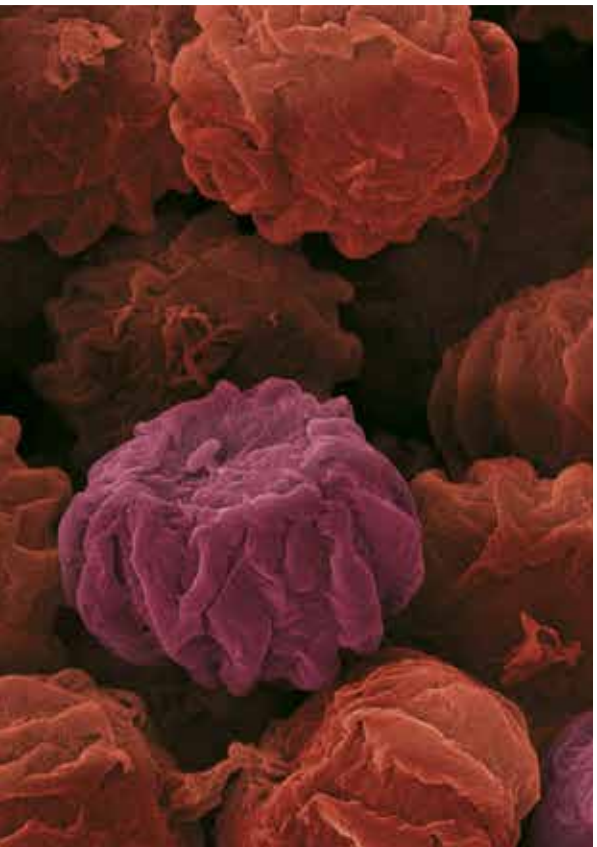
The big problem with ergot is that no one realised that it was a problem! For





Coloured scanning electron micrograph of *C. purpurea* growing on wheat. Ted Kinsman / Science Photo Library

Fig. 1. **Ergots emerging from heads of barley (left), wheat (centre) and rye (right).** P. Nicholson



hundreds of years ergot caused mayhem and death across Europe and nobody had any idea that it was all due to the sclerotia and the fungus that produces them.

During the Middle Ages frequent epidemics occurred in which people suffered terribly from convulsions, hallucinations, and gangrene of hands and feet that caused limbs to fall off. Between 990 and 1130 AD it is estimated that over 50,000 people died from ergot poisoning in southern France. Thousands more were afflicted across Europe. The sclerotia contain a cocktail of alkaloids and these have different effects on the consumer. Two forms of ergotism (the disease caused by eating the ergot "spurs") were prevalent during the Medieval period. Convulsive ergotism caused spasms, sharp pains and convulsions that, in some instances, were accompanied by hallucinations, manic or psychotic behaviour. Gangrenous ergotism caused nausea and severe pain in the limbs. This burning sensation led to the disease being called *ignis sacer* which is Latin for "holy fire". Later, limbs would turn black because of the action of the vasoconstrictive alkaloids and even break off at the joints. Strangely, convulsive ergotism was more common to the east of the river Rhine while gangrenous ergotism was more

common to the west of the river. The reasons for this remain unknown but are probably due to different populations of *C. purpurea* to the east and west of the Rhine, with each population producing a different cocktail of alkaloid poisons: one causing convulsive ergotism and the other gangrenous ergotism.

St Anthony's Fire

Ergotism was so frequent and severe that a religious order called the Order of Hospitallers of St Anthony was founded in southern France in 1095, to help sufferers. The Order built over 370 hospitals to treat ergotism patients and the disease became known as St Anthony's Fire. Many patients did benefit from their time in the hospitals, quite possibly because of the lack of rye bread in their diets during their stay. Epidemics of ergotism were most serious when weather conditions favoured infection of rye flowers and were most severe among those who subsisted on a diet high in rye. These included the unfortunate French peasants of the 15th century. It was reported that "they drink water, they eat apples, with bread right brown with rye. They eat no flesh, but if it be seldom a little lard, or of the entrails or heads of beasts slain for the nobles and merchants of the land."

Convulsive ergotism has been suggested as a cause of some of the outbreaks of dancing mania that occurred sporadically across Europe between the 14th and 17th centuries. However, the symptoms of dance mania are not entirely those associated with ergotism so this must remain conjecture. Convulsive ergotism has been linked to another widespread phenomenon during this period – witch hunts. The symptoms

Coloured scanning electron micrograph of a fruiting body of *C. purpurea*. Eye of Science / Science Photo Library

While it was not until the middle of the 20th century that ergot-derived compounds were being used as psychoactive drugs, a look back into history suggests that the ancient Greeks were well aware of the mind-altering effects of ergot.

of hallucination, cramps and convulsions may have led many to believe that they were victims of witchcraft. Again, witch trials were most prevalent in areas where rye consumption was highest.

Catching the culprit

During all this time *C. purpurea* was quietly getting away with murder and no-one linked it to the crime. The spurs (ergots) were thought to be a natural part of the plant itself and not the result of a parasitic fungus. Even when it was discovered that ergotism was caused by consumption of the spurs it was not believed. The link was first made by a German physician (W. Thelius) in 1596 and it was almost 100 years later, in 1670, that a French physician, Dr Thuillier, realised that the disease did not conform to the usual contagious diseases raging at the time. Ergotism was most common in poor rural areas and not in congested urban areas. It did not appear to be infectious and the rich seemed to be immune. Dr Thuillier thought that the cause lay in some foodstuff and after dismissing potato as the possible cause he made the link between the spurs common in the rye fields and ergotism. Ergot spurs were used in medicine to help speed up childbirth but it was not thought that they could have a negative effect if consumed in high quantities. Dr Thuillier even found that ergotism epidemics were most serious in years when the spurs were most common. This evidence was, unfortunately, not enough to convince the farmers who continued to believe that they were harmless for another two centuries. It was Louis Rene Tulasne, an early mycologist, who in 1853 determined that the ergot was produced by a fungus (now known as *C. purpurea*), rather than the rye itself.

Ergot – the highs

Like most things, Ergot is not entirely bad. For centuries extracts of ergot spurs were given to hasten childbirth as they cause contractions of the uterine muscles. Such practices are extremely risky as there was no way to determine what cocktail of vasoconstrictive and psychoactive alkaloids were present, what dose was being given and no way to counteract the effects if too much was administered.

It was early in the 20th century that chemists began to isolate individual ergot alkaloid components of the cocktail. Ergotamine, one of the alkaloids with vasoconstrictive properties, was isolated in 1918. Ergotamine is still used in the treatment of acute migraine. In 1935, ergometrine, the substance that induces uterine contractions, was isolated and this is used to stop postnatal bleeding. A few years later, in 1938, two chemists (A. Hofman and A. Stoll) derived D-lysergic acid diethylamide (LSD) from the ergot alkaloid ergine. This chemical was not thought to be particularly interesting or useful until Albert Hofman accidentally absorbed some and experienced its powerful effects on his thought processes. His next step was to deliberately take a small dose. Within an hour he was suffering feelings of anxiety, alternating in his beliefs that his next-door neighbour was a witch, that he was going insane and that the LSD had poisoned him. LSD went on to become famous in the 1960s and 1970s during the hippie movement. The introduction of LSD into the American middle class was promoted by two Harvard psychology professors who proposed the motto, "turn on, tune in, and drop out". Rather than "dropping out" they were "booted out" of Harvard.

While it was not until the middle of the 20th century that ergot-derived compounds were being used as psychoactive drugs, a look back into history suggests that the ancient Greeks were well aware of the mind-altering effects of ergot. Kykeon, a drink made from water, barley and herbs was consumed by initiates during the Rites of Demeter in the city of Eleusis. Kykeon enabled them to experience the mystery of death and rebirth in the ritual which became known as The Eleusinian Mysteries. It is believed that the psychoactive properties of the Eleusisian kykeon were caused by ergots growing on the barley gathered around Eleusis.

So there we have it. One small fungus with an enormous impact.

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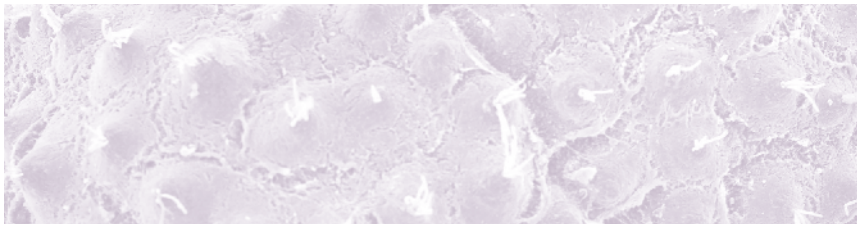

Ant brains manipulated by a fungus

Hilary Hurd

There can be few things more frightening than the thought of an alien organism taking over your brain and directing your behaviour for its own purposes, yet this is the fate of carpenter ants that have been infected by *Cordyceps* fungi. These so called "zombie ants" and their parasitic masters have been the inspiration for Hollywood movies and video games, not only because of the bizarre actions the ants are made to perform, but due to the grotesque structures that grow out of them.

Carpenter ants (*Camponotus* sp.) on wood. Ted Clutter / Science Photo Library

Cordyceps fungi

There are about 400 species of fungi in the genus *Cordyceps*, many of which parasitise insects and other arthropods. Medicinal properties have been attributed to compounds produced by some of them and they have attracted particular attention due to the bizarre forms that their fruiting bodies grow into when they emerge from the dead bodies of their hosts. Some of those with particular mind-bending abilities have now been placed in the genus *Ophiocordyceps*, the most studied being *Ophiocordyceps unilateralis*. This species was first recognised in 1859 by Alfred Russel Wallace, the biogeographer and conceiver, along with Charles Darwin, of the theory of evolution through natural selection. *O. unilateralis* is now known to be a large species complex with members distributed throughout tropical rainforests worldwide; indeed four new species were recently described infecting carpenter ants in Minas Gerais, Brazil.

The behaviour of zombie ants

Ants encounter the spores of *O. unilateralis* when walking along their foraging trails. Enzymes, secreted by the fungal spore, help it to penetrate through the hard outer skeleton of the ant and the fungal hyphae then grow inside its body, eventually taking over its nervous system. Infected ants leave their nests and trails in the tree canopy, wander around and twitch convulsively until their movements cause them to fall to the ground. In the leaf litter they search for areas within a very specific range of temperature and humidity then, at a particular time of day, they begin to climb up stems to reach the underside of leaves at a particular height from the forest floor. Here they bite into the central vein of a leaf and their mandibles (jaws) clamp down and enter a state of lockjaw caused by the atrophy of the mandibular muscles. They cannot release themselves from the bite, which is known as the "bite of death" and remain hanging underneath the leaf when dead. Interestingly, David Hughes and colleagues at Penn State University's Genomics Institute have identified a compound produced by the *Cordyceps* fungus that causes this muscle atrophy.

Although the ant is dead, the fungus continues to grow inside the cadaver. Eventually, out of the back of the head of the ant a long tube slowly emerges. This is the stalk of the fruiting body of the fungus. The tip of the tube swells and fills with fungal spores that are

Multiple compounds in the fungus secretome are probably involved in manipulating host behaviour.

Dead ants infected with *O unilateralis*. David P. Hughes, Maj-Britt Pontoppidan – *PLoS One*

then shed into the path of new foraging ants below. The release of spores in the specific environment that the fungus dictated the ant to select is essential for spore dispersal. Recent investigations have shown that when cadavers of ants infected with a similar species of *Cordyceps* are placed in an ant's nest they are rapidly removed before spores can be produced and infect the nest mates. Furthermore, the fungus cannot complete its development if infected cadavers were placed in an empty nest. Clearly, the humidity, temperature and elevated position of the leaf selected for the ant's death bite is highly adaptive as it provides the ideal environment for the fungus to continue growing and gives its spores a better chance of dispersal to areas where they will encounter more ants.

The mechanism behind manipulation

The woods of South Carolina, USA, are also home to a species of the *O. unilateralis* complex that has recently been investigated. This species causes carpenter ants to die gripping onto the underside of twigs rather than leaves, as do their Brazilian relatives. Only two of the four species of carpenter ant in this area of woodland are naturally infected with the fungus, although it will grow in all four ants when injected into them in the laboratory. When each species was injected they were all killed by the fungus (one too quickly for further investigations). After death, fruiting bodies grew out of the back of the two species of ants that were found naturally infected in the forest. However, no such tube emerged from the third species (the one that was not infected in the wild) even though fungal spores were found inside its cadaver. The behaviour of the ants also differed. The two ant species infected with the fungus in the wild climbed up and bit into the twigs provided in their cage, hanging there before they died, but the other species did not exhibit this behaviour. It would seem that the fungus could only manipulate the behaviour of the two naturally infected species and only grew properly in the ant it had co-evolved with.

To determine whether the fungus could distinguish between its natural hosts and a novel ant, and therefore secrete different molecules into the ants, the investigators grew the fungus in culture with the brains of each of the four different ant species. They collected and analysed the substances secreted by the fungus and found that it responded by secreting a specific set of metabolites in response to each brain type, suggesting it could recognise the different signals given off by each one. Altogether the secretion of 73 compounds was significantly increased in response to one ant brain alone.

One of the molecules secreted by the fungus was identified as guanidinobutyric acid. This molecule is known to be involved in the transport of compounds across the blood–brain barrier and has been involved in convulsions and epileptic discharges in rodents. A putative identification

Fruiting bodies of a *Cordyceps* fungus (*O. unilateralis*) growing out of the body of an ant. Chains of spores released by the fruiting bodies are visible.
Dr Morley Read / Science Photo Library

of a sphingosine was also made. The research group then tried to mimic the action of the fungus on the behaviour of the ant by injecting various dilutions and combinations of these two metabolites into uninfected ants. Unfortunately, these attempts were fruitless and they concluded that multiple compounds in the fungus secretome are probably involved in manipulating host behaviour. It is likely that more candidate manipulation molecules will be identified in the future when the fungus metabolome is better annotated.

Meanwhile, it is not surprising that manipulation signals may be multiple as the behavioural changes that the ant exhibits are actually a complex series of behaviours that occur in a specific sequence. They are remarkably reminiscent of behavioural changes induced in shrimps when infected with the immature stages of a spiny headed worm. The shrimps are induced to swim upwards and grip vegetation floating on the surface, the muscles of their pincers undergoing a tetanus-like reaction, and they stay there until accidentally eaten by the next host in the parasite's life cycle.

This study of one species of *Cordyceps* fungus demonstrates how specific these interactions can be. The fungus responds differently to chemicals from the brains of different ant species and only some of these brains will stimulate the fungus to produce the chemicals that create zombie ants that aid the fungus to disseminate its spores.

Acknowledgement

This article is based on a blog posted by BugBitten: **http://blogs.biomedcentral.com/bugbitten/**

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Viruses as the for eukaryote lessons from

Julien Varaldi

In the minds of most of us (including researchers), viruses are associated with illness. They are expected to debilitate, in one way or other, the host they infect. This is true for many viruses and a recent, sinister example of the Ebola epidemic in West Africa entrenches this view.

Yet, human beings, and all organisms that produce a placenta, wouldn't have this property if a common ancestor had not captured some retroviral genes. Nowadays, these ancestral viral proteins that are encoded by these genes are crucial and participate in the formation of the placenta. This "domestication" of ancient viral genes (syncitins) likely gave an evolutionary advantage to these lineages. This illustrates that not all interactions with viruses have a negative impact on the host, or at least, the host may ultimately take benefit from this interaction on a long-term evolutionary scale. Recent sequencing of genomes revealed that all types of viruses (not only retroviruses that naturally integrate into their host's genome) do integrate on some occasions into the chromosomes of their hosts. If these integration events occur in germline cells then they can be vertically transmitted (from parent to offspring) and may provide new genetic material for host evolution. On some occasions, such endogenous viral elements (EVEs) may give rise to evolutionary novelty.

Thanks to a virus, insects instigated gene therapy 100 million years ago

Gene therapy is the use of nucleic acid to treat a disease by delivering it into a patient's cells. As you would expect, this therapeutic method requires a vector to deliver the nucleic acid into the cells. The DNA is usually packed into an engineered virus that serves as a vector, to get the DNA into the cells, and incorporated into the target chromosome. The first human attempt of gene therapy dates back to 1990. One hundred million years before, when primates still didn't exist, this technique had already taken place in tiny parasitic wasps. These insects, called parasitoids, have a special way of life in the sense that they lay their eggs into the body of other insects, in this case caterpillars. They then develop as a true parasite inside the cavity of the caterpillar until they pierce the skin and emerge from their, now nearly dead, host to metamorphose and give rise to an adult wasp. This lifecycle has been said to have inspired Ridley Scott when he

raw material evolution: parasitic wasps

Aleiodes indiscretus wasp parasitising a Gypsy Moth (*Lymantria dispar*) caterpillar.
USDA / Science Photo Library

wrote the scenario of his famous 1979 movie *Alien*.

Most parasitoids are hymenoptera wasps and represent a huge diversity of species. For instance, the microgastroid complex whose ancestor instigated gene therapy 100 million years ago encompasses several thousands of species. Nowadays, when a female of this group (microgastroid complex) parasitises a host, she injects her eggs and also some viral particles. These viral particles contain different circular molecules of double-stranded (ds) DNA. This special genomic structure inspired their names, polydnaviruses. Thanks to the viral particles, these packed dsDNA molecules are delivered into various cells of the caterpillar where they are then actively transcribed and translated by the caterpillar cell machinery. The consequence of this phenomenon is that the caterpillar can no longer eliminate its parasite (the wasp egg) though encapsulation, which is the typical immune response of insects against foreign bodies. Furthermore, the expression of those "viral" genes manipulates the development of the caterpillar to create its parasite.

Although viruses are classically viewed as pathogenic entities, reducing the survival of their hosts, studies in the parasitoid wasp clearly demonstrate that the interactions may be more subtle.

Polydnavirus: a hybrid organelle

The evolutionary origin of these polydnaviruses has been elusive. When researchers obtained the first sequencing data on the circular dsDNA molecules packed within the viral particles, they were surprised to observe that these had nothing to do with viral DNA, but instead showed all typical properties of eukaryotic DNA. For instance, most of them contain several exons while viral genes typically contain only one. However, the link with viruses was made when they studied the way the "virus-like" particles are produced. Polydnaviruses are produced in the calyx of the reproductive apparatus of females, which is a region at the base of the ovaries. By studying the expression of genes during the production of these particles, it became clear that many had a viral origin: 29 genes resembling nudivirus genes were highly expressed and involved in the production of particles. However, as previously mentioned, no nudiviral genes are packed inside the particles. The hypothesis is that eukaryotic genes, important for parasitism success, gradually replaced the viral genes packed within the particles. Thus polydnaviruses are a kind of chimeric organelle composed of proteins of viral origin responsible for the production of the particles and DNA encoding eukaryotic virulence factors that are incorporated into the particles and expressed in the caterpillar. And this invention gave rise to the diversification of this clade leading to more than 12,000 species of wasps. All of them are totally dependant on this hybrid organelle for development.

Coloured scanning electron micrograph of a parasitic wasp, *Eretmocerus eremicus*.
Steve Gschmeissner / Science Photo Library

Coloured scanning electron micrograph of *Drosophila melanogaster* larvae.
Steve Gschmeissner / Science Photo Library

A diversity of interactions

Another fascinating example of a peculiar virus–wasp interaction has been described in a parasitoid-attacking fruitfly larva. This wasp (*Leptopilina boulardi*) lays its eggs into fruit fly larvae (*Drosophila*) and the offspring then develops as a parasite until it emerges from its host. No more than a single parasitoid can develop in one *Drosophila* host. One would therefore expect that parasitoid females would not lay their eggs in already parasitised hosts, thus avoiding a highly risky competition for their offspring. Accordingly, some females are able to discriminate between parasitised and unparasitised larvae and refuse to lay in previously parasitised larvae. However, some females readily decide to lay an additional egg into an already parasitised host, a behaviour called superparasitism. This puzzling behaviour is inherited through the maternal lineage. When "superparasitising" females laid eggs into larvae already parasitised by "normal non-superparasitising" females, it was observed that the offspring of normal females also adopted the "superparasitising" behaviour at the adult stage. This indicated that the "superparasitism" behaviour was transmitted contagiously within the superparasitised *Drosophila* larva. Electron microscopy and molecular work revealed that this "superparasitism" behaviour was in fact induced by a virus, later called LbFV, that manipulates the behaviour of the wasp toward its own benefit. The virus imposes the superparasitism behaviour on its host and thereby increases its own spread through horizontal transmission. The effect of the virus seems very much limited to this behaviour, with no noticeable effect on the wasp's survival.

Conclusion

Although viruses are classically viewed as pathogenic entities, reducing the survival of their hosts, studies in the parasitoid wasp clearly demonstrate that the interactions may be more subtle, like in the case of the behaviour-manipulating heritable virus of *L. boulardi*. They may have a strong positive effect on long-term evolution, like in the polydnavirus example. Finally, it is now known that the domestication of viruses has occurred repeatedly and independently in parasitoid wasps. Each of them led to slightly different outcomes but the general picture remains the same: the integrated virus allows the wasp to efficiently circumvent the immune response of its host. This indicates that wasps and viruses have had intimate interactions for millions of years and that viruses have greatly contributed to their present diversity and distribution. One remaining question is what type of interaction did the ancestral wasps have with the ancestral polydnaviruses? One may speculate that the ancestor of polydnaviruses first evolved vertical transmission (from mother to offspring) like LbFV, thus selecting for reduced virulence. Possibly, it may also have benefited from the same behavioural manipulation that LbFV induces to spread and maintain in wasp populations, thus increasing the stability of the association and the opportunities of genetic exchanges between the wasp and the virus. Future genome sequencing programmes of these wasp and their associated viruses will likely shed light on the processes at play.

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Further reading

Feschotte, C. & Gilbert, C. (2012). Endogenous viruses: insights into viral evolution and impact on host biology. *Nat Rev Genet* **13**, 283–296.

Herniou, E. A. & others (2013). When parasitic wasps hijacked viruses: genomic and functional evolution of polydnaviruses. *Phil Trans R Soc Lond: Biol Sci* **368**, 20130051.

Varaldi, J. & others (2003). Infectious behavior in a parasitoid. *Science* **302**, 1930.

The Master Puppeteer? The impact of microbes on brain and behaviour

"Master of Puppets I'm pulling your strings
Twisting your mind and smashing your dreams"
***Master of Puppets*, Metallica**

In medicine, the fields of microbiology and neuroscience have evolved in parallel trajectories with limited overlap. However, recent advances in studying the effects of microbial colonisation on host physiology, metabolic and event behaviour have raised the question if we as hosts are manipulated by our microbial companions.

Roman M. Stilling, Timothy G. Dinan & John F. Cryan

A *Dicrocoelium dendriticum* fluke, a parasite of herbivores such as sheep. Eye of Science / Science Photo Library

Parasitism is often acknowledged as one of the greatest accelerators of evolution, which has lead to the so-called "Red Queen Hypothesis" to describe rapid host–parasite co-evolution. Among the many outcomes of this evolutionary arms race are fascinating examples of host behaviour manipulation in order to increase parasite fitness. Researchers find a growing variety of parasites in all domains of life that depend on altering host behaviour for completion of their complex life cycles. Well-known examples are the small liver fluke *Dicrocoelium dendriticum*, directing ants to climb grass blades in order to enhance transmission to a ruminant host, or the Gordian worm *Paragordius tricuspidatus,* forcing infected grasshoppers to search for water, where the worm can reproduce. In addition, we also know behavioural manipulation as symptoms of mammalian diseases such as rabies, which induces aggression and water avoidance behaviour, or toxoplasmosis, best known for inducing attraction of rodents towards cat urine scent, which is also implicated in schizophrenia.

However, other forms of symbiosis (especially mutualism) have long been neglected with respect to their potential to manipulate host behaviour. With a rising interest in microbiome research they now emerge to be just as important – although their influence is subtler.

Much of the research demonstrating a role for the microbiota in behaviour modulation stems from rodent studies. At the centre of many of these studies are germ-free animals that have been raised without microbiota. But also behavioural studies on animals with either defined infections, antibiotic treatment or administration of probiotic bacteria have been carried out and the most commonly reported phenotype was altered anxiety-related behaviour.

There is now an increasing number of studies focusing on the positive behavioural effects of various bacterial strains, mostly *Bifidobacterium*, *Lactobacillus* and *Bacteroides* species but also transient commensals such as *Mycobacterium vaccae*.

In almost all studies the authors also reported biochemical and molecular changes in the brain. Specifically germ-free mice have an exaggerated stress response coupled with gene expression changes in different brain regions. In addition, alterations in neurotransmitter signalling, including neurotransmitters and associated metabolites and receptors, have been described.

Moreover, an increasing number of studies in animal models of stress, anxiety and depression also implicate a role for the microbiota in psychopathology, including irritable bowel syndrome (IBS) and also autism spectrum and other neurodevelopmental disorders.

Mechanisms, mechanisms, mechanisms!

In contrast to this considerable wealth of data and tight correlations, to date no closed chain of molecular events or mechanisms links the presence or absence of a certain microbe to a specific host behavioural output. The exact details of routes of communication between gut-dwelling microbes and the brain are poorly understood and must be a priority of future advancements in this area. Clearly important is the autonomic nervous system, especially the vagus nerve, as it was shown that some of the effects were absent

in vagotomised animals. Another interface for microbe–host interactions is the immune system that is severely underdeveloped in germ-free animals but plays an important role during brain development. Finally, bacterial metabolites that are secreted into the gut lumen and taken up by the host could lead to changes in host brain physiology. The microbiota is not only capable of producing a range of neurotransmitters and neuroendocrine compounds (hormones), but is also the major source for short-chain fatty acids, which can regulate host metabolism and gene expression.

The gut microbiota is a directly tractable target (e.g. via diet) to develop new "psychobiotic"-based strategies for therapy in neuropsychiatric and neurological disease. However, solid mechanistic evidence, illuminating the black box between the gut lumen, brain and behaviour is needed to drive the field forward.

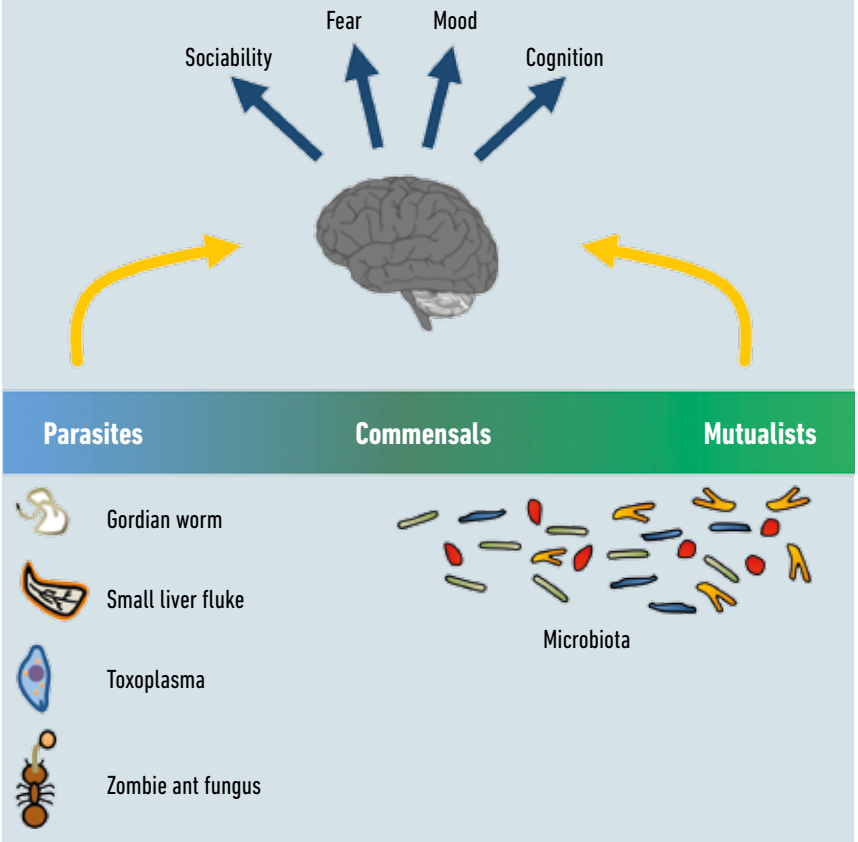


Fig. 1. **The effect of microbes on brain and behaviour. Although some well-known examples of parasites evidently manipulate host behaviour in their own favour (see examples on left of figure), it is unclear where on the parasitism–mutualism spectrum our microbiota should be placed due to their long-shared history of co-evolution. However, it is clear that the microbiota can also affect brain function and behaviour. Understanding the mechanisms of these interactions and placing them in an evolutionary context is an important endeavour for scientists working in this field today.** R. Stilling, T. Dinan, J. Cryan

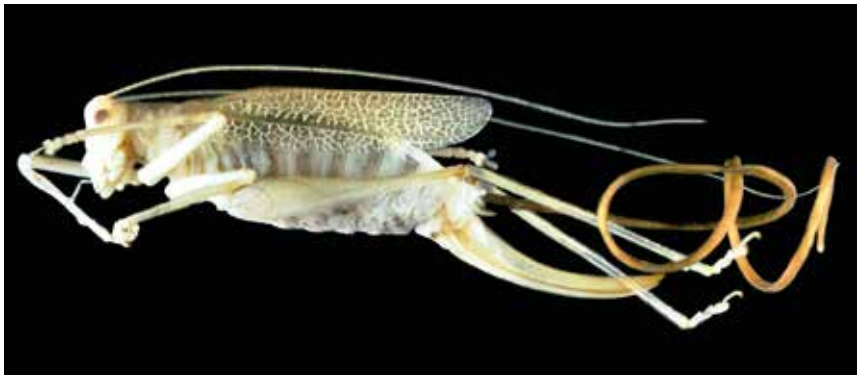
Confusing interactions: good, bad, or just ugly?

Many of the findings described above have resulted in dramatic headlines in the media and may lead to the impression that our decisions and emotions – good or bad – are driven by our ever-present microbiome.

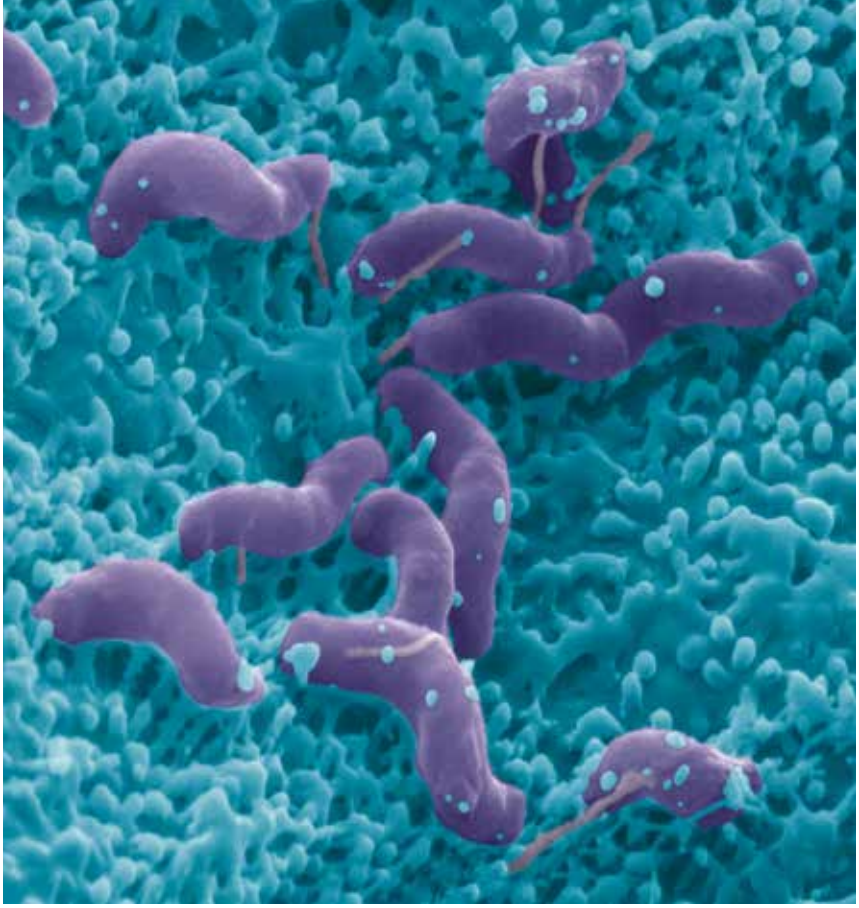
Speculations are rising that, for example, feeding behaviour of the host might be manipulated by the special interests of particular microbes to influence what nutrients will be available in the gut. Also, we have previously argued that the microbiota may promote social behaviour and group living to more easily spread to new hosts and thereby reproduce more efficiently.

However, in many cases it turns out to be challenging to determine where a

The answer to why a "normal", healthy microbiota should influence behaviour may be a lot less spectacular than the term "manipulation" would suggest.



The parasitic worm *Spinochordodes tellinii* with its bush-cricket host (*Meconema thalassinum*).
Dr Andreas Schmidt-Rhaesa



Coloured scanning electron micrograph of *Helicobacter pylori* bacteria on the surface of the human gut.
Eye of Science / Science Photo Library

given micro-organism is located on what appears to be a mutualism–parasitism spectrum (Fig. 1). In contrast to the unambiguous parasitic manipulations, classification of host–microbe interactions is complicated by the need to define benefits and disadvantages for either side. As such, it is highly debatable whether strict commensalism, where only one partner benefits, while the other has neither advantages nor disadvantages, actually exists. Also, in apparently mutualistic relationships, many cases are not clear-cut. Here, both species are required to mutually benefit from one another. For example, the gut microbiota benefits from a constant supply of nutrients, while the host benefits from increased nutrient availability through microbial enzymic activity (e.g. digestion of fibre). But, since these advantages of the relationship may have compensated possible disadvantages during evolution, negative side effects of the association may be masked or not recognised as detrimental in retrospect today.

In addition, changes in the environment may revise the nature of an association. Evidence for a strong dependency on environmental conditions determining how a particular microbe is associated with the host comes from a recent study on *Helicobacter pylori*, which exhibits differing degrees of virulence in independent human populations. Thus, a causal timeline of symbiosis is hard to reconstruct in retrospect and even what appears as obligate mutualism today may not have started as mutually beneficial. Finally, the microbiome is a diverse ecosystem and what's good for one bacterium may not be good for another.

In summary, the answer to why a "normal", healthy microbiota should influence behaviour may be a lot less spectacular than the term "manipulation" would suggest. The problem is that we tend to think about this matter as a unidirectional process and impose intentions on the bacteria. Furthermore, we tend to forget that all eukaryotic evolution has always occurred in the presence of microbes. Animals have never lived, and could never live, develop and evolve "germ-free" outside artificial laboratory isolators. From this perspective the question is just the wrong question to ask and there is probably no satisfactory answer to it, because the microbiome just became part of multicellular bodies while these formed and now shares a long history of co-evolution. Given this tight association, we cannot simply imply opposing intentions for the microbiota and the host. This new understanding of the microbiome has led to formulation of the hologenome theory of evolution that views the host and its microbiome as one integrated unit, the holobiont.

Conclusions

The question of who controls who therefore has no answer. While there are certainly microbes that harm us and may even not only influence but actively manipulate our behaviour, consciously or unconsciously, there is little reason to be worried about the intentions of the throngs of symbiotic bacteria living in our guts and body cavities.

Yet, to understand who we really are as a species and also to find new therapies for neuropsychiatric conditions, it is key to understand the cues and influences the microbes set on our nervous system, both during development and throughout life, and which mechanisms and pathways they use.

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Annual Conference
Prize Lectures 2015

Congratulations to the following microbiologists who have been awarded Society prizes. They will be delivering their lectures at the Society's Annual Conference 2015, which takes place from 30 March to 2 April at the ICC, Birmingham, UK.

PRIZE MEDAL
Sir David Baulcombe

Sir David Baulcombe

Sir David Baulcombe, Royal Society Research Professor and Regius Professor of Botany at the University of Cambridge, has been awarded the 2015 Prize Medal. This award is presented annually to an outstanding microbiologist who is a global leader in his or her field and whose work has had a far-reaching impact beyond the discipline of microbiology.

Sir David is awarded the Prize for his discovery of siRNAs in plants, which has led to huge advances in the field of medicine. Highly regarded by the science community, he was made a fellow of the Royal Society in 2001 and received their 2006 Royal Medal. Sir David received his knighthood for services to plant science in 2009 and has also been awarded the 2014 Gruber Prize in Genetics.

Sir David heads the RNA Silencing and Disease Resistance Research Group at the University of Cambridge working on small RNA silencing and epigenetics.

FLEMING PRIZE LECTURE
Professor Mike Brockhurst

The 2015 Fleming Prize has been awarded to **Mike Brockhurst**, Professor of Evolutionary Biology at the University of York, in recognition of his exceptional research on the evolutionary biology of microbes.

The Fleming Prize Lecture is awarded to an early-career researcher who has achieved an outstanding research record. Mike completed both his BA and PhD at the University of Oxford, before working as a Lecturer, Senior Lecturer and Researcher at the University of Liverpool before taking up his Chair at the University of York in 2012, as one of the University's 50th Anniversary chairs.

University of York

Mike currently has nine competitive grants running either as principal supervisor or as joint principals. He is a coordinator on two research networks and collaborates widely both nationally and internationally, having been a member of the organising committees for two international conferences and been invited to give plenary talks at four international meetings.

MARJORY STEPHENSON PRIZE LECTURE
Professor Robin Weiss

Robin Weiss, Emeritus Professor of Viral Oncology at University College London has been awarded the 2015 Marjory Stephenson Prize. Robin was awarded the Prize for his outstanding contribution to microbiology through his pioneering work on retroviruses, particularly endogenous retroviruses and the identification of CD4 as a co-receptor for HIV-1, HIV-2 and SIV.

Robin also co-developed the HIV diagnostic antibody test (Wellcozyme) that was adopted for screening blood donations throughout the UK and in many European and British Commonwealth countries. He also assisted in the work that showed that "Slim" disease in Africa was actually AIDS and was associated with HIV infection, thus confirming the suspected pandemic of AIDS in Africa.

During his career, Robin has been Director of the Institute of Cancer Research, managed an international HIV vaccine discovery consortium and co-authored over 180 publications. He was also President of the Society for General Microbiology between 2006 and 2009.

His laboratory continues to address the immune response to HIV and why no successful vaccine to HIV has yet been developed. Their research is funded by the Medical Research Council, the European Union and the Bill & Melinda Gates Foundation.

COLWORTH PRIZE LECTURE
Professor George Lomonossoff

John Innes Centre

George Lomonossoff, John Innes Centre, Norwich, has been awarded the 2015 Colworth Prize. The Prize, awarded to a researcher who has demonstrated outstanding contribution to translational microbiology, recognises George's work developing the CPMV-HT protein expression system, which allows plants to become "bioreactors", capable of producing molecules like antibodies or vaccines. George has had a distinguished career in the area of plant virology and in 2012, George was co-awarded the BBSRC's Innovator of the Year Prize, for his work on the system.

In addition to promotion of his work to scientific audiences, George also engages with members of the public through talks at schools, Friends of John Innes (FoJIC) events and a variety of other BBSRC-sponsored events. He also engages productively with commercial organisations to ensure his research achieves maximum impact.

PETER WILDY PRIZE LECTURE
Dr Simon Park

The 2015 Peter Wildy Prize has been awarded to **Simon Park** from the University of Surrey, in recognition of his outstanding work in the area of scientific communication. Simon uses a highly imaginative approach to science communication, using methods usually confined to creative arts practice to attract large numbers of the public to engage in various concepts of microbiology. Projects include a Wellcome Trust-funded initiative in collaboration with artist Anne Brodie, in which Park explores the communication and light-producing properties of bioluminescent bacteria outside of the usual confines of pure scientific practice. One of the outcomes of this project was the "Bioluminescent Photobooth", which is a darkened and portable booth into which people enter to have photographic portraits taken using only the ethereal light generated by the bioluminescent bacterium.

University of Surrey

Dr Parks' own research is directed towards applying the techniques of molecular genetics and functional genomics to problems of specific relevance to food safety.

2016 PRIZE LECTURES

Nominations for the 2016 Prize Lectures and the 2017 Prize Medal are now open.

For full details on the process and criteria, visit **www.sgm.ac.uk/prizelectures**. Nominations should be sent to **appointments@sgm.ac.uk** and submitted no later than **30 April 2015**.

Rosie Waterton
Governance Manager
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Society Champions

We called and you answered! Last year we put the call out for Society "Champions" – members who would be prepared to do that little bit more for us in their local areas, and we weren't disappointed as more than a dozen of you put your hands up. We now have Champions in many areas of the UK; from Dundee to Lincoln, Glasgow to Norwich, London to Birmingham and beyond. We also have Champions in Turkey, Nepal and Nigeria. Champions are now out there spreading the Society word far and wide.

As the number of Champions grows, so too does the list of activities and initiatives planned. The main objective of Champions is to give the Society more of a local presence and to form closer relationships with existing – and prospective – members, wherever they are.

At the recent Champions Day, we asked our Champions to come up with their ideas about what they would like to do to raise our profile in their place of work or study. We were amazed at the variety, scale and ambition of many of the proposals. When it comes to passion and commitment, our members have it in abundance and this became very evident as soon as the ideas started to come in.

Here is just a selection of recent Champion events, either planned or already delivered. Keep an eye on our website for details of forthcoming Champions' events.

Hot topic seminars

London-based Champion Ed Wright is organising a series of topical talks on important human and animal pathogens. These will be pitched to a broad audience and cover a range of current issues of public interest.

Pub quiz

Hops, yeast and sugar. It doesn't get more relevant than that! Dundee-based Champion Marilia Costa ran a very popular pub quiz successfully blending questions about alchemy with all things microbiological. It proved to be a great way of raising the profile of microbiology and the Society. I wonder why?

Early-career research symposium

Norwich-based Champion Alistair Walsham ran a symposium for early-career researchers in the Norwich area. "There are a number of groups here who work on different sorts of microbes (gut microbes, nitrogen-fixing bacteria and *Streptomyces* to name a few) and it has been great to get these groups together", said Alistair.

Micro_talks

An evening of high-impact short talks is being planned for the June 2015 Glasgow Science Festival by Champion Connor Bamford. Connor has a couple of high-profile speakers in his sights to help create an event that will be both entertaining and informative. Look out for further details on the Society's website.

Specially for Students

Two Champions – Hajah Mohd Afsar from the University of Surrey and Nicola Crewe from Lincoln University – have both run a series of activities aimed at new microbiology students within their respective universities. Conferences and

Champions enjoying their day at Charles Darwin House in London.

stands at Freshers' Week to introduce the Society to new students were both well received.

Lunchtime goodies

Another London-based Champion, Arikana Massiah, arranged a very successful lunchtime talk at the Royal London Hospital for colleagues. "We had a very good turn-out from all departments. In total there were 55 attendees. I have received a lot of positive feedback about the event".

Careers events

Nottingham-based Champion Laura Bennett has been busy working with sixth form students to enthuse them about the wonders of microbiology, with the hope they will carry this through into their university studies. Liverpool-based Champion Maria Afonso is organising a careers panel, to show students already enrolled in microbiology degrees what they can do with their expertise.

Other Champions too, are all engaged and working to help promote the Society in their areas. Recent additions to the group include Agah Ince from Istanbul in Turkey, who is keen to do what he can. "Personally, I have experienced a lot from the Society. Now I would like to contribute something back". Our Champions in Nigeria, Adegboyega Oladipo, and Nepal, Manoj Pradhan, are also busy doing what they can in their work places too.

If the idea of becoming a Champion appeals to you, why don't you get in touch? We are looking to expand the network and do even more to raise the profile of the Society at the local level.

You don't need any special skills to become a Champion. Enthusiasm for your subject material and a willingness to share it are all we ask. In return, we will provide you with the necessary resources, training and support to undertake your Champions role successfully. UK-based Champions will be invited to a Champions Day in London – where we bring all the Champions together for a day to share experiences and learn from each other's successes (and near misses!). Plus, you will receive free Society membership for the duration of your Championship. Becoming a Champion will help enhance your CV and bring you into contact with other members who could also help progress your career and professional development.

Paul Easton
Acting Head of Membership Services

*Contact Paul, **p.easton@sgm.ac.uk**, if you would like to know more about becoming a Champion.*

Outreach

Public engagement: antimicrobial resistance discussion panel

For the second time, our education and outreach team joined up with the Biochemical Society to deliver a public engagement panel discussion on antimicrobial resistance (AMR).

From left to right Paul Hoskisson, Caroline Barker, Laura McCaughey and Ian Harvey attending the AMR public engagement event in Cambridge.

The first event, held in conjunction with the European Congress on Biotechnology in Edinburgh in July was standing room only, with a good mixture of congress delegates and the general public. This time, a further 75 members of the public joined us at Hills Road College in Cambridge in November for an evening discussing AMR. It was held the day after European Antibiotic Awareness Day, so everyone who came had seen many relevant stories in the media beforehand.

The evening started with our three panellists each giving a short presentation. The Head of the Society for General Microbiology's Communication Committee, Dr Paul Hoskisson, gave a great potted history of antibiotics, what resistance is, our current position and what could happen in the future if too little action is taken. Laura McCaughey from the University of Glasgow explained the science behind antibiotic resistance, how resistance spreads and how resistant bacteria spread. Our final speaker was clinician Dr Caroline Barker from the University of East Anglia, who gave some interesting examples of what happens in a GP's surgery, and about the decisions we all make when using antibiotics.

After the presentations the floor was opened up for questions and discussion. The audience were engaged, with almost everyone putting their hand up and the organisers were sitting on the edge of their seats keen to interact and discuss. The questions were wide-reaching, and included asking if antibiotic resistance is inevitable, what individuals can do, why antibiotics are mis-prescribed, the future of phage therapy and even whether we should be looking for novel antibiotics in crocodile blood! Each audience member took away an information booklet and hopefully these very important conversations will be continued with their friends and families.

> The speakers were excellent and the whole evening was a great success. I've spoken to several [attendees] today and all were very appreciative and complimentary.

We would like to thank Society for General Microbiology school member Ian Harvey of Hills Road College for his support in setting up this event and for being an invaluable helper on the night. We would also like to extend thanks to our three speakers, Dr Paul Hoskisson, Laura McCaughey and Dr Caroline Barker, for giving up their time and being such engaging panellists. As we continue our partnership with the Education team at the Biochemical Society, more panel discussions will be organised in 2015 throughout the UK.

> As a teacher of sixth formers, the challenge of antibiotic resistance is going to be a real factor in the lives of my pupils. Twenty of my students were in the audience and the feedback from them has been very positive and appreciative of the opportunity. Many of them will be going to university to study a biological or medical course and who knows, maybe some of them have been inspired to directly contribute to tackling the future challenges of antibiotic resistance.

Theresa Hudson
Education and Outreach Officer
t.hudson@sgm.ac.uk

Obituary

John Postgate.

Professor John Postgate 1922–2014

Professor John Raymond Postgate FRS died, aged 92, on 22 October 2014, after a short illness. Postgate had three main passions – his family, science and playing traditional jazz on his cornet.

After obtaining a first class degree in Chemistry from Balliol College, Oxford he began his microbiological research studying bacterial resistance to sulfonamide drugs under the supervision of D. D. Woods. He then moved to the Chemical Research Laboratory at Teddington working with K. R. Butlin on sulfate-reducing bacteria. There his most startling and influential finding was that these, strictly anaerobic, bacteria contained cytochrome c_3. Cytochromes had previously been thought to be confined to aerobic organisms.

In 1958, when Butlin's group was disbanded, John moved to the Microbial Research Establishment at Porton, to study fundamental aspects of the survival of bacteria.

In 1962 he took leave-of-absence in the USA for seven months. On his way home he met Joseph Chatt FRS in New York. Chatt was Director-designate of a new Agricultural Research Council-funded unit for the study of biological nitrogen fixation. Bacterial growth experiments indicated that the metal molybdenum might be involved and Chatt, a distinguished inorganic chemist, would direct chemical attempts to emulate the process. John agreed to act as Assistant Director and to lead the complementary biological studies. Initially, these focused on the biochemistry, microbiology and physiology of free-living nitrogen-fixers. However, in 1969 Postgate put a student, Ray Dixon, onto the study of the genetics of nitrogen fixation. They managed to transfer the genes encoding the nitrogen-fixing ability to *Escherichia coli* that had never had that ability. The promise of the genetic approach led to an expansion of the Unit's programme and in 1980 John became the Director.

John was made a Fellow of the Royal Society in 1977 and received many other awards. He retired in 1987, published over 200 research publications, and many more "popular" articles and several books. These included *A Plain Man's Guide to Jazz* and *Microbes and Man*, first published in 1969, widely translated, and remaining in print in its 4th edition.

He lost his wife Mary in 2008 but leaves three daughters and seven grandchildren.

Barry Smith
Head of the Nitrogen Fixation Laboratory from 1987 until 2000.

Schoolzone

Schoolchildren learning about yeast while taking part in the balloon experiment. woodleywonderworks

Microbiology in Schools Fund

One of the many grants the Society offers is the Microbiology in Schools Fund. Launched in 2014, the grant offers school members up to £1,000 for any microbiology-based activity for their pupils. The scope is very broad, anything related to microbiology is considered. So with this much choice, how do you choose what to do?

Some possible ideas:

- **Run a practical workshop** for primary schools based around hand washing, the power of yeast to blow up balloons, or building models of microbes. More advanced workshops for secondary schools could include microscopy experiments, culturing microbes from the environment, or creating debate cards to discuss important ethical considerations around microbiology.
- **Set up a microbiology club** in your school – using the fund to buy equipment that can be reused with each new school year.
- **Visit a place of interest** that is important to the history of microbiology or relates to current research.
- **Invite an external speaker** to talk to a group of students and facilitate a discussion on a microbiological topic.
- **A group of pupils could visit a local university or institution** to do some practical work, or have a tour of a lab and discuss the research that takes place there.

Some of our funded projects are large in scale. The fund can go towards funding a big event or it can be a small project, working with just one group of pupils. The limit really is your imagination!

Case study:

Petroc College, Devon

Petroc College in Devon successfully applied for the Microbiology in Schools Fund to set up a microbiology after-school club, the *Microbug Club*. The six-week club was attended by 17 pupils; all enthusiastic about learning microbiology. The club had many aims, including understanding the basics of microbiology: how important microbes are to life on Earth, the importance of hand washing and their role in biodegradation. The sessions also had the benefit of allowing the pupils to learn the importance of the scientific method.

A lot of the work aligned with the national curriculum, but, as it was an after-school club, it was intended to be fun, interactive and relevant to the pupils. The sessions were a great mixture of simple experiments, with speakers coming in at the start of each session, and activities such as crosswords and games. The pupils were engaged and enjoyed the hands on activities, and on the feedback forms the only suggestion for improvement was to have even more time for experiments.

> **I learned very interesting facts about microbes and we made snot! *Microbug Club* is amazing!**

Grant deadlines

The Microbiology in Schools Fund supports microbiology-related teaching projects by Schools members.

Closing dates for applications are **15 March** and **15 September** for activities taking place after **1 May** and **1 November**, respectively.

Grants of up to £1,000 are available to support microbiology teaching initiatives and events. So long as it is relevant to microbiology, we are interested in hearing from you! The fund is available to School Corporate or School Representative members. For more information or to discuss potential projects and opportunities, please contact either our Education and Outreach Team (**t.hudson@sgm.ac.uk**) or our Grants Team (**m.fernandes@sgm.ac.uk**), or look on our website: **http://microb.io/182prpR**.

Theresa Hudson
Education and Outreach Officer

Small World Initiative

On European Antibiotic Awareness Day in November 2014, the Society launched the **Small World Initiative**, which will give the general public, students and educators the opportunity to work with scientists as part of a global initiative to discover new antibiotics from soil bacteria.

The Initiative, first organised by Yale University, is an innovative and authentic research project, which uses crowdsourcing to discover new antibiotics from soil bacteria. It is now running in higher education institutions across the USA. It is hoped that exposing their undergraduates to research experiences will inspire them to major in a science-based degree. The Society is taking the project further by including school pupils and the general public (citizen science).

Undergraduate and school students will analyse their samples for antimicrobial compounds and investigate any potential compounds that are found. The Small World Initiative will run in undergraduate courses at 10 universities and a further five universities partnered with a school. A series of "pop-up" events will also take place at locations across the UK, giving the public the opportunity to submit their soil samples, which they can then make observations and comment on as they are tracked online through the analysis process.

Both the undergraduate programme and the schools and universities programme are now open for applications. Applications for the PhD studentship will open shortly. If you are interested, please see details at **http://www.sgm.ac.uk/smallworld** or contact our Education and Outreach Team on **smallworld@sgm.ac.uk** or **0207 685 2682**.

Soil samples will be taken as part of this citizen science project. juhide / iStock / Thinkstock

Conferences

Annual Conference

30 March–2 April, ICC, Birmingham, UK

The Conference will feature a range of scientific sessions, including:

- Antimicrobial resistance
- Clostridia – the good, the bad and the beautiful
- Microbes in space
- Microbial archaeology
- Microbiome in health and disease
- Mitochondria and related organelles in microbial eukaryotes
- Natural and unnatural virus evolution
- Sensory perception in microbes: coping with change
- The building blocks of microbial evolution
- The rhizobiome
- Virus assembly – let's get together and get out of here

Virology workshops will cover:

- Antivirals and vaccines
- Clinical virology
- Evolution and virus populations
- Gene expression and replication
- Innate immunity
- Pathogenesis
- Plant virology

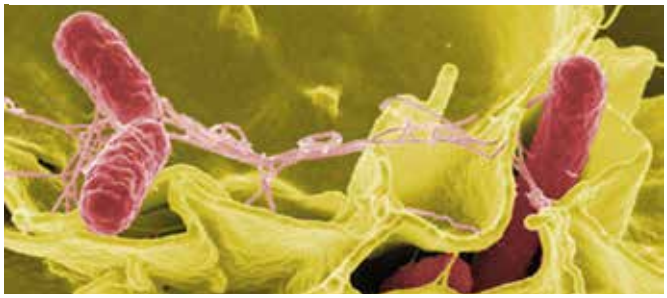
In addition, the conference will feature a number of prokaryotic forums that will cover four broad areas of prokaryote biology, including infection, genetics, cell biology and environmental microbiology. All sessions are listed on the Society's website: **www.sgm.ac.uk/conferences**

Conference snapshot: Microbes in space session

Wednesday 1 April

The vast and hostile environment of outer space represents a major challenge to all forms of life; exposure to microgravity, extremes of temperature, galactic cosmic rays and solar energetic particles within a vacuum is guaranteed. However, experiments performed aboard Earth-orbiting spacecraft indicate that some micro-organisms are able to survive outside these platforms for lengthy periods of time and there is compelling evidence that many microbes respond to the unique environment associated with spaceflight in ways that shed light on their adaptive behaviour.

Currently, the primary platform for conducting research into the response of microbes to the space environment is the International Space Station, a facility supporting a number of



***Salmonella* invading cultured human cells.** Rocky Mountain Laboratories, NIAID, NIH

2015

Grants

Grants are available to eligible members:

- **Society Conference Grants** for Postgraduate and Full Concessionary members. Full Concessionary members must be postdocs, technicians or retired.
- **Inclusion Grants** for Full, Full Concessionary or Postgraduate Members with cogent reasons for applying for the grant.
- **Undergraduate Conference Grants** for Undergraduate members who have data to present.

Apply online: **www.sgm.ac.uk/grants**

well-equipped laboratories that has been continuously manned and able to conduct scientific experiments since 2000. Following a UK governmental decision in November 2012 to subscribe to the European Space Agency's Programme for Life and Physical Sciences, it was recently announced that Major Tim Peake, the first Briton to be selected as an astronaut by the European Space Agency, will spend time on the International Space Station in late 2015. He will undertake scientific research with the potential to include microbiological experiments on his agenda.

The session will present Major Peake's plans and review the current state of knowledge of the behaviour of microbes in real and simulated space environments.

Networking workshop and supper for early-career delegates

Sunday 29 March

The workshop brings together early-career delegates before the start of the conference. Delegates who attend will get to know some friendly faces and pick up tips and advice on making the most of conference networking opportunities.

The session costs **£12**, includes supper and can be booked when registering to attend the conference. Space is limited so do book early.

Irish Division Meeting 2015

17–19 June
University of Galway, Ireland

The Irish Division Meeting 2015 is titled Microbial Interfaces and will take place at the University of Galway, Ireland.
Topics will include:

- The host–microbe interface
- Health from the environment
- Microbiology for engineering and the bioeconomy
- The pathogen–device interface
- Ecosystems microbiology

Abstracts can be submitted online:
http://microb.io/1uSPCqI

Quadrangle in Galway.
Elzbieta Sekowska / iStock / ThinkStock

Membership Q&A

Kerstin Voelz

Where are you currently based?

I am currently based at the Institute of Microbiology and Infection at the School of Biosciences, University of Birmingham. I joined as a postdoctoral researcher in 2010 and was appointed to my current position as Lecturer in Eukaryotic Microbiology in June this year.

What is your area of specialism?

In broad terms, infectious disease and eukaryotic microbiology.

And more specifically?

My lab is interested in host–pathogen interactions, particularly in the interaction between fungal pathogens and the innate immune system. We focus on a fungal infection called mucormycosis and want to understand how the host immune system tries to fight off the fungus while, at the same time, the fungus manipulates the host immune response to its advantage. We are using zebrafish larvae as an exciting new live whole animal model system to investigate this interaction in real-time.

Tell us about your education to date

I went to school in Germany. I always enjoyed maths and physics. Though, initially, I didn't like biology very much. However, that changed when we started discussing more aspects of cellular and molecular biology and also microbiology at secondary school. Hence, I found it very difficult to decide which university degree to pursue. Looking into the timetables, it seemed that biology had a great mix of STEM subjects and so I decided to do an undergraduate degree in Biology at the Friedrich Schiller University in Jena, Germany. I then moved to the UK in 2007 to do my PhD in host–pathogen interactions under the supervision of Professor Robin May at the University of Birmingham.

Where did your interest in microbiology come from?

It developed over time, I guess. There was a strong focus on microbiology in my undergraduate studies and I very much enjoyed the lectures and practical classes in this context. My final year undergraduate thesis was also on a microbiological topic. All together it strengthened my interest and encouraged me to further develop my career in microbiology.

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

In the past couple of years, becoming independent was probably one of the biggest challenges. What really helped me were persistence, initiative and the guts to take unexpected opportunities. For example, about a year ago, I was talking to a colleague at a conference about my research ideas and we discussed a research visit to his lab in the USA so that I could learn how to use a new model system, the zebrafish larvae. All this came very unexpectedly, but at the same time I thought – this is an amazing opportunity. I had to use my initiative to find financial support for the research visit – part of which I received through the Society's President's Fund (now the Research Visit Grants scheme). It all paid off; I had a great time and the work I conducted during my visit laid the foundation for my own research group.

The current challenges are more about juggling teaching versus research and the responsibilities that come with having my own research group. It helps a lot that I had already been teaching over the past few years and enjoy the contact with students. So that is not really a problem. I find the responsibility towards my group much more challenging. The current job market is incredibly competitive and students struggle to find PhDs and/or employment thereafter. I often ask myself: how can I support them best so that their hopes and expectations are being fulfilled? I try to be sympathetic and reassuring. It helps that I have an understanding and supportive mentor to discuss these aspects with.

What is the best part about "doing science"?

"The Friday Evening Experiment" – by that I mean those experiments you wonder if they are worth doing because they are unlikely to work. However, your curiosity convinces you to "just give it a go" and you get an exciting and unexpected result that opens up so many new questions to investigate.

Who is your role model?

My PhD and postdoc supervisor, Professor Robin May. I am very grateful to have been trained under his supervision and to have been introduced to his collaborative, open and friendly approach to science. It made me believe that everyone working together

leads to the best results and in the context of science can enable big progress. For example, exchanging research findings with colleagues within and outside your own field can put your results in a very different light and open up new avenues.

What do you do to relax?

I climb. I sometimes find it difficult to switch off as my mind is always buzzing. I am constantly trying to figure out things, e.g. finding new ways to answer a scientific question, developing new research ideas. Climbing helps me to switch off by focusing my mind on something completely different. At the same time it can be physically very demanding and a way of releasing any frustration.

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

I love 1980s music. Being on a desert island, this cheesy kind of music would be uplifting. As for the luxury item, I would probably take a fully equipped boat – that way I could always attempt to make my way back. Something similar to Craig Venter's *Sorcerer II* would be great. It wouldn't matter how long I take to get back as I could do some research on-board in the meantime.

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

I am trained in how to deal with potential polar bear attacks. A few years back I went up to a research station on the arctic island Svalbard (or Spitsbergen). There is always a chance, though very small, of encountering a polar bear while being out on fieldwork. Hence, researchers need to do a "polar bear and weapon for protection" course.

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

I would own and work in a little café in the countryside – I love baking cakes.

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

Review

Phage Therapy: Current Research and Applications

Edited by J. Borysowski, R. Międzybrodzki & A. Górski

Caister Academic Press (2014)

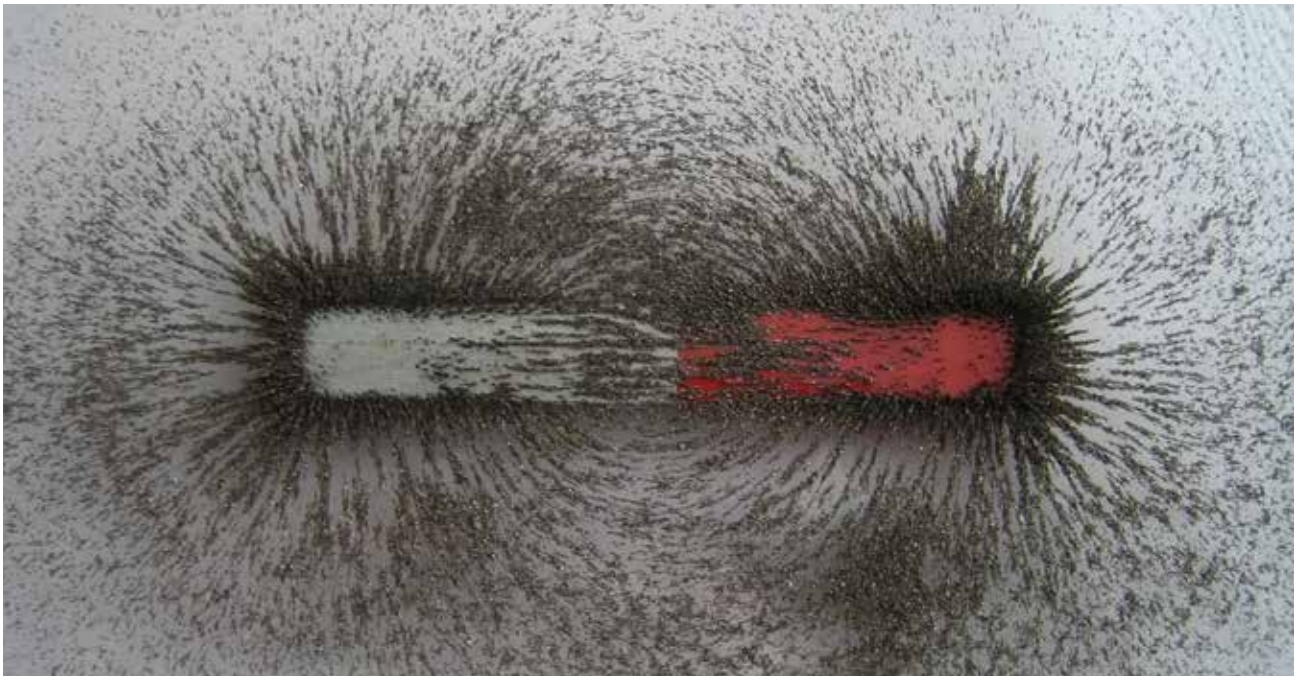
£180.00 ISBN 978-1908230409

Viruses have been reported to infect numerous phyla of bacteria, including many bacteria that cause human disease. Replication of most of these bacterial viruses results in destruction of the host cell by lysis. This is why these viruses were originally termed "bacteriophages" – bacterial "eaters". Unlike mammalian cells, bacteria possess rigid cell walls so these bacteriophages have had to evolve efficient means to lyse their host cells in order to facilitate the exit of progeny bacteriophages, allowing them to infect new hosts. Shortly after their discovery, it was suggested that bacteriophages might be exploited for the treatment of bacterial diseases and numerous studies have been carried out, particularly in Eastern Europe. The discovery and use of "small molecule" antibiotics has taken the focus away from the development of bacteriophages; however, with the ever-increasing problem of resistance to conventional antibiotics, interest in the potential of bacteriophages has grown. This book describes the characteristics of bacteriophages, more theoretical aspects of their use as antibacterial agents, the need to select the most appropriate one and the issues of the resistance of bacteria to them. It also presents the intellectual and regulatory issues, the use of animal models of human disease and the results of clinical trials. In addition, this book discusses the modification of bacteriophages so that they kill bacteria without lysing them and releasing toxic bacterial products into the body, thus rendering them safer, to extend their host range to a larger number of pathogens and to use them as delivery vehicles for therapeutic genes.

The issue of resistance to conventional antibiotics should encourage the development of novel treatments for bacterial infection and the use of bacteriophages that have evolved over millions of years to kill their hosts is an obvious choice. This book effectively presents the current situation and points us to future developments. The book will be of interest to those in the fields of medicine, infectious disease and antimicrobial drug development, whether they be students or experienced researchers or practitioners. Unfortunately, the £180 purchase price means that it is only likely to be within the budget of institutions.

Christopher Ring
Middlesex University

Magnetic field shown by iron filings. Dayna Mason



Best of the blog

Before we get too far into another new year, it's time to cast our gaze back over the last few months to look at some of the great posts we've had on the Society's blog, Microbe Post. We spent some time with Fred McMahon, a PhD student at Maynooth University, who told us all about the exploding microscopic mites that live on your face. Not an obvious microbiology story at first glance, but Fred has been researching the bacteria that live within the mites, which may be the root cause of the skin condition rosacea (**http://microb.io/1xvb9a0**).

Elsewhere, we spoke to Dr Zachery Oestreicher from Kanazawa University, who has been investigating a yet to be named new species of aquatic bacterium that uses the Earth's magnetic field to avoid making any horizontal movement – these microbes only move up and down, looking to find the optimum oxygen concentration in the water they're found in (**http://microb.io/1wdi9c4**).

Staying with the aquatic theme, we learnt all about attempts by researchers at the Massachusetts Institute of Technology to create super-sticky adhesives, by mixing the glues produced by *Escherichia coli* and the Mediterranean mussel. Ultimately, the team are hoping to produce enhanced adhesives that can be used during surgery, or self-repairing substances (**http://microb.io/1xE6kfv**).

In 1877, Louis Pasteur submitted his report *Charbon et septicémie* (*Anthrax and septicaemia*) to the French Academy of Sciences, in which he summarised and dissected existing research about anthrax. We spoke to Dr Keith Turner, from the University of Texas at Austin, who studied a translation of the document to look at how it resonates with modern microbiology practices (**http://microb.io/1sprznk**).

Finally in this roundup, we learnt about the ability of probiotics to prevent antibiotic-related infections. Specifically, a probiotic drink containing particular strains of *Bacillus subtilis* has shown promise at reducing levels of antibiotic-associated diarrhoea (AAD), which can be a significant problem – particularly in a healthcare setting. In this post, we spoke to Dr Iryna Sorokulova from Auburn University, Alabama, who organised a double-blind, placebo-controlled trial and showed that Biosporin, a probiotic approved for clinical use in Russia and Ukraine appears to significantly lower levels of AAD (**http://microb.io/1x3zQx5**).

Benjamin Thompson
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Comment

Ebola virus disease – a challenging situation

Veena Rodrigues & Anne Swift

Ebola virus disease (EVD) is a viral haemorrhagic fever caused by infection with Ebola virus, a member of the *Filoviridae* family. EVD is a zoonosis, a disease transmitted to humans from animals, with a natural reservoir probably in fruit bats.

Ebola in Guinea. European Commission DG ECHO

The virus is usually introduced to humans through close contact with blood, secretions, organs or other bodily fluids of infected animals such as fruit bats, monkeys and antelope. The incubation period of EVD ranges from 2 to 21 days and cases are infectious only after they start showing symptoms. These are a sudden onset of fever, fatigue, muscle pain, headache and sore throat, followed by vomiting, diarrhoea, rash, and in many cases, internal and external bleeding.

Ebola spreads through human-to-human transmission via direct contact through broken skin or mucous membranes with the blood, secretions, organs or other bodily fluids of infected people, and with surfaces and materials like contaminated bedding and clothing. Healthcare workers can get infected while treating patients when infection control precautions are not practiced strictly. Burial ceremonies in which mourners have direct contact with the body of the deceased person can also play a role in the transmission of Ebola. People remain infectious as long as their blood and body fluids, including semen and breast milk, contain the virus.

The lack of previous exposure to the virus facilitates rapid spread. Between March and November 2014, there have been over 17,000 cases and 6,000 deaths from EVD across affected countries in West Africa, mainly Liberia, Guinea and Sierra Leone. The case fatality in this outbreak is estimated at around 50% but the figures are likely to be underestimates as it is likely that not all cases nor all EVD deaths are identified and reported. There is no treatment, apart from supportive care to replenish lost fluids and blood, and currently (Dec 2014) no vaccine is available.

Prevention and control

Control measures include case management, surveillance and contact tracing, efficient laboratory services, safe burials and community engagement. Raising awareness of risk factors and protective measures that individuals can take is key to reducing human transmission in local communities. Within healthcare settings, standard precautions such as hand hygiene, respiratory hygiene, use of personal protective equipment, safe injection practices and safe burial practices are required when caring for patients, regardless of their presumed diagnosis. Healthcare workers caring for patients with suspected or confirmed EVD need to take extra precautions to prevent contact with infective material. Laboratory workers are also at risk and samples should be handled by trained staff and processed in suitably equipped laboratories.

International response to Ebola

It took several months for the current outbreak to be recognised as a public health emergency of international concern. Preparedness is key – where there is risk of cases being imported into unaffected countries, with adequate levels of preparedness, the disease can be contained before it develops into large outbreaks, as demonstrated in Nigeria and Senegal. The other neighbouring African countries have now been prioritised for technical assistance on preparedness from specialist international teams. Away from Africa, several countries are also undergoing preparedness checks and exercises to test levels of readiness to respond if necessary. Enhanced screening at key UK ports is expected to ensure that travellers arriving from infected countries know the symptoms and how to access healthcare services rapidly. In October, several USA states announced quarantining measures for healthcare workers returning to the USA from West Africa to ensure the safety of the local population in the wake of a doctor returning from Guinea to New York developing the disease. However, restrictive measures such as these only serve to discourage volunteering in West Africa at a time when international help is most needed.

In response to the call for international aid, the UK Government is assisting in preventative, healthcare and humanitarian efforts, through provision of financial support, troops and staff deployment. However, Médecins Sans Frontières warns that the international response to the Ebola crisis has been slow and uneven leaving local people, national governments and non-governmental organisations to do most of the practical, hands-on work.

Consequences of the outbreak

The scale of the outbreak has put a huge strain on the already weak healthcare infrastructure in these countries and is crippling communities with a devastating impact on the local economy, education, food security and livelihoods. The focus on Ebola has led to a shift of attention away from ongoing healthcare issues and treatable diseases such as diarrhoea, respiratory infections and malaria which contribute to significant morbidity and mortality. Fear of contracting the disease from other patients is preventing people from seeking healthcare but existing medical facilities are also overwhelmed and under-resourced, many health facilities are closed and some are no longer dealing with non-Ebola cases.

What next?

Testing for three experimental Ebola treatments is expected to begin soon in West Africa. These are: brincidofovir, an antiviral developed for use against cytomegalovirus or adenovirus infections; favipiravir, developed for use against influenza; and convalescent whole blood and plasma treatment, giving antibody-containing blood or plasma from Ebola survivors to infected patients to boost survival chances.

Efficacy trials of Ebola vaccines have also been proposed. Two recombinant vector vaccines, ChAd3-ZEBOV (US National Institutes of Health and GlaxoSmithKline) and rVSV-Ebov (Public Health Agency of Canada and NewLink) are currently undergoing phase 1 trials. It is a hoped that a new vaccine becomes available by mid-2015.

Veena Rodrigues

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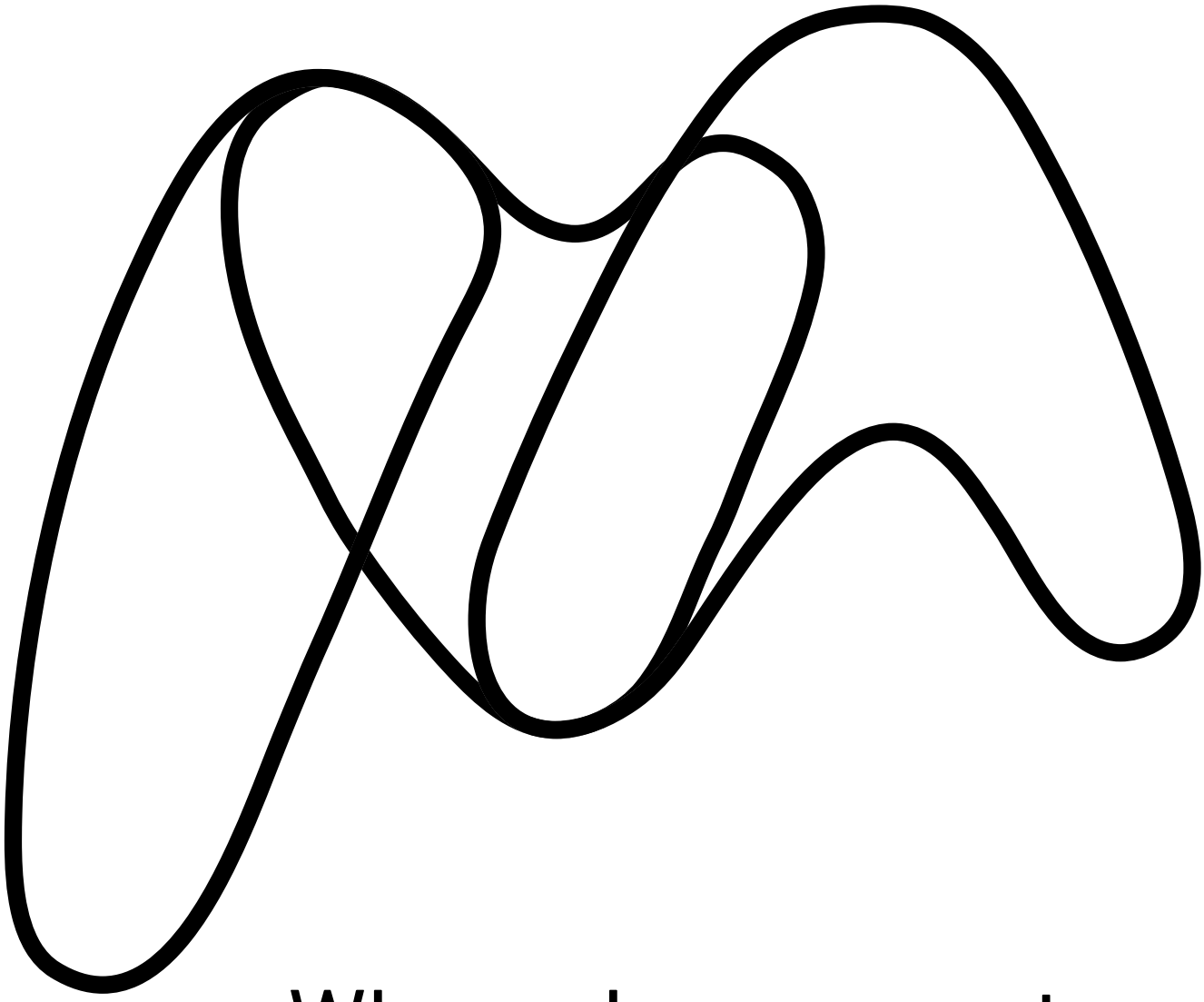
Further reading

Ebola virus disease. World Health Organization. **www.who.int/csr/disease/ebola/en/**. *Last accessed 16 December 2014.*

Ebola resource centre. *The Lancet*. **http://ebola.thelancet.com/research**. *Last accessed 16 December 2014.*



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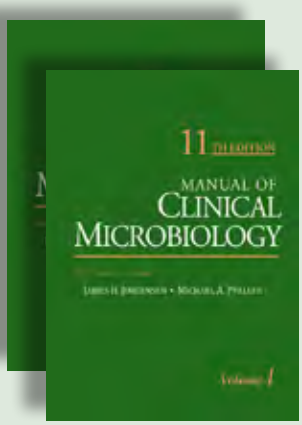

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James H. Jorgensen, University of Texas Health Science Center, USA, and
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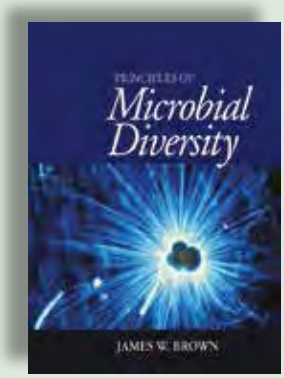
PRINCIPLES OF MICROBIAL DIVERSITY



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James W. Brown, North Carolina State University, USA

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