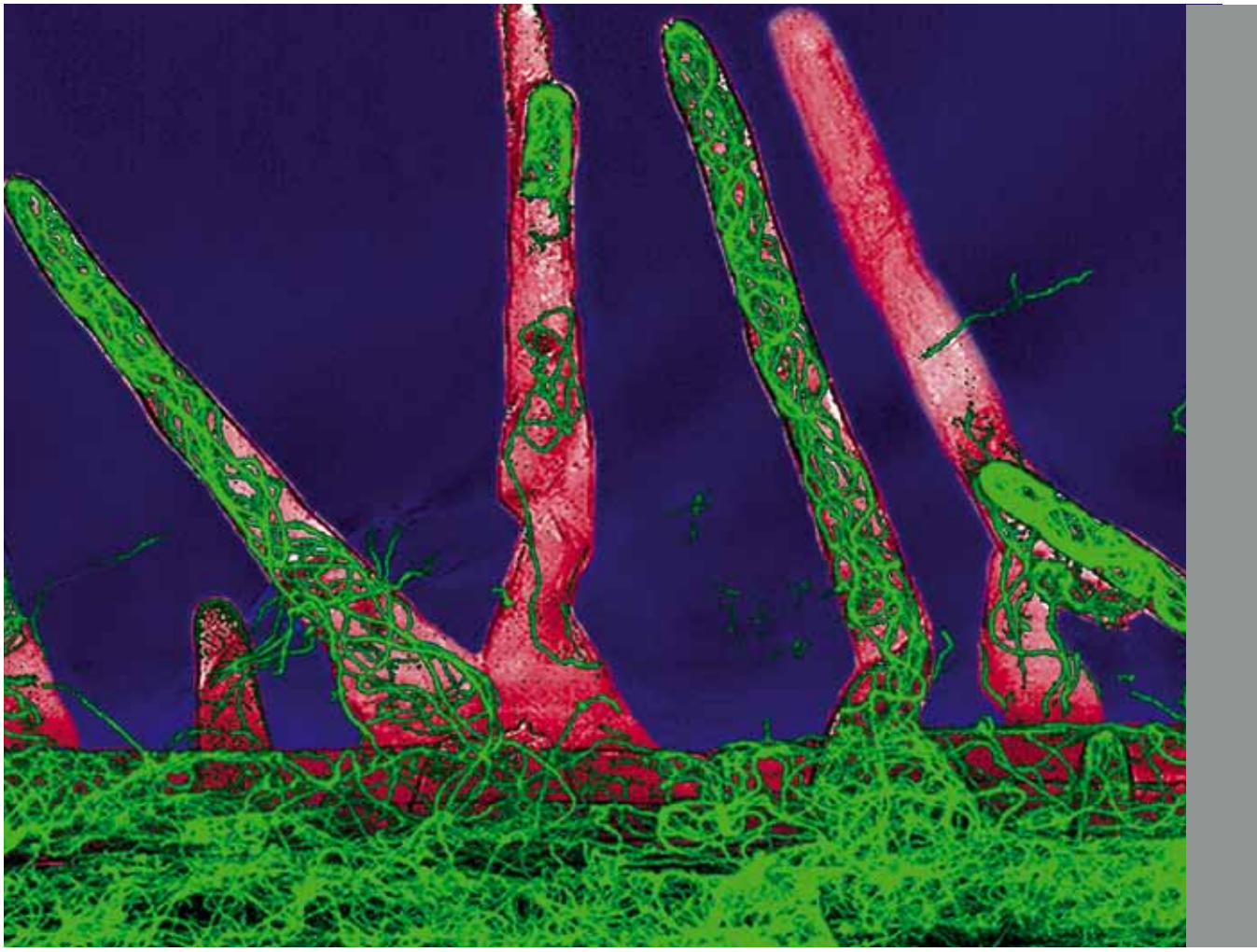
microbiologytoday

vol**34** | may**07**
quarterly
magazine of
the society
for general
microbiology



actinobacteria

streptomyces – not just antibiotics

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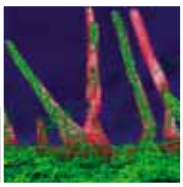

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Cover image False colour image of GFP-tagged *Streptomyces turgidiscabies* colonizing radish seedling root hair cells. *Simon Moll & Kent Loeffler*

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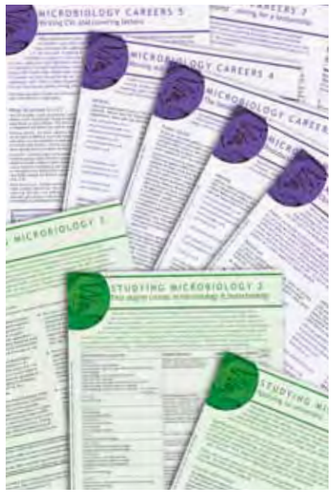
Regular feature images pp. 55 *SGM*; 82, 85, 97 *Comstock / Jupiter Images*; 89, 91 *Stockbyte*; 99 *Digital Vision/Getty*

 ISSN 1464-0570 Printed by Latimer Trend & Company Ltd, Plymouth, UK

Promoting microbiology

A poster with a difference

We have produced a colourful and striking poster to raise the profile of microbiology. It contains high quality images of a range of micro-organisms and some descriptive text, plus the relevant contact details to obtain further information from the SGM. The poster will liven up your lab wall, but is also intended for distribution to schools and colleges.



Careers matters

Our factsheets to promote microbiology degree courses and careers after graduation have been updated and printed in a new format. The first set, aimed at school students, is called *Studying Microbiology* and includes three leaflets: (1) Applying to university; (2) First degree courses in microbiology & biotechnology; and (3) Vacation work. The second set describes various career paths for graduates. Under the heading *Microbiology Careers*, it features (1) Options after graduation; (2) Postdoctoral research; (3) The healthcare sector; (4) Moving out of the laboratory; (5) Writing CVs and covering letters; (6) Job interviews; and (7) Postdoc and beyond – aiming for a lectureship.

All of the factsheets are packed with useful practical information and lists of further resources. You can see them online at **www.biocareers.org.uk**

Copies of these resources are available from the External Relations Office. Email **y.taylor@sgm.ac.uk**

JGV back archive now online!

The entire back content of *JGV*, from volume 1 issue 1 (January 1967), is now available free online at HighWire at **http://vir.sgmjournals.org**

The project involved scanning a total of 73,378 pages and constructing full text PDFs for 8,716 articles. This fills the gap to January 1997, when 'regular' online content begins. Full text searching is available from the entire archive. Work continues on mounting the back archives of *Microbiology*, *Journal of Medical Microbiology* and *International Journal of Systematic and Evolutionary Microbiology*.

Annual General Meeting 2007

The AGM of the Society will be held on **Tuesday, 4 September 2007** at the Society Meeting at the University of Edinburgh. Agenda papers, including reports from Officers and Group Conveners, the Accounts of the Society for 2006 and a Resolution to amend the Memorandum of Association will be circulated with the August issue of *Microbiology Today*.

SGM's charitable status

The Society has enjoyed the benefits of charitable status since the 1950s, through registration with the Charity Commission for England and Wales. Historically, there was no Scottish equivalent of the Charity Commission: charitable status north of the border was approved by the Inland Revenue. Recently, however, with the advent of the Scottish Parliament and Executive, moves have been made to introduce a regulatory regime broadly similar to that in England and Wales, and in December 2003 the Office of the Scottish Charity Regulator (OSCR) was formally launched. Since then it has been moving forward the process of registering Scottish charities.

Most charities registered in England and Wales are able to have a certain level of activities in Scotland without the need for registration there. However, the advice received was that the scale of SGM's meetings in Scotland – not least because Edinburgh is a very popular venue for our events – indicated that registration was required. Accordingly, an application was made to OSCR, giving full details of the Society's objectives, activities and finances. The application has been approved, subject to a minor amendment to one of the Society's governing documents, the Memorandum of Association. This needs to include an additional clause, to the effect that the Society's charitable purpose is regarded as charitable both in the law of England and Wales, and the law of Scotland. A special resolution to this effect will be put to the Annual General Meeting on 4 September – appropriately in Edinburgh.

***Ron Fraser**, Executive Secretary*

SGM Council

February Meeting Highlights

European virology

Council agreed to proposals to support both the European Society for Clinical Virology and the European Virology Forum in their activities.

SGM Prize Lectures

Council discussed some proposed revisions of the SGM Prize Lecture rules. They decided that self-nominations will no longer be permitted and that some existing restrictions on eligibility for the Fleming Prize lecture will be removed. Details of the revised rules are available on the SGM website. Nominations for the 2008 SGM Prize Lectures are now invited (see p. 58).

SGM journals

Council was informed of developments in scientific journal publishing which it continues to monitor carefully, in particular with regard to the issue of 'open access'.

SGM finances

Council members heard that the audit of the SGM 2006 accounts had successfully taken place. The financial situation of the Society at the end of the year was healthy.

FIS Conference 2006

SGM provided the organizing secretariat for the 2006 Conference of the Federation of Infection Societies (FIS), at the request of the British Infection Society. The conference took place in Cardiff in November 2006, was well attended and very successful. In 2007 SGM will again provide the organizing secretariat for the FIS conference as well as acting as the host scientific society.

Meetings

The Scientific Meetings Officer noted that the working party to review the SGM meetings and group structure would be meeting at the end of February to start its deliberations. It is hoped to make recommendations for any changes to June Council.

MP to visit to Marlborough House

Sue Assinder informed Council that the shadow Minister for Energy, Science and Technology, Charles Hendry MP, will visit the SGM offices at Marlborough House in April to learn more about the Society's work.

***Ulrich Desselberger**, General Secretary*

The longest biological experiment on record?

Member **Dr Richard Jackson** much enjoyed Dr Jean Lindenmann's contribution to the February issue of *Microbiology Today* on the serial passaging of the rabies virus in Saigon from 1891 to 1953. In suggesting that this must be one of the longest biological experiments on record, he feels sure that Dr Lindenmann will have expected, and perhaps hoped, that the claim would be challenged.

'*Since I worked for 10 years of my career as a soil microbiologist at Rothamsted Experimental Station, I immediately thought of the classical field experiments which were initiated by John Lawes and Henry Gilbert on Lawes estate, now the site of Rothamsted. The most famous of these field experiments is Broadbalk, a field that was divided into strips that receive either no or differing fertilizer treatments. This experiment was started in 1843 and is still continuing with only a few changes during its 164 years. Regular assessments are made of such parameters as crop yield, soil chemistry and microbiology. I look forward to hearing of other experiments that have continued for more than 100 years.*'

Can any reader rise to this challenge? If so, email **mtoday@sgm.ac.uk**

Federation of Infection Societies (FIS) Conference 2007

28–30 November 2007, Cardiff City Hall

This year the SGM is hosting and organizing the FIS annual meeting. The event provides a forum for clinical microbiologists and other professionals working on infectious diseases. The varied programme includes plenary sessions, workshops, clinical lessons, case studies, prize lectures, poster walks, social events and a trade exhibition. You can find information on the programme, abstract submission and registration at **www.fis2007.org.uk**

News of Members

Education Officer **Dr Sue Assinder** has taken over as chair of the BioSciences Federation Education Committee.

Edinburgh University has appointed **Professor Dorothy Crawford** as Assistant Principal for the Public Understanding of Medicine. Professor Crawford, who has a chair in medical microbiology, has written a popular book on viruses, *The Invisible Enemy*, and has another book in the pipeline *Deadly Companions – How Microbes Shaped Our History*. In her new role, she will explain the relevance of cutting edge findings at the university to the public. Professor Crawford will also continue her own research career.

The Society notes with regret the death of **Professor Simon Baumberg** (honorary member), **Professor L.I. Pizer** (member since 1984), **Dr J.O. Tobin** (member since 1948) and **Dr A.H. Varnam** (member since 1977).

An obituary of **Dr Tom Flewett**, who died last year, appears on p. 98.

An obituary of **Professor Simon Baumberg** will appear in a future issue of *Microbiology Today*.

Staff news

Congratulations to Public Affairs Administrator **Faye Stokes**, who gave birth to baby Edward on 22 March. He weighed in at a bouncing 8 lbs 12 oz. Mum and baby are doing well.

Welcome to Faye's maternity cover, **Lucy Goodchild**, who is taking on the role of external relations assistant.

Lucy is a graduate in genetics and microbiology from the University of Leeds, but she has also recently successfully completed a master's degree at Imperial College London in the History of Science, Technology and Medicine. She will be helping out with a range of activities, as well as dealing with public affairs administration. Many members will have met Lucy at the Manchester meeting in March, which she helped to staff only a few days after joining the SGM.

Royal Society Summer Exhibition 2007

www.royalsociety.org

The Department of Food Bioscience at the University of Reading has been selected to exhibit at this year's event. From 2 to 5 July, **Professor Bob Rastall**, who is also convener of the SGM's Food & Beverages Group, and his team will be mounting an interactive display entitled *A microbial journey through the gut*. The Summer Exhibition is open to the public and takes place at the Royal Society's premises in Carlton Place Terrace.

Reconciling microbial systematics and genomics

www.asm.org/Academy/index.asp?bid=49252

A new report has been released by the American Academy of Microbiology, focusing on how our understanding of the relationships between different micro-organisms has been fundamentally changed by the advent of genomic sequencing and genetic analysis. The report considers what exactly is the definition of a microbial species, and how should microbiologists be categorizing micro-organisms?

UK State Veterinary Service

www.defra.gov.uk/animalhealth

The State Veterinary Service (SVS), an executive agency of Defra with a central role in preventing, identifying and responding to animal disease in the UK, changed its name to Animal Health on 1 April. The move brings together the SVS, the Dairy Hygiene and Egg Marketing Inspectorates, and the Wildlife Licensing and Registration Service.

2007 ISICR Meeting, Oxford

15–19 September 2007; www.iscir.org

Many SGM members will know that 2007 marks the 50th anniversary of the discovery of interferon by Isaacs and Lindenmann at the NIMR, London. To help celebrate that occasion the 2007 meeting of the International Society for Interferon and Cytokine Research will be held on 16–19 September in Oxford. The main ISICR meeting will be preceded by a special Historical Pre-Meeting on 15 September when some of the interferon pioneers will review the early days of these fascinating cytokines.

Microbiology Today readers should note that to mark this anniversary, cytokines will feature as the theme of the November issue of the magazine.

Grants

New in 2007

Scientific Meetings Travel Grants

This scheme offers members who are early-career scientists limited grants to present their work at scientific meetings. Applicants in the following categories are eligible to apply: postgraduate students, resident and registered for a higher degree in a country in the EU; postdoctoral scientists within 3 years of their first appointment in a country in the EU, graduate scientists within 3 years of their first appointment to a microbiological post in the UK or Republic of Ireland; university lecturers (LA or equivalent) within 3 years of appointment to their first post in the UK or Republic of Ireland.

International schemes

International Development Fund

The fund exists to provide training courses, publications and other assistance to microbiologists in developing countries.

President's Fund for Research Visits

The fund enables early career scientists, as defined in the scheme rules, to visit any other country for 1–3 months to carry out a defined piece of microbiological research. Grants contribute towards travel, subsistence and some consumables.

The Watanabe Book Fund

Members who are permanently resident in a developing country may apply for funding to acquire microbiology books for their libraries. These annual awards are available as a result of a generous donation from Professor T. Watanabe of Japan.

Closing date for these schemes: **21 September 2007**.

SGM has a wide range of grant schemes to support microbiology. See **www.sgm.ac.uk** for details.

Any enquiries should be made to the Grants Office, SGM, Marlborough House, Basingstoke Road, Spencers Wood, Reading RG7 1AG (**t** 0118 988 1821; **f** 0118 988 5656; **e** grants@sgm.ac.uk).

Check out the current schemes, to ensure that you don't miss any deadlines.

Student schemes

Postgraduate Student Meeting Grants

Grants cover travel and accommodation expenses for attendance at ***one*** SGM meeting each year.

Applications for a grant to attend the Edinburgh meeting (3–6 September) must be submitted by **31 August**.

GRADschool Grants

Limited awards to contribute the full course-fees of a UK GRAD national (personal or career development) residential course.

Applicants must be resident and registered for a PhD in the UK. Funds are limited so early application is advised.

Elective grants

These enable UK/Ireland medical, dental or veterinary science undergraduates to work on microbiological research projects in their elective periods.

The second round of applications closes on **21 September 2007**.

Wellcome Trust Arts Awards

www.wellcome.ac.uk/arts

These awards provide funding for projects that bring together any art form and any area of biomedical science. Collaboration is encouraged between professionals from different disciplines, between adults and young people and between experts and the public. There are two levels of funding:

Small–medium projects (up to £30k)
To develop new project ideas, small productions or workshops and new collaborative relationships between artists and scientists.

Large projects (>£30k).
To fund production costs for large-scale arts projects, and to support high-quality, multi-audience, multi-outcome projects.

The awards are part of the Wellcome Trust's Engaging Science programme which funds projects that investigate biomedical science and its social contexts.

Examples of previous projects funded by this scheme can be found on the Wellcome website.

microshorts

Prize Lectures and Awards

A range of prestigious awards is made by the Society in recognition of distinguished contributions to microbiology. Nominations are now sought for the 2008 prize lectures. The award panel will consider the submissions in the autumn and take their recommendations to November Council for approval. The outcome will be announced in the February 2008 issue of *Microbiology Today*. Prize lecture rules and a nomination form are on the SGM website: **www.sgm.ac.uk/about/prize_lectures.cfm**

Fleming Award

This is awarded annually for outstanding research in any branch of microbiology by a young microbiologist in the early stages of his/her career. The winner receives £1,000 and gives a lecture based on his/her work to a Society meeting. The text is usually published in a Society journal.

Marjory Stephenson Prize Lecture

This is the Society's principal prize, awarded biennially for an outstanding contribution of current importance in microbiology. The winner receives £1,000 and gives a lecture on his/her work at a Society meeting. The lecture is usually published in a Society journal.

Peter Wildy Prize for Microbiology Education

This is awarded annually for an outstanding contribution to any area of microbiology education. The winner receives £1,000 and gives a lecture on a topic of his/her choice at a Society meeting.

Completed nomination forms, together with the supporting documents, should be sent to **Dr Ulrich Desselberger**, c/o SGM HQ. The closing date for all nominations is **30 September 2007**.

Undergraduate Microbiology Prizes

The prizes aim to encourage excellence in the study of microbiology by undergraduate students and to promote scholarship in, and awareness of, microbiology in universities. The prizes are awarded annually to the undergraduate student in each qualifying institution who performs best in microbiology in their penultimate year of study for a Bachelor's degree. Each winning student will be awarded £100, a certificate and a free one-year undergraduate membership of the SGM.

One prize is available to each university in the UK and Republic of Ireland offering a degree course with a significant content of microbiology. The university chooses the assessed microbiological work for which the prize is awarded. The submission should be supported by formal marks, not an informal assessment. Winning students should have attained at least 2(I) overall in their degree examinations at the stage at which the award is made.

▲ James Dewar receiving a 2006 SGM Undergrdauate Prize from Dr Alan Wheals. He also won a poster prize for his work at the HPA Porton Down. *Chris Davey*

Universities are now invited to nominate a student for a 2007 SGM Undergraduate Microbiology Prize. Submissions can only be accepted on the form which has been sent to all institutions. The full rules and further copies of the form may be downloaded from the SGM website or obtained from the Grants Office at Marlborough House. The closing date for nominations is **31 August 2007**.

Lucy Goodchild takes a look at some stories that have hit the headlines recently.

Cooksey Review

The House of Commons Science and Technology Committee recently published a report in favour of the majority of Sir David Cooksey's recommendations. The Cooksey Review identifies many strengths of the current research system, pointing out that the UK produces excellent 'basic science', which attracts substantial R&D investment. However, two areas for improvement are suggested: translation (from research idea to product) and implementation (of resulting products). Ultimately, the report outlines the way in which collaborations should be secured to raise the profile of UK health research. Focus is on increasing inter-industry contact and decreasing development costs. The Committee was concerned that allied health research sectors could be overlooked in the new schemes and that, as a result, sectors such as preventive and public health research would suffer. Their main warning was reserved for funding, suggesting that basic research should not be ignored.

www.hm-treasury.gov.uk/media/56F/62/pbr06_cooksey_final_report_636.pdf
www.publications.parliament.uk/pa/cm200607/cmselect/cmsctech/204/204.pdf

Bird 'flu dominates the news

PR Week's Health Watch has revealed that immunology was the most popular subject for journalists in January and February 2007. Almost 49 % of the reports were part of the blanket coverage of the avian influenza outbreak at a Norfolk poultry plant, which included TV images of quarantined and slaughtered turkeys. Questions were raised over biosecurity at the plant and the company's honesty about the transfer of poultry. Hill & Knowlton, the PR company responsible for handling the crisis, relayed the message that products were safe to eat by communicating with consumers, retailers, politicians and the media. Over-communication, they say, is key. Less than 3 weeks after the outbreak was first suspected, 130 redundancies were announced at the plant, due to a 40 % crash in turkey sales.

PR Week 30 March 2007, p. 27

Billions may be affected by wheat fungus

Wheat, the most used food on the planet, is in danger of being devastated by a fungus that was stockpiled as a biological weapon during the cold war. Ug99, a virulent strain of *Puccinia graminis* or black stem rust fungus, has evolved so that no crops are resistant. The fungus spread across Africa and the hardy spores were blown to Yemen in January. It is expected now to spread to Egypt, Turkey, the Middle East and finally to India, where a billion people are dependent on wheat in their diets. Scientists estimate the replacement of crops with resistant wheat will take 5–8 years. Norman Borlaug, who was awarded the Nobel Peace Prize in 1970 for developing resistant wheat, blames complacency after 40 years of rust-free crops for the outbreak.

New Scientist, 7 April 2007, pp. 6–7

Gonorrhoea increasingly resistant to antibiotics

The Gonococcal Resistance to Antimicrobials Surveillance Programme (GRASP) has revealed that resistance to antibiotics is rising. Figures released by the UK HPA in October 2006 show a marked increase in prevalence of the second most common bacterial STI. Resistance to ciprofloxacin increased from 14 % in 2004 to 21.7 % in 2005, and penicillin from 11.4 to 17.9 %. Incidence was highest in homosexual males, rising from 26.2 to 42.4 %. The findings reinforce the need to use condoms and to treat the infection with more effective antibiotics such as ceftriaxone or cefixime. Doctors are urged to forward samples for resistance testing if infection persists.

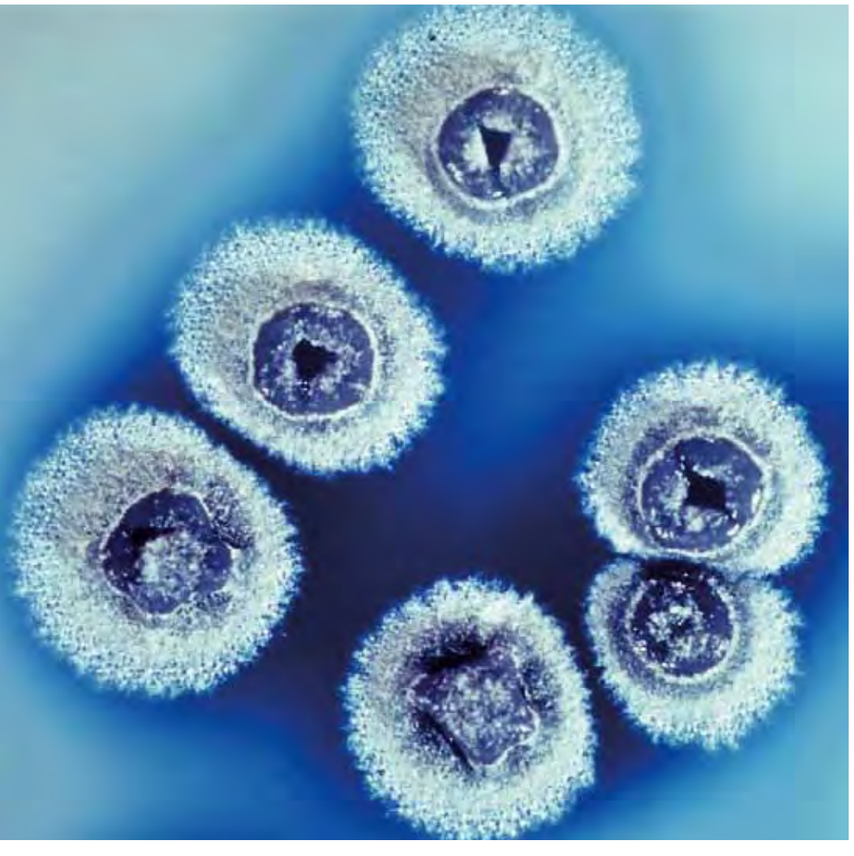
Health Protection Matters, Spring 2007, p. 25

Hepatitis C in the spotlight

PR Week reported that 19 % of all immunology coverage was owing to Dame Anita Roddick's announcement that she has Hepatitis C. The virus is carried in the blood and the six different forms resist propagation in the laboratory, making the development of a vaccine very difficult. Despite this, Japanese researchers have isolated a strain that grows successfully in liver cell lines, which will pave the way to the development of a vaccine. New diagnoses of Hepatitis C have risen from 2,116 in 1996 to 7,580 in 2005, according to HPA figures (December 2006). The biggest problem is the scale of under-diagnosis: in 2003 an estimated 231,000 people were infected. *FaCe It*, the Hepatitis C Awareness Campaign, aims to deal with the rising number of UK cases.

PR Week, 23 March 2007, p. 10
Health Protection Matters, Spring 2007, p. 32.

An introduction to the actinobacteria



From plant pathogen to life-saving antibiotic producer, members of the Actinobacteria are as fascinating as they are diverse, as **David Hopwood** describes.

◀ Fig. 1. A *Streptomyces coelicolor* culture making the blue antibiotic actinorhodin.

▶ Fig. 2. A group of *Streptomyces* strains freshly isolated from soil.

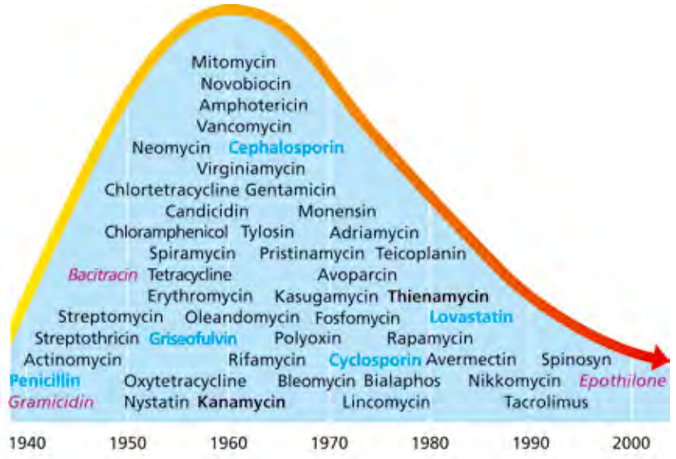
Images reproduced from Hopwood, D.A. (2007), Streptomyces in Nature and Medicine: the Antibiotic Makers *with permission from Oxford University Press.*

Nearly all microbiologists know the name *Streptomyces*, but fewer will recognize Actinobacteria, the group to which it belongs and which is showcased in this issue of *Microbiology Today*. Identified from the 1870s onwards, these organisms confused their discoverers by sharing characteristics of both bacteria and fungi: they grew like moulds as filaments, or at least as wavy, occasionally branching rods, but had the tiny dimensions of bacteria. Naming of the first to be described, *Actinomyces bovis* from cases of lumpy jaw in cattle, laid a false trail (*Actinomyces* means 'ray fungus') while the next two examples, causing leprosy and tuberculosis, came to be called *Mycobacterium* ('fungus bacterium'). Only in the late 1950s was the true position of the actinomycetes revealed by molecular and genetic studies. They are true prokaryotes, forming a distinct branch of the Gram-positive bacteria characterized by a high content of G and C in their DNA compared with the low-G+C staphylococci, streptococci and bacilli, but are no more closely related to the eukaryotic fungi than any other bacterial group.

Members of the genus *Streptomyces* remained an obscure family of soil-living microbes through the 1920s and 1930s. Interest in them was kept alive largely by Selman Waksman at Rutgers University in New Jersey, who isolated them in their hundreds (Figs 1 & 2) and studied them as members of the varied community of microbes that recycle plant and animal debris into humus. Then, in 1939, stung by the discovery of the first medically important antibacterial drugs – gramicidin from a *Bacillus* and, especially, the fungal product penicillin – he switched his laboratory overnight to a search for other life-saving antibiotics. His group was soon rewarded by finding that *Streptomyces* species are the most prolific antibiotic producers, with streptomycin becoming, by 1946, the first effective cure for tuberculosis. There followed two decades of fruitful searching, mainly by commercial companies, which revealed a gamut of important antibacterial, antifungal, antiparasitic and anticancer compounds (secondary metabolites) from *Streptomyces* species and organisms split off into new genera such as *Saccharopolyspora* and *Amycolatopsis* (Fig. 3 and Table 1).

By the mid-1960s the rate of discovery of useful compounds – especially antibacterials – declined sharply and by the 1980s large pharmaceutical companies concluded that all the good natural compounds had been found. They switched their efforts back to the synthetic chemistry that had dominated the industry before the antibiotics era, spurred on by the invention of robotic or 'combinatorial' chemistry. This technique churned out huge numbers of compounds, but almost without exception they did not prove 'drugable': they lacked the features, often depending on precise stereochemistry, essential for interaction with biological targets. But in an exciting alternative approach, small biotech start-ups exploited the newly developed ability to clone and manipulate the clusters of actinomycete genes that specify complex natural products, especially of the polyketide class that includes a disproportionate number of important compounds. This ability to 'do medicinal chemistry by genetics' is meeting with some success, with anticancer and immunosuppressant candidates in clinical trials.

Meanwhile, at the turn of the millennium, *Streptomyces* genetics took a quantum leap with the sequencing of the genomes of two species, the academic model *Streptomyces coelicolor* and the avermectin producer *Streptomyces avermitilis*. Amongst the large gene complements of these organisms – nearly 8,000 genes, twice the number in the bacteria *Escherichia coli* and *Bacillus subtilis*, and one-third more than in the yeast *Saccharomyces cerevisiae* – 20–30 clusters of genes that would specify secondary metabolites with novel structures were predicted. Most of them were unexpected from prior screening tests, and nearly all were different between the two species. This finding tells us that many potentially useful compounds are missed during routine screening but



◀ Fig. 3. Discovery of useful secondary metabolites. Compounds in blue are from fungi and those in magenta from non-actinomycete bacteria; all the other compounds are made by actinomycetes. *Reproduced from Hopwood, D.A. (2007),* Streptomyces in Nature and Medicine: the Antibiotic Makers *with permission from Oxford University Press.*

might be found if 'silent' gene clusters could be expressed. On this hypothesis the decline in the discovery rate seen in Fig. 3 may reflect limitations of screening rather than exhaustion of Nature's potential to make interesting compounds.

If this newly predicted source of novel drugs is to be exploited, we need a much deeper understanding of the regulation of secondary metabolite production in response to environmental signals. The gene clusters that remain unexpressed during standard laboratory screening are surely adaptive to the organisms under specialized conditions in the soil, or in response to competition by other soil inhabitants. There are several recent examples where individual pathways have been activated by changing the screening conditions, but the current challenge is to find generic ways of awakening sleeping genes; no company can justify spending years trying to understand a single strain. Amongst the myriad regulatory genes predicted in the *Streptomyces* genome sequences, there are some indications of 'master' switches of secondary metabolism, so this is certainly not a forlorn hope.

Both from this practical point of view and as part of our desire as microbiologists to reveal all aspects of microbial life, we need to gain more insights into the ecology of these fascinating organisms and how they interact with plants and animals. Two articles in this issue describe actinomycetes as pathogens. The deadly *Mycobacterium tuberculosis* kills more than 2 million people annually and infects, at some time in our lives, one-third of the human race, often leaving the pathogen in a dormant state that can flare up into TB decades later – see the article by Matt Hutchings on p. 78. How is this intimate relationship between bacterium and eukaryotic host regulated? As a plant pathogen, *Streptomyces scabies* causes scab disease of potatoes (as Rosemary Loria describes on p. 64). These diseases though are probably the exception rather than the rule for actinomycete interactions with higher organisms: symbiosis may be more typical. Members of the genus *Pseudonocardia* interact symbiotically with female leaf-cutting ants to protect their fungal food gardens from marauding moulds, and there are increasing numbers of reports of actinomycetes inhabiting not only the roots but also the aerial parts of plants where they probably protect the host from fungal attack. Five genera accommodated the actinomycetes in Waksman's day, but now there are at least 150, representing a huge range of structural and physiological types, as Paul Hoskisson relates on p. 68. Nor is antibiotic production the only industrially important actinomycete activity. As described by Michael Bott on p. 74, members of the genus *Corynebacterium* underpin a huge fermentation industry dedicated to amino acid production, representing one of the finest examples of rational strain improvement in applied microbiology.

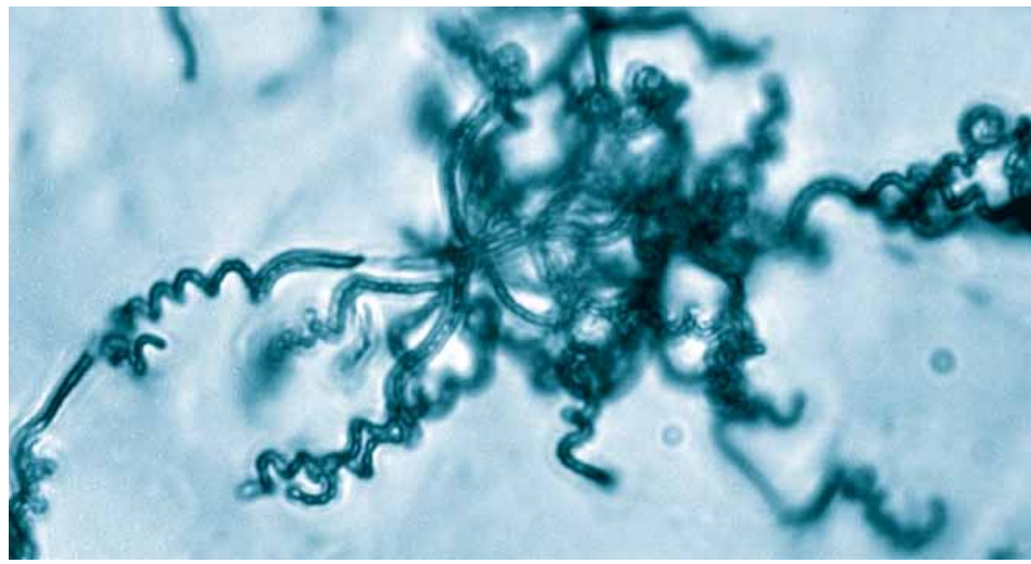
Our knowledge of the Actinobacteria has expanded beyond recognition since the 1870s, as I describe in my recent book (reviewed on p. 96), but much more needs to be done and is now within our grasp in the era of functional genomics and systems biology. Hopefully, this issue of *Microbiology Today* will help to bring the Actinobacteria to the attention of some bright young microbiologists who might decide to devote their careers to them as I have done.

Sir David Hopwood, FRS
John Innes Centre, Norwich, Research Park, Colney, Norwich NR4 7UH, UK (e david.hopwood@bbsrc.ac.uk)

Table 1. Some important actinomycete products

Compound	Biochemical target	Application
Tetracycline	Bacterial ribosomes	Respiratory tract infections
Erythromycin	Bacterial ribosomes	Respiratory tract infections; *Legionella*
Vancomycin	Bacterial cell wall	Resistant pathogens like MRSA
Rifamycin	Bacterial RNA polymerase	Tuberculosis, leprosy
Amphotericin	Fungal membranes	Human fungal infections
Adriamycin (doxorubicin)	DNA replication	Cancer
Avermectin	Nervous conduction	Animal parasites (nematodes, warble fly); river blindness in Africa
Rapamycin	Immune system	Organ transplantation

► Potato scab, an aptly named disease, occurs in most potato production regions of the world and is economically important in many. Infection of the rapidly expanding cells at the apical growing point by *S. scabies* and other pathogenic species cause these symptoms. *Madhumita Joshi*



► Opposite page. Members of the genus *Streptomyces* are filamentous, producing spore chains from aerial hyphae, reminiscent of fungi. The image shows *S. scabies* spore chains, displaying a typical corkscrew morphology. *Rosemary Loria*

▼ Opposite page. Thaxtomin A. Synthesis is via a non-ribosomal peptide synthase and nitration of the tryptophan moiety involves a nitric oxide synthase. All scab-causing plant-pathogenic streptomycetes produce this toxin. *Rosemary Loria*

Streptomyces: not just antibiotics

Streptomyces species are not all beneficial, according to **Rosemary Loria**, **Madhumita Joshi** and **Simon Moll**. Many cause diseases which can ravage food crops.

We often hear scientists extol the virtues of *Streptomyces*, and indeed this genus is a powerhouse of secondary metabolism, producing antibiotics, antitumour drugs, and other invaluable molecules. However, there is a dark side to these organisms – some of them cause disease. Potato scab is a classic example of an economically important plant disease incited by *Streptomyces scabies*. Though not as famous a disease as late blight, potato scab is the bane of potato growers on several continents. These filamentous bacterial pathogens can penetrate expanding plant cells, including potato tubers, producing raised or pitted scab-like lesions. The potato crop is propagated vegetatively and seed tubers are shipped around the globe, allowing this soil-borne bacterium a free ride to new production areas. Pathogenic species retain the excellent saprophytic ability that is characteristic of this genus, and are therefore impossible to eradicate once they are introduced into cultivated soils.

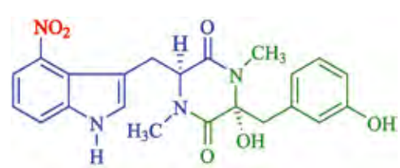
Emergent pathogens

The best known and most widely distributed of plant-pathogenic streptomycetes is *S. scabies*. This actinomycete was initially misidentified as a fungus in the late 1800s, an error that persisted in some plant pathology textbooks into the 1980s. Because of its economic importance, *S. scabies* has been the subject of research on host range, population dynamics, infection mechanisms and disease resistance for more than a 150 years. Breakthroughs in potato scab control have evaded scientists over the decades and this effort has been complicated by the emergence of new pathogenic species in many potato production areas.

In the 1940s, after formaldehyde seed treatments were banned in the USA, a new potato scab pathogen emerged in the north-eastern part of the country. The pathogen was named *Streptomyces acidiscabies*, for its ability to produce disease in low pH soils – soil with a pH below 5.2 suppresses *S. scabies*. In the 1990s, yet another scab pathogen was described from the potato-producing areas on the island of Hokkaido, Japan. This pathogen produced erumpent lesions, and was named *Streptomyces turgidiscabies*. Subsequently, reports of new scab-causing streptomycetes became relatively common; today there are more than a dozen described plant-pathogenic *Streptomyces* species and probably many more uncharacterized species.

Thaxtomin biosynthesis – leveraging secondary metabolism

In targeting living plants as a nutrient source, *Streptomyces* species have used their strengths in secondary metabolism to develop a novel cellulose biosynthesis inhibitor. Thaxtomin, a dipeptide, is one of only a few nitrated natural products and is the lone biosynthetic pathway known to contain a nitric oxide synthase. Cellulose microfibrils are extruded from cellulose synthase complexes embedded in the plant cell membrane. These fibrils wrap around the cell in a defined pattern that dictates the shape of the cell and limits its expansion. Thaxtomin inhibits cellulose synthesis through an unknown mechanism, thereby compromising cell wall integrity and permitting isotrophic swelling of the cell. *Streptomyces* are unique among plant pathogens in their ability to structurally compromise plant cell walls through inhibition of cellulose production. However, by doing so



they probably facilitate their penetration of plant cells; most bacterial pathogens are confined to the space between plant cells, because of their inability to penetrate the rigid cell wall.

We think of *S. scabies* and the other potato scab pathogens as specialists in infection of potato tubers and expanded tap root crops, such as beet and radish. However, these pathogens can cause disease in essentially any underground plant part, though penetration must occur through expanding cells in which the primary cell wall is still forming. For example, they can colonize the apical regions of roots of both monocot and dicot plants. The reason for this tissue-specific, but not host-specific, behaviour is thaxtomin. This phytotoxin apparently interacts with highly conserved components of the cellulose synthesis mechanisms, explaining the lack of highly resistant potato cultivars, despite more than half a century of breeding effort.

Pathogenicity island

All scab-causing streptomycetes produce thaxtomin, while closely related non-pathogenic species do not. How did these newly emergent pathogens acquire the novel thaxtomin biosynthetic pathway? Molecular genetic analysis has yielded evidence for a DNA fragment that is mobilized from a donor, during streptomycete mating, and site-specifically inserted into the recipient's chromosome. This fragment, about 660 kb in size, contains a pathogenicity island (PAI) – a cluster of genes responsible for the pathogenic phenotype, including those required for thaxtomin biosynthesis. Other genes on the PAI are known, or implicated, to be involved in plant pathogenicity; streptomycete pathogens have multiple virulence strategies, as do other microbial pathogens.

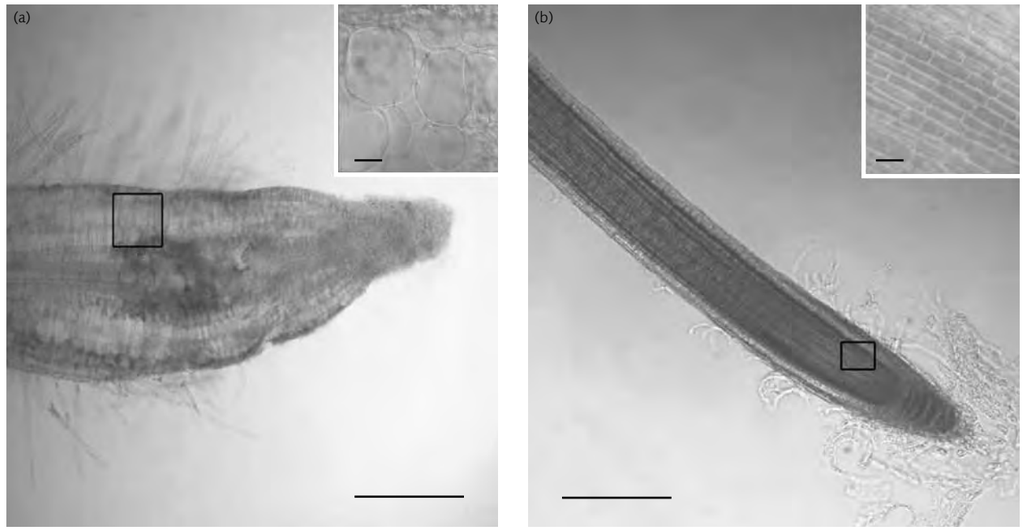
Streptomycetes are a powerhouse of secondary metabolism, producing antibiotics and antitumour drugs … however, there is a dark side to these organisms.

The DNA sequences of the thaxtomin biosynthetic genes and other virulence genes on the PAI have been used to develop probes specific to pathogens. Since multiple pathogenic species exist in infested fields, species-specific DNA probes are not useful. These probes can be used to detect and quantify pathogenic streptomycete populations, in the presence of the hundreds of non-pathogens present in soil and on plant surfaces. When combined with extraction methods that allow recovery of high quality DNA from soil, these very sensitive techniques can estimate the population densities of pathogenic populations in soil, allowing growers to make informed disease management decisions. This is a large step forward in our efforts to develop practical disease control recommendations for growers.

The PAI is conserved in all scab-causing pathogens, but it is clearly still under evolutionary pressure. The *S. turgidiscabies* PAI has acquired a set of genes, called the *fas* operon, which are involved in disease development in the closely related genus *Rhodococcus*; these genes are absent in other streptomycetes. The *fas* genes constitute an unusual cytokinin biosynthetic pathway that allows *S. turgidiscabies* to produce leafy galls at the apical meristems of plants, identical to galls caused by *Rhodococcus fascians*. The *fas* genes are not essential for pathogenicity in *S. turgidiscabies*, but they probably enhance reproduction of this pathogen on potato tubers.

Genomic age

Plant-pathogenic streptomycetes have followed their antibiotic-producing cousins into the genomic age. The 10 Mb genome sequence of *S. scabies* has been sequenced at the Sanger Institute and is available at **www.sanger.ac.uk/Projects/S_scabies/**. More plant pathogens are in the sequencing pipeline elsewhere. Genome-wide analysis will undoubtedly reveal additional facets of these organisms that allow them to manipulate eukaryotic cells for their own gain. For example, all pathogens must be able to suppress host defences – do streptomycetes use mechanisms similar to those employed by other pathogens, or have they devised a novel strategy? There is much we can learn about the strategies and evolution of these streptomycetes from their genome sequences.



▲ Radish root tip. When inoculated onto radish seedlings, *S. turgidiscabies* causes extensive swelling of the root tip, in the meristematic zone (a). Swelling is due to the production of the phytotoxin, thaxtomin, which interferes with plant cell wall synthesis, resulting in a dramatic unilateral expansion of cells (inset). (b) A normal, non-inoculated radish root tip of the same age. Bars, 300 µm; in insets, 25 µm. *Simon Moll*

▶ Although *S. turgidiscabies* can produce leafy galls when inoculated onto the aerial portion of tobacco plants, these symptoms have never been reported in nature. Unlike other described pathogenic streptomycetes, this species produces a cytokinin – a plant hormone required for gall production. *Madhumita Joshi*

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Further reading

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Good, bad, but beautiful: the weird and wonderful actinobacteria

Diversity in form and function is fundamental to the success of bacteria. **Paul Hoskisson** believes that actinobacteria demonstrate this better than any other group.

The actinobacteria provide us with some of the most beneficial micro-organisms to mankind and also with some of our biggest foes; this is even true within genera! In addition to these costs or benefits, there is a morphological diversity which beggars belief, from the familiar bacterial shapes of cocci and rods, through to hyphal organisms, with a lifestyle pioneered before the fungi. Actinomycetes also demonstrate some of the most elaborate sporulation and dispersal mechanisms of all micro-organisms. In this short survey, I will describe the most astonishing group of bacteria.

In soil: providers or pathogens

Actinobacteria are typically thought of as soil organisms, and this environment is where some of the most diverse forms are isolated. In the early days of bacteriology many were overlooked due to their slow growth, until an appreciation of this and enhanced selective isolation procedures began to realize the true diversity of the group. Their importance in the rhizosphere was recognized in the heyday of soil microbiology in the 1950 and 1960s, and since then, organisms such as *Frankia* have come to the fore. This group forms intimate symbiotic relationships with *Alnus* (Alder) especially, although more than 200 plant hosts from 21 genera are known.

A nitrogen fixer

Frankia species fix atmospheric nitrogen, through *nif* and *nod* genes which appear to be highly conserved with those of the alphaproteobacterium *Rhizobium*. *Frankia* is a slow-growing organism (doubling time 2–5 days) now attracting attention, given the availability of two genome sequences (*Frankia* sp. Cluster 2 and *Frankia* sp EAN1pec). Endophytic *Frankia* species tend to be microaerophilic, and can be cultured *in vitro* where they form branching vegetative hyphae. Aerial hyphae appear to be absent, and the non-motile spores are found on the vegetative mycelium, inside sporangia. The use of actinorhizal plants for the reclamation of land damaged by mining and flooding, and also for dune stabilization has proved successful in Canada and China, and given the availability of the genome sequences, the biotechnological impact of *Frankia* species may only just be in its infancy.

Plant pathogens

Of course, in the soil not all organisms are plant-friendly. Take the pathogen *Leifsonia*, a genus of rod-shaped actinobacteria which strikes fear into the hearts of sugar cane farmers. The sequenced strain (*L. xyli*) invades the canes, and through a broad armoury of hydrolytic enzymes literally dissolves the cane from the inside out, exploiting the plant transport system, the xylem, for its progress. This organism has never been isolated from soil, or from wild sugar cane in south-east Asia, suggesting that it is a recent association between host and pathogen in the main farming region of Central and South America. In addition to *Leifsonia*, another important plant pathogen is from a genus normally considered as one of the 'good guys'. *Streptomyces scabies* is the aetiological agent of scab disease and is an important pathogen of potatoes (covered in detail by Rosemary Loria on p. 64).

Jekyll and Hyde bacteria

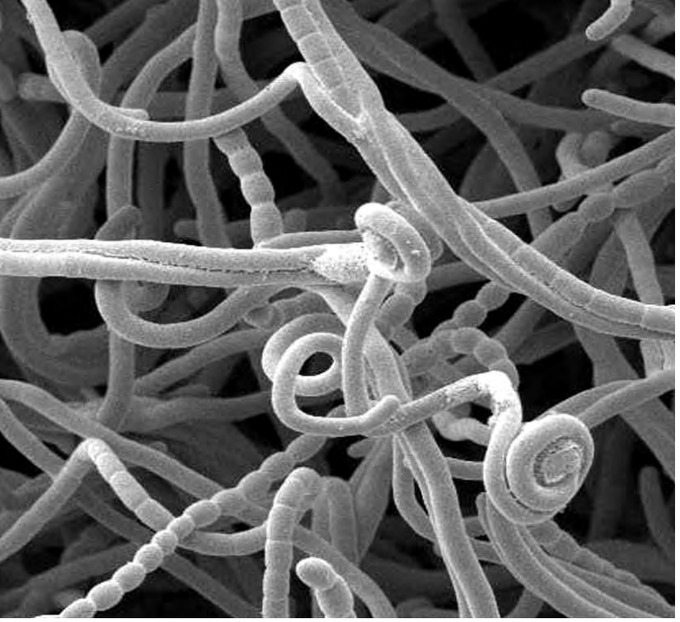
The diversity of lifestyles in soil, and the ability to utilize a variety of substrates, has also been to the benefit of biotechnology, due to the isolation of several strains of *Rhodococcus*. These organisms are usually rod-shaped and, occasionally, branching fragmenters, and are voracious consumers of hydrocarbons and other complex organic materials in soil. Recently, the genome sequence of one such isolate, *Rhodococcus* sp. RAH1 was completed, and it is predicted to harbour pathways for the degradation of 30 aromatic compounds, with gene clusters containing 203 oxygenases. Given this catabolic diversity, it is little surprise that these organisms have received much attention in recent years as possible agents for bioremediation, both as whole organisms and as sources for gene clusters for heterologous enzyme production.

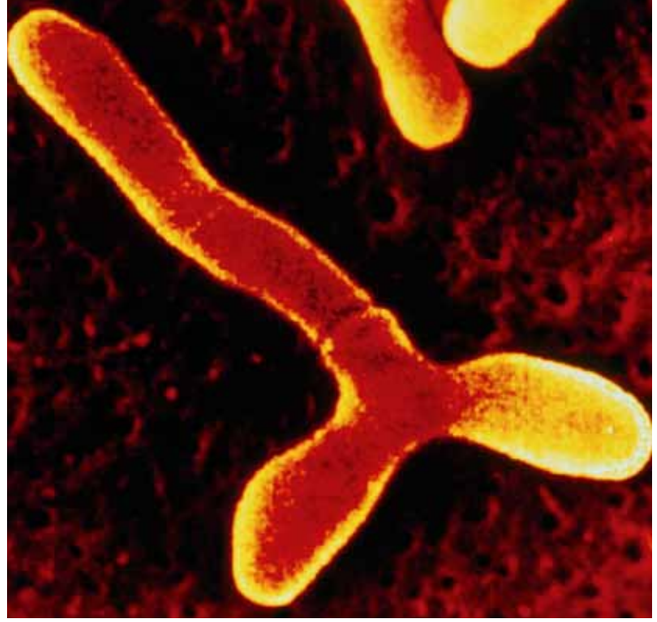
The Jekyll and Hyde characteristics of actinobacterial genera are typified by the rhodococci. The persistent equine pathogen *Rhodococcus equi* is ubiquitous in the environment, and grows rapidly in horse manure. It is thought that the main route of infection is via the inhalation of *R. equi* from manure-contaminated dust. The infection proceeds in the lungs, causing a pneumonia-like disease, especially in foals. The genome of *R. equi* is currently being sequenced at the Sanger Centre in Cambridge, and the provision of such a resource may aid in the development of a vaccine. Additionally, *R. equi* pneumonia is also emerging as a significant human pathogen in patients with HIV, yet currently we know little about its pathogenicity in humans.

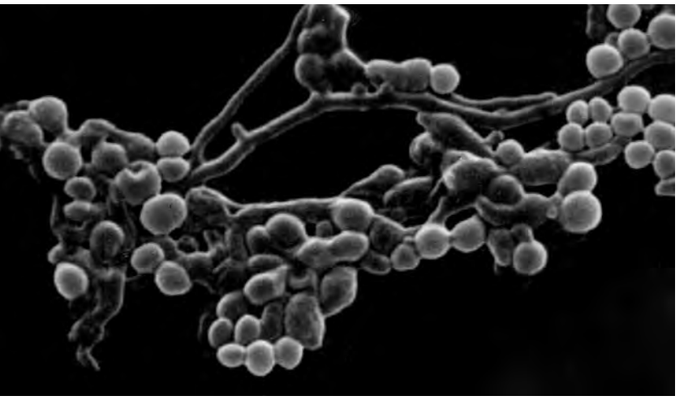
Food spoilers, producers and probiotics

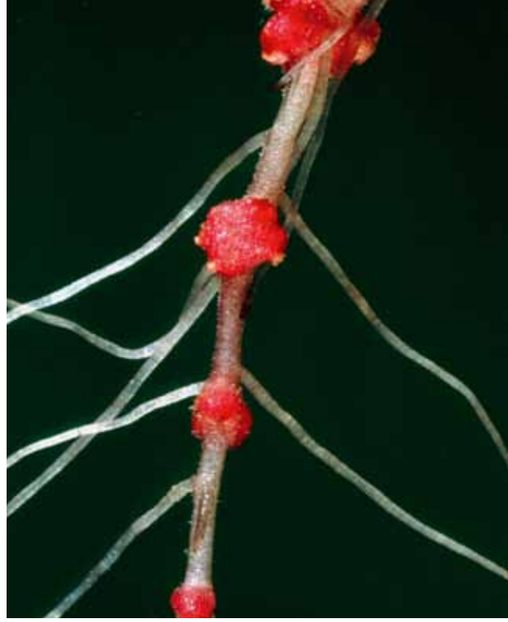
Compared with lactobacilli and lactococci, actinobacteria have a relatively low profile in the food industry. Yet genera

◀ A typical Swiss cheese. The holes in these types of cheese are often formed by propionibacteria, such as *Propionibacterium freudenreichii*, when added to the starter culture. The bacteria secrete various peptidases and hydrolytic enzymes. *IT Stock / Jupiter Images*









▲ Top left. *Streptomyces coelicolor* aerial hyphae and spores. *Paul Hoskisson*

▲ Bottom left. *Micromonospora echinospora*, note the spores borne directly on the substrate mycelium. *Paul Hoskisson*

▲ Top right. Coloured scanning electron micrograph of a Y-shaped *Bifidobacterium* sp. bacterium. *Bifidobacterium* are non-motile and inhabit the human gut, mouth and vagina, but are rarely pathogenic. *BSIP / Science Photo Library*

► Opposite page. Red nitrogen-fixing nodules containing symbiotic *Frankia* sp. bacteria on the roots of a black alder tree (*Alnus glutinosa*). *Biophoto Associates / Science Photo Library*

such as *Propionibacterium* and *Bifidobacterium* are important for flavour enhancement in cheeses and as probiotics, respectively.

Say cheese

Propionibacteria are considered beneficial organisms in cheeses and are even added to the starter cultures for hole formation in Swiss-type cheeses. These organisms, especially *Propionibacterium freudenreichii*, tend to succeed the lactic acid bacteria during cheese production, and through the secretion of peptidases and other hydrolytic enzymes, play a major role in the development of flavour in ripening by the generation of aromatic amino acids.

The ability of these organisms to produce hydrolytic enzymes, such as peptidases and lipases, is also postulated to be the pathogenic mechanism of *Propionibacterium acnes*, a related human commensal, which is implicated in the formation of acne. Normally a harmless inhabitant of the sebaceous glands within the skin, little is known about how this organism switches from commensal to pathogen. It seems from the genome sequence that several immunogenic factors are present that may be responsible in triggering acne inflammation.

Friendly bacteria

Recently, there has been an upsurge of interest in probiotic micro-organisms and their potential health benefits. At the forefront of this movement is the obligate anaerobe *Bifidobacterium* (the 'friendly bacterium' of TV fame). These long rods, or occasionally 'Y'-shaped organisms, are abundant in the human gut, fermenting a wide variety of oligosaccharides which are unusable by the human host. The presence of such oligosaccharides is important for boosting *Bifidobacterium* numbers in the gut, and this has been referred to as the 'prebiotic effect'. It has been estimated that bifidobacteria represent only 3–6 % of the adult gut flora yet their presence has been associated with many benefits to health such as prevention of diarrhoea, aiding in lactose intolerance, and even helping to prevent food allergies and chronic gut inflammation diseases through their immunomodulatory action. These favourable effects have led to the widespread use of bifidobacteria in health-promoting foods, yet we still understand

Actinobacteria provide us with some of the most beneficial micro-organisms to mankind and also with some of our biggest foes. In addition, their morphological diversity beggars belief.

little of their physiology, ecology and genetics. The genome sequence of one isolate, *Bifidobacterium longum* shed some light on their biology, such as extensive gene arrays for oligosaccharide metabolism being often duplicated within the genome, or horizontally acquired and accounting for almost 10 % of the genome. These organisms also contain many genes for the production of glycoprotein binding fimbriae and other structures which may be important for adhesion and persistence within the gut. Continuing studies of these fascinating actinobacteria will undoubtedly lead to a better understanding of how diet and probiotics can affect the health and well-being of the human gut.

The developmental biologists' delight

Rods and cocci

Bacteria are often thought of as morphologically simple, and this is true for many genera, yet sporulation as a means of dispersal, propagation and survival has been adopted by some actinobacteria. The level of morphological complexity within the actinomycetes can represent an amazing tool for evolutionary and developmental biologists interested in how these processes have evolved. The last common ancestor of the actinomycetes is estimated at around 2–1.5 gigayears, with morphologically complex actinobacteria such as *Streptomyces* appearing around 440 million years ago. In the simplest form, the actinomycetes are cocci, represented by the ubiquitous *Micrococcus*, whose bright yellow colonies blight those with poor aseptic technique! *Micrococcus*, and the related *Arthrobacter*, represent the morphologically simple actinobacteria; however, even these species exist in a pleiomorphic lifestyle, where under ideal conditions favouring rapid growth they grow as rods, yet starvation induces the shrinkage of cells and the rounding of cells to appear as classic cocci (quasi-spores?). This morphological change, coupled with the accumulation of storage material provides the perfect environmental survival mechanism. Moving to the rod shaped actinobacteria, whilst *Mycobacterium*, *Corynebacterium* and *Clavibacter* are morphologically unremarkable, they are all medically or biotechnologically significant.

Hyphal lifestyles

It is difficult to speculate on the emergence of the hyphal lifestyle in the actinobacteria, yet given the presence of this phenomenon in broadly separated taxonomic lineages, it would be interesting to know if it has arisen on more than one occasion during evolution. The hyphal actinobacteria occur in all ecological niches. The *Nocardia* are remarkable organisms, with members of this group representing significant opportunistic pathogens (such as *Nocardia farcinica*) as well as being producers of important bioactive molecules. They are intermediate organisms in terms of their morphology as some species are hyphal and, in response to poorly defined signals, simply fragment into short rods. Other species form short, specialized hyphae which grow up into the air, where spores develop. The taxonomy of this group is difficult, yet it is clear from various studies that the *Nocardia* are closely related to *Corynebacterium*, *Rhodococcus* and *Gordonia*.

The hyphal fragmenting lifestyle almost shows a progression from rods to the next group of morphologically complex actinomycetes which form branching hyphae, and true spores directly on the substrate mycelium. This group includes *Micromonospora* and *Salinospora*, both of which are important producers of pharmaceutically useful products. The micromonosporas are extensive producers of aminoglycoside antibiotics, with gentamicin being the most well known. Other metabolites, such as calicheamicins and other enediynes, are attracting attention as promising anti-cancer therapeutics. The recently discovered genus *Salinospora* was isolated from deep-sea sediments and the new strains appear to have a requirement for salt in their growth medium. They are an exciting source of potential new metabolites.

Dispersal strategies

The *Micromonosporaceae* exhibit some of the most amazingly complex dispersal strategies found within the actinobacteria. Several species have evolved the formation of sporangia-like structures, as in fungi, essentially small sacks for holding spores. These can be relatively simple in structural terms such as *Microbispora*, where a small sporangium contains two spores, to *Dactylosporangium*, which, as the name suggests forms finger-

like sporangia, each containing 3–5 spores. There is some anecdotal evidence that *Dactylosporangium* can also form *Micromonospora*-like spores directly on the mycelium, and the sporulation mechanism chosen may be related to growth conditions. One of the most fascinating genera which broadly falls in to this category is *Actinoplanes*, which forms sporangia on its substrate mycelium, which can contain up to 100 motile spores. This mechanism of sporulation represents a significant evolutionary step in terms of complexity. With many of these organisms we know very little about their ecology, evolution or genetics, yet they are fascinating in terms of their developmental biology.

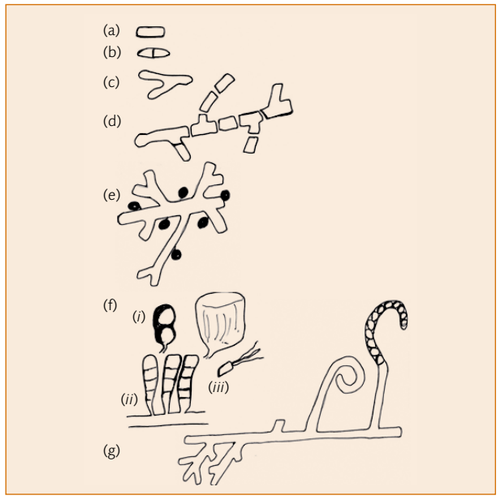
Aerial sporulation

Of course, in contrast to the poorly studied developmentally complex actinomycetes, the prokaryotic developmental paradigm *Streptomyces* is relatively well understood in terms of its developmental biology. This genus and other closely related genera form a branching substrate mycelium which, in response to nutrient limitation, develops aerial hyphae, which grow up from the aqueous environment into the air, where they mature into unigenomic spores. This lifestyle presents two major problems. First, the breaking of the surface tension, to allow the aerial hyphae to extend into the air to complete their development, achieved by the production of several hydrophobic proteins and molecules and secondly, the co-ordinated division of the aerial hyphae into spores, which can number up to 100. This process requires the co-ordinated and simultaneous septation of all compartments; an amazing biological phenomenon.

The formation of aerial hyphae has been utilized by several actinomycete genera (*Amycolatopsis*, *Streptomyces* and *Saccharopolyspora*) within their sporulation mechanism and represents an interesting problem for these organisms in that the aerial hyphae can only receive nutrients via the substrate hyphae for their growth.

Summary

The actinomycetes provide not only microbiologists, but also mankind, with some of their biggest challenges and rewards; either as a pathogen, as a producer of a pharmaceutically useful product or as a biological system for study. There are almost 50 genome sequences for actinobacteria available for interrogation, yet we have barely scratched the surface in terms of diversity in form and function. They are certainly a remarkable and diverse group of bacteria, which will continue to fascinate and occupy microbiologists for years to come.



▲ A schematic representation of the diverse forms of morphology exhibited by the actinomycetes. (a) Rods, e.g. *Mycobacterium*, *Micrococcus*; (b) rods, e.g. *Corynebacterium*, some *Rhodococcus*; (c) Y-shaped, short, sometimes branching rods, e.g. *Bifidobacterium*; (d) hyphal and branching fragmenters, e.g. *Nocardia*, some *Rhodococcus*, some *Amycolatopsis*; (e) hyphal branching, spores or sporangia (see f), e.g. *Micromonospora*, *Salinospora*; (f) specialized sporulation structure in the actinobacteria, (i) two-spore sporangia, e.g. *Microbispora*, (ii) finger-like sporangia, e.g. *Dactylosporangium*, and (iii) sporangia containing many motile spores, e.g. *Actinoplanes*; (g) branching hyphae, forming aerial mycelium and spores, e.g. *Streptomyces*, *Saccharopolyspora* and some *Amycolatopsis*. *Paul Hoskisson*

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Further reading

www.genomes online.org
Genomes online provides summaries and links to all the actinobacterial genome sequencing projects.

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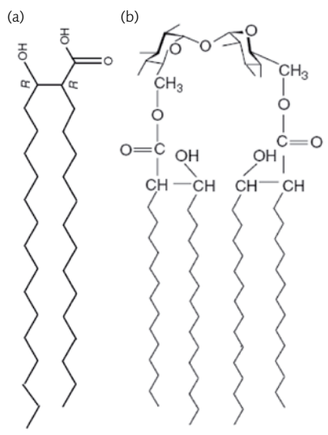
Corynebacteria: the good guys and the bad guys

Whilst some species of corynebacteria cause life-threatening illnesses, others are used in industry to produce food additives, as **Michael Bott** explains.

► The flavour of Asian food is often enhanced by the use of monosodium glutamate which is synthesized industrially using *C. glutamicum*. *Liquid Library / Jupiter Images*



▼ Fig. 1. Structures of the C_{32} mycolic acid of *C. diphtheriae* (a) and of trehalose dicorynomycolate (b). The latter is a characteristic constituent of the outer lipid bilayer present in most *Corynebacterium* species. *Michael Bott*

The suborder *Corynebacterineae* within the order *Actinomycetales* accommodates nine genera, the most well known of which are *Corynebacterium*, *Mycobacterium*, *Nocardia* and *Rhodococcus*. A characteristic feature of these genera is the presence of mycolic acids (2-alkyl-3-hydroxy acids of variable chain length). There is evidence that these compounds, either linked to the cell wall sugar polymer arabinogalactan or esterified with trehalose (Fig. 1), are part of an outer lipid bilayer, reminiscent of the outer membrane of Gram-negative bacteria. In accordance with the existence of an outer lipid bilayer, pore-forming proteins (porins) have been found in corynebacteria and mycobacteria. Thus the common textbook statement that only Gram-negative bacteria possess an outer membrane is probably wrong.

Bad guys: pathogenic corynebacteria

About 35 *Corynebacterium* species are considered to be of medical relevance as commensals on the skin or mucous membranes and/or as pathogens in man and animals. The most important pathogenic species is *C. diphtheriae* (Fig. 2), which was shown in 1884 by Friedrich Loeffler to be the causative agent of diphtheria, an acute, contagious disease responsible for much childhood mortality until the beginning of the 20th century. After infection, *C. diphtheriae* usually colonizes the upper respiratory tract and secretes the potent diphtheria toxin (DT), causing the symptoms of the disease. DT is absorbed by the circulatory system and damages remote organs such as the heart, potentially resulting in death. At the local site in the respiratory tract, a whitish and later grey pseudomembrane develops (Fig. 3), which gave the disease its name: the Greek word '*diphthera*' means 'leather hide'. The pseudomembrane can reduce the air flow and may eventually result in complete blockage, causing suffocation and death.

Shortly after the identification of DT by Roux and Yersin in 1888, an animal serum with a DT antitoxin was used successfully by Emil von Behring to treat a case of diphtheria. For the development of serum therapy, he was awarded the first Nobel prize in Physiology or Medicine in 1901. The major breakthrough in the fight against diphtheria was the discovery by Gaston Ramon in 1923 that treatment of diphtheria toxin with formaldehyde eliminates its toxicity without destroying its immunogenicity. Formaldehyde-treated DT is called diphtheria toxoid and is still the preferred vaccine against the disease. DT is toxic because it inhibits protein synthesis by catalysing ADP-ribosylation of a modified histidine residue (called diphthamide) in elongation factor 2 (EF-2). The susceptibility to DT depends on the presence of its receptor at the surface of eukaryotic cells, the heparin-binding epidermal growth factor (HB-EGF) precursor. Binding of DT to this protein triggers receptor-mediated endocytosis. Upon acidification of the resulting endosomes, the catalytic domain of DT (the A fragment) is translocated across the endosomal membrane into the cytosol and becomes active. Only strains of *C. diphtheriae* that carry certain temperate bacteriophages, such as corynephage β, are toxinogenic, because DT is encoded by the *tox* gene on the phage genome. Its expression is triggered

by iron limitation. Under iron excess, the DT repressor DtxR, encoded by the *C. diphtheriae* genome and active when complexed with Fe^{2+}, represses *tox* gene expression. DtxR functions as the master regulator of iron homeostasis in corynebacteria. Due to insufficient vaccination, outbreaks occurred in Russia and independent states of the former Soviet Union in the 1990s. They indicated just how little is known about the biology of *C. diphtheriae*, a situation that will hopefully change in future based on the availability of the 2.49 Mb genome sequence of strain NCTC 13129 and the development of an animal model based on DT-susceptible mice.

Besides *C. diphtheriae*, *C. jeikeium* has gained increasing importance in recent years; it is the most frequently recovered corynebacterial species in hospital intensive care facilities. It is considered part of the normal flora of the human skin, particularly of in-patients, and the causative agent of a variety of severe nosocomial infections, usually in the immunocompromised. A critical feature of many clinical isolates of *C. jeikeium* is multidrug resistance, making glycopeptides such as vancomycin the only remaining weapon. Recently, the 2.46 Mb genome sequence of strain K411 was established, which led to the identification of candidate genes involved in drug resistance. Moreover, the genome sequence uncovered the absence of fatty acid synthase, explaining the well known lipid auxotrophy of *C. jeikeium*. It appears that lipids play a major role in the metabolism of this species, the reason for its prevailing habitats being areas of the skin which are known to contain hydrolipid films, such as the axilla. As in the case of *C. diphtheriae*, the availability of the genome sequence paves the way for future studies on the molecular basis of *C. jeikeium* virulence.

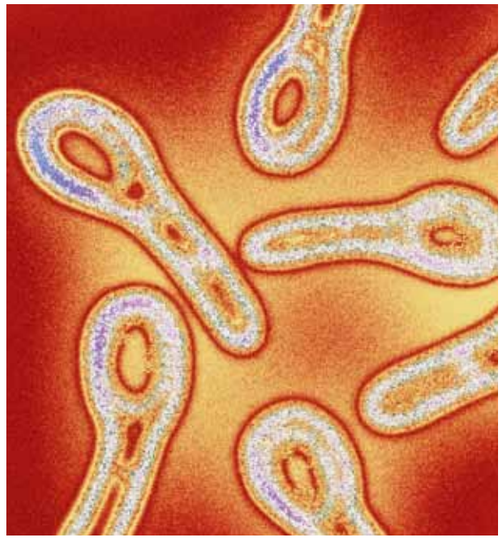
Due to its industrial importance and favourable properties for research, C. glutamicum has become an important model organism.

Good guys: corynebacteria of industrial relevance

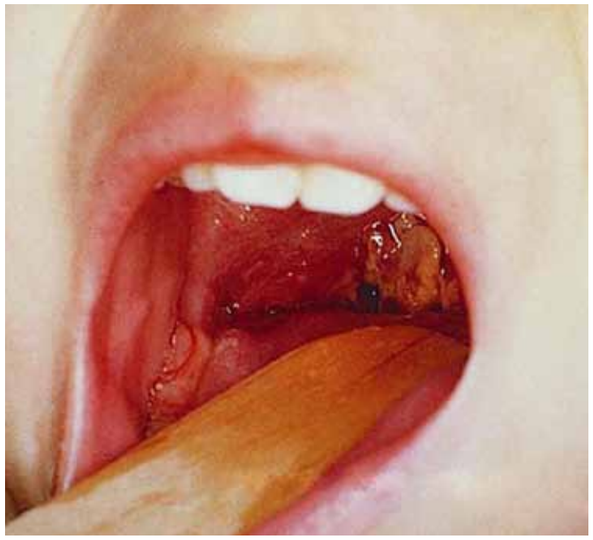
Monosodium glutamate was discovered in 1908 by Kikunae Ikeda in Japan as a new taste called *umami* and was used as a flavouring compound for food after extraction from wheat gluten. In 1956, a screening programme by the Kyowa Hakko Kogyo company (Tokyo), headed by S. Kinoshita and S. Udaka, led to the isolation of a biotin-auxotrophic soil bacterium, now known as *C. glutamicum*, that excreted large amounts of L-glutamate when cultured aerobically in a simple synthetic glucose medium under biotin limitation. This was the birth of biotechnological amino acid production. Currently, 1.5 million tons of L-glutamate are produced using *C. glutamicum* annually, making it the number one amino acid in terms of production capacity and demand. Interestingly, there is still some mystery about the molecular mechanisms of glutamate overproduction. Besides biotin limitation, the addition of surfactants, like Tween-60, or of cell wall antibiotics, like penicillin, can trigger glutamate secretion. In the past, alterations of the cell envelope (cell membrane and/or cell wall) that alter the activity of a not yet identified glutamate efflux carrier were proposed to be responsible for glutamate efflux. More recent studies indicate that the different induction methods are accompanied by a decrease in the activity of the 2-oxoglutarate dehydrogenase complex and thus cause an increased flux of 2-oxoglutarate towards L-glutamate via glutamate dehydrogenase or via glutamine synthetase and glutamate synthase. The decisive role of 2-oxoglutarate dehydrogenase is supported by observations that a mutant lacking this enzyme secretes glutamate without any induction, whereas a mutant lacking a newly discovered inhibitor protein of 2-oxoglutarate dehydrogenase (OdhI) is drastically impaired in its ability to produce glutamate (Fig. 4).

Besides glutamate, several other amino acids are produced using *C. glutamicum*, most of which belong to the nine essential amino acids that are not synthesized in animals and humans but must be ingested with feed or food. The most important of these is L-lysine which is used as a feed additive in pig and poultry breeding. Its demand rose from less than 50,000 tons in 1970 to 850,000 tons in 2005 and is expected to increase further. In contrast to glutamate, which can in principle be produced with wild-type *C. glutamicum*, L-lysine producers were originally obtained by random mutagenesis and selection. With the establishment of gene technology, the rational development of producer strains by metabolic engineering became possible. Since the 1980s, a large number of studies have been performed with *C. glutamicum*, focusing on amino acid biosynthesis, provision of precursors and amino acid transport. Many molecular targets are meanwhile known and patented that are critical for lysine overproduction, such as aspartate kinase, pyruvate carboxylase, or the lysine exporter LysE.

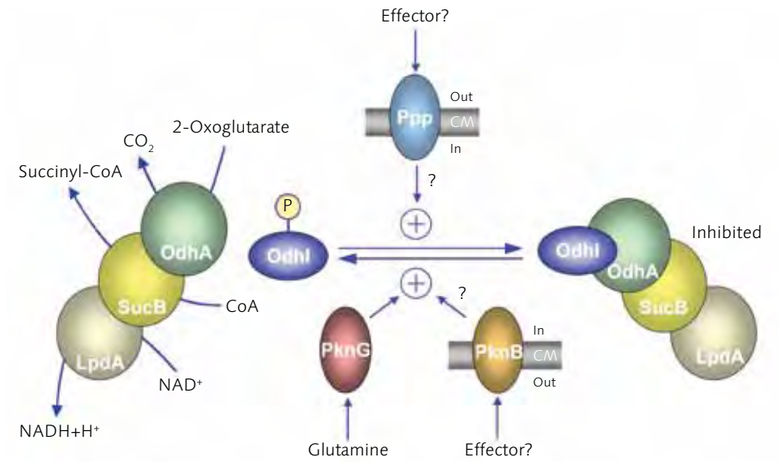
A new era in rational strain construction began with the availability of genome sequences for *C. glutamicum* in 2003. Comparison of classically obtained lysine producers with the wild-type allows the identification of new targets for strain improvement. New producer strains are created starting from the wild-type that carry a minimal set of mutations required for efficient lysine production (genome breeding), but lack unfavourable mutations that are always present in strains obtained by random mutagenesis and selection. Another important research field boosted by the genome sequence and the 'omics' technologies built on it concerns regulation. In recent years several key regulators of carbon, nitrogen, phosphorus, sulfur and iron metabolism have been identified and the corresponding studies revealed significant differences compared to regulation in Gram-negative and low G+C Gram-positive bacteria. Due to its industrial importance and favourable properties for research, *C. glutamicum* has become an important model organism for the *Actinomycetales*, whose metabolic potential will be further increased and exploited in the future by applying systems biology approaches.



◀ Fig. 2. False-coloured transmission electron micrograph of *C. diphtheriae* bacteria, the cause of diphtheria. *Alfred Pasieka / Science Photo Library*



◀ Fig. 3. A diphtheria patient showing the pseudomembrane. *Dr C.W. Leung, Dept of Paediatrics and Adolescent Medicine, Princess Margaret Hospital, Hong Kong*



▲ Fig. 4. Model of post-transcriptional control of 2-oxoglutarate dehydrogenase complex (ODHC) activity in *C. glutamicum*. ODHC is composed of three subunits, OdhA, SucB and LpdA. In its unphosphorylated state, the oxoglutarate dehydrogenase inhibitor protein, OdhI, forms a complex with OdhA and inhibits ODHC activity. Upon phosphorylation of OdhI by serine/threonine protein kinase G (PknG) and possibly by serine/threonine protein kinase B (PknB), the OdhA–OdhI complex dissociates and ODHC becomes active. Dephosphorylation of OdhI is presumably catalysed by the phospho-Ser/Thr protein phosphatase (Ppp). *Michael Bott*

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The mycobacteria

The mycobacteria are an important cause of disease worldwide, and include the agent of tuberculosis, one of the greatest challenges to global health today. **Matt Hutchings** describes this fascinating group.

The mycobacteria belong to the *Corynebacterineae* subclass of the actinobacteria and are remarkable mainly for their ability to cause disease in animals. They can be divided into two groups based on their growth characteristics. The fast-growing mycobacteria include non-pathogens such as the model organism *Mycobacterium smegmatis*, and opportunistic pathogens such as *Mycobacterium chelonei*, which can cause septicaemia. The slow-growing mycobacteria include all the nasty animal pathogens, such as *Mycobacterium leprae* and *Mycobacterium tuberculosis*. The slow-growing mycobacteria also include *Mycobacterium marinum*, which has potential as a model organism for studying mycobacterial infections. It causes tuberculosis-like granulomas in fish and amphibians and can also cause skin infections in humans. Human infection, often referred to as 'swimming pool granuloma', is rare and is thought to occur when water containing *M. marinum* enters a break in the skin. The genome sequence of *M. marinum* was recently completed by the Sanger Centre in Cambridge and shares very high identity with that of *M. tuberculosis*. Since it can be grown under containment level II facilities it can be used to study virulence genes in mycobacteria, using fish or amphibians as animal models.

Acid-fast bacteria

The key to the success of the mycobacteria as pathogens appears to lie in their unusual cell envelopes. The existence of an odd outer layer in these bacteria was first postulated by Robert Koch in 1882 when he noted that the tubercle bacilli he had isolated from infected lung tissue were very difficult to stain. Despite belonging to the Gram-positive actinobacteria, they are impermeable to Gram stain and have cell envelopes that more closely resemble those of Gram-negative bacteria. This includes an outer mycolic acid layer similar to the outer membrane of Gram-negative bacteria. This 'outer membrane' also contains porins, which were first isolated from the cell envelope of *M. chelonei* and shown to form pores in liposomes and artificial lipid bilayers. Although the gene(s) encoding these porins have yet to be identified in *M. chelonei*, similar porins have been identified in *M. smegmatis*, including MspA, which forms a single pore and allows the diffusion of small hydrophilic molecules across the cell envelope. Curiously, while *M. tuberculosis* encodes no homologue of MspA it is known to contain at least two porins. Despite the presence of these pores, the mycolic acid layer makes mycobacteria highly resistant to dessication and to a wide range of antibiotics. It is also essential for intracellular survival and gives them perhaps their best known property: they are 'acid-fast'. This refers to a staining technique in which the bacteria are stained red with carbol-fuschin, washed in a dilute acid/alcohol solution and then stained again with methylene blue. Mycobacteria retain the red dye (they are acid-fast) while other cells are stained blue.

▲ A patient at the Acworth Municipal Hospital for Leprosy, Mumbai, India. *WHO / P. Virot*

◀ Coloured scanning electron micrograph of a macrophage (green) engulfing *Mycobacterium bovis* bacteria (orange). This is the BCG strain of the bacteria used in the vaccination against TB. *Science Photo Library*

Mycobacterium leprae

M. leprae was the first member of this genus to be identified, back in 1873 in Norway. Armauer Hansen discovered the bacterium while studying the skin nodules of patients in the leprosy hospitals in Bergen and immediately proposed that it was the cause of the disease. Unfortunately, he was unable to culture the bacterium in the laboratory or to find a non-human animal host and was therefore unable to prove his hypothesis. This was a problem that persisted for over 100 years until the strange (and fortuitous) discovery that the nine-banded armadillo was susceptible to infection with *M. leprae*. It was this armadillo that facilitated the sequencing of the genome in 2001 and led to the discovery that half the genome of *M. leprae* has decayed into pseudogenes. *M. leprae* has lost a large number of the genes it would need for survival outside of a host, hence its status as an obligate intracellular pathogen.

Although it is rarely fatal, leprosy is a disfiguring disease that has created fear for hundreds of years. The bacillus inhabits host macrophages and accumulates in the extremities. Most of the destructive damage is caused by infection of the Schwann cells in the sheaths of nerves, typically leading to the loss of digits and, in extreme cases, facial features and limbs. The cardinal symptoms of infection are anaesthetic skin patches, nerve damage and acid-fast bacilli in the skin. Following diagnosis leprosy is treated with a combination of drugs to prevent drug-resistant bacteria from arising. The World Health Organization (WHO) provides free multi-drug therapy (MDT) to leprosy

patients in all endemic countries and treated an estimated 2 million people between 1996 and 2000. MDT is a combination of the antibiotics dapsone and rifampicin and the anti-inflammatory clofazimine. The WHO report that the number of people affected is falling drastically every year and MDT is part of a programme aimed at eradicating this disease.

The *Mycobacterium tuberculosis* complex

Unlike leprosy, tuberculosis is still a growing problem, with more than two million deaths worldwide every year. Staggeringly, the WHO estimate that one-third of the world's population is infected with the tubercle bacillus (TB). The disease is most commonly caused by *M. tuberculosis* but can also result from infection by *Mycobacterium bovis*, *Mycobacterium africanum* and *Mycobacterium microti*. Together these four species make up the *M. tuberculosis* complex. *M. bovis* also causes tuberculosis in cattle which, although rare in most of the UK, is a big problem for farmers with infected herds since it spreads rapidly. Badgers have been blamed for spreading bovine tuberculosis (bTB) and have been culled in the south east of England. However, while it is clear that badgers can carry bTB, it is still unknown whether they transmit bTB to cattle or vice versa. In recent years the human tuberculosis problem has been exacerbated by the HIV epidemic, particularly in sub-Saharan Africa. Incorrect use of antibiotics has led to widespread multi-drug resistant (MDR) TB and, more recently, new strains of extensively drug resistant (XDR) TB have been reported. MDR TB strains are resistant to at least isoniazid and rifampicin, the two most powerful anti-tuberculosis drugs. In addition to this, XDR TB strains are resistant to at least four second line drugs (Table 1).

TB is spread through sneezing and the bacteria can remain air-borne in droplets of water for hours. Remarkably, only two or three bacteria need to reach the lungs to cause infection. They express cell surface proteins that advertise them to macrophages and invite phagocytosis. Once inside the macrophages, they block phagosome maturation and can remain dormant for years. Active infection occurs when T cells attack the site of infection and create lesions, or tubercles, in which the TB can remain hidden for long periods of time. The WHO estimate that one person with active, untreated TB can infect up to 15 people a year. This highlights the desperate need for accurate and rapid diagnosis and for effective treatment programmes that go hand in hand with treatments for HIV. Patients infected with HIV are much more susceptible to infection with TB and the two infections appear to exacerbate one another. Furthermore, treatment for one infection can seriously hinder treatments for the other and this creates a serious problem for healthcare workers. The WHO, with funding from the Bill and Melinda Gates Foundation, have formulated a global plan to halt the rise in TB by 2015. This extends their previous DOTS (directly observed therapy) programme and includes plans to put three million people co-infected with HIV and TB on retroviral drugs over the next 8 years. Important research goals include the development of rapid and inexpensive tests for TB, development of a new vaccine to replace BCG (Bacille Calmette–Guérin), and the development of the first new anti-tuberculosis drug in 40 years.

Table 1. Modern-day treatment of TB

First line drugs	Second line drugs
Isoniazid	Fluoroquinolone
Rifampicin	Capreomycin
Pyrazinamide	Kanamycin
Apicomplexa	Amikacin
	Cycloserine
	Thiacetazone
	Ethionamide
	Ciprofloxacin

▶ The European badger (*Meles meles*) foraging. Although it is clear that badgers can carry bovine tuberculosis, it is still not known whether they actually transmit the disease to cattle or vice versa. *Duncan Shaw / Science Photo Library*

▶ A coloured chest X-ray showing scarring (green) of the lungs after a case of chronic tuberculosis. The heart (red) is also seen. Scarring of the lungs often occurs if treatment is delayed. *Du Cane Medical Imaging Ltd / Science Photo Library*

A combination of new and powerful antibiotics and an effective vaccine might finally lead to the eradication of the ancient and terrible disease of tuberculosis.

Vaccination

The BCG vaccine is still the most widely effective vaccine against *M. tuberculosis* and *M. leprae*. It has an overall efficiency of between 15 and 80 %, probably because it doesn't work very well on people who have been exposed to environmental mycobacteria (such as *Mycobacterium avium*). BCG is a live attenuated strain of M. bovis isolated by Albert Calmette and Camille Guérin at the Pasteur Institute in Lille between 1906 and 1919. They subcultured a virulent culture of *M. bovis* on potato slices soaked in ox bile and glycerol. It took a total of 230 passages of 3 weeks each, during which time the bacterium gradually lost its ability to cause disease. The fact that no better vaccine has been introduced for human use since BCG in 1921 highlights the difficulties of producing a vaccine against an intracellular pathogen of the immune system. However, huge efforts are underway to develop new vaccines and some of these have reached the stage of human trials. The effort will be worthwhile because a new vaccine offers the best hope of combating this disease now that drug-resistant strains are becoming widespread.

New targets for drug discovery?

Since existing antibiotics have a fairly limited range of targets (namely the cell envelope, protein and nucleic acid biosynthesis), hopes for a powerful new anti-tuberculosis drug hang on the availability of genome sequences for pathogenic mycobacteria. Ideally these new targets will be proteins that are essential either for viability or infection and which are absent from the host cell. Cell-surface proteins are of particular interest due to the impermeability of the cell envelope. Transcriptomic approaches have already identified a wide range of genes that are expressed upon host-cell infection. This, combined with biochemical and structural studies, could lead to the development of antibiotics targeted at specific cellular structures. A combination of new and powerful antibiotics and an effective vaccine might finally lead to the eradication of this ancient and terrible disease.

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Further reading

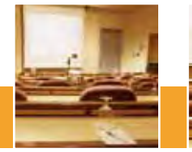
Cole, S.T., Eisenbach, K.D., McMurray, D.N. & Jacons, W.R., eds (2005). *Tuberculosis and the Tubercle Bacillus*. Washington, DC: American Society for Microbiology.

Hopwood, D. (2007). *Streptomyces in Nature and Medicine: The Antibiotic Makers*. Oxford: Oxford University Press.

World Health Organization Stop TB website – www.who.int/tb/en/

World Health Organization Leprosy website – www.who.int/lep/en/

meetings



Autumn**07** | University of Edinburgh

3–6 September 2007 | 161st Meeting

Plenary Food, fluids, fingers, faeces and flies – food- and water-borne pathogens

3–4 September 2007

Organizers N. Dorrell, P.H. Everest, K. Grant, H.M. Lappin-Scott, R.A. Rastall, C.E.D. Rees & P. Wyn-Jones

From farm to fork

H. Dalton London *Government directives and scientific realities*

R. Mandrell USA *Pathogen survival and minimal processing*

C.E.R. Dodd Nottingham *Processing pigs to pork: do critical control points exist for* Salmonella*?*

C. Hill Cork *Pathogen survival in dairy products*

Food-borne disease

R. Adak Colindale *Epidemiology of food-borne infection in the UK*

E. Duizer The Netherlands *Emerging food-borne Hepatitis E and porcine transmission*

C. Low Edinburgh *The epidemiology of VTEC in animal reservoirs and implications for human infections*

R. Glass USA *Gastrointestinal viruses*

Water-borne disease

J. Rose USA *Science in the fight against water-borne diseases*

P. Hunter Norwich *Significance of water-borne* Cryptosporidium

K. Jones Lancaster *Survival and transmission of* Campylobacter *in water*

P. Wyn-Jones Aberystwyth *Water-borne viruses*

Intervention strategies

T. Brocklehurst Norwich *Safety or flavour? Preservatives out, bacteria in?*

G. Mycock The Netherlands *Natural products as an intervention strategy*

L. De Vuyst Belgium *Control of food-borne pathogens by probiotic bacteria*

D.K.R. Karaolis USA *Food bioterrorism? Measures for protecting the food chain*

Hot topic symposium
with support from NERC

Post-genomic analysis of microbial function in the environment

5–6 September 2007

Organizers A.M. Osborn, P.L. Bond & J. Snape

Anaerobe 2007
with support from Oxoid

Changing perceptions and patterns of anaerobic infection

5–6 September 2007

Clinical Microbiology Group / Society for Anaerobic Microbiology

Organizers S. Patrick, M.M. Tunney & I.R. Poxton

Other symposia

Ecology of viruses

3–4 September 2007

Environmental Microbiology / Virus Ecology Groups

Organizers D.A. Pearce, M. Clokie & N.H. Mann

Physiology of non-growing microbes

3–4 September 2007

Physiology, Biochemistry & Molecular Genetics Group

Organizer D.J. Clarke

Monitoring in bioprocesses

4 September 2007

Fermentation & Bioprocessing Group

Organizers B. McNeil & D. Papadopoulos

Mechanisms of diarrhoeal disease

5–6 September 2007

Cells & Cell Surfaces / Microbial Infection Groups

Organizers P. Everest, B. Kenny & A.F. Cunningham

Eukaryotic microbial pathogens, attack and counter attack

5–6 September 2007

Eukaryotic Microbiology Group

Organizer A.S.H. Goldman

Workshops

Molecular detection of food and water pathogens

5 September 2007

Food & Beverages / Systematics & Evolution Groups

Organizer K. Grant

Getting it right: risk assessment and recording in microbiology

6 September 2007

Education & Training Group

Organizers L.M. Lawrance & M.J. Tully

Annual General Meeting

4 September

Young Microbiologist of the Year Competition

4 September

The competition is sponsored by the Society to encourage excellence in scientific communication by young microbiologists. This year's finalists will be making short oral presentations on their work. The three best entries will win cash prizes: 1st £500, 2nd £200 and 3rd £100. All finalists receive a free year's SGM membership.

General information

Contact details of organizers are included in the meeting programme on the SGM website.

A poster to promote the meeting is enclosed with this issue. Please display it in your department.

Abstracts

Deadline for receipt of titles and abstracts for offered presentations: **4 May 2007**.

Registration

Registration is via the SGM website at **www.sgm.ac.uk/meetings**

The deadline for discounted earlybird registration is **Friday 3 August**. Thereafter full registration fees will be payable.

Meetings on the web

For up-to-date information on future Society meetings and to book online see **www.sgm.ac.uk**

Meetings organization

The SGM meetings programmes are organized by the committees of the special interest groups, co-ordinated by the Scientific Meetings Officer, **Professor Hilary Lappin-Scott**. Suggestions for topics for future symposia are always welcome. See p. 99 for contact details of Conveners.

Administration of meetings is carried out by **Mrs Josiane Dunn** at SGM Headquarters, Marlborough House, Basingstoke Road, Spencers Wood, Reading RG7 1AG (t 0118 988 1805; f 0118 988 5656; e meetings@sgm.ac.uk).

Offered papers & posters

Many Groups organize sessions for the presentation of short oral papers or allow intercalated papers within their symposia. Offered posters are welcome at all Society meetings.

Offered posters

Each poster should be associated either with the Plenary topic or with a Group. The subject content of the latter should be relevant to the remit of a Group (see website for details); it does not have to relate to the topic of the Group Symposium taking place at a particular meeting. General Offered Posters will not be accepted.

Abstracts

Titles and abstracts for all presentations are required in a standard format and should be submitted through the SGM website. Deadlines for submissions are published in *Microbiology Today* and on the web. For further information contact the Events Administrator.

Spring**08** | Edinburgh International Conference Centre

31 March–3 April 2008 | 162nd Meeting

Plenary Bacterial secretion systems: commonality and diversity

Hot topic Microbes and climate change

Other sessions

Type V secretion / Biological basis of infection control / How to pass the MRCPath Part 2/ Vaccines against viral infections / Communicating microbiology / Microbial biogeochemical cycling / Commercial industrial bioprocess development / Toxins in food and beverages / The horizontal gene pool / Cell biology / Cyanobacteria / Virus modulation of host defences / Control of virus gene expression

Autumn**08**

Trinity College Dublin

8–11 September 2008

Plenary Biofilms

Abstract**Book**

Manchester Meeting, March 2007

The full text of the abstracts book is available as PDF on the SGM website.

Irish**Branch**

Microbial functions in response to the environment

Queen's University of Belfast

30–31 August 2007

Organizer John McGrath

Regulatory mechanisms in host–pathogen interactions

National University of Ireland, Galway

27–28 March 2008

Organizer Conor O'Byrne

For details of Irish Branch activities contact Evelyn Doyle (e evelyn.doyle@ucd.ie).

Other**Events**

Third European Congress of Virology

Nürnberg, Germany

1–5 September 2007

Virus molecular interactions: therapeutic targets (SGM/RSC joint meeting)

Oxford

16–18 September 2007

14th Conference of the Federation of Infection Societies

Cardiff

28–30 November 2007

Schools Membership costs only £10 a year. Benefits include *Microbiology Today*, advance copies of new teaching resources and discounted fees on SGM INSET courses. To join see **www.sgm.ac.uk/membership**. Enquiries: **education@sgm.ac.uk** or go to **www.microbiologyonline.org.uk** for full details of resources and activities.

Projecting microbiology

www.nuffieldfoundation.org/go/grants/nsb/page_390.html

www.the-ba.net/the-ba/YPP/BACRESTAwards/index.html

There are several schemes that aim to raise the profile of science to school students. **Jane Westwell** describes Nuffield Bursaries and the Crest Awards, whilst **Sue Assinder** takes a trip to Dublin to visit the largest school science fair in Europe.

SGM provides funds each year to the Nuffield Foundation to support microbiology-based projects under its Science Bursary Scheme. This gives school students the chance to work alongside research scientists or technologists in universities, research institutes or industry. Projects take place for 4–6 weeks during the summer vacation before the final year of A-levels and the student receives a bursary of up to £70 per week. Supervisors are encouraged to provide a project that is real and useful to their overall work, perhaps by exploring a strand that may not otherwise be investigated or to add a new dimension to an existing project.

▲ Hannah Bradon (left) and other award winners with Dr Kevin Cheesman from AstraZeneca. *The British Association for the Advancement of Science*

After completing their projects, students attend local events where they display them to an invited audience of teachers, other students and representatives from industry, universities and research institutes. The best students at each event are encouraged to nominate their projects for entry to the BA Crest Science Fair which is held in London each February. Jane Westwell from the External Relations Office was judging at this year's event and was delighted to meet **Hannah Bradon**, an enthusiastic student whose project on salmonellosis in garden birds so impressed the judges that she won a prestigious AstraZeneca Young Innovators Award. This included a lap-top computer and a summer placement with AstraZeneca tailored to the student's interests and training needs. Coincidentally, her project was hosted by SGM member **Paul Wigley**, so Jane asked both Paul and Hannah to share their impressions of the Nuffield Bursary Scheme.

The supervisor's view

Paul Wigley
Dept of Veterinary Pathology, University of Liverpool

I acquired a Nuffield Bursary student accidentally as the faculty had agreed to take a number of students, but could not place them in research groups at the main campus. Following encouragement from a colleague who had hosted these projects previously, I agreed. Hannah Bradon, the bursary student, then contacted me and we developed her project together.

The Department has a strong interest in wildlife infectious disease and as such had become involved with the Garden Bird Health Initiative. Through this we have a PhD student investigating a range of infections in garden birds. Salmonellosis is one of the more common infections and we had collected a number of *Salmonella enterica* serovar Typhimurium strains from dead greenfinches throughout the north of England. My main research interest is in the pathogenesis of salmonellosis in poultry so I was curious to find out if these strains were similar to those associated with poultry or human disease and to begin to understand a little of their molecular epidemiology. Together Hannah and I developed a number of questions that her project would address:

1. Was greenfinch salmonellosis the result of a clonal strain or lots of different strains?
2. Did these *Salmonella* isolates have virulence factors common to human or poultry strains and do they behave in the same way in cell culture infection models?
3. Are these strains resistant to antibiotics like many found in livestock?

We approached each of these questions with a range of techniques, including PFGE, PCR, plasmid isolation and cell invasion assays. Hannah conducted the work with genuine enthusiasm, always eager to learn more and much less afraid to ask questions than I expected. We found that there were just two closely related clonal strains affecting greenfinches, that they possessed genes associated with disease and that they were highly invasive into cultured epithelial cells. Unlike many isolates that come through the department, they were susceptible to most antibiotics.

Following Hannah's project, we have expanded the work considerably to look at a larger panel of virulence factors and strains from a range of bird species and have investigated their biology in cell culture models in further detail. We are now in the processes of analysing avian *Salmonella* isolates from throughout the UK in conjunction with the Zoological Society of London and hope to publish these data in the next year.

The project was quite an intellectual challenge for me as it required me to learn some new techniques and applications too. It was extremely rewarding to see Hannah's confidence and ability in the lab grow. By the end of the project a visitor to the lab thought she was a postgraduate student as she was so confident! The project did involve some thought and planning, but provided an excellent pilot study. It has proved a very worthwhile experience for me and I hope for Hannah. The one thing I would suggest for anyone considering taking on such a project is to be realistic in its scope, but design a real project related to your ongoing research. A goal that means something to your research helps the student really value their contribution and learn more about research than a small unrelated piece of work.

▶ Hannah working on her project at the University of Liverpool. *Hannah Bradon*

The student's view

Hannah Bradon
West Kirby Grammar School

Q *Congratulations on winning such a great prize at the BA Crest Science Fair 2007. What led you to enter the event?*

A I attended the BA Gold Crest regional award ceremony for people taking part in Nuffield Schemes or similar throughout the North West. The judges were able to recommend six projects that were good enough to self-nominate for the National BA Crest Science Fair in London. I was delighted (if not a little surprised) at being selected for this event, particularly when I saw the high standard of projects I was up against!

Q *How did you find the experience?*

A I found it extremely enjoyable, although very tiring. It was a long day and I had nine judging sessions, which kept me on my toes!

But I really enjoyed talking to the judges about my project and it was interesting as some of them obviously knew a lot about the subject whereas others didn't, so I found myself communicating on different levels, depending on who I was talking to. I also liked being able to see all of the other fabulous science and technology projects that people had carried out. Again, I was very surprised when the prizes were given out and I won AstraZeneca's award!

Q *Why did you decide to apply for a Nuffield Bursary to carry out a research project?*

A It was my school physics teacher who first mentioned the Nuffield Scheme, recommending that I should apply for a bursary over the summer holidays. I thought that this would be a fantastic opportunity to meet people with a science-based career and I knew that wherever I would be working and whatever I would be doing, I would benefit greatly from the whole experience.

Q *What attracted you to the project with Paul?*

A First, when my Nuffield co-ordinator told me that I would be working at the Pathology Department based at Leahurst (the veterinary teaching hospital of Liverpool University) I was really pleased, having done work experience at the large animal hospital a couple of years earlier.

When I first went to Leahurst to meet Paul I could see that he was looking forward to being able to do this project as it was novel and nobody knew what kind of results would be obtained. Despite having never worked in a lab and knowing practically nothing about *Salmonella* Typhimurium, I was really excited about the project. I have always been interested in animal health and welfare and having the chance to do my own research into *Salmonella*-induced deaths in greenfinches was a fantastic opportunity for me and will probably be very useful for me in the future.

Q *How did you find working in a research lab?*

A Having never worked in a lab before, my 4 weeks of research were a completely new experience. I definitely had a steep learning curve, having to pick up techniques and carrying out various experiments. At the beginning of the project I didn't know how to streak out an agar plate or use a pipette, yet by the end I had followed a protocol for Pulsed-Field Gel Electrophoresis.

I found the reality of lab work very different from the theory, some of which I had learnt about in school – the text book descriptions of PCR or electrophoresis don't tell you about the waiting involved! Working in a research lab also enabled me to meet and talk to students and professionals who were carrying out their own research projects.

Q *Do you have any advice for students thinking of doing something similar?*

A If anybody is thinking of doing a research project, the best advice I can give is 'don't hold back!' I would definitely recommend it. Although the project takes up spare time and does require a fair bit of work, not many students get the chance to carry out something like this and there are only limited places on the Nuffield scheme, so if you do get the opportunity, go for it!

Q *What are your plans for the future?*

A I'm studying Biology, Chemistry and Maths at A-level and have recently received a conditional offer to study Veterinary Science at university next year. This project made me aware of the importance of veterinary scientists in research and I would definitely consider research as a career in the future. So I'm keeping my fingers crossed for this summer's exams!

Jane Westwell
External Relations Office

▲ The 2007 BT Young Scientist & Technology Exhibition, Dublin (top), and just what it means to win – Abdusalam Abubakar and friends with their prizes (bottom). *Gill Madden, Fleishman-Hillard International Communications*

Showcasing science in Ireland

How do you get young people interested in science? An approach used in America for many years is the school 'Science Fair', at which budding young scientists get the chance to present the results of their hands-on science projects, with the best going on to compete at a high-profile national competition. Back in the 1960s, two physicists from University College Dublin were so inspired by this model that they set out to emulate it back home.

Now in its 43rd year, the *BT Young Scientist & Technology Exhibition* is one of the largest and longest running science exhibitions in Europe. It is a showcase for secondary pupils from all over Ireland to display their originality and research skills. It is also a hugely enjoyable event which gives young people the chance to meet their peers from across the country and to explore the wider world of science and technology. Approximately 1,500 proposals were submitted for the 2007 Exhibition, from which 500 projects were selected to compete in a 3-day event in January, attended by some 35,000 members of the public.

I had the pleasure of visiting the exhibition on the day on which the prize winners were announced. As I entered the Exhibition Hall at the Royal Dublin Society I was taken aback by the scale of the event, the diversity and quality of the science on show … and the noise! The enthusiasm and excitement of the young participants was almost tangible.

I spent a fantastic day wandering around the posters and talking to the pupils about their work. It was pleasing to see a lot of microbiology projects on display, albeit most of them variations on a theme. Many pupils had chosen to look at surface contamination by microbes (on hands, feet, mobile phones, money and the staff room floor) or at food spoilage (in thawed meat and student lunch boxes). It was a bit disappointing that a lot of these projects involved taking swabs and streaking agar plates, rather than having any sort of quantitative element. However, just getting these young people interested in microbiology is an important first step. My favourite project compared the antibacterial properties of New Zealand Manuka honey with its Irish counterpart. The students were delighted to be able to conclude that the home-grown product was just as good (and a snip at about a quarter of the price).

The highlight of the day was the prize-giving. Expecting something along the lines of a school speech day, I was stunned to be led into a 2,000-seater auditorium, with flashing lights, booming music … and Ronan Keating. Hand-held cameras followed the prize-winners as they made their way to the stage, projecting their delighted faces onto huge video screens. It was like a cross between the Oscar ceremony and the final of X-Factor.

Microbiology projects scooped a fair share of the prizes, with the Manuka Honey project coming second in its category and also winning a special food safety award. However, the overall winner was a 16-year old mathematician, Abdusalam Abubakar, whose project demonstrated weaknesses in a widely used computer encryption system. His grasp of complex mathematics impressed the judges, but may be appreciated less by those in charge of the security of bank details and internet commerce!

So how do you get young people interested in science? Give them the freedom to develop their own research project, the thrill of showcasing their work and then make them feel special by publicly celebrating their successes. And having Ronan Keating on hand doesn't do any harm either!

***Sue Assinder**, Education Officer*

gradline

Gradline aims to inform and entertain members in the early stages of their career in microbiology. If you have any news or stories, or would like to see any topics featured, contact **Jane Westwell** (e j.westwell@sgm.ac.uk).

PhD – what's next?

You've almost finished your PhD or maybe you've already started a postdoctoral contract. Are your thoughts turning to the future? Are you considering your next career move or maybe even the one after next? **Jane Westwell** shows how to maximize your chances of success.

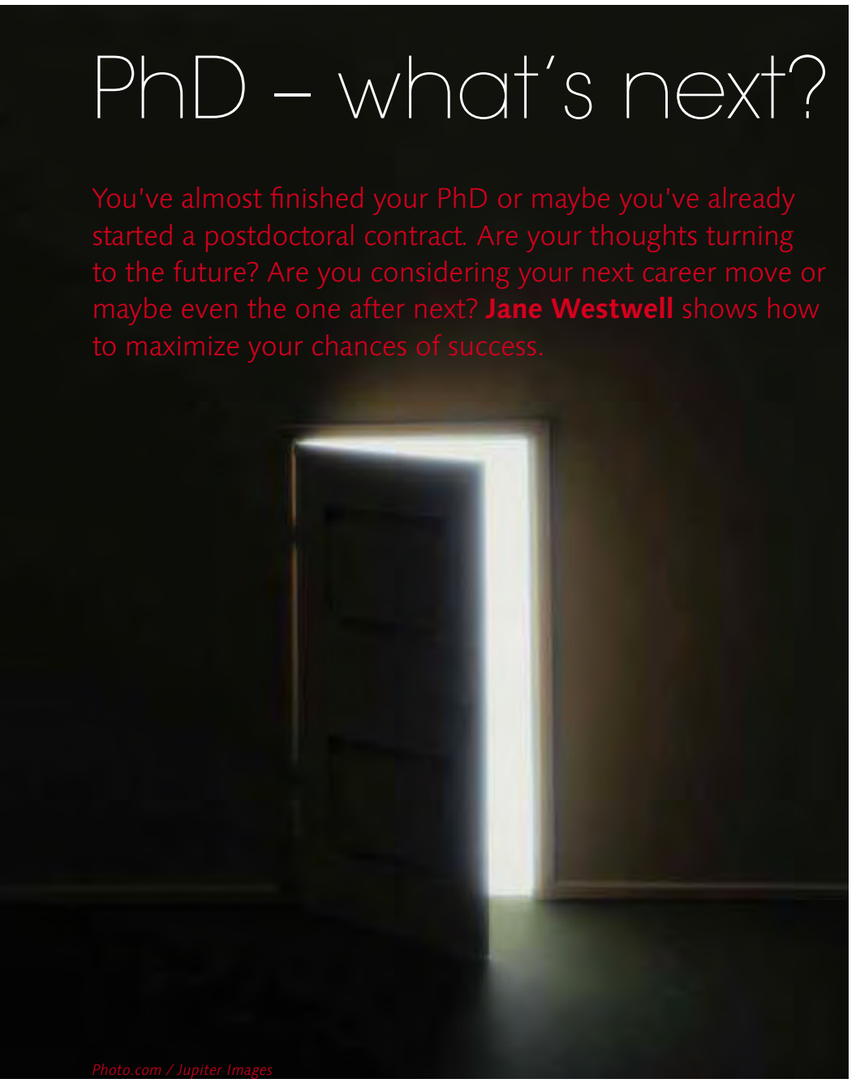


Photo.com / Jupiter Images

More than 150 PhD students and early career postdocs were thinking about their careers when they attended the *PhD – What Next?* session at the recent SGM Meeting in Manchester. Our focus was employability or using the skills developed during research to move on in your career. **Joanna Verran**, Convener of the SGM Education and Training Group, chaired the workshop which started with a plenary talk on employability by **Belinda Bray** who is the Project Officer for UK GRAD NW Hub based in Manchester.

Employability tactics

Belinda pared down the concept of employability to getting a job and talked about the key points to consider: what type of job do you want, what skills and experience do you have already, and what skills do you need to develop to get the job you want? She emphasized the importance of reflecting carefully on what you might want from a career – likes and dislikes about work, what you are good at, what makes you get up in the morning and, importantly, what you want to avoid. Belinda then highlighted the direct skills that a PhD researcher develops and identified key transferable skills that may not be immediately obvious (troubleshooting, strategic planning, and project management). She encouraged the audience to take time out to develop skills by taking full advantage of the postgraduate development courses that all universities offer and also going on a GRADschool course. She also suggested strategies to acquire new skills such as teaching, presenting work at conferences (by volunteering for the oral rather than poster presentation) or maybe through voluntary or part-time work. Belinda rounded off her talk with some hints on finding work and making applications. Her talk is available as a PowerPoint presentation from **www.biocareers.org.uk/res.htm**

Case studies

Three short presentations followed from microbiologists who have fairly recently made their next step from PhD research.

Paul Hoskisson (a recently appointed lecturer at University of Strathclyde) shared his experiences as an academic researcher. He outlined his career pathway and the actions he took to progress it. After graduating with a BSc in Applied Microbiology from Liverpool John Moores University, Paul spent 18 months working in industry. He then went back to Liverpool to do a PhD. During this time he realized that molecular biology would be a key element of microbiology in the future and decided to focus on this area. For his first postdoctoral position he identified a big research group and used email and networking to approach them. His choice of second post was guided by several considerations: what skills he needed to develop, which group had the funding to make appointments and whether or not to work overseas for a period of time. Again, networking (at an SGM meeting) helped to secure a job. Paul gave an honest assessment of the pros and cons of postdoctoral research and advised on how to make the most of it – have a purpose, don't drift into it and take advantage of any opportunities offered. Paul's talk illustrated how an enthusiasm for research coupled with planning and balanced decision-making can result in an academic post.

Our next speaker, **Anne Kjerrström** described the career choices that led to her current post at Pfizer Global Research and Development in Sandwich. Her school and university education was in Sweden – a different system to the UK – but the approaches she used to develop her career would work well in any situation. Anne took every opportunity throughout her education to gain research experience and followed her MSc with a 3 month project in Japan. After working for a PhD with an industrial focus at the Karolinska Institute and a 6-month postdoctoral position in Sweden, she went to a Marie-Curie funded position at Pfizer in 2003. This led to a permanent position the following year and her current post in antiviral research in 2006. Anne advised delegates to find a career that really interests them and look for opportunities; she also emphasized the need to build up a network of contacts and the advantages of having a career mentor to offer unbiased support.

Lucy Chappell (Press and Communication Officer, HPA) rounded off the talks from the perspective of a researcher who made a definite decision to move from a PhD at the Institute for Animal Health to a career outside the lab. She outlined her current role and described the variety of work it involves (dealing with press enquiries, briefing journalists, organizing interviews with experts, writing press releases, articles and reports and editing technical pieces for a non-technical audience). Lucy identified the skills she developed during her PhD (writing, presentation and technical, practical skills) and then found ways to gain some diverse non-research based experience that would help in her future job-hunting. She became a Researcher in Residence – developing teaching and communication skills to a school audience – which led to further schools liaison work. She also wrote non-technical articles for the *IAH Bulletin* and got involved in Biotechnology YES which developed her business awareness, presentation and marketing skills. Lucy also took the opportunity to organize the IAH exhibit at the 2006 Royal Agricultural Show. Lucy's talk highlighted the importance of identifying the skills needed to change career and gave examples of how to make the most of opportunities available to many PhD researchers. She also encouraged the audience to think of ways to enhance their own skills and experience to make their application really stand out from the competition when applying for jobs.

Q, A & supper

Following the presentations, our speakers and chair formed a panel to answer questions from the audience. They were joined by three more experts: **John Peberdy** (Biotechnology YES), **Fillipa Vance** (Science Programme Manager, Wellcome Trust) and **Sarah Ashworth** (Postdoctoral Development Officer, University of Manchester). After some lively discussion, workshop delegates and speakers carried on networking over a buffet and wine reception. The External Relations Office is very grateful to our chair, speakers and panel members for their contribution to the success of this event and to ScienceCareers.org for their sponsorship.

Further information

www.grad.ac.uk – resources to support postgraduate researchers and information about GRADSchools

www.sciencecareers.org – job postings, career tools from NextWave, grant information, CV database, workshops and career events

www.biotechnologyYES.co.uk

www.researchersinresidence.ac.uk/rir/

hotoffthepress

Science writer **Meriel Jones** takes a look at some recent papers in SGM journals which highlight new and exciting developments in microbiological research.

Iron-Age TB

Taylor, G.M., Murphy, E., Hopkins, R., Rutland, P. & Chistov, Y. (2007). First report of *Mycobacterium bovis* DNA in human remains from the Iron Age. *Microbiology* **153**, 1243–1249.

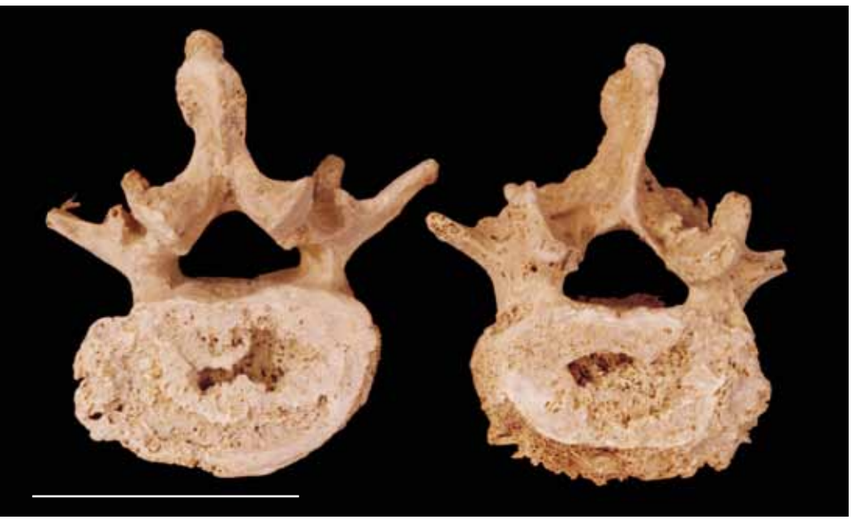
Tuberculosis has been a serious disease for thousands of years. It is usually caused by the bacterium *Mycobacterium tuberculosis*, although several other closely related species within the *M. tuberculosis* (MTB) complex can also cause illness. One of these is *M. bovis*, which more usually infects cattle and other animals. This source of disease is now rare in countries like the UK where herds and milk have been tested since the 1930s. Without these control measures, there would be many more infections caused by drinking or eating milk and animal products.

As well as the lungs, TB can damage bones. Exactly the same type of lesions have been found on ancient skeletons and in modern patients, allowing palaeopathologists to speculate with some confidence about the disease in ancient populations. Researchers are also now convinced that the DNA from *Mycobacterium* species can survive for thousands of years and still be detectable within bone, and the very sensitive polymerase chain reaction can be used to retrieve short sequences of ancient DNA. To be confident that the DNA is not contaminated with modern molecules, researchers have learnt to take a series of very careful precautions. These include repeating the analyses on separate extracts of the bone specimens in at least two separate laboratories.

The importance of TB means that several molecular methods have been developed to identify individual MTB strains from modern patients. Examining bone lesions cannot distinguish between the different causes of the disease, but molecular typing can. A collaboration between Yuri Chistov (Russia), Eileen Murphy (Ireland) and researchers in the UK has allowed a study of five Iron-Age individuals recovered from a cemetery in Siberia. This part of the world has one of the oldest traditions of pastoralism and so might have seen some of the earliest cases of TB. Lesions on vertebrae on all the five skeletons indicated at least the possibility that these people had suffered from TB.

Michael Taylor and Richard Hopkins (Imperial College of Science, Technology and Medicine), and Paul Rutland (University College London), working in a laboratory where research on TB had never been conducted before, carried out two completely separate sets of analyses of DNA from the bones. The researchers tested for two markers specific to all members of the MTB complex as well as others that distinguish between strains and species, and had success with DNA from four of the five individuals. The markers indicated, for the first time, that the DNA was from *M. bovis* rather than *M. tuberculosis*, found in all other archaeological remains so far. These semi-nomadic, Iron-Age pastoralists would probably have been infected by raw milk or poorly cooked meat from their cattle or other domestic animals such as goats or sheep. A further insight from the molecular analysis was that the strains had several hallmarks of 'classic' *M. bovis*, indicating that its features have existed for at least 2,000 years.

The researchers hope in the future to continue the molecular characterization of *M. bovis* strains from these pastoralists. This should not only enable them to place the strains more accurately within the evolutionary scheme for the bovine lineage of the MTB complex, but may even help with improving current genotyping tools for modern isolates of *M. bovis*.



◀ Large abscess cavities in the bodies of LV3 and LV4 of skeleton XXXI.34 (25- to 35-year-old female). Scale bar, 5 cm. *Mike Taylor*

A new bioinsecticide against Colorado beetle

Martin, P.A.W., Gundersen-Rindal, D., Blackburn, M. & Buyer, J. (2007). *Chromobacterium subtsugae* sp. nov., a betaproteobacterium toxic to Colorado potato beetle and other insect pests. *Int J Syst Evol Microbiol* **57**, 993–999.

▼ Colorado potato beetle larva (2nd instar). *Peggy Greb*

Some of the most serious agricultural pests are insects, making agricultural scientists always interested in anything that kills them while not harming plants or people. A few bacterial species have insecticidal properties and researchers at the USDA are keen to add to this number. They became interested in brightly coloured bacteria isolated from soil gathered beneath hemlock trees (*Tsuga canadensis*) in the Catoctin Mountains, Maryland, USA. The bacteria were an unusual violet colour. Being aware that pigment-producing bacteria often have a reputation for producing antibiotics and at times seem to have the genetic capacity to produce insecticides, the team embarked on a series of tests to both identify the bacterial species and test whether it had any insecticidal properties.

Many features of the bacteria matched those of *Chromobacterium violaceum*, but others differed substantially, indicating a novel species. For example, there were significant differences in the utilization of substrates between the two species, as well as very low DNA–DNA relatedness and differences in their toxicity to insects. The researchers were particularly pleased to discover that, although *C. violaceum* had no effect, a small amount of the violet bacteria put Colorado potato beetle larvae off their food. Often the first sign that bacteria are toxic to insects is feeding inhibition. Colorado beetle is a very serious pest of potato crops. It originated in the USA, but has now spread to many potato-growing regions, including most of Europe, the Middle East and central Asia. It has developed resistance to most major insecticides, so new control methods are needed. The purple bacteria were also toxic to several other species of insect pests.

The researchers therefore propose that they have found the type strain of a novel species of *Chromobacterium*, called *C. subtsugae*. Its insecticidal properties are certain to be the subject of further study.

Vaccinia virus fights back

Cooray, S., Bahar, M.W., Abrescia, N.G.A., McVey, C.E., Bartlett, N.W., Chen, R. A.-J., Stuart, D.I., Grimes, J.M. & Smith, G.L. (2007). Functional and structural studies of the vaccinia virus virulence factor N1 reveals a Bcl-2-like anti-apoptotic protein. *J Gen Virol* **88**, 1656–1666.

One strategy used by animals to combat virus infections is apoptosis, the programmed destruction of infected cells, which prevents multiplication of the virus and so restricts infection. Apoptosis requires activation of a series of proteins that disassemble the cell components and dispose of them neatly. Many viruses have evolved ways to evade this defensive manoeuvre and several of them produce anti-apoptotic proteins that interfere with apoptosis. Proteins are formed from linear chains of amino acids that are frequently similar in order and chemical nature to proteins of similar function. Indeed, several viral anti-apoptotic proteins have been identified through the similarity of their amino acid sequence to other proteins with known anti-apoptotic properties. However, researchers at Imperial College London and the University of Oxford have now identified a viral protein where the three-dimensional structure, rather than amino acid sequence, was the key to identifying its function.

Vaccinia virus is used to vaccinate against smallpox and produces many proteins that affect the immune response of human cells. The precise function of many of these is not known, and the researchers were working on one protein called N1 that contributes to the virulence of the virus in some way. The breakthrough in understanding its function came after they worked out the three-dimensional structure of the N1 protein. Despite many technical improvements, this is still a challenging process. It involved producing and purifying a substantial amount of modified N1 protein, and then inducing it to form crystals. Finally, tuneable X-ray sources were used to reveal the hidden three-dimensional protein structure, helped by a series of computer analyses of the data.

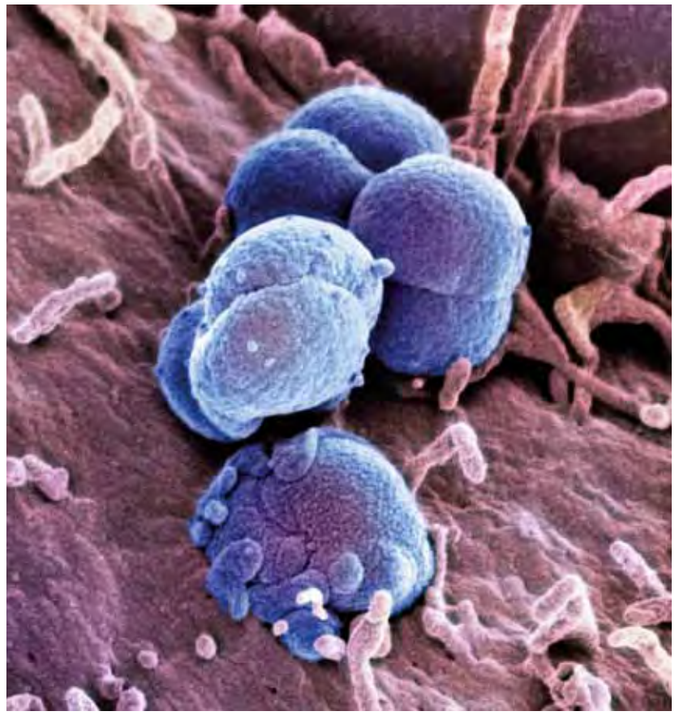
Remarkably, the structure of N1 closely resembled that of Bcl-x_L, a human cellular protein within the Bcl-2 protein family, which includes individual members with both pro- and anti-apoptotic functions. There was even a groove on the surface of N1 very like a groove in anti-apoptotic family members that binds to pro-apoptotic Bcl-2 proteins, so inhibiting their function. Once the similarity of N1 and Bcl-2 proteins was known, the researchers tested whether the N1 protein was able to block apoptosis. They showed this was the case during virus infection and also when the N1 protein was expressed on its own. Lastly, they showed that N1 bound to some pro-apoptotic Bcl-2 family proteins.

This result is a convincing example that strong evolutionary pressure can drive retention of a particular functional three-dimensional structure, regardless of amino acid sequence, as well as explaining more about how vaccinia virus works.

Gonorrhoea in court

Martin, I.M.C., Foreman, E., Hall, V., Nesbitt, A., Forster, G. & Ison, C.A. (2007). Non-cultural detection and molecular genotyping of *Neisseria gonorrhoeae* from a piece of clothing. *J Med Microbiol* **56**, 487–490.

The bacterium *Neisseria gonorrhoeae* causes gonorrhoea, a disease which is almost exclusively transmitted during sexual intercourse. Although tests requiring cultures of the bacterium are considered to be best for a definitive diagnosis, molecular methods relying on only bacterial DNA are improving in sensitivity and specificity. These can permit detection and typing of *N. gonorrhoeae* in situations where the bacterium cannot be cultured. For medico-legal cases there is a need to not only confirm the presence of *N. gonorrhoeae*, but to prove a link, or the absence of one, between the strains isolated from each individual. DNA markers therefore need be selected so that they accumulate variation sufficiently rapidly to exclude unlinked individuals who happen to suffer from gonorrhoea, while still allowing identification of individuals who are sexual contacts or part of a short transmission chain. A database of suitable DNA markers for *N. gonorrhoeae* acceptable in a court of law is not yet available. However, researchers have a database from two of the bacterium's most variable genes containing information on over 4,000 different strains. This is the *N. gonorrhoeae* multi-antigen sequence typing database (NG-MAST), but since the strains were collected during specific studies, they do not give a complete picture of all the types present within a particular geographical area. However, researchers were recently faced with a request for *N. gonorrhoeae* confirmation that utilized NG-MAST, and provided the first reported typing of gonococcal DNA from clothing for medico-legal reasons.



Staff at the UK Government's Health Protection Agency Centre for Infections and the Forensic Science Service in London, collaborating with colleagues in the London NHS Trust, used DNA markers, supported by biochemical and immunological tests, to confirm that a strain of *N. gonorrhoeae* obtained from a vaginal swab of a child was indistinguishable using NG-MAST from the DNA found on the underwear of a man suspected of sexual abuse. Bacteria cultured from the swab could be identified by conventional tests as *N. gonorrhoeae*. After extracting DNA from the bacteria and stained regions of the underwear, both were tested for DNA markers. The analysis using NG-MAST showed that all the samples were from the same sequence type of *N. gonorrhoeae*. There were only two previous records of this type, both from London in 2004. However, since NG-MAST has a relatively small number of records, it is impossible to know whether particular molecular types are shared because they are common in a geographical area, or because the two cases are truly linked. The strength of this evidence was not tested in court because the man changed his plea to guilty when presented with the evidence. The researchers are now reviewing the number and type of supplementary tests that might be necessary to make the results sufficiently robust for use in courts.

▲ Coloured scanning electron micrograph of *Neisseria gonorrhoeae* bacteria (blue) infecting a human epithelial cell (purple). *Science Photo Library*

In the early stages of your career and annoyed by how your area of science is portrayed in the media? You don't have to fume in silence. There is a network of people out there who feel the same about their subject. And as **Frances Downey** describes, there are even training workshops to help you make your voice heard where it counts.

Getty Stock / Jupiter Images

What do you mean 'Stand up for science'?

www.senseaboutscience.org/voys

On Friday 18 May 2007, Sense About Science will be running a *Standing Up for Science* media workshop with the SGM. This event, focused on biological sciences and bioengineering, will be the eighth in a hugely successful series of workshops, the attendees of which have contributed to the Sense About Science VoYS (Voice of Young Science) Network. This workshop follows the launch of the VoYS Network's first publication – *Standing up for Science*, a guide to the media by early career researchers for early career researchers. The guide includes personal stories from researchers about their experiences with the media, explanations from leading journalists about what they do (and how they do it) and top tips from university press officers. It has proved very popular – in just a few months over 10,000 postgrad and postdoc students have been sent their own copy; 19,000 more have downloaded it from the Sense About Science website. One consequence of the workshop and guide is that more early career researchers than ever are contacting Sense About Science to talk about how to promote good evidence to the public and stand up for science.

But what does it mean to 'stand up for science'? It's all very well feeling passionate about science and wanting to defend its principles, but who is really going to want to talk to an early career scientist (unless the discussion is specifically about their own research) when there are so many high profile scientists out there? Look at the current debate around the use of hybrid and chimera embryos in stem cell research. You may have insights into how this will affect research and views on whether proposed regulations are coherent, but who do you think most journalists will want to talk to? You, or Dr Stephen Minger, director of the Stem Cell Biology Laboratory at King's College London?

Well, even if the answer is Dr Stephen Minger (and it isn't always!), should you just leave it at that and hide away in your lab? No! Of course you shouldn't – there are a lot of challenges out there in public debate, and, despite big improvements, still not enough scientists taking them on. You just have to identify the opportunity. It is unlikely a journalist will call you to ask what you think about a new national policy, but that does not mean you cannot tell them yourself: write a letter to the national newspapers; work out how to interest local and regional media in the subject; contact your university or learned society magazine; and offer to write articles from an early career researcher perspective.

But also think beyond the more familiar territory. Science is used to selling us face creams, remedies, food, taxes, cuts, health initiatives; does the information we are given come from sound, evidence-based science? Time and again these claims are dressed up in the clothes of science and are misleading the public, and yet we allow them to go uncontended. The government bans full fat milk in primary schools over health fears for young children; a homeopathic remedy claims to treat asthma; a supermarket removes MSG from all of its own products. What are these claims based on? Shouldn't we, the up and coming generation of scientists, find out? Let's start asking some awkward questions and get to the bottom of these claims. The decisions we make about how we live and how our society governs itself should not pander to exaggerated claims, but be grounded in clear, evidence-based science. At Sense About Science we have discovered that when scientists are prepared to stand up and make their voices heard, it does make a difference. So get vocal, join our VoYS Network, apply for the workshop and start your letter writing, phoning and visiting.

Frances Downey
(e fdowney@senseaboutscience.org/voys)

Copies of the Standing up for Science leaflet are available from the External Relations Office of the SGM (e pa@sgm.ac.uk)

Members' reports

SfAM/SGM microbiology in the regions grants provide support for one- to two-day microbiology meetings. These events can either be on a special topic or held by local microbiology groups. The scheme has proved popular, as shown by the following accounts of some events in the past year. For full details of the scheme, see **www.sgm.ac.uk/grants/sfamsgm.cfm**

2006 All Wales Microbiology Meeting

20–22 March, Gregynog Hall, Powys, Wales

58 participants from the universities of Aberystwyth, Bangor, Cardiff and Swansea, as well as researchers from the Institute of Grassland and Environment Research at Aberystwyth, attended the meeting. After an ice-breaking and intriguing microbiology quiz hosted by Greg Jones (a PhD student at Swansea) on the first evening, there were five scientific sessions covering topics in clinical, environmental and industrial microbiology. Of the 25 presentations, 19 were from a mixture of postdoctoral researchers and PhD students and 5 from invited speakers.

Kevin Ashelford (Cardiff University) opened the meeting with a valuable talk on the quality of 16S rRNA gene sequences available in the databases. He described how at least 5 % of the deposited sequences were often inaccurate chimeras from two or more organisms and also talked about the software tools which he has developed to identify such problematic sequences. Chris Wright (University of Swansea) presented his group's research on using Atomic Force Microscopy as a nanotechnology for probing microbial structure and interactions with surfaces. Adam Baldwin (University of Warwick) described the nucleotide-sequence-based typing method of Multilocus Sequencing Typing and how he has used it to track the epidemic spread of *Burkholderia cepacia* complex infections in cystic fibrosis patients. Brian Jones (University of Cork) presented research from his first postdoctoral position examining the microbial metagenome present in the human gut and described the complexities of creating and screening large-scale genomic libraries. Finally, Tony Campbell (Cardiff University) gave an absolutely 'glowing' after-dinner talk on the use of bioluminescence in microbiology and the science which has resulted from his pioneering discovery of the proteins which enable jellyfish and other deep-sea marine organisms to emit light.

The SfAM/SGM competition for the best presentation by a young microbiologist was judged by Tony Campbell and Paul Dyson (University of Swansea). The judges agreed that the standards of presentation had been excellent throughout the meeting but awarded the prize to Prysor Williams, a third year PhD student at the University of Bangor for describing his studies on the role of earthworms as potential vectors for the enteric bacterial pathogen *Escherichia coli* O157.

We thank the two societies for providing a Regional Meeting Grant to assist with the costs of inviting speakers and hosting the meeting.

Gareth Griffith* & *Eshwar Mahenthiralingam

▲ Left. All participants in the 2006 All Wales Microbiology Meeting in front of Gregynog Hall. *Gareth Griffith*

▲ Right. Prysor Williams receiving his Communication Prize from Professor Tony Campbell. *Gareth Griffith*

◀ Miriam Banner, a PhD student from the University of Manchester, receiving her Communication Prize from Professor Henri Verbrugh at the *Staphylococcus* GBI '06 conference held at the University of Liverpool. *Mal Horsburgh*

▲ Michael Ravensdale, winner of the SGM/SfAM Communication Prize at the Birnham Institute, with the two runners-up, Mary Illes (Oxford) and Lauren Ryder (Exeter). *Leighton Pritchard*

Staphylococcus GBI '06 conference

11–12 April, University of Liverpool

This was the third conference held to bring together the sizeable *Staphylococcus* research community from Great Britain and Ireland. To enhance the freshness of the science, the emphasis was on talks by junior researchers and successfully demonstrated their excellent presentation skills and the high-quality science they were doing in this field. 25 talks covered a diversity of topics, ranging from vaccine development to host–pathogen interactions and structural biology of colonization factors to MRSA in companion animals. Several presentations by postdocs stood out for the quality of their science and presentation style, notably Jorge Garcia-Lara from the University of Sheffield who described his elegant studies on the functional determination of essential gene products in *S. aureus*. Two further excellent talks were given by Tony Loughman and Mághnus O'Séaghdha from Trinity College Dublin on the activation of platelets by *S. aureus* and the interaction between protein A from *S. aureus* and von Willebrand factor, respectively. They highlighted our rapidly improving knowledge regarding the complexity of host–*S. aureus* interactions.

The SfAM/SGM Communication Prize was awarded to Miriam Banner, a PhD student from the University of Manchester. She described the increasing problem of nosocomial infection by *S. epidermidis* via in-dwelling devices and the continuing search for structures involved in adhesion and biofilm formation. Her careful and thorough studies identified the localization and composition of fibrillar appendages that were observed by scanning electron microscopy.

A plenary talk at the conference was delivered by Professor Henri Verbrugh, a clinician from the Erasmus Medical Centre at the University of Rotterdam who gave an engaging overview of the history, the importance and his own current investigations of nasal colonization by *S. aureus*. Via studies in the 1960s to determine the extent and anatomical location of *S. aureus* carriage, he brought us right up to date with recent work to find host determinants that increase carriage and factors that might account for why some individuals are carriers while others show intermittent or no carriage. Erasmus MC has the only licensed human nasal colonization model in the world which is used for the study of strains of *S. aureus* with mutations in putative colonization factors in order to determine host and bacterial aspects of carriage.

Overall the conference was a tremendous success and plans are already underway to hold a further meeting in 2008.

Mal Horsburgh

Molecular Biology of Plant Pathogens 2006

18–20 September, Birnham Institute

Over 70 delegates, including some 40 students or postdocs, heard a series of presentations on a wide range of plant pathogens. This event started life as a *Molecular Biology of Fungal Plant Pathogens* get-together and the group continues to be strongly represented. However, talks on bacteria (*Pectobacterium*, *Pseudomonas*, *Xanthomonas*), phytoplasma and nematodes (*Longidorus*, *Globodera*) were also delivered. The vast majority of the talks were by students and post-doctoral scientists and included a series of breathless 8-minute presentations by workers in the earliest stages of their projects.

Social events included a talk entitled *Beer today, champagne tomorrow* from Chris Ridout (John Innes Centre) on a play recently performed at the British Association Science Festival in Norwich. It explored some of the issues associated with climate change by assessing whether land in Norfolk currently used to grow barley might, in the event of significant global warming, be used for growing grapes. The play itself was a collaboration between experts in plant biology, soil sciences and climate change modelling. Chris outlined the issues involved in staging a major Public Understanding of Science exercise of this nature as well as some of the benefits. The talk was followed by an opportunity to sample the beverages being discussed in the form of a local beer (Lia Fail from the Inveralmond brewery in Perth) and cava (as the MBPP budget would not – even with SGM/SfAM support – stretch to champagne!).

The SfAM/SGM Communication Prize was won by Michael Ravensdale from SCRI for his presentation entitled *Phytotoxins and suppression of resistance: new mechanisms of disease induction in the plant pathogen* Erwinia carotovora *subsp.* atroseptica.

The organizers would like to express their gratitude to SGM and SfAM for supporting the meeting and enabling the hire of a wonderful venue (The Birnam Institute). We look forward to welcoming workers in the field to the next meeting in Bath.

Leighton Pritchard* & *John Jones

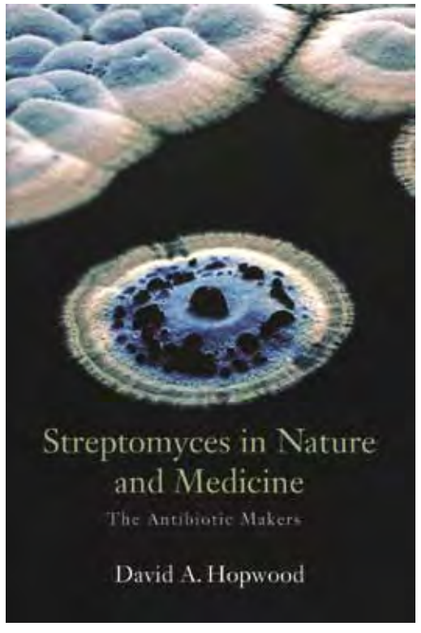
reviews

If you would like your name to be added to our database of book reviewers, please complete the book reviewer interests form at **www.sgm.ac.uk**. A classified compendium of reviews from 1996 to the present is also available on the website.

Streptomyces in Nature and Medicine: The Antibiotic Makers

By D.A. Hopwood
Published by Oxford University Press (2007)
£29.99 pp. 272
ISBN 0-19515-066-X

This book tells the remarkable story of David Hopwood's career, spent studying a single genus of bacteria, *Streptomyces*. David is a former president of the SGM and was Professor of Genetics at the University of East Anglia and the John Innes Centre (JIC) for 40 years, until his official retirement in 1998. He is still Professor Emeritus at the JIC and has spent the time since his retirement writing this book, an intriguing narrative that interweaves the histories of natural product discovery, bacterial genetics and *Streptomyces* biology with an account of his own 50-year career. We learn that when David began studying the streptomycetes, it was still unclear if they were bacteria or eukaryotes. At the time it was thought that these organisms, with their strange life cycles featuring mycelial growth and sporulation, might represent an intermediate between the two Kingdoms. It was David, along with the crystallographer Audrey Glauert, who determined that streptomycetes are true bacteria, quickly concluding that they had evolved their growth form independently of the fungi.



Over the next 40 years the streptomycetes became model organisms for studying complex morphological development in bacteria. This, along with their well documented importance as producers of useful secondary metabolites, makes them a truly remarkable group of bacteria. As we learn from this first hand account, David was central to the development of genetic tools for manipulating these weird and wonderful bacteria, using the model streptomycete *Streptomyces coelicolor*. He describes the advances in *Streptomyces* genetics, from the early days of bacterial mating, gene mapping and chromosome analysis experiments, all the way through to the completion of the genome sequence at the beginning of this century. He also devotes several chapters to the actinomycetes, the group to which *Streptomyces* belongs. The first chapter describes their importance as antibiotic producers while the second discusses the spread of antibiotic resistance genes, now widely believed to have originated in the producing organisms. The penultimate chapter in the book discusses two of the first, and most fearsome, actinomycetes to be discovered, *Mycobacterium leprae* and *Mycobacterium tuberculosis*. From a personal point of view it was satisfying to discover how (and why) the nine-plated armadillo became the model organism of choice for growing *M. leprae*!

This is a big story crammed into a relatively short book (at only 250 pages). There are inevitably a few things I would have liked to hear about that are missing from the book. Most notably how David felt on receiving a knighthood for services to science in 1994. I'm sure this was omitted due to natural modesty, with the science always coming first. Overall this is an extremely well written book, with a clear and concise narrative that is immensely readable. I would highly recommend it to anyone with an interest in the history of bacteriology, microbial genetics or antibiotics (which probably covers just about all SGM members!). It is also essential reading for anyone working on *Streptomyces*. I spent 4 years as a postdoc at the JIC working on *S. coelicolor* genetics and ended up totally hooked. It is satisfying to read this book and learn that we, together with colleagues in the worldwide *Streptomyces* community, are continuing the story. In an age when many students consider papers more than 10 years old to be out of date, this should perhaps be compulsory reading for new PhD students. Learning about the history and development of microbiology is both satisfying and inspiring, and I hope that in 40 years time I can look back on my career with the same pleasure and satisfaction that David clearly feels.

***Matt Hutchings**, University of East Anglia*

Communicating Science – A Practical Guide

By P. Laszlo
Published by Springer-Verlag GmbH & Co. KG (2006)
£16.62 pp. 214
ISBN 3-54031-919-0

As a veteran of numerous talks in draughty village halls and hands-on science events for over-excited 10-year-olds, I was looking forward to reading this book. I was interested to see what Laszlo, a respected science communicator, had to say about this important subject. Also, as the book was subtitled *A Practical Guide*, I was hoping to pick up some tips to improve my own skills in science communication.

Beginning enthusiastically at p. 1 (Abstract), I was initially confused to reach Conclusion on p. 9 (via Acronyms and Body language) without passing Introduction en route. It was at this point that it belatedly dawned on me that the sections were organized in alphabetical order. Admittedly, I would have been forewarned of this fact if my enthusiasm had not caused me to skip the Preface. However, it is this organizational quirk that, for me, is the greatest weakness of this book.

The essential problem is that knowing how the book is organized does not make it any easier to use. In particular, the organization detracts from the book's usefulness for the novice reader who would benefit from being presented with a logical overview of the topic, rather than being forced to navigate their own way through a rather bewildering array of intertwined and overlapping topics. There is nothing wrong in principle with writing a book with the intention that the reader dips into it, rather than reading it from cover to cover. However, this approach requires careful signposting so that the reader can easily identify material of potential interest. Although the author claims that the Table of contents serves also as an index, it is not always obvious what the reader might find in each section. Whilst those entitled Bibliography, and Figures and captions speak for themselves, the average reader would find it difficult to predict what might be revealed in Ideographic vs. nomothetic, whilst readers fast-forwarding to the enticingly entitled section on Seduction might be disappointed. The section on The necessary reconstruction (surprisingly filed under T!) in fact contains some useful tips on the use of anecdote and narrative when communicating science to the public, but might be overlooked because of the opaqueness of its title.

Adding to the confusion is the decision to organize the book into two main parts, corresponding to the type of communication task at hand: addressing peers, the general public (plus a third briefer section on how to inform decision-makers). Inevitably this leads to duplication.

Leaving aside the organizational flaws, the content takes a commendably wide-ranging view of communication, embracing the after-dinner speech, conference presentation, keynote lecture, magazine article, research proposal, press release and obituary. Laszlo is a professional scientist, with extensive experience in authoring and editing papers and popular science books. In some sections, he allows this knowledge and experience of the field to shine through, and this is when the book is at its best, written in a style which is entertaining and engaging. However, there are many parts where the style is laboured and the choice of words apparently aimed more at impressing than communicating. In the section on Vocabulary, Laszlo states that he aims to use a '*learned, seldom-used word*' every 2000 words or so on the basis that any reader loves to learn a new word. This may be a worthy aspiration, but the fact that I needed to resort to a dictionary (aporia, a philosophical puzzle) served just to irritate me.

The book claims to be geared to '*anyone having to convert scientific data into an easily intelligible and interesting narrative*'. However, in trying to appeal to a broad audience, it loses its focus. Although some of the practical advice is helpful, some of it veers towards the trivial or over-obvious, whilst other suggestions are simply unrealistic (engaging a personal coach to advise us on our body language is not an option open to most people). The presentation of the material as short vignettes means that the author has a tendency to give all topics approximately equal weighting, so some subjects do not get the coverage that they would merit if the content were organized in a more conventional way. Other sections could have been omitted without major detriment, particularly those dealing with the niceties of English grammar, which are dealt with more effectively in specialist texts.

Overall, the book contains some useful tips that could point the novice science communicator in the right direction, but I do not think that it offers much to the more experienced practitioner.

***Sue Assinder**, University of Wales*

Reviews on the web

Reviews of the following books are available on the website at www.sgm.ac.uk/pubs/micro_today/reviews.cfm

Handbook of Microbiological Media for the Examination of Food, 2nd edition

Advanced Quantitative Microbiology for Foods and Biosystems Models for Predicting Growth and Inactivation

Handbook of Hygiene Control in the Food Industry

In situ *Remediation Engineering*

Mycology, Volume 1 (DVD)

Science of Microscopy, Volumes I and II

New Treatment Strategies for Dengue and other Flaviviral Diseases

Oral Microbiology and Immunology

Bacterial–Epithelial Cell Cross-talk: Molecular Mechanisms in Pathogenesis

Phagocytosis of Bacteria and Bacterial Pathogenicity

MRSA in Practice

Functioning of Microphytobenthos in Estuaries

Handbook of Media for Clinical Microbiology

Coffee House Notes on Virology

Fundamentals of Molecular Virology

Thomas Henry Flewett
(29.06.**1922**–12.12.**2006**)

Thomas Henry Flewett MD, FRCPath, FRCP and Consultant Emeritus, was formerly Consultant Virologist at East Birmingham Hospital. Tom was born in India where his father worked for the Indian Civil Service. He was educated at Campbell College, Belfast and graduated with honours in medicine from Queen's University in 1945. After periods working at NIMR, Mill Hill and as a Lecturer at University of Leeds, he was appointed Director of the newly established Regional Virus Laboratory at East Birmingham Hospital. Here his interests in virus diseases and electron microscopy led him to provide a comprehensive service and into research on the viral causes of childhood diarrhoea, an important and worldwide problem. It was also to make his reputation.

Norwalk virus had been discovered in the US in 1971 and other, larger viruses had been seen in gut biopsies in Australia. Tom showed that these latter viruses could be seen readily by EM in stool extracts and, from their wheel-like appearance, called them rotaviruses – a name now used everywhere.

Other viruses (e.g. adenoviruses, caliciviruses, astroviruses) were also noted, but it was his work on rotaviruses that made the greatest impact. Similar rotaviruses were found in the diarrhoeal stools of virtually every animal species in which they were sought. Tom was in the thick of this research that involved collaborators in many countries, many of who visited, and often worked in, his laboratory, which was designated as a WHO Reference and Research Centre for Rotavirus Infections from 1980 until his retirement in 1987.

Tom's work on rotaviruses brought him international fame both as a virologist and as an electron microscopist. He was, inter alia, a World Health Organization consultant in Spain, Kenya, Nigeria, Ivory Coast, Brazil, Mexico – all countries in which childhood diarrhoea was, and is, a major problem. He was Chairman of the WHO Steering Committee on Viral Diarrhoeal Diseases, 1990–93, and a Member until 1996. He was in demand as a consultant, external examiner, visiting lecturer and journal editor, as well as a friend and helpful colleague. He was also a member of the Board of the Public Health Laboratory Service from 1977 to 1983 and Chairman of the PHLS Committee on Electron Microscopy from 1977 to 1987. He published over 120 papers on a variety of virological topics, many on the viruses of childhood diarrhoea.

The bare factual bones of career do not, though, convey the nature of the man. Small of stature, silver-haired and quick of thought and action, he was a hands-on leader of his laboratory. Naturally short-sighted, he wore thick-rimmed glasses and, like many with the same difficulty when asked to examine something such as an EM negative, he shifted his glasses down his nose and peered over the lenses. This gave him the air of an inquisitive bird, an impression reinforced by a crisp incisive manner and speech in short and rather jerky phrases.

Within his own laboratory, he was tolerant of people, but intolerant of mistakes, and known to all as someone who loved gadgets. He was a born tinkerer, and electron microscopy with its mystique and its machinery suited his temperament exactly. Whenever his microscope developed a fault, the coat was off, the tools were out and the column stripped. Very few had his level of technical knowledge or were so capable of doing maintenance on their own microscope.

Outside the laboratory, his other great love was golf. At his best, he had a handicap of 2 and he remained competitive well into retirement, confirmed by the trophy boards at Moseley Golf Club being peppered with his name. He won their Seniors' Trophy in 1990 and the Over-70s Cup in 1992.

Tom was a major force in the development of British diagnostic virology at the time when it led the world in routine diagnosis. His working life covered the time when it was all new and exciting, and his contribution to virus diagnosis by electron microscopy cannot be over-emphasized. He showed what could be done by dedication, underpinned by sound technical knowledge, and made it fun.

Tom and his wife June were excellent hosts, providing hospitality to the many scientists who visited his laboratory. She predeceased him, but two daughters survive them.

Alasdair Geddes & **Dick Madeley**

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comment

review of uk microbial science

Microbiology Editor-in-Chief **Charles Dorman** was recently invited to chair the BBSRC UK microbial science review panel. Here he gives a brief description of the process.

The Biological and Biotechnological Sciences Research Council (BBSRC) is the largest funder of non-medical microbiology in the United Kingdom. Many readers of *Microbiology Today* will be aware that the BBSRC Strategy Board commissioned a review of UK microbial science and that the 66-page review document (which makes nine recommendations) was delivered to the Strategy Board last September and published at the end of January 2007. A review panel was established in late 2005 and I had the responsibility of chairing it. Strenuous efforts were made to ensure that the panel membership was representative of the main microbiological constituencies. It consisted of academic and industrial scientists working with bacteria, viruses, yeast, filamentous fungi, parasites, and archaea. Thirteen of the 18 panel members belonged to SGM with five, including the chairman, being members of SGM Council.

The panel was asked to review research that is currently supported by BBSRC and to consider its strengths and weaknesses and the opportunities and threats that it may face over the coming 5–10 years. It examined the relationship between BBSRC funding of microbiology and funding provided by other bodies, including other research councils and Government departments, and to make this assessment in an international context that took into account the needs of industry. Panel members were invited to advise on funding priorities for future research and to recommend mechanisms to promote collaboration within and among BBSRC Institutes, between these Institutes and UK universities, and between BBSRC and other funding agencies in the UK and abroad. We were required to consider how best to optimize arrangements for funding and training in order to support microbiology in the institutes and the universities and to make recommendations on how the fruits of microbiological research can best be translated into practical application.

A consultation exercise was carried out in December 2005 among academic, industrial, non-governmental and other stakeholder organizations. Over 600 individuals and organizations received a 27-question consultation document consisting of four sections headed *Research and its implications*, *Utilization of research*, *Resources and facilities*, and *Funding*. The responses informed our discussions during a series of meetings held in London.

It rapidly became apparent that microbiology is a very big subject that plays and will continue to play a pivotal role in the scientific and economic life of the UK. Despite its breadth, broad agreement was discernable among its practitioners about its strengths and weaknesses, and about the nature of the risks and opportunities that lie ahead. Not all of the issues raised are specific to microbiology. Some, such as concerns about the quality of students coming through PhD programmes, affect many areas of science. Others, such as the perceived reduction in the amount and quality of practical training received by microbiology undergraduates are specific to the discipline, but are largely beyond the control of BBSRC. Naturally, there were differences of opinion about the best way to capitalize on the opportunities while minimizing the impact of the treats, and these were reflected in the discussions of the panel. Many microbiologists enthusiastically embrace the new 'omics' methodologies, while others are sceptical and emphasize the importance of reductionist approaches. There is widespread suspicion of special funding initiatives and almost universal support for a greater emphasis on responsive mode funding.

An important lesson concerns the importance of interactions between the SGM and BBSRC (and other funders) for the benefit of microbiology. BBSRC recognizes the critical role played by our learned society nationally and internationally, and desires greater engagement. This is something upon which SGM Council can capitalize in the future.

▲ Which way forward?
Ablestock / Jupiter Images

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The Review document is available at www.bbsrc.ac.uk/about/pub/reports/06_sept_microbialreview.html

Please note that views expressed in Comment do not necessarily reflect official policy of the SGM Council.