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microbes in the air

the spontaneous generation debate

microbes and climate

microbe-laden aerosols

birds and the spread of disease

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Cover image Seagulls flying across the Minato-ku skyline in Japan. *Toshihide Gotoh / Dex Image / Creatas*

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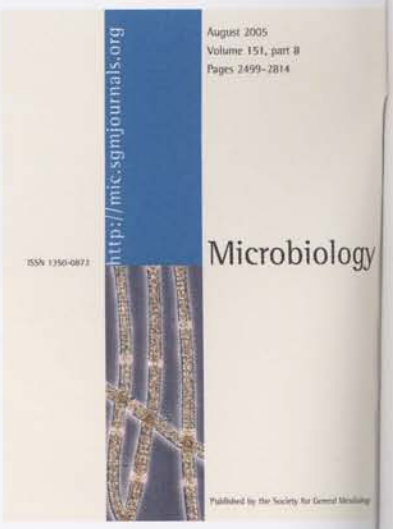
A tale of two impact factors

When Thomson ISI published the 2004 impact factors in *Journal Citation Reports*, we were pleased to see a large increase in the impact factor for *Journal of Medical Microbiology*, to 2·484, and a useful increase in that for *Journal of General Virology*, to 3·221. Less pleasing were the decreases recorded for *Microbiology* and *International Journal of Systematic and Evolutionary Microbiology*, to 2·617 and 2·456, respectively.

Careful examination of the underlying data for *Microbiology* by Charles Dorman, the Editor-in-Chief, suggested that the 2004 impact factor published for this journal was in fact incorrect. When notified of this, Thomson ISI checked their internal citation reports and discovered that some citations had not been credited to *Microbiology* 'due to a change in procedure at our data processing centres'. The correct 2004 impact factor for *Microbiology* is **3·114**.

Subsequent queries of Thomson then established that *IJSEM* and *JGV* had been affected by the same procedural change, and that their correct 2004 impact factors should be **3·015** and **3·327** respectively. The data for *JMM* appear to be collected in a different manner, and the published increase in impact factor is correct. Thomson will publish the correct impact factors when *Journal Citation Reports* is updated shortly.



SGM Council

July meeting highlights

Council

Colin Harwood, as Treasurer-elect, was duly confirmed as a member of the Council of Management of the Company. It was reported that the search for an Industrial Liaison Officer was still on-going. Nominations had been received for the three up-coming vacancies for elected members of Council and various places on Group committees. The ballot papers were now coming in from Ordinary Members and the results of the elections would be announced at the Society AGM in September. The President thanked the retiring elected members: **Keith Jones**, **Pauline Handley** and **Al Brown** for their contributions over the years.

Representation on other bodies

Council plays an important role in the activities of international microbiological organizations. The proposed six voting UK delegates (jointly with SfAM and BMS) to the forthcoming IUMS General Assembly in San Francisco, along with SGM representatives at the Council meetings of the IUMS Divisions, were all approved. Council also agreed to the nominees for places on the Executive Board of the European Federation of Biotechnology.

SGM finances

The Treasurer presented the budget for 2006. He explained that it was based on the assumption that Council's current pattern of spending on Society activities would be maintained next year. In order to do this, modest increases to journal subscriptions and membership fees would be necessary as income was derived from these sources plus investments. These charges were approved by Council ready for presentation at the forthcoming AGM. This was **Peter Stanbury**'s last Council meeting after a 7-year stint as Treasurer and the President gave a hearty vote of thanks for all of the excellent work Peter had put in to ensure that the SGM's finances were in such good shape.

Microbiology undergraduates

Council considered an initiative to distribute *Microbiology Today* and a range of careers material to final-year undergraduate students of microbiology. It was agreed that this was a valuable way to promote both the subject and the Society to future microbiologists. Distribution would go ahead as soon as it was feasible, initially through the network of SGM local representatives.

Publications

Council was concerned to learn of the continuing uncertain effect of open access issues on SGM journals business. It approved a statement of SGM policies for authors in relation to the conditions being proposed by certain funding bodies such as NIH. The 'Washington DC Principles', drawn up by a group of learned society publishers, which set out the benefits to science of publishing by such non-commercial bodies, was also discussed. It was agreed to sign up, alongside other prestigious bodies such as the ASM, Company of Biologists and Royal College of Psychiatrists.

***Janet Hurst**, Deputy Executive Secretary*

Groups

New committee members, elected by postal ballot (Environmental Microbiology, Microbial Infection, Physiology, Biochemistry and Molecular Genetics, and Virus Groups) or elected unopposed (all other Groups) to serve for 3 years from 13 September 2005 are as follows.

Cells and Cell Surfaces

S.G. Smith *Trinity College Dublin*
I.R. Henderson *University of Birmingham* has taken over as Group Convener

Clinical Microbiology

No vacancies

Clinical Virology

A.R. Fooks *Veterinary Laboratories Agency, Weybridge*
W.L. Irving *University of Nottingham*
E. O'Kelly *National Virus Reference Laboratory, Dublin*

Education and Training

R.P. Allaker *Queen Mary's London*
M.J. Tully *De Montfort University, Leicester*
B.A. Unsworth *Leeds Metropolitan University*

Environmental Microbiology

J.W. McGrath *Queen's University Belfast*
A.M. Osborn *University of Sheffield*

Eukaryotic Microbiology

A. Harwood *University of Wales, Cardiff*
E.J.C. Mellor *University of Oxford*

Fermentation and Bioprocessing

P. Bentley *Pierre Guerin Technologies, Tewkesbury*
M. Ganzlin *AstraZeneca, Macclesfield*
S. Stocks *Novozymes A/S, Bagsvaerd, Denmark*
D.J. Glover *UCB Celltech, Slough* has been co-opted as an industrial representative
C. Hewitt *University of Birmingham* has taken over as Group Convener

Food and Beverages

No vacancies
J.F. Rigarlsford *Independent consultant, Tansley* has been co-opted as an industrial representative

Irish Branch

C.C. Adley *University of Limerick*

Microbial Infection

H. Allison *University of Liverpool*
P.H. Everest *University of Glasgow*
P.R. Langford *Imperial College London*
N. Dorrell *London School of Hygiene and Tropical Medicine* has taken over as Group Convener

Physiology, Biochemistry and Molecular Genetics

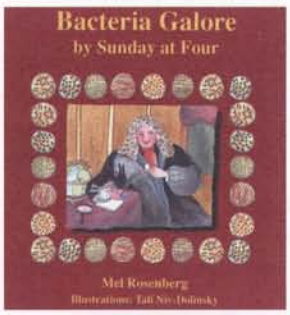
J.A. Downie *John Innes Centre, Norwich*
D.H. Edwards *University of Dundee*

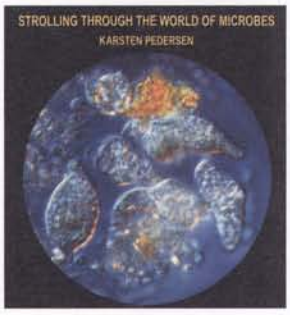
Systematics and Evolution

No vacancies

Virus

S.V. Graham *University of Glasgow*
B.A.B. Martin *University of Birmingham*





Popularizing microbiology

Communicating the fascination of micro-organisms to the public is not easy because the subjects are usually invisible. Now there are two books available that aim to show the diversity of microbes and their impact on our lives.

Mel Rosenberg, Professor of Microbiology at Tel Aviv University, has produced a colourful volume for children called *Bacteria Galore by Sunday at Four* (ISBN 9-652-74221-X). It is illustrated with charming colour pictures and describes in verse where bacteria are found, what they look like, how they grow and what they do. SGM has a few copies for sale at £6 (incl. postage). Please contact Janet Hurst (**e** j.hurst@sgm.ac.uk).

Karsten Pedersen's book is entitled *Strolling Through the World of Microbes* (ISBN 9-163-15686-5). This professor of microbiology at the University of Göteborg enjoys microscopy and he has illustrated the book with his own micrographs of a wide range of organisms. The text is aimed at adults rather than children. Contact the author at karsten.pedersen@gmm.gu.se

Jobs on the web

Are you a recent graduate looking for a job or a studentship?

Do you have a vacancy to fill?

In either case, SGM can help. We now advertise microbiology jobs and studentships on the SGM website. No subscription is required. The service is free to members. To search for posts or for information on how to advertise, see **www.sgm.ac.uk/jobs**

New Council officers

With effect from 13 September 2005, **C.R. Harwood** (University of Newcastle) commences his 7-year term as Treasurer. **C.J. Dorman** (Trinity College Dublin) commenced his 5-year term as Editor-in-Chief of *Microbiology* on 1 July 2005. A profile of Professor Harwood appeared in the August issue of *Microbiology Today*.

Charles Dorman

I am the Professor of Microbiology at the University of Dublin and a Fellow of Trinity College. I hold degrees from University College Dublin (BSc) and of the University of Dublin, Trinity College (MA, PhD, ScD) and was formerly a lecturer in biochemistry at the University of Dundee, where I also held a Royal Society Research Fellowship. My research interests include the regulatory mechanisms governing transcription in Gram-negative enteric bacteria, with a special emphasis on the roles of nucleoid-associated proteins. The SGM has previously recognized my work in this field by conferring the Fleming Award and in 2005 I was elected to membership of the Royal Irish Academy, Ireland's highest academic honour. At the end of 2005 I will chair the BBSRC review of UK microbial science.

News of members

Council member **Professor Jeff Errington** has been appointed Director for Cell and Molecular Biosciences at the University of Newcastle-upon-Tyne.

The Society notes with regret the deaths of **Dr T. Collen** (member since 1991) and **Professor Charles Fewson** (member since 1964) who was a former Editor of *Journal of General Microbiology* (1979–1984) and Member of SGM Council (1982–1986).

New elected members of Council

Following the ballot to fill three vacancies for elected members of Council, the following have been elected to serve for 4 years from 13 September 2005.

Professor Neil Gow

My main field of interest is in fungal pathogenesis and cell biology, in particular fungal cell wall biosynthesis and its regulation, chitin synthesis and glycosylation of cell wall proteins in *Candida albicans*. I am also interested in directionality and polarity of growth of fungi and in fungal morphogenesis and have also worked in the past on zoosporic oomycetes. I have had a number of roles in the SGM serving as a member of the Cell Biology Group Committee (1988–1991), on the Editorial Board of *Journal of General Microbiology* (1990–1994) and as an Editor of *Microbiology* (1994–1997). I am currently the Senior Editor of *Fungal Genetics and Biology*. I have also acted as Vice President (2000–2001) and President (2001–2003) of the British Mycological Society and have been active in the British Society for Medical Mycology.

Dr Petra Oyston

I graduated in bacteriology and virology followed by a PhD on *Bacteroides fragilis* at the University of Manchester. My first postdoctoral position was studying *Streptococcus mutans* at the University of Florida in Gainesville. At the completion of that post, I returned to the UK and joined what is now known as the Defence Science and Technology Laboratory (Dstl) at Porton Down, where I am a Dstl Fellow. My work here has primarily concentrated on producing vaccines suitable for licensing and identifying novel antimicrobial targets for the pathogens of interest, primarily *Yersinia pestis*, *Francisella tularensis* and *Burkholderia pseudomallei*. I am a Fellow of the Institute of Biology and possess Chartered Biologist status through the Institute. I have served for several years on the SGM Microbial Infection Group, lately acting as the Group's Convener.

Professor Rick Randall

My main areas of research are (paramyxo)virus–host cell interactions, interferon, antiviral responses, viral countermeasures and vaccines. I undertook a BSc (Hons) in microbiology/biochemistry at the University of Leeds (1974), followed by a PhD at Leeds working on herpes simplex virus (supervisors D. Watson/R.A. Killington, 1977). In 1978, I worked on hepatitis B virus in Professor Jan Desmyter's lab at the Rega Institute, Belgium. I then moved, via a temporary lectureship in virology at Reading University, to a position at NIMR, Mill Hill, working with R.W. Honess on herpesvirus saimiri. In 1985 I emigrated (!), with Professor W.C. Russell, from NIMR to a lectureship at St Andrews University, being promoted to Professor of Molecular Virology, via Reader. Currently I am Convener of the SGM Virus Group.

Grants

What's new?

FEMS Congress, Madrid, 4–8 July 2006
Integrating microbial knowledge in human life

SGM Travel Grants

Grants of up to £700 to provide a contribution towards registration fees, accommodation and travel to the congress are available to eligible members of the Society. Full details of the rules and an application form are on the website. The scheme aims principally to help SGM members who are ineligible for a Royal Society grant (see below), such as postgraduate student members and research assistants. The closing date for applications is **17 February 2006**.

Royal Society Conference Grants

(www.royalsoc.ac.uk; **e** conferencegrants@royalsoc.ac.uk)

Eligible SGM members should apply to the Royal Society in the first instance. Applicants must be of at least PhD status and normally resident in the UK. Civil servants, employees of research councils, government-funded bodies and commercial concerns are ***not*** eligible for these awards. Ordinary Members applying to the SGM will have to provide evidence that their application to the Royal Society has been unsuccessful.

Vacation Studentships

The 2006 scheme is now open for applications. It offers a limited number of awards to enable undergraduates to work on microbiological research projects during the summer vacation before their final year. The awards aim to give students experience of research and to encourage them to consider a career in this area. The studentships provide support at a rate of £170 per week for a period of up to 8 weeks. An additional sum of up to £400 for specific research costs may also awarded. Applications must be from SGM members on behalf of named students. The closing date for applications is **24 February 2006**.

Group European Fund Grants 2006

Grants will be available by competition to assist members who are postgraduate students or first postdocs to attend the following joint meetings with SGM Groups:

> SGM Clinical Virology Group/ESCV Joint Meeting
> *Viral infections: diagnosis, clinical management and prevention*
> 3–6 September 2006, Birmingham

> SGM Virus Group/ Italian Society of Virology joint meeting
> 18–20 September 2006, Orvieto, Italy

See SGM website for the rules and forms. Preference will given to applicants who are presenting work. Deadline for applications: **9 June 2006**.

SGM has a wide range of grant schemes to support microbiology. See **www.sgm.ac.uk/grants** for details and closing dates.
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).

Student schemes

President's Fund

Limited grants to young microbiologists making short research visits, attending courses or presenting work at scientific meetings. Open to Society members resident and registered for a PhD in an EU country or in their first postdoctoral position in an EU country. Closing dates for research visit grants: **21 April 2006** and **14 October 2006**.

Postgraduate Student Meetings Grants

Grants cover travel and accommodation expenses for attendance at one SGM meeting each year. Applicants must be Student Members resident and registered for a PhD in an EU country. Closing date for the Warwick Meeting: **31 March 2006**.

Elective Grants

Funding for medical/ dental/veterinary students to work on microbiological projects in their elective periods. The closing dates for applications in 2006 are **21 April** and **27 October**.

Student Society Sponsored Lectures

These cover the travel and other expenses of up to two speakers on microbiological topics per Society each year at student society meetings.

Other schemes

Public Understanding of Science Awards

Are you planning any projects to promote the public understanding of microbiology? Have you got a National Science Week event in mind? SGM can help. Grants of up to £1,000 are available to fund appropriate activities. Applications are considered on a first come, first served basis throughout the calendar year.

Seminar Speakers Fund

Awards cover the travel and other expenses of up to two speakers on microbiological topics in annual departmental seminar programmes. Applications are by written submission (no form) throughout the academic year.

SGM membership subscriptions 2006

The following rates were agreed at the AGM of the Society on 13 September 2005.

Membership category	Annual subscription		Additional subscriptions for publications (print only)							
			Microbiology		*JGV*		*IJSEM*		*JMM*	
	£	US$	£	US$	£	US$	£	US$	£	US$
Ordinary	48	88	94	169	94	169	94	169	50	90
Postgraduate Student	21	38	42	76	42	76	42	76	42	76
Retired	21	38	42	76	42	76	42	76	42	76
Technician	20	n/a	42	76	42	76	42	76	42	76
Undergraduate	10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
School	10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Corporate Tier 1	350	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tier 2	500	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

For airmail dispatch of *Microbiology Today*, add £16/US$28 to subscription.

Members are reminded that their 2006 subscriptions are due for payment by **1 December 2005**.

As in previous years, no journal or meetings information will be despatched to members who are in arrears, and there will be no guarantee of provision of back numbers of journals for members who pay their subscription late.

Payment by direct debit or continuous credit card

Subscription notices were despatched recently to all members paying by direct debit or by continuous credit card arrangement. To continue your present status and journal requirements, no further action is necessary. However, if you pay by continuous credit card, you should check that the card number and expiry date on the subscription notice are correct. To change your membership status or journal requirements for 2006 or your credit card details, you should have amended your subscription notice and returned it to the membership office by **11 November 2005**. However, if you have missed this deadline, your amended notice will be accepted if it is submitted immediately.

Payment against invoice

Invoices were despatched recently to all members who pay by this method. If you did not receive one, please inform the Membership Office.

Subscriptions waived for unemployed members

As in previous years, subscriptions may be waived at the discretion of the Society for unemployed members under the age of 35 who are resident in the UK. If you are eligible and wish to benefit in this way in 2006 you should send a signed statement that you are currently unemployed to the Membership Office before **30 November 2005** (please note that no increase in journal requirements will be permitted).

Income tax relief on membership subscriptions

Members who are liable for UK income tax are reminded that their annual subscriptions to the Society have been approved by the Inland Revenue as qualifying for income tax relief. Any member who would like further information or has difficulty in obtaining this relief should contact the Executive Secretary.

PhD one-stop shop

Following on from the successful *Surviving Your PhD* workshop in 2005, the SGM is pleased to bring you the *PhD One Stop Shop* at the Warwick meeting on **Tuesday 4 April 2006** from noon to 1400. Experts will be on hand to offer information and guidance on such topics as: post-doccing overseas, career planning, managing your supervisor, writing skills, surviving your viva and careers in publishing. A free buffet lunch will be served, but advance registration is essential if you wish to attend. You need to complete the correct section of the meeting booking form to secure a place.

New society for 'flu experts

The International Society for Influenza and Respiratory Viruses was launched on 11 September in Malta. **Geoffrey Schild** is the Acting Chairman and the Secretary is **John Wood** of NIBSC. See **www.isirv.org**

Staff news

Julia Trusler has recently left her post as a staff editor on the SGM journals. We wish her well in her future career as a researcher for the Nuffield Council on Bioethics.

Lister Institute Research Prizes 2006

Applications are now invited from young clinicians and scientists for the 2006 Lister Research Prize Fellowships. The Prize Fellowships offer £150,000 to be spent on the recipients' research in whatever way they choose, other than for personal salary, and therefore provides unfettered research funding. Prizes will be allocated on the basis of the applicant's research proposal and track record. Applications may be in any area of biomedical research, but must potentially relate to preventive medicine in its broadest sense. Further information and application forms are available from the Lister's website, **www.lister-institute.org.uk**, or directly from the Institute's Administrator.

The closing date for applications is **2 December 2005**, which is earlier than in previous years, with final selection by interview in May 2006 and availability of prizes from October 2006.

Young Microbiologist of the Year Competition

The Keele meeting saw the finals of the SGM's science communication contest. Five keen postgrads, selected as finalists by the Special Interest Groups and Irish Branch on the basis of their offered presentations (either oral or poster) at recent SGM meetings, gave 10-minute talks on their research. The standard was amazingly high and the judges, chaired by Jo Verran, had a very difficult job. The winners were announced at the Society Dinner later that evening. The first prize of £500 went to **James Edwards** of York University for his presentation *Biodegradation of the high explosive RDX by* Rhodococcus *sp*. The second prize of £200 was won by **Fiona Stirling** (Glasgow), and it was so hard to differentiate between the other contestants that they each were awarded a third prize. **Ying Jia** (Warwick), **Matthew Lambert** (Dublin) and **Claire Walker** (Aberdeen) all received £100. All finalists get free membership of the Society in 2006.

Further details of the competition and an entry form are available on the meetings page of the SGM website. Why not enter by submitting an offered poster or oral presentation for the spring meeting at Warwick next year? The closing date for abstracts is **2 December 2005**, so get cracking!

New Corporate Member

NovaBiotics Ltd™
Taking Nature's Lead in Antimicrobials

Welcome to *NovaBiotics*, a biotechnology company focused on the design and application of novel antimicrobials to treat diseases for which there are currently no effective, safe or resistance-free treatments. The first application of its technology will be in the treatment of nail fungus.

For further information contact Deborah O'Neil, NovaBiotics Ltd, Balgownie Technology Centre, Aberdeen Science & Technology Park, Aberdeen AB22 8GW (t 01224 356210; f 01224 356211; e deborah@novabiotics.co.uk; w www.novabiotics.co.uk).

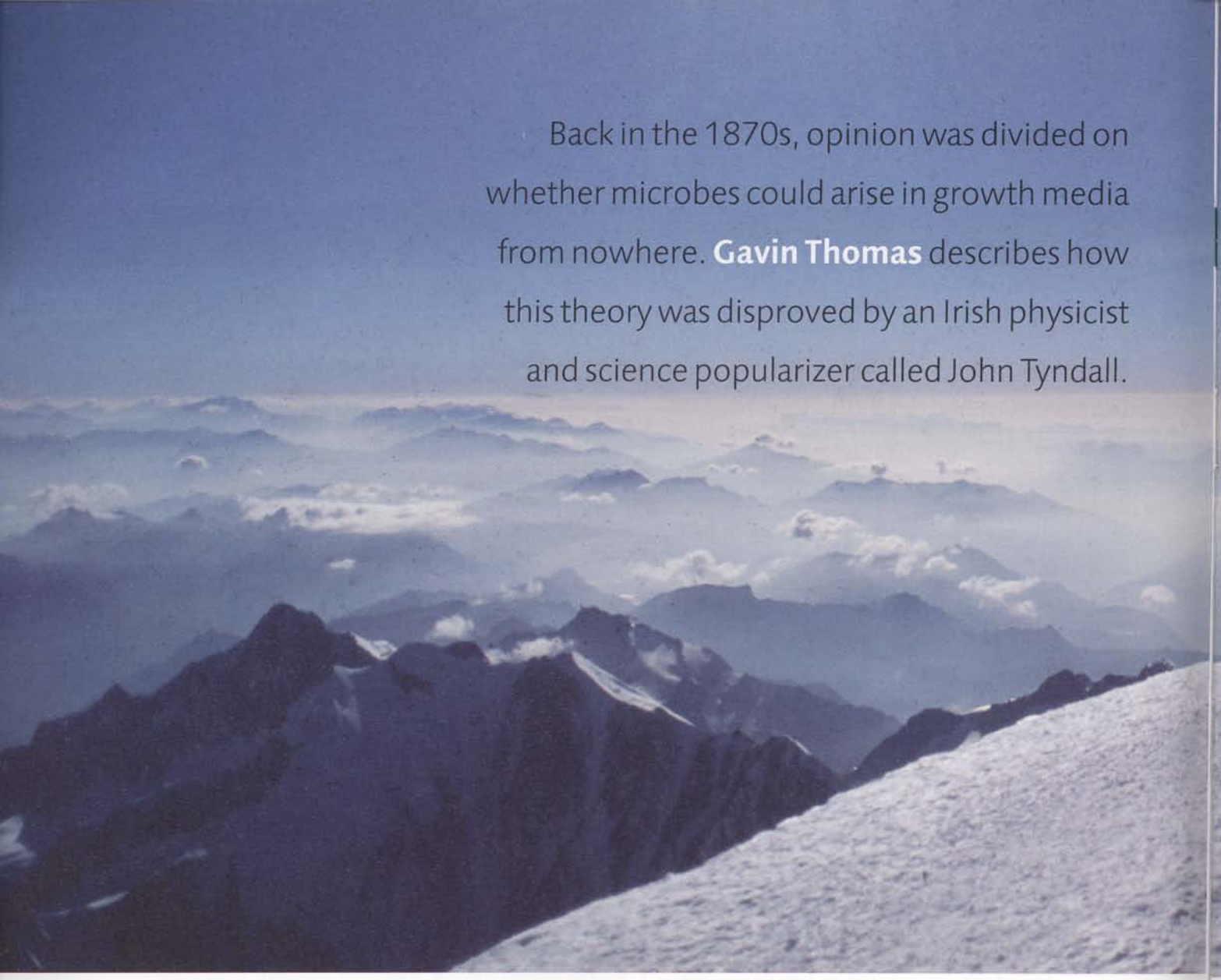
Technician membership

This recent category of membership is open to microbiologists employed as technicians, research assistants (not registered for PhD) and biomedical scientists who work in universities, research institutions, hospitals/HPA and commercial organizations. Their salary in 2006 must be no greater than £23,000 (gross or Euro equivalent) and they must be resident in the UK or Republic of Ireland.

For only £20 a year Technician Members enjoy:

- Attendance at SGM meetings free or at reduced registration fees
- The opportunity to apply for a grant to attend one SGM meeting a year
- Scientific sessions approved for CPD by the IBMS
- Special workshops and events
- Networking with other microbiologists
- *Microbiology Today*
- Discounted prices on SGM publications

Please encourage your staff to join and publicize the scheme in your institution. Attractive promotional material is available and application forms can be downloaded from the website or obtained from the Membership Office (e members@sgm.ac.uk).



Back in the 1870s, opinion was divided on whether microbes could arise in growth media from nowhere. **Gavin Thomas** describes how this theory was disproved by an Irish physicist and science popularizer called John Tyndall.

Microbes in the air: John Tyndall and the spontaneous generation debate

▲ The summit of Mont Blanc, French Alps. *O.T. Chamonix No. 120 / M. Colonel*

If, on a sunny day, you sit near a window in a darkened room and follow a beam of light streaming in, you can observe particles of dust reflecting the sunlight into your eye. The microbial content of these small pieces of 'floating matter' is well known to many of us, which is why we work by a Bunsen flame. However, the development of methods to 'see' the particulate contents of the air and analyse its constituents helped resolve some important issues of late 19th century biological science.

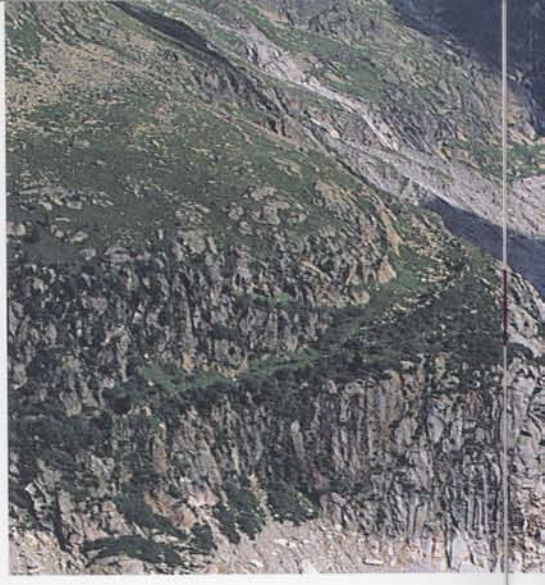
John Tyndall

The man who exploited light and dust to advance biology was not in fact a biologist, but rather an Irish physicist and science popularizer called John Tyndall (Fig. 1). He worked at the Royal Institution in London and had published scientific works on heat, light and sound, as well as popular books and lectures. For some of his experiments on light and gases he needed to cleanse the air of particles and so developed a completely novel way to assay the purity of air. '*The eye being kept sensitive by darkness*', Tyndall reported, '*a concentrated beam of light was found to be a most searching test for suspended matter – a test indeed indefinitely more searching than that furnished by the most powerful microscope*'. Using his new piece of equipment, which relied on observing light scattered by dust particles, Tyndall quickly made a series of important observations on the properties of the 'floating matter' of air.

Dust and disease

He presented this work in January 1870 in a lecture to the Royal Institution entitled *Dust and disease*. Here, he first reported experiments demonstrating that dust was mainly composed of organic matter, something he had not

▼ Fig. 1. Carte de visite of John Tyndall taken during his lecturing tour of the USA in 1872–1873. *Author's collection*



▲ Fig. 2. A surviving chamber tracked down in the archives of the Royal Institution. *Gavin Thomas*

▲ Fig. 3. Flasks containing various different infusions recovered from Tyndall's chalet in the Bel Alp now at the Royal Institution. *Gavin Thomas*

▲ The Mer de Glace, Chamonix, France. *O.T. Chamonix No. 99 / F.E. Cormier*

anticipated. He then demonstrated, using his light scattering assay, that air filtered by cotton wool was 'optically empty', meaning that the path of the beam appeared black, which he also saw with air that had been left to settle for long periods of time in a sealed glass chamber. Finally, he reported that his own breath, especially the end of his expiration, was remarkably free of floating matter. He had recently been taken by Lister's methods for antiseptic surgery, which argued that infection spreads through the air due to the microbes contained within it and viewed his data as entirely consistent with these. Hence, Tyndall extrapolated his conclusions to make a strong statement in favour of the germ theory of disease; an idea which had not yet found acceptance with the majority of the English medical profession.

Following Tyndall's 1870 lecture, there was much criticism of his conclusions from prominent physicians who believed that ideas relating to the nature of disease '*pertain most to the biologist and the physician*' and that a physicist should know better the facts of epidemic disease before delving into the living world. The pathologist Charlton Bastian confronted Tyndall directly in a series of letters to *The Times*, playing down the evidence supporting germ theory and discussing his own experiments which disagreed with previous work by Pasteur, Lister and the like. Bastian then published a 1,115-page book in 1872 describing many experiments that he argued proved that microbial growth could occur in conditions in which Pasteur would claim they should not, i.e. after boiling of a sealed liquid growth medium for 30 minutes. Bastian concluded from his experiments that '*life arises* de novo *in animal and vegetable infusions*'. This agitated Tyndall, who was a strong believer in Pasteur's experiments disproving spontaneous generation, so he decided to address this topic directly, becoming embroiled in a debate which was to occupy him for the next 7 years of his life.

Tyndall's chamber

The most famous piece of apparatus developed by Tyndall during this period was a wooden chamber that was key in demonstrating the causal link between the presence of dust and the subsequent growth of microbes in liquid broth (Fig. 2). The chamber had a glass front, small side windows and a back door. A pair of thin glass tubes was inserted in the top, bent in a way to prevent passage of dust from the outside. Test tubes were sealed into the base, open to the chamber above, and there was a movable pipette that pierced the top and could be used to add medium to the flasks. The walls of the chamber were coated in glycerine, which was effective at binding and holding the dust particles. Tyndall would seal these chambers and shine light through the side windows to follow the settling of dust particles until they had vanished from the beam. Culture medium was then added to the test tubes via the pipette and a vat of boiling oil was brought up underneath to sterilize them. The chamber was then left to see if anything would grow in the test tubes; Tyndall did hundreds of these experiments with different infusions where he would see no growth. The chamber was open to the air, so it could not be argued that some other element of the air was required for growth; rather it clearly demonstrated that when particles were absent from the air, the test tubes would remain sterile.

To the mountains

Tyndall was also a mountaineer of some repute, being drawn to the Alps in 1856 to study glaciers with Thomas Henry Huxley. He grew to love the Alps as they

provided him with an annual escape from the rigours of science, and he quickly became an accomplished mountaineer, climbing Mont Blanc in 1857 and later being the first to climb the Weisshorn in 1861. This was not without its dangers and in 1858 when solo climbing Monte Rosa he dropped his ice axe at the summit and had to watch it slide away towards the mountain edge. The descent would have been impossible without the axe, but fortunately it stopped before reaching the drop and Tyndall was able to make his descent successfully.

Tyndall took a series of 'infusions' with him to the Alps which he had prepared at the Royal Institution. These were glass flasks shaped as in Fig. 3 containing liquid broth which had been boiled and then sealed by heating the glass and drawing out the end until it was fused. He took about 50 of these flasks, which contained infusions of beef, mutton, turnip and cucumber, to perform a series of experiments one summer while staying at his cottage on the Bel Alp. Tyndall had demonstrated that upon opening these flasks there was a brief inrush of air, but that the shape of the neck prevented any further entry of particulate matter. He opened half of them in a hayloft near his cottage and the other half on a ledge overlooking the Aletsch glacier, making sure he was himself downwind of the flasks and using a spirit lamp to sterilize the steel pliers that were used to break off the top of the flask. Tyndall then incubated all his opened flasks over his kitchen stove for 3 days and found that all but two of the flasks opened in the hayloft were 'invaded by organisms', while not one opened in the 'cleaner vivifying mountain air' had any growth. Tyndall hence demonstrated that air from the mountain top was largely free from organic material and no life was produced in the flasks, while the flasks opened in the closed environment of the hayloft, in the presence of an abundance of organic material, almost always had growth. This particular experiment was a continuation of an earlier demonstration by Pasteur that air from the Mer de Glace was cleaner than that from the town below, but was typical of the many experiments Tyndall performed during the 1870s to provide convincing quantitative evidence supporting the spread of microbes in the air.

A bale of hay

Tyndall's experiments hit difficulties in 1876 when, for a reason that eluded him, he could no longer keep his infusions sterile. He only managed to reproduce his experiments again after moving his lab to Kew Gardens. Earlier in 1876 Tyndall had met the German botanist Ferdinand Cohn, who discussed his recent description of spores in the life-cycle of the hay bacillus (*Bacillus subtilis*) and also mentioned Robert Koch's observations of spore formation in *B. anthracis*. Tyndall had brought a bale of hay into the Royal Institution at about the time that his experiments became contaminated and he reasoned that spores from the hay were now in the air of his lab and were able to survive the heating process he used to sterilize his infusions.

It is of interest to note that this had been observed previously by Bastian, who had used these data to support his ideas of spontaneous generation. Now, however, Tyndall had a potential explanation and investigated the heat resistance of spores in more detail. After a few months of work he discovered that a series of boiling and cooling steps in the treatment of his growth medium could completely prevent any growth in his flasks. By heating and cooling the spores were germinating and were then being killed during the next exposure to boiling. This process of fractional sterilization, sometimes known as Tyndallization, is still used today to sterilize certain diagnostic growth media that cannot tolerate autoclaving.

By 1880 the debate was effectively over due to the hard work of Tyndall and others, including the Englishmen William Dallinger and John Drysdale, who had demonstrated that Bastian's experiments could be explained simply by improved knowledge of microbiology and did not need to imply continual *de novo* creation. Spontaneous generation was removed from the frontlines of science into the history books – all started by a chance observation made while pursuing a completely different field of science.

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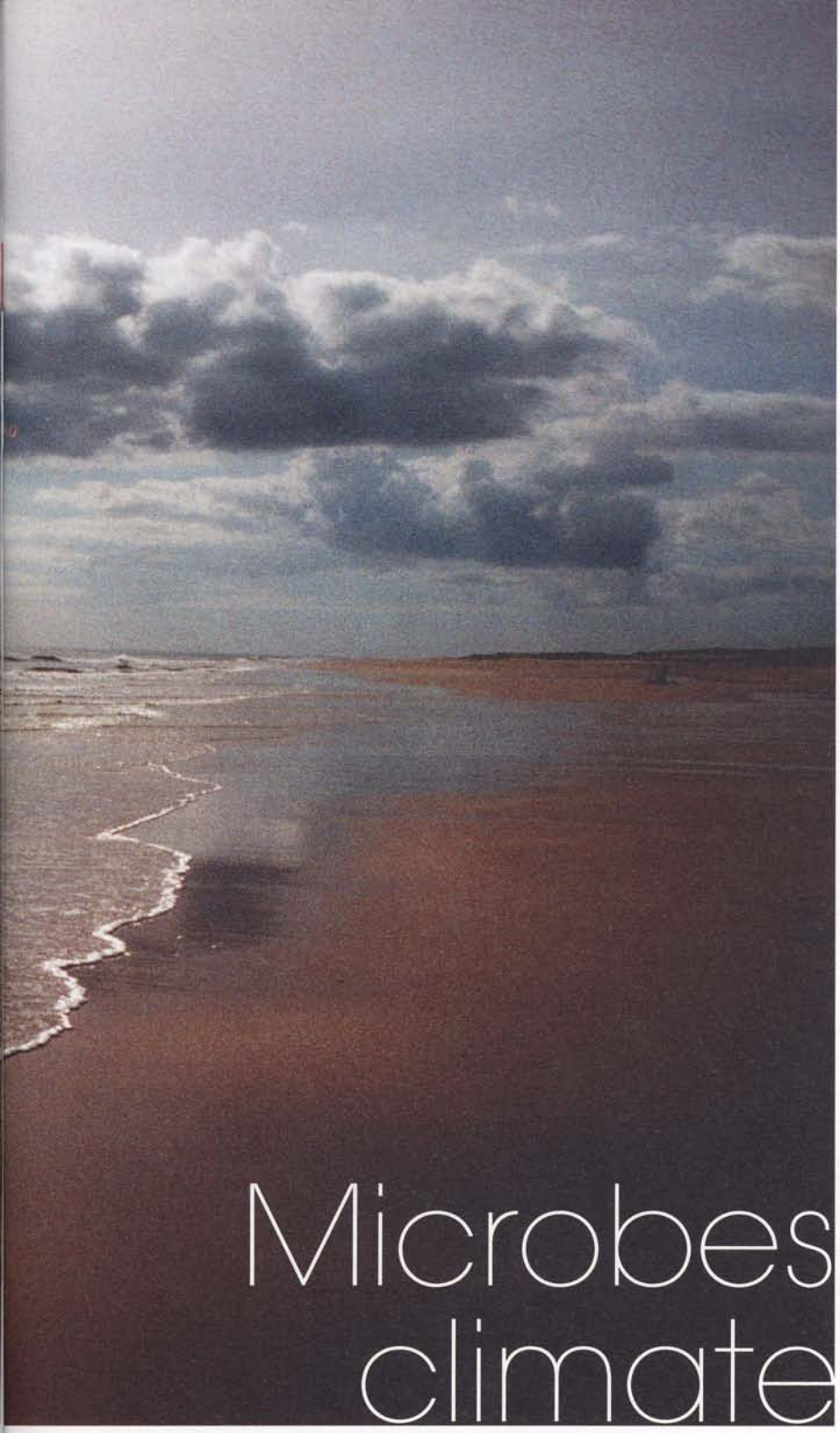
Acknowledgements

Tyndall's tubes and chamber will be available for general viewing at the Royal Institution after a major redevelopment due to be completed by the end of 2007. The author would like to thank Prof. Frank James and Katharine St Paul for locating the chamber and for allowing it to be photographed, and Prof. James Strick for comments on this article.

▲ A calm sea and sky. *IT Stock Free / Creatas*

Photosynthetic marine microbes have been inhaling, metabolizing and expelling gases for about 3 billion years. This microbial gas exchange contributed in large part to the creation of our CO_2-poor and O_2-rich atmosphere, generating an environment conducive to the evolution and continued existence of eukaryotic life. The oxygen-rich atmosphere on Earth exists in a state of chemical disequilibrium as a result of the metabolic processes of living organisms. Earth's atmosphere consists of about 20·9 % O_2 and 0·03 % CO_2. In contrast, the atmosphere on Mars is in equilibrium, containing approximately 95 % CO_2 and only 0·13 % O_2. The early photosynthetic microbes were cyanobacteria; their descendants (Fig. 1) now flourish in most of the world's oceans and, indeed, often dominate photosynthetic pro-



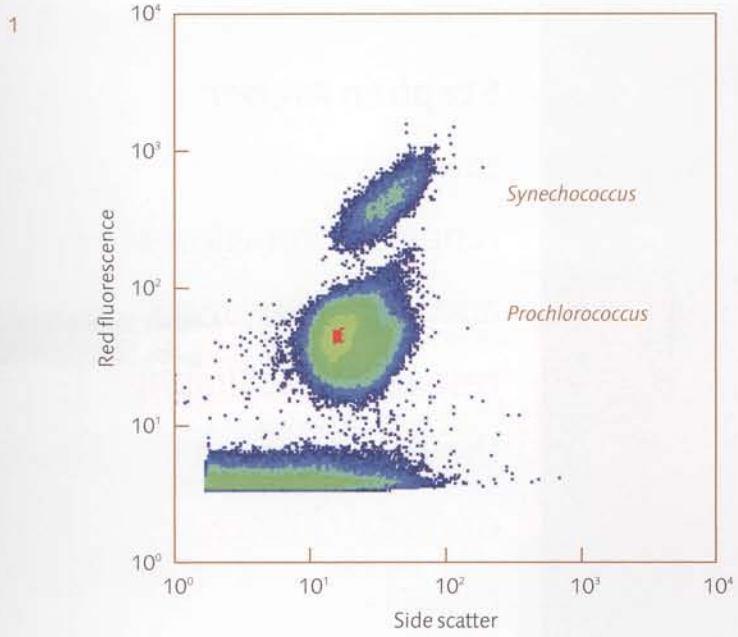
Microbes and climate

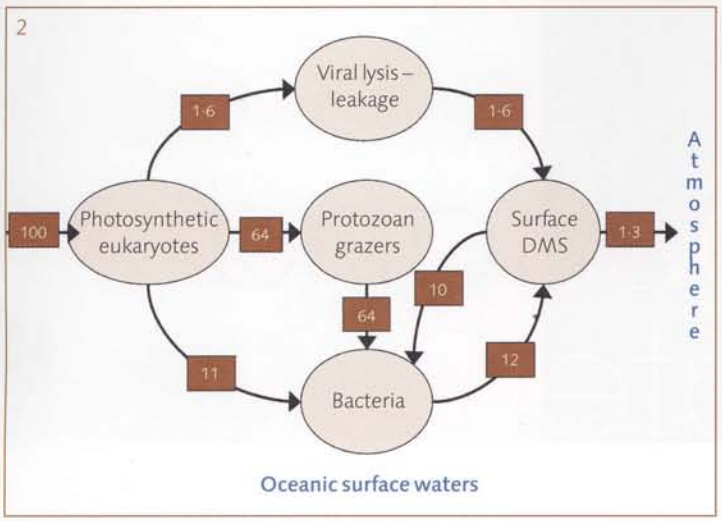
The impact of microbial life on the climate of our planet is vast and complicated. **Stephen Archer** touches on the range of interactions and explains how research is facilitating the development of global climate models.

duction in the vast tropical and subtropical oceanic gyres. Today diverse communities of *Bacteria*, *Archaea*, *Protista* and their viruses inhabit the oceans and it is no surprise that they play an important role in determining the direction and magnitude of the flux between ocean and atmosphere of many climatically active gases. What has altered is the diversity of the microbial communities and the complexity of the influences they now have on atmospheric composition and climate, including possible homeostatic feedback processes.

When microbes and man interact

Even more complicating are the interactions between anthrogenic impacts on the composition of the atmosphere and the natural biogeochemical cycles. Marine microbes are by no means the only communities that influence the atmospheric composition and hence, our climate. Methane is a critical component of our atmosphere, accounting for as much as 30 % of the anthropogenically enhanced greenhouse effect and influencing rates of ozone depletion. Methanogenic





▲ Fig. 1. Today's oceanic cyanobacteria, whose autofluorescence and light scattering properties are visualized by flow cytometry. These members of the *Synechococcus* and *Prochlorococcus* groups are approximately 0·9 and 0·6 µm in diameter. In this sample, taken from 30 m depth in the equatorial upwelling region of the Atlantic, *Synechococcus* abundance was $18{\cdot}5 \times 10^3$ cells ml^{-1} and that of Prochlorococcus, 210×10^3 cells ml^{-1}. *Glen Tarran, Plymouth Marine Laboratory*

▲ Fig. 2. Pathways and rates by which DMSP was produced and transformed to atmospheric DMS during a phytoplankton bloom in the northern North Sea. DMSP is an osmolyte, but appears to have a variety of alternative physiological roles. Once released to the dissolved phase, in this case chiefly by protozoan grazers, the DMSP is rapidly metabolized by bacteria. Bacteria cleave some of the DMSP to DMS, but also act as the major sink for DMS in surface waters. Only 1·3 % of the DMSP synthesized by the photosynthetic eukaryotes entered the atmosphere. Minor changes in the metabolism of any of the microbial groups could have a major impact on the level of DMS sea-to-air flux. *Data from Archer* et al. *(2002) Deep Sea Res II* **49**, *3067–3101*

Archaea growing in natural anaerobic wetland environments account for about 75 % of the natural source and hence, about 30 % of the total flux of methane to the atmosphere.

Methane production provides an example of how complicated it is to predict anthropogenic impacts on climate. Increased wetland productivity due to rising CO_2 levels and temperature might be expected to elevate methane flux to the atmosphere. Not so simple; industry-derived sulfate deposition in wetland environments may give sulfate-reducing bacteria a competitive advantage and inhibit methanogenesis because sulfate reduction is energetically favourable if sulfate is readily available. Sulfate aerosols have a cooling impact on our climate through direct backscatter of solar radiation and because they act as cloud condensation nuclei, increasing cloud reflectance. It seems likely that they add to this cooling effect by also reducing methane release from some wetlands.

Biospheric climate regulation

The major natural source of sulfur gases to the atmosphere is oceanic emission of dimethylsulfide (DMS). DMS is derived largely from the enzymic cleavage of dimethylsulfoniopropionate (DMSP), a product chiefly of eukaryotic phytoplankton. Ever since it was proposed that DMS may be part of a natural climate feedback mechanism, the CLAW hypothesis, this area of research has received enormous scientific [the Charlson *et al.* (1987) paper receiving more than 1,300 citations according to the *Web of Science*] and public interest. In brief, the hypothesis runs: rising temperature raises oceanic primary production and therefore DMSP and DMS production; increased DMS in surface waters elevates the flux to the atmosphere with correspondingly increased atmospheric sulfate concentrations and, hence, increased global albedo and reduced temperatures.

Despite the intense interest we are still not sure whether the feedback will be negative or positive in the face of rising CO_2 concentrations and temperatures. One of the reasons for this is our lack of understanding of the controls on DMS concentrations in the surface ocean. This in no way detracts

from the fascinating work that has been done in this field. Since we know more about DMS(P) cycling in the ocean than possibly any other compound, it only illustrates the complexity of the processes involved. DMS is always supersaturated in the oceans and so the flux across the air–sea interface is chiefly a product of surface mixing (related to wind speed) and seawater concentrations. An ever increasing network of processes appear to impact on DMS surface concentrations (Fig. 2), not least the physiological role(s) of DMSP and the intricate microbial foodwebs involving eukaryotic protozoans that have evolved in the oceans. Charlson *et al.* were largely unaware of this complexity when they proposed the CLAW hypothesis.

Integration and prediction

I have only touched on the microbial processes that impact on atmospheric composition and climate. The nitrogen cycle is largely microbially driven and affects atmospheric concentrations of the greenhouse gas nitrous oxide (N_2O), whilst microbial sources and sinks of ammonia impact on aerosol formation and the acid–base chemistry of the atmosphere. Atmospheric chemistry and hence, climate, is influenced by levels of carbon monoxide, a suite of volatile halocarbon compounds, oxygenated volatile organic compounds (low-molecular-mass alcohols, ketones and aldehydes) and non-methane hydrocarbons (e.g. isoprene, toluene), all of which are controlled to varying extents by microbial processes.

In each case, one of the major challenges is to identify the key physiological and community interactions by which microbes control atmospheric concentrations and to develop ways in which they can be integrated into global models. Predictive models of climate will have to integrate processes from massively different scales: microbial gene expression to ocean circulation to variations in solar radiation. In the case of oceanic DMS emissions, satellite-derived data can potentially be used to define microbial community composition and function, including primary and heterotrophic production rates. Information of this type may help to characterize microbial processes at sufficiently large scales to facilitate the development of more realistic global climate models.

▲ Fig. 3. Microbial processes affect the exchange between ocean and atmosphere of a diverse cocktail of gases. In remote regions such as here in the mid-Atlantic aboard *RRS Charles Darwin*, interactions between these gases are likely to impact on aerosol formation and the extent of cloud formation. *Stephen Archer*

Microbes play an important role in determining the direction and magnitude of the flux between ocean and atmosphere of many climatically active gases

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Don Clark explains how micro-organisms survive and are spread in the air.

Microbe-laden aerosols

The term aerosol has become associated over the years with the products of spray cans that produce coarse droplets or particles of materials as diverse as deodorants and oven cleaners. The term has also become associated, in the minds of many people, with the CFCs that were used as propellants in cans, and so 'aerosols' are often, quite wrongly, blamed for the destruction of the protective ozone layer.

In fact the term aerosol was originally coined to describe a quasi-stable suspension of particles, either solid or involatile liquid, in air. Of course stability is relative and may be applied differently in various contexts, but as far as aerosols of the type that might contain micro-organisms are concerned they may have lifetimes that range from at least an hour or two to weeks or even months.

Atmospheric aerosols

The air we breathe is an aerosol. The concentration of particles varies enormously with location, altitude and weather conditions, but even 'clean' air will normally contain billions of particles in every cubic metre. The majority are very tiny indeed, typically some tens of nanometres in diameter, but there will be a significant number (perhaps 10^5 or 10^6 per cubic metre) that have micrometre dimensions and of these a significant proportion will be of biological origin.

The atmosphere acts, like the oceans, as a global medium of transport for a wide range of different materials. This enables the living world to function by distributing the components vital to maintaining ecosystems and diluting or enabling the destruction of waste products. Many living systems use the atmosphere as their means of distribution, perhaps the most obvious example being plant pollens that are wind-disseminated. This has an interesting side-effect for the human population. As the probability of a pollen grain that becomes air-borne being deposited in the appropriate part of a plant of the same species is tiny, to be successful the plant must disseminate huge numbers of pollen grains. This results in seasonal clouds of pollen that cause allergic reactions when they are inhaled by susceptible individuals.

Bacteria and viruses can also use the atmosphere for distribution. An infected host can be induced, by a variety of mechanisms, to release the organisms into the atmosphere. Once air-borne, these can be inhaled by a new host where they will deposit in the airways to begin a new infection cycle.

Generation of microbiological aerosols

All aerosols of micro-organisms are generated by some type of disruptive process. This may be by the break-up of sheets or columns of liquid suspensions or by air movement lifting deposited particles and separating them into single units.

An example from the natural world of the break-up of liquid suspensions to generate a potentially infectious aerosol is sneezing. A sneeze is caused by a rapid muscular spasm that expels

▲ High speed photograph showing jets of droplets erupting from a man's nose as he sneezes. *Dr John Brackenbury / Science Photo Library*

► A mucus droplet containing bacteria. *Don Clark*

air at high velocity through the nose where the shear forces tear the mucus from the nasal hairs and lining, breaking up the ligaments into droplets. The greater the energy input to the process, the smaller will be the droplets that are produced.

At the other end of the energy scale is the dispersion of pollens and spores. Here, plants have evolved complex strategies that use the geometry of the pollen grains, coating of the grain and the lining of the pollen sac to overcome the effect of Van der Waals forces that hold small particles both to surfaces and to each other. So pollens and spores are effectively dispersed even in very light winds.

Clearly natural systems have evolved so that, whatever the aerosolization process, the mechanism does not compromise the viability of the organism. However, generation techniques used in the laboratory or field to produce aerosols artificially, are generally highly energetic and can deliver very high shear and impaction forces. It is important to understand, when designing experiments, that such forces can seriously damage delicate organisms and may reduce viability or culturability significantly.

Dispersion

An aerosol, being a quasi-stable suspension of particles in air, will act in many ways just like one of the gaseous components of the atmosphere. So wherever the wind blows or convection currents move the air, the particles will be carried with it. However, there are some important differences in the way that particles behave as compared to gaseous components of the atmosphere and these can be of particular significance in the case of micro-organisms.

Diffusion. When a source of gas is added to the atmosphere, it will dilute very rapidly as the molecules diffuse through the other gaseous components. When a source of particles enters the atmosphere they will also diffuse, due to Brownian motion, but very much more slowly and with a diffusion coefficient that is a function of particle size. So for micro-organisms, which are relatively large particles, their diffusion coefficient will be many orders of magnitude smaller than that of a gas molecule. This can be important in the spread of disease. For example, a flock of coughing sheep infected with foot-and-mouth disease may produce an aerosol cloud that will travel many miles with only a low dilution factor and so retain the potential to infect any other animals it passes over.

Table 1. Velocity of fall in relation to particle size

Particle size (μm)	Velocity of fall (mm s^{-1})
0·1	0·00085
1·0	0·035
5·0	0·78
10·0	3·0

Deposition. Particles, unlike gas molecules, do fall through the atmosphere under the influence of gravity, the rate of fall being, once again, a function of their size. As can be seen from Table 1, the velocity of fall is extremely slow, even for particles larger than a micrometre and so the effects of convection and Brownian motion can result in particles being kept in semi-permanent suspension.

Impaction. When the wind carries particles among solid objects, particles can be deposited due to their greater inertia carrying them to the surface of a body as the air flows around it. This is the principal mechanism by which air-borne pollen grains reach their target.

Rain. This is undoubtedly the mechanism by which most particles are removed from the atmosphere. Removal occurs either by the particles acting as condensation nuclei on which rain clouds grow or by the scavenging of particles, beneath the clouds, by falling raindrops.

Survival of micro-organisms in the atmosphere

Microbes can remain in suspension in the atmosphere almost indefinitely, but this is a challenging environment and for many species their lifetime in it will be limited. Clearly, some organisms have evolved to survive in the atmosphere: pollens and spores are obvious examples, but also some bacteria, such as the bacilli, have evolved techniques by which they form spores that are highly resistant to environmental attack.

The primary destructive agent is the ultra-violet component of sunlight, which, with long exposure, is effective in sterilizing most living cells. Other factors include humidity (both low and high) and a variety of pollutant materials commonly found in the atmosphere. It is well established that the combined effects of these factors needs to be taken into account when attempting to predict air-borne lifetimes. However, experiments carried out in laboratories have often shown poor correlation with field observations and this has led some investigators to invoke an 'open air factor'. This is perhaps another way of saying that there is some destructive mechanism, or combination of mechanisms, that has not been reproduced effectively in the laboratory.

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Flying hazards:

birds and the spread of disease

Birds are a lovely sight as they soar through the air. But as **Keith Jones** explains, they can also be aerial reservoirs of infection.

Our view of wild birds is mostly positive: they are the attractive embodiment of a diverse and healthy environment. On the negative side they can be viewed as vectors for disease, polluters and pests. We admire their freedom to fly, but it makes them difficult to control. Witness the speed with which wild birds spread the West Nile Virus throughout the USA and the worries that migrating wild fowl have brought avian 'flu to Europe from south-east Asia via Russia.

Wild birds as sources of major diseases

Psittacosis (ornithosis, parrot fever), caused by the bacterium *Chlamydophila psittacci*, is carried by budgerigars, parrots, cockatoos and pigeons, both in the wild and in captivity, and by doves, birds of prey and shore birds in the wild. We get it by breathing in the aerosolized dried faeces or respiratory secretions of infected birds when, for example, flocks of birds congregate close to inlets of ventilation ducts, people kiss their pet birds or during the handling of plumage. In England and Wales there are around 10 cases a month and the disease can kill. After a high profile death of a young mother in 2000, a coroner warned the public to stay away from pigeons in public places. This is one of the reasons for the decision to remove pigeons from London's Trafalgar Square, albeit you still see people feeding them.

Influenza A viruses have been isolated from 90 species of free-flying birds from 12 orders. All 15 haemoglutinin and 9 neuramidase subtypes of the virus have been found in wild birds which, although they are largely unaffected themselves, excrete the viruses in their faeces. The usual scenario is for infected waterfowl to fly into wetlands where they mingle with domesticated ducks and pass on the virus. The ducks then transmit it to chickens and they in turn transmit it to pigs. Influenza virus is not normally transmitted directly from birds to humans, but because avian influenza virus and human influenza virus can co-exist within pig cells, pigs serve as a conduit for the transmission of new strains of the virus to humans. This happens most frequently in south-east Asia, largely due to the close proximity of waterfowl, ducks, chickens, pigs and people. In most years, a new influenza A strain arises and is transmitted globally. Occasionally, a highly virulent strain evolves and causes a major pandemic, for example, Spanish 'flu in 1918–1919, Asian 'flu in 1957–1959 and Hong Kong 'flu in 1968–1969.

Bird 'flu (avian 'flu) is caused by influenza A virus subtype H_5N_1 which specifically infects birds. It has a reservoir in wild birds where virulent strains periodically evolve and cause disease. Poultry, particularly chickens, are highly susceptible and the current highly virulent strain can kill them on the same day that symptoms appear. Control measures include biosecurity (prevention of small wild birds gaining access to poultry houses), slaughter of infected birds, vaccination and restrictions of bird movements and trade. The most recent outbreak, which began in 2004, has mainly been confined to south-east Asia, but shows every indi-

◀ A flock of seagulls in flight. *Brand X Pictures / Creatas*

cation of becoming pandemic. It has been detected in migrating waterfowl in Siberia and gulls in Finland, and the President of the British Veterinary Association has warned that it is inevitable that the virus will reach the UK. In Europe and the USA, testing of migratory birds for the virus is being stepped up and it has been proposed that free-range poultry in Europe should be taken inside to prevent them mixing with wild birds. It will be interesting to see how this plays out given the UK public's infatuation with free-range, organically reared chickens.

Up to now the problem has been largely economic with millions of chickens slaughtered. However, since this strain of bird 'flu has already killed 60 people in south-east Asia through contact with dead or diseased chickens and has jumped the species barrier by infecting pigs, tigers and civet cats, it seems only a matter of time before person-to-person transmission evolves. A hugely impressive worldwide surveillance operation is in place and many countries are stockpiling vaccines against this eventuality.

West Nile Virus (WNV) is endemic in parts of North Africa and the Middle East and appeared in the USA in 1999. Since then it has spread to all of the mainland US states and into Mexico. Wild birds are the amplifying host for the virus and in the US over 160 species have been infected. Its expansion across North America has been due to migratory birds, some of which fly huge distances, and by local birds such as songbirds. It is transmitted from bird to bird and from birds to humans and horses by mosquitoes. Since 1999 there have been 15,000 confirmed human cases and over 500 deaths from WNV encephalitis in the US (2,539 cases and 100 deaths in 2004). Several theories have been put forward to explain its appearance in the US. These include bioterrorism, illegal import of birds and 'lost' storm-driven birds. I favour the law of unforeseen consequences. Cynics suggest that US quarantine laws were relaxed in the late 1990s to encourage American Israelis to vote in Israeli elections by allowing them to take their pets with them. It is possible their pet birds were exposed to the virus in Israel and brought it back to the US.

Wild birds are also environmental reservoirs for Equine, Japanese and St Louis encephalitis viruses.

Lyme disease, caused by the bacterium *Borrelia burgdorferi*, is usually associated with deer and rodents. However, seabirds and ground-foraging birds, such as grouse and pheasant, are reservoirs for both the bacteria and the ticks that transmit them to other animals and humans. The ticks attach to the birds for around 24–48 hours for a blood meal and then fall off. This is long enough for migrating birds to carry them hundreds of miles from the original source of the infection.

Diseases of plants and crops

Intuitively, we would assume that birds would play a major role in the transmission of fungal and viral diseases of crop plants. Rather surprisingly, this appears not to be the case.

Wild birds as polluters

Wild birds excrete a variety of human gastrointestinal pathogens in their droppings, including the bacteria *Campylobacter*, *Listeria*, *Salmonella*, *Aeromonas*, *Vibrio cholerae*, *Yersinia* and *Escherichia coli* O157, the protozoa *Giardia* and *Cryptosporidium*, as well as the bacterial indicators of pollution, faecal coliforms and enterococci. Therefore, wherever wild birds congregate, they are likely to pollute their immediate environment with some or all of these pathogens.

Wild birds are the attractive embodiment of a diverse and healthy environment, but they can be viewed as vectors for disease, polluters and pests

Birds and the pollution of water bodies

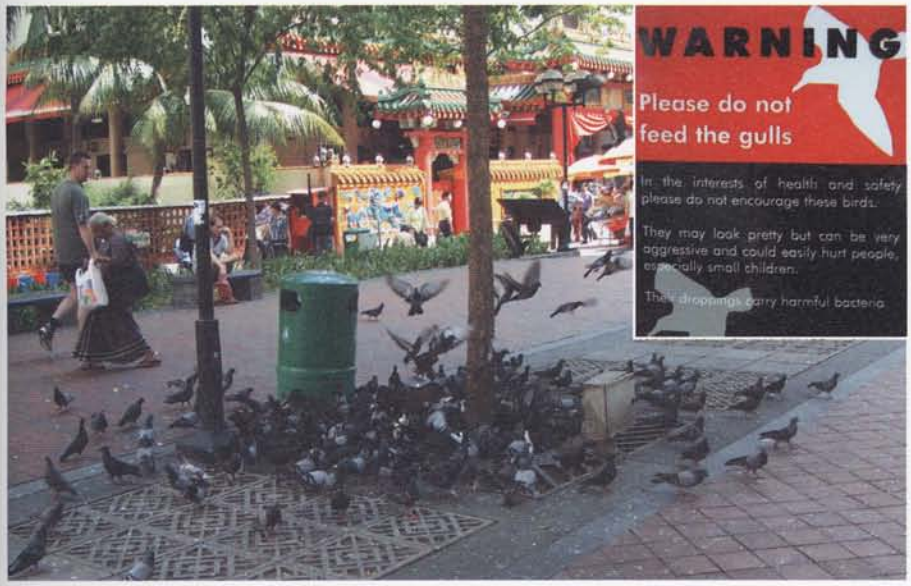
In previous articles in *Microbiology Today* we showed that birds excrete huge numbers of faecal coliforms and that up to 50 % of *E. coli* in coastal seawater can originate from their droppings. Indeed, flocks of birds can cause problems with compliance with the EU Shellfish and Bathing Water Directives. They may well be responsible for sporadic failures, such as that of Lancashire's Morecambe South Beach this summer.

The situation with *Campylobacter* is even more dramatic. The intestinal environment of birds is favourable for the growth of *Campylobacter* with the result that large numbers are excreted in droppings. As campylobacters survive relatively poorly outside the birds, their presence in water is a sign of recent pollution and we have exploited this to investigate sources of pollution. In Morecambe Bay, the seasonal pattern of campylobacters in seawater is similar to those of the main waders, gulls and wildfowl (oystercatchers, bar-tailed godwits, lapwing, migratory geese, knot and various gulls). This, together with evidence that the species profile of *Campylobacter* found in seawater and mussels is similar to that in the birds and not sewage, suggests that birds and not sewage effluent are responsible for campylobacters in coastal waters.

A similar situation, but with different birds, occurs at the Crook O'Lune, a local freshwater bathing site. Here, the large number of mallards pollutes both the water and the surrounding picnic area. Interestingly, the species of *Campylobacter* found at the Crook O'Lune, *C. jejuni*, is the same as that causing disease in the community. *Campylobacter lari*, the species found in marine waters, rarely causes disease. Hence, you are more likely to get campylobacteriosis from swimming in freshwater than seawater.

Wild birds are a major source of faecal pollution for drinking water reservoirs. At a large local reservoir there was concern that the water was being polluted by a newly arrived flock of Canada geese. We were able to show from the profile of *Campylobacter* strains that the polluting culprit was actually black-headed gulls roosting on one of the islands. In the 1970s and 1980s there was considerable interest in the role of birds, particularly gulls, in the pollution of reservoirs with *Salmonella*. A local outbreak of salmonellosis was caused by the contamination of a drinking water reservoir by gulls travelling from sewage outfalls and waste tips to their night-time roosts in the hills. This lead to a programme of culling that continued for many years. In the US the pollution and health risks caused by wild birds on reservoirs is well recognized and speedboats have been used to frighten away roosting flocks.

Amenity lakes and ponds in parks contain a number of different types of water bird, both resident and visiting migrants, together with attendant microbes. Bizarrely, when attending health-



◀ A flock of oystercatchers and knots at Morecambe, and the mess they left behind! *Keith Jones*

◀ People eating fish and chips at an outdoor cafe in Brighton, with some uninvited avian guests. *Keith Jones*

◀ It is difficult to stop people feeding the birds, despite warning notices and antisocial behaviour orders (ASBOs). Indeed, according to Environmental Health Officers, most towns in the UK contain at least one person who encourages pigeons or gulls by feeding them. The problem is international – even where there are worries over bird 'flu. This picture, showing the perpetrator exiting left, was taken recently in a busy market area in highly-regulated Singapore. *Keith Jones*

related microbiological conferences at some university campuses and conference centres, it is difficult not to tread bird faeces and bacteria into the carpets of the residences and the lecture rooms!

Billions of birds are involved in annual migrations in which they carry and deliver microbes over thousands of miles. On arrival at their destination, and at nodal stop-off points, there is the potential for a gloriously complex interchange of microbes between resident and migrant birds of different countries.

Farms and farmland

Wild birds act as a link between aquatic and farm environments for the transfer of disease-causing microbes. For example, the strain of *E. coli* O157 we isolated from waders and gulls on Morecambe Bay was identical to that found in cattle on farms in the region. Gulls that feed on sewage effluents and waste tips contaminate pasture with *Salmonella* when foraging or loafing on farmland, sometimes attracted by the spreading of muck, farm slurries or sewage sludge. In the early 1980s in Scotland, *Salmonella* Zanzibar was traced from an infected person to milk via sewage, gulls, pasture and cows. An epidemic of abortion in sheep on a Lancaster farm was caused by gulls contaminating feeding troughs with *Salmonella* while finishing off food meant for sheep. The sheep licked the droppings and the *Salmonella* caused the foetuses to rot in the ewes.

Similar events occur with *Campylobacter*. We have watched calves and lambs lick starling droppings from gates and fences. They then became infected with the same strains of *Campylobacter* as the birds roosting in the farm buildings and nearby trees.

Farm ponds, with their resident and migrating ducks, geese and wildfowl, are a particularly rich source of pathogens, such as *Salmonella* and *Campylobacter*, for livestock. Migrating birds have the potential to bring new, more virulent strains into the farm environment. Faecal contamination of crops by birds is an important issue, particularly for growers of salad vegetables such as lettuce and spring onions.

Other contact with birds and their droppings

Besides eating poultry and game birds, it is hard to envisage situations where there is direct transfer of pathogens from birds to humans. Here are a few.

The first person I met who had had *Campylobacter* confessed that she contracted it by kissing her pet peacock! Milk from bird-pecked bottles is said to transmit *Campylobacter*.

In hard water areas it is quite the vogue to wash your hair in 'soft' rainwater collected in water butts. As this water is washed off roofs contaminated with bird droppings, it is unsurprising that it can be contaminated with pathogenic bacteria. Outbreaks of *Campylobacter* enteritis have been traced to birds defecating in the header tanks of tower blocks.

A school in Newcastle ran into problems with a 'show and tell' exercise with nursery school children. A parent who was a farmer gave duck and chicken eggs to the school, which hatched out. The children, aged 2–4, were told not to touch the chicks and ducklings, but were known to do so. Surprised? Thirty-two of the children caught *Salmonella*. Children are at risk in petting zoos when they are in contact with poultry or more exotic birds, such as ostriches or emus.

Open-air restaurants, pubs and picnic areas frequently have bird droppings on the seats and tables. In some restaurants people are encouraged to feed wild birds at the table. This can lead to obvious contamination of food.

We are in contact with bird faecal material at bird tables in the garden. Often, too much food is put out and it falls to the ground where it attracts rats and mice. It is probably here that many of our garden birds pick up strains of *Salmonella*, which are pathogenic to them (and can then be transmitted back to humans!).

Putting the problems to flight

There is not a lot that can be done to limit the microbial hazards caused by birds other than be aware of the problems and pay attention to hygiene. It would also help if people did not feed pigeons and gulls. On a domestic level, we can call in a saviour, the cat. The humble moggie is a natural born killer that kills 275 million animals each year in Britain alone!

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Brian Wood read the report of the debate on problem-based learning in the last issue with interest. He ponders on the appropriateness of modern teaching methods.

Training medical personnel

I note with interest the report of a debate on the appropriateness of newer methods for training the next generation of medical doctors. A couple of years ago I was referred to a shoulder surgeon for assessment. Happily, he eventually decided that I was enjoying life too much to be subjected to surgery at that time. He picked up that I am a microbiologist and began a discussion of the part bacteria play in rejection of joint replacements, with particular reference to *Propionibacterium acnes*. This was obviously enjoyed by the two students with him.

Later, I had a second appointment with him, and this time he was accompanied by a whole batch of students, maybe ten or so. I made a comment about *Propionibacterium* being the cause of the holes in certain cheeses, and this led on somehow to a discussion of the distribution of bacteria and other microbes in various parts of the human body. The students were enraptured; the exchanges went on for about a half hour and must have created chaos for the group's schedule in Glasgow Royal Infirmary. I also wonder what waiting patients made of the amount of laughter that was generated. Eventually the surgeon and I realized that we simply had to call this to a close, and the students gave me an impromptu heartfelt vote of thanks.

I particularly recall one boy who was so enthralled that he stopped by to offer further thanks. These were obviously not first-year students, and clearly had no knowledge whatsoever of the microbial world. When I asked the surgeon about it, he confirmed that they no longer received that sort of basic training. He added that he was required to teach them about the problems of the most complex joint in the human body, when they had no firm grounding in skeletal or muscular anatomy.

I had so enjoyed the exchanges with the students (as did they, to my judgment) that I asked if I could give the students a more developed seminar, but they were not with his group for long enough for that to be possible. However, I was invited to give a talk to one of his clinical group meetings on the subject of our microbial partners, a semi-popular one that I call *We are all ecosystems*. It seemed to be well received, but sadly the surgeon died soon afterwards, in a terrible loss to medicine, so I was not able to take this matter any further.

I am emphatically not a clinical microbiologist; brewing, fermented foods and certain environmental issues are my preferred fields, but I am gravely worried that students could advance that far along their training without any direct exposure to microbiology. Microbial infections are surely still an everyday part of medical experience? My limited knowledge of the disciplines relating to their chosen profession was sufficient for me to hold those students' attention and excite them with the possibilities of the microbial world. I found myself wishing that I was not retired, as I felt that the student who was so utterly enthralled at what I had to say would have welcomed the opportunity to work for a time in a microbiological area, but I had no capacity to offer him anything.

I do understand that the 'didactic' education of my student years is no longer considered acceptable; we must not run the risk of boring the students, or of suggesting that we know better than they what they should be studying. I wonder what would happen if some university had the courage to return to the structured courses of four or five decades ago, and made it absolutely clear that they would only accept students who would work in that disciplined atmosphere? Of course they would need to return to proper pass marks for sessional examinations; no 40 % 'pass' mark with 'compensation' for some marks at 35 %. Surely there are still some potential students with aspirations high enough to accept those conditions? I am certain that there are employers longing to employ the successful survivors of such a system. Could it be that, after a time, there would be a real demand for places in such a draconian institution from discerning students with real ambitions?

I find it ironic that the fictional Hogwarts School is presented as offering a curriculum more crowded and pressured than any real school would ever dare to use, but children and adults avidly consume Harry Potter's adventures there.

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Clouds of desert dust and microbiology: a mechanism of global dispersion

Although desert soils and sediments in Earth's atmosphere are derived from arid regions around the globe, the majority of 'desert dust' originates from two locations, the Sahara and Sahel regions of Africa, and the deserts of Asia. In the months from June through October, dust originating from Africa routinely impacts the Caribbean and Central and North America. In the remaining months, the African dust storms typically impact South America, Europe and the Middle East. Dust storms originating in the Asian deserts usually occur from February through to April of each year, and although the Asian deserts are smaller than the Sahara and the dust season only 3 months long, the larger Asian dust events are capable of global dispersion in the Northern Hemisphere.

The current estimate of the quantity of soil moving some distance in Earth's atmosphere each year is approximately 3 billion metric tons (Fig. 1). If that 3-billion-ton estimate was converted into 1964 Volkswagen Beetles (based on weight and dimensions), there would be enough Beetles to create a 42-km-tall tower with a base area equivalent to the walled city of Chester, UK. From a microbiology perspective, there is an additional piece of trivia – the 3-billion-ton estimate converts to 3×10^{15} g. At a conservative estimate of 10,000 bacteria per gram of arid soil (microbial ecology studies have shown that actual concentrations range from 10^6 to 10^9), the bacteria would form a 38-cell-wide bridge between Earth and Jupiter if placed end to end (assuming an average bacteria size of 0·75 μm). This conservative estimate is based on bacterial species alone and does not include the fungi and viruses also known to inhabit soils. Even more interesting than these bits of trivia are the questions that arise from such a large quantity of dust and dust-borne micro-organisms moving through the atmosphere. Are there any benefits to dust movement? What influence does this process have on global microbial ecology issues? Can dust-borne pathogenic micro-organisms survive long-range atmospheric transport and cause infection in downwind ecosystems? These are questions with global implications, questions that are being addressed by surprisingly few.

Benefits

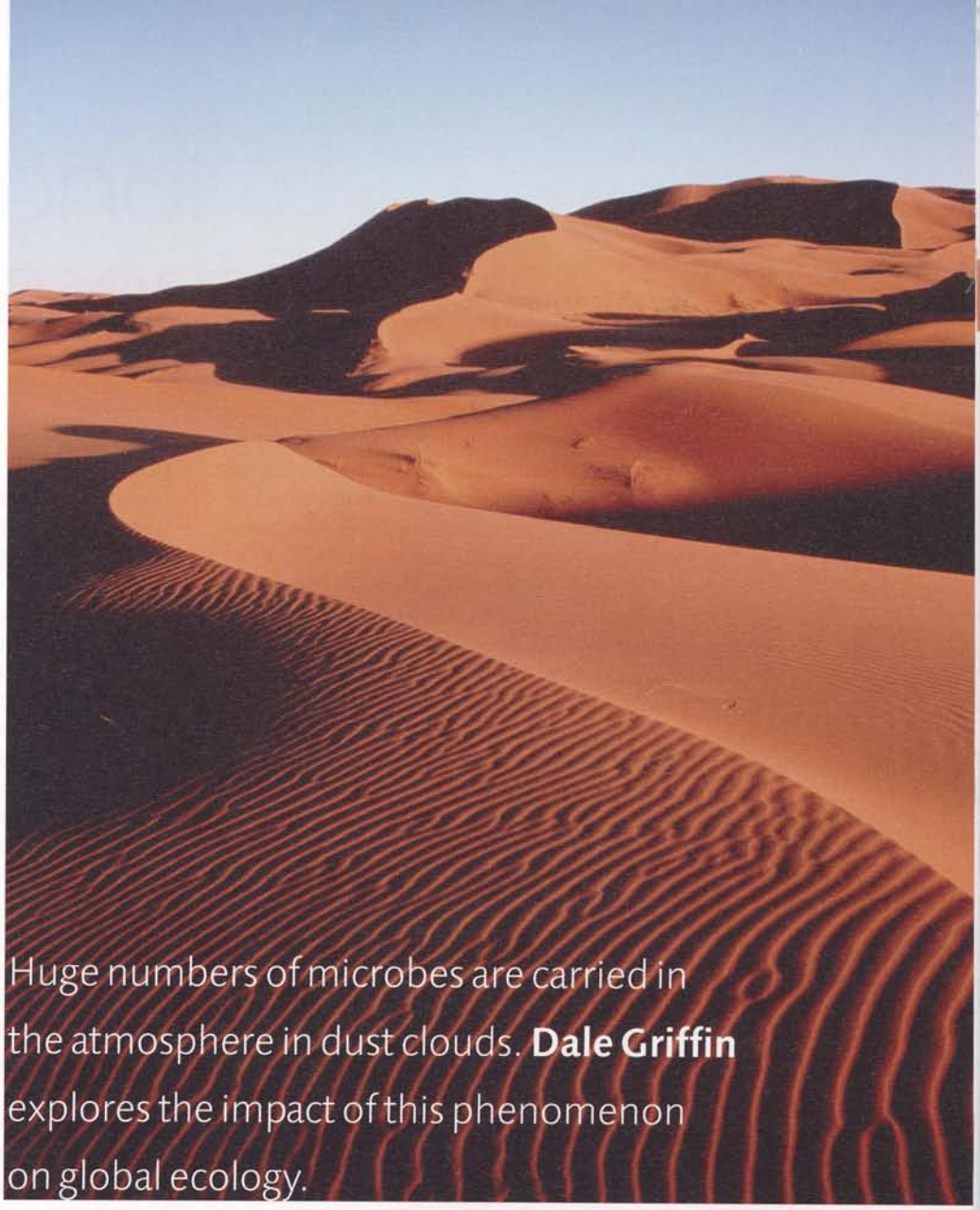
Plant life in both terrestrial and aquatic ecosystems has evolved to take advantage of the nutrient-rich particles (iron, phosphate and organic detritus) in clouds of desert dust. Research has shown that plant life in the upper canopy of the Amazon rain forest derives nutrients from African dust. Rain forests located on the northern Hawaiian Island chain are believed to obtain a significant fraction of their nutrient budget from Asian desert dust. Increases in marine biomass have been documented following deposition of desert dust in our oceans. African dust deposition in the Caribbean, through time, provided the clays in Bahamian soils that enabled pre-Columbian Indians to produce pottery

from an otherwise clay-limited soil. Clearly, the global movement of dust has benefitted both ecosystems and humanity.

Microbial ecology

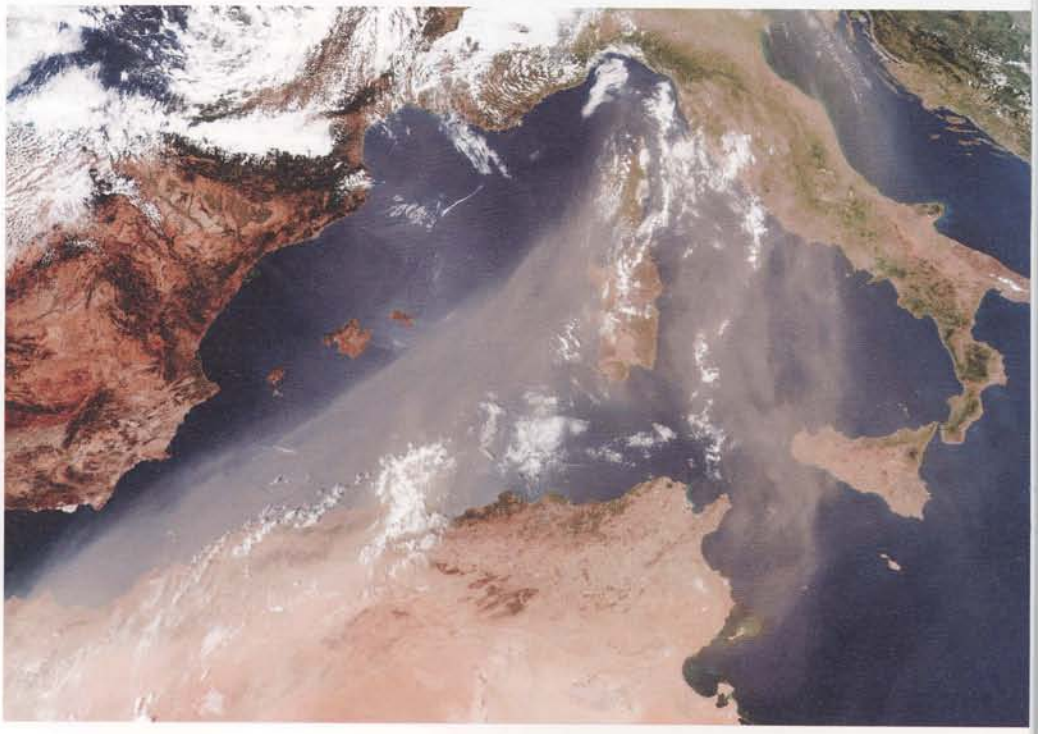
Whereas far too few microbiologists study dust-borne microbiology, the field has at times in the past sparked interest. In the early 1800s, C.G. Ehrenberg identified 'infusoria' in samples of African dust collected aboard *HMS Beagle* by Charles Darwin while traversing the coast of north-western Africa. Research in the 1970s by Russian scientists using rockets to collect high-altitude microbiological samples noted that greater numbers of cultivable micro-organisms were present when dust was in the atmosphere.

At a number of different locations, including Bamako in Mali, Erdemli in Turkey, the tropical mid-Atlantic Ocean, and the US Virgin Islands, our research groups have found elevated concentrations of very diverse populations of bacteria and fungi when



Huge numbers of microbes are carried in the atmosphere in dust clouds. **Dale Griffin** explores the impact of this phenomenon on global ecology.

▲ Sand dunes in the Sahara desert, photographed in Morocco. *Noboru Komine / Science Photo Library*



▶ Fig. 1. Terra satellite image of a dust plume crossing the Mediterranean sea. Sand and dust from North Africa and the Sahara has blown north towards Italy in a large plume. This image was taken on 16 July 2003 by NASA's Moderate Resolution Imaging Spectroradiometer (MODIS). *NASA / Science Photo Library*

desert dust is in the atmosphere. During dust events in Bamako, Mali, the bacterial and fungal colony-forming units (c.f.u.) averaged 6,655 (m air)$^{-3}$ (Fig. 2). Ninety-seven percent of the c.f.u. were bacteria. In the US Virgin Islands, during dust events, those concentrations dropped to 10^4 m^{-3} (72 % bacteria), indicating a die-off of over 90 % due to the stresses of atmospheric transport. At the Turkey research site, c.f.u. were dominated by fungi (93 % of isolates), and we believe this is due to differences in source regions of dust (dust impacting the Mediterranean region typically originates from the northern Sahara, whereas the dust moving across the Atlantic typically originates from the southern Sahara/Sahel). Numerous isolates collected over a site in the tropical mid-Atlantic Ocean were genetically (16S rDNA sequences) similar to various Mali isolates. Other research groups conducting microbial surveys during Asian dust events in South Korea have documented elevated concentrations of diverse fungal populations in a number of independent studies.

It is obvious that despite the physical stresses of atmospheric transport (UV-induced DNA damage, desiccation, temperature, etc.), many species of fungi and bacteria are capable of surviving long-range atmospheric transport.

Dust-borne pathogens

One of the best examples of dust-borne pathogens is the small outbreaks of coccidiomycosis (caused by the fungal pathogen *Coccidioides immitis*) that occur annually in the Americas following dust events. One of the first links to be made between long-range transport of desert dust and ecosystem health was the isolation and identification of a terrestrial fungus (*Aspergillus sydowii*) as the causative agent of a Caribbean-wide sea fan disease from atmospheric samples collected in the US Virgin Islands. An outbreak of aspergillosis in caged desert locusts was documented following a dust event in Bikaner, India. Of those dust-associated isolates we have identified using DNA sequencing of the ribosomal gene, ~20 % are species known to cause disease in a broad range of plant and animal life and ~10 % are known opportunistic human pathogens. Although dose is certainly an issue when determining risk from exposure, it should not be surprising that dust-borne pathogenic species capable of surviving atmospheric transport are capable of causing disease in downwind ecosystems.

The implications of the global dispersion of dust-borne micro-organisms are what make this field so interesting. Do dust-borne micro-organisms influence regional microbial ecology in downwind environments? How do fate and survival issues change with location, distance, and season? What is the true risk of infection from dust-borne pathogens? This article is but a brief synopsis of what dust-associated microbiology has shown us and where it is leading us. Hopefully, this wide-open field will attract other microbiologists in our quest to understand its regional and global implications.

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► Fig. 2. Atmospheric sample taken during a dust event in Mali, Africa, showing heavy growth of bacteria and fungi. The volume of air filtered was ~75 litres. *Dale Griffin*

International Development Fund report

Teaching microbiologists from the Western Balkans to work with pathogenic bacteria

Lancaster Environmental Centre (LEC) at Lancaster University is a partner in Water Web (www.waterweb.dk), an EU programme designed to contribute to development in the Western Balkans by introducing strategic water management for drought alleviation and sustainable agriculture. The main function of microbiologists in WaterWeb is to investigate the microbial quality of irrigation water and monitor any contamination of salad vegetables and fruit grown in that water. This fulfils one of the core functions of the World Health Authority, which is to assess the impact of water quality on food quality. The lead WaterWeb microbiologists from the Western Balkans are predominantly experts in agricultural and food microbiology but have limited experience of isolating pathogens, such as *Campylobacter* and *Listeria*, from environmental sources. To help with this, the SGM funded a research visit to LEC by microbiologists from Belgrade and Skopje.

In March 2005 Dr Vera Raicevic, Associate Professor specializing in soil and water microbiology in the Institute of Land Management, Faculty of Agriculture, University of Belgrade, Serbia, and Dr Vladimir Kakurinov, Teaching Professor and Research Associate specializing in food microbiology in the Department of Microbiology, Faculty of Agriculture Sciences and Food, University St Kiril and Metodij, Skopje, Republic of Macedonia, visited Lancaster.

Environmental samples, i.e. farm slurries, rabbit faeces and watercress, were tested for the presence of *E. coli*, *Salmonella*, *Campylobacter*, *Listeria* and *Aeromonas* using enrichment, selective media and appropriate incubation. Positive cultures were isolated, obtained in pure culture and identified phenotypically using microscopy and either API or MAST identification kits. The laboratory work was co-ordinated by Joanna Heaton, a PhD postgraduate researching microbial contamination of salad vegetables in the UK, also funded by WaterWeb.

We are confident that the appropriate skills were transferred as we have already received a report from Belgrade on the level of indicators and pathogens in irrigation water used in the area.

We are extremely grateful to the Society for their support for this visit.

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▲ *Listeria*, *Salmonella*, *Aeromonas* and *E. coli* isolates.

▲ Vladimir Kakurinov on the side of a slurry tank.

▲ Vera Raicevic sampling farm slurry.

All photos Keith Jones

RCUK consultation

Open access is a thorny issue for not-for-profit scientific publishers. **Ron Fraser** describes the latest UK research council proposals which may have long-reaching effects on journals publishing.

The eight UK Research Councils have recently held a consultation exercise on their proposals for public access to research outputs – that is papers published from work they have funded. Their position is based on four principles:

> Ideas and knowledge derived from publicly funded research must be made available and accessible for public use, as widely, rapidly and effectively as practicable.

> Published research outputs must be subject to rigorous quality assurance, through peer review.

> Mechanisms for publication and access must be efficient and cost-effective in the use of public funds.

> Outputs of current and future research must be preserved and remain accessible not only for the next few years but for future generations.

It would be difficult to disagree with the generality of these principles. However, many publishers and learned societies have expressed extreme misgivings about RCUK's proposals for implementation. These *require* researchers to deposit a copy of published journal articles or conference proceedings in an appropriate institutional or subject-based e-print repository, where they would be freely accessible. Deposit *should take place at the earliest opportunity, wherever possible at or around the time of publication*, although it would be *subject to copyright and licensing arrangements*. The RCUK position paper is somewhat ambiguous about the format of papers to be deposited, but they should contain a clear statement of whether they have been peer-reviewed. It seems likely that most deposits would be of authors' manuscripts as accepted for publication, that is as author-prepared PDFs incorporating changes suggested by editors and referees, but before copy editing and formatting by the publisher.

The Association of Learned and Professional Society Publishers (ALPSP), of which SGM is a member, is concerned that immediate free availability of 'good enough' versions of journal articles would encourage librarians to save money by cancelling subscriptions, especially if other research funders follow the RCUK example. This could threaten the financial viability of journals, and hence their ability to support peer review and other value-adding processes. Many learned society publishers, including SGM, already make older papers freely available online, but recognize that the most recently published papers need to be under access control to maintain subscription income. Those publishers who have experimented with very short periods under access control have had some nasty experiences at subscription renewal time.

There is also concern about the proliferation of different versions of papers, and the effect of citation of versions other than the definitive published one, as already happens in some areas of physics. Papers in e-print repositories, outside of the publisher's ongoing quality controls on version stability and corrigenda, may be more prone to errors and even deliberate misrepresentation. It also has to be said that institutional e-print repositories still have a long way to go to prove themselves as an effective means of information dissemination, despite the assertions of their more evangelical supporters. By no means all UK universities have chosen to set them up, perhaps because of the significant costs involved. Those that do exist cannot yet compare in functionality and content with 'gold standard' operations such as SGM's online journals.

The Biosciences Federation, on behalf of and after consultation with a number of its journal-publishing member societies, has written to RCUK pointing out the threat that their proposals constitute to the viability of learned society publishing, and describing the wider benefits that learned societies bring to science in the UK. Learned society journals are produced to high standards and at very reasonable prices. The surpluses that societies make on their journals businesses are ploughed back into support of science, through grants to young members, educational, training and outreach activities, organization of conferences and more. The point is made strongly that the UK academic community is underpinned by the learned societies to a much greater extent than is often appreciated. This, and the concerns of learned society publishers, are referred to briefly in the very last paragraph of the RCUK position paper. It tries to offer a reassurance that *RCUK's requirement to deposit papers in e-print repositories will operate in accordance with copyright and licensing agreements which learned societies are themselves party to*. It is not made clear whether this includes respecting the publisher's access control periods.

The RCUK paper does comment briefly on alternative business models for journal publishing, including the possibility of 'author-side' charges as a trade against loss of subscription revenue on open access publications. There is to be no RCUK-wide fund to support these, although investigators *may be allowed to include predicted costs of publication in author-pays journals in their grant applications, subject to justification of cost-effectiveness*. However, it then appears that such author charges will be regarded as one of the elements of full economic costing, which is currently being implemented, so it remains to be seen how available such funds would be. RCUK admits that the viability of the author-pays model is still far from certain, and that the costs to research-led universities could be significant. Many learned society publishers are at present grappling with the question of whether and how to experiment with author-side charges. The RCUK statement that they *will discuss with the learned societies ways in which they can adapt to and exploit new models of publication* may or may not be seen as reassuring.

A group of learned societies who produce their online journals with HighWire Press, including SGM, have written to RCUK suggesting that they should recognize publication in those HighWire-hosted journals that make back content free after an access controlled period as sufficient in itself to represent compliance with RCUK's requirements. This would have the advantage that authors publishing in these journals would not have to make any additional efforts to self-archive their papers, and would automatically be within the copyright and licensing arrangements with the publisher. Furthermore, publication would then be focussed on the definitive, copy-edited and highly functional publisher-maintained version and proliferation of second-tier versions would be unnecessary.

It is worth looking across the Atlantic to see what has happened to similar proposals from the US National Institutes of Health (NIH). There, authors were initially to be 'required' to deposit publications arising from NIH-funded work on PubMed Central, and for them to be freely available 6 months after the time of publication. This was swiftly changed to 'requested' to deposit, and publishers' wishes for longer delays before the papers become freely available are now respected. It is highly likely that the relaxation stemmed at least in part from NIH recognition that the earlier requirements would place authors in breach of their copyright and licensing agreements with publishers. Current indications are that the compliance rate, i.e. the number of NIH-funded papers posted on PubMed Central, is only about 3 %. This, together with the small numbers of papers that authors in UK universities seem to have posted on their institutions' repositories or departmental websites, suggest that most authors may be content with publication through 'traditional' means in real journals of recognized quality and defined subject area, and that change to a system where authors become quasi-publishers themselves would require a major culture shift.

SGM, through its Publications Committee, Treasurer's Committee and Council, and as an active participant in outside bodies such as ALPSP, the Biosciences Federation, and HighWire Press, will monitor developments closely, with the objectives of maintaining the high quality of our journals, the high standards of service to authors, editors, referees, readers and librarians, and the wider underpinning of microbiological science. The Society has already shown its willingness to embrace change where this is consistent with sensible policy to the benefit of science and prudent management in an economically sustainable manner. RCUK is being urged by many parties to give further consideration to its proposals, and to engage in a dialogue with learned societies and researchers about the best way forward.

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The web version of this article at www.sgm.ac.uk/pubs/micro_today/current.cfm includes links to the RCUK position paper and responses from a number of organizations.

on research outputs

Many publishers and learned societies have expressed extreme misgivings about RCUK's proposals

The nitrogen cycle

Nutrient cycling

Various processes are responsible for recycling the chemicals necessary for life on Earth. The nitrogen cycle is the most complex of these. Carbon, sulfur and phosphorus are the other main cycles. In this article we are going to explore how nitrogen is cycled and the important role of microbes in this cycle. See Fig. 1.

Nitrogen

Nitrogen is required by all living organisms for the synthesis of organic molecules such as amino acids, nucleic acids and proteins. The Earth's atmosphere contains almost 80 % nitrogen gas. It cannot be used in this form by most living organisms until it has been fixed, that is reduced (combined with hydrogen), to ammonia. Green plants, the main producers of organic matter, use this supply of fixed nitrogen to make proteins that enter and pass through the food chain. Micro-organisms (the decomposers) break down the proteins in excretions and dead organisms, releasing ammonium ions. These two processes form part of the nitrogen cycle.

The nitrogen cycle

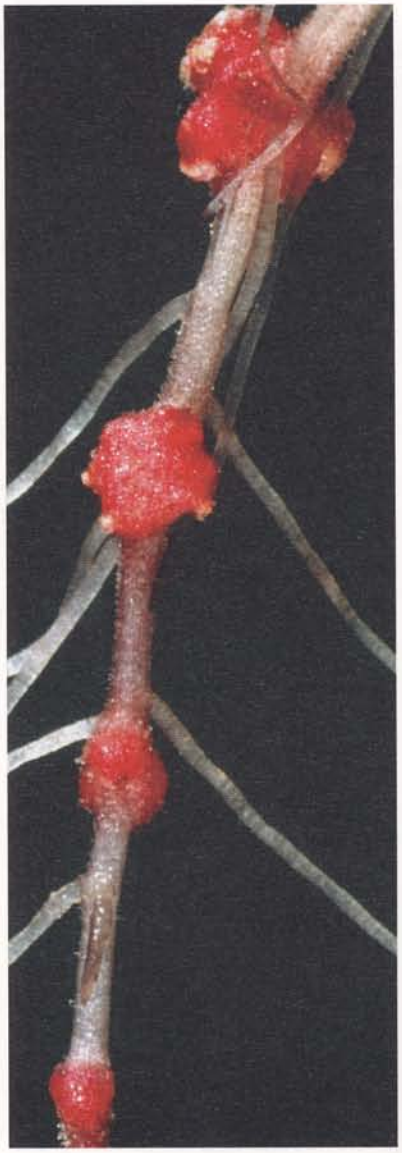
The nitrogen cycle is the movement of nitrogen between the earth and the atmosphere. It consists of a series of processes that convert nitrogen gas to organic substances and these back to nitrogen in nature. It is a continuous cycle maintained by the decomposers and other bacteria. The nitrogen cycle can be broken down into four types of reaction and micro-organisms play roles in all of these (see Table 1).

Nitrogen fixation

Nitrogen gas is composed of two atoms of nitrogen linked by a very strong triple bond. This makes it chemically unreactive and large mounts of energy are required to break the bond.

Nitrogen gas can be fixed in three ways.

1. **Atmospheric fixation.** This occurs spontaneously by lightning; a small



▲ Red nitrogen-fixing nodules on the roots of a black alder tree (*Alnus glutinosa*). The nodules contain symbiotic *Frankia* sp. bacteria, which take nitrogen from the air and convert it into forms the tree can use for nutrition. In return, the bacteria feed on sugars produced by the tree. This symbiosis means that the alder can grow in less fertile soils than many other plants. *Biophoto Associates / Science Photo Library*

Table 1. Reactions of the nitrogen cycle

Reaction	Micro-organism	Conditions	Process
Nitrogen fixation	Nitrogen-fixing bacteria e.g. *Rhizobium*	Aerobic/anaerobic	The first step in the synthesis of virtually all nitrogenous compounds. Nitrogen gas is fixed into forms other organisms can use.
Ammonification (decay)	Ammonifying bacteria (decomposers)	Aerobic/anaerobic	The decomposers, certain soil bacteria and fungi, break down proteins in dead organisms and animal wastes, releasing ammonium ions which can be converted to other nitrogen compounds.
Nitrification	Nitrifying bacteria e.g. *Nitrosomonas*, *Nitrobacter*	Aerobic	Nitrification is a two-step process. Ammonia or ammonium ions are oxidized first to nitrites and then to nitrates, which is the form most usable by plants.
Denitrification	Denitrifying bacteria	Anaerobic	Nitrates are reduced to nitrogen gas, returning nitrogen to the air and completing the cycle.

amount (5–8 %) only is fixed this way. Lightning allows nitrogen and oxygen to combine to produce various oxides of nitrogen. These are carried by the rain into the soil where they can be used by plants.

2. **Industrial fixation.** The Haber process is used to make nitrogen-containing fertilizers. This is a very energy inefficient process.
3. **Biological fixation.** Nitrogen-fixing bacteria fix 60 % of nitrogen gas in the atmosphere.

Biological fixation

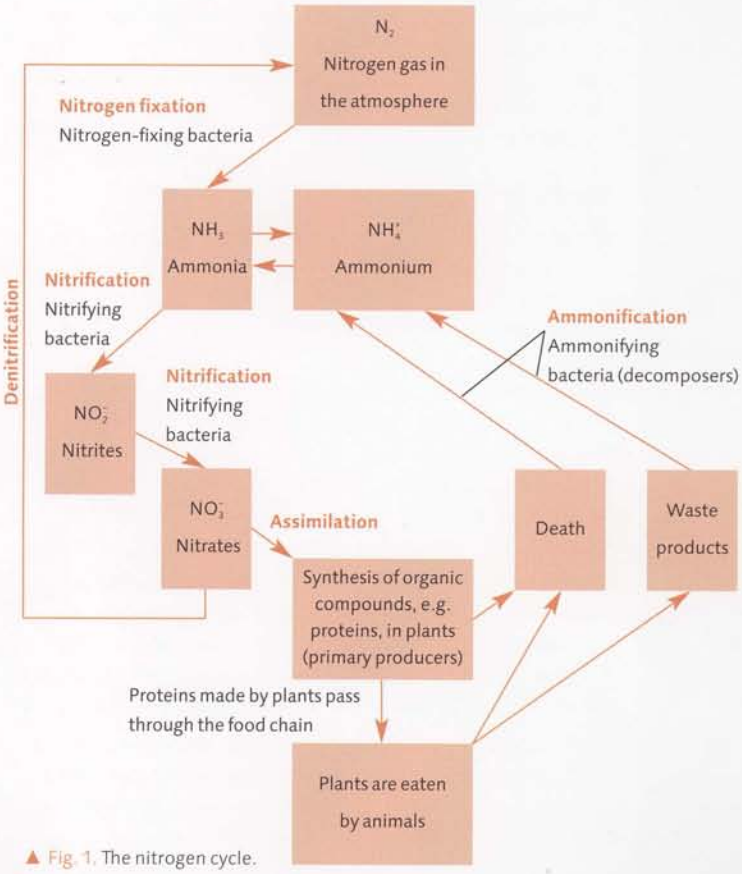
The reduction of nitrogen gas to ammonia is energy-intensive. It requires 16 molecules of ATP and a complex set of enzymes to break the bonds so that the nitrogen can combine with hydrogen. Its reduction can be written as:

$$N_2 + 3H_2 \xrightarrow{energy} 2NH_3$$

Only a relatively few bacteria (the nitrogen-fixing bacteria) are able to carry out this reaction. Fixed nitrogen is made available to plants by the death and lysis of free-living nitrogen-fixing bacteria or from the symbiotic association of some nitrogen-fixing bacteria with plants.

Types of nitrogen-fixing bacteria

Some nitrogen-fixing bacteria are free-living in the soil, fixing nitrogen independently of other organisms, e.g. *Azotobacter* (aerobic) and *Clostridium* (anaerobic).



▲ Fig. 1. The nitrogen cycle.

Some nitrogen-fixing bacteria form symbiotic associations with plants.

Root-nodulated legumes, such as peas and beans, with, e.g. *Rhizobium*. Free-living rhizobia invade the legume through an infection thread formed in the root hair of the plant. The infection thread is constructed by the root cells and not the bacteria and is formed only in response to infection. The infection thread grows through the root hair cells and penetrates other root cells nearby, often with branching of the thread. The root cells then proliferate to form a root nodule. Within a week of infection small nodules are visible to the naked eye. Each root nodule is packed with thousands of living *Rhizobium* bacteria (known as bacteroids).

Root-nodulated non-legumes, a diverse group of woody species such as alder with e.g. *Frankia*. These filamentous bacteria infect the roots of plants forming actinorhizal root nodules.

Azolla (tiny free floating water ferns) with, e.g. *Anabaena azollae*. This is a cyanobacterium that infects new leaves of *Azolla* as they develop from the stem. Strings of *Anabaena* get caught in tiny leaf hairs that grow from a dimple on the developing leaf. The dimple grows larger into a pouch-like structure that eventually closes up, locking the *Anabaena* inside the leaf.

◀ The floating leaves of the waterfern *Azolla filiculoides*. *Dr Jeremy Burgess / Science Photo Library*

Adapting to their environment

Nitrogen-fixing bacteria contain an enzyme complex called nitrogenase which catalyses the conversion of nitrogen gas to ammonia. It supplies hydrogen as well as energy from ATP. The nitrogenase complex is sensitive to oxygen, becoming inactivated when exposed to it. This is not a problem with the free-living anaerobic bacteria such as *Clostridium*. Free-living aerobic bacteria have a variety of different mechanisms for protecting the nitrogenase complex, including high rates of metabolism and physical barriers. *Azotobacter* overcome this problem by having the highest rate of respiration of any organism, thus maintaining a low level of oxygen in their cells.

Rhizobium contains leghaemoglobin. Leghaemoglobin functions similarly to haemoglobin, i.e. it binds to oxygen. This provides sufficient oxygen for the metabolic functions of the bacteroids, but prevents the accumulation of free oxygen that would destroy the activity of nitrogenase.

Frankia and *Anabaena* are able to exclude oxygen by carrying out the fixation in specialized structures known respectively as a vesicle and a heterocyst. The thick walls of the vesicle and heterocyst form an oxygen diffusion barrier.

Nitrification

This is the oxidation of ammonium compounds to nitrites and then to nitrates by the nitrifying bacteria. During these oxidation reactions energy is released. The nitrifying bacteria are chemoautotrophs and are able to use this source of energy to produce organic compounds from inorganic ones. (Photoautotrophs use light energy to produce organic compounds from inorganic ones.)

Nitrification is a two-step process.

Bacteria of the genus *Nitrosomonas* convert ammonium ions to nitrites (NO_2^-). (Nitrite is toxic to plants and animals in high concentrations.)

Bacteria of the genus *Nitrobacter* convert nitrites to nitrates (NO_3^-). The nitrates can then be taken in by plants.

Nitrification occurs in well drained and aerated soils at neutral pH.

Denitrification

This is the conversion of nitrates into primarily nitrogen gas but also nitrous oxide gas by the denitrifying bacteria, e.g. *Pseudomonas*.

$$NO_3^- \longrightarrow N_2 + N_2O$$

Denitrifying bacteria transform nitrate in extremely wet soils and swampy grounds, where there is very little oxygen, i.e. the conditions are anaerobic. The bacteria get the oxygen they need for respiration from the breakdown of nitrates. The gases that are formed escape into the atmosphere completing the nitrogen cycle. This can be a harmful process as fixed nitrogen is removed from the soil making it less fertile.

Ammonification (decay)

This is the conversion of organic forms of nitrogen (e.g. in dead organisms and their excretions) into inorganic nitrogen. A wide range of soil fungi and bacteria called the decomposers carry out the ammonification process. The decomposers consume the organic matter and the nitrogen contained in the dead organism is converted to ammonium ions. The ammonium is then converted to nitrates by the nitrifying bacteria.

Dariel Burdass
SGM Education Projects Administrator

Further reading

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Moran, R. (1997). The little nitrogen factories. *Biol Sci Rev* **10**, 2–6.

Websites

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http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/N/NitrogenCycle.html

Astrobiology
a useful oxymoron

In response to the recent Comment by Howard Gest, **Milton Wainwright** points out that while 'astrobiology' is an oxymoron, it remains a useful term.

Howard Gest is clearly less than enthusiastic about the 'science of astrobiology' (Comment, *Microbiology Today* **32**, 156). He is right to point out that the word astrobiology refers to life in relation to the stars (i.e. generally space) and since no life has yet to be found there his etymological pronouncements cannot be faulted. Of course, we may yet prove that fossil bacteria do exist in the Allen Hills meteorite, while Gil Levan remains convinced that the Viking Lander found life on Mars. For the moment, however, we can accept the premise that life has yet to be definitely found in space. As one who had an old fashioned grammar school education I would be the first to argue against the use of etymologically meaningless terms. However, as Fowler frequently pointed out in his *Modern English Usage*, language is nothing if it is not useful. The term astrobiology is certainly useful, in that it brings together a whole range of diverse subjects.

Professor Gest is also correct to point out that astrobiology has a ridiculously wide remit. We microbiologists could solve this perceived problem by using the term astromicrobiology and limiting this science to microbial life in space.

There is also no doubt that many people, particularly those studying extreme environments, have jumped on the 'life in space' funding band wagon. Astrobiology meetings are, for example, frequently populated by people discussing the arctic environment in relation to space; since such environments are relatively warm, perhaps we have found yet another new science, namely 'tropical astrobiology'; the word 'model' covers many sins! For my part I would wish to restrict astrobiology to studies on non-Earth environments. For example, we have yet to determine how far into space the biosphere extends; perhaps some of the large amounts of money spent in Antarctica might be diverted to help answer this question.

I also agree that NASA somehow rediscovered the subject of extremophiles. Similarly, it is always amusing to view TV science programmes like *Horizon*, and learn that some postgraduate student has recently discovered that the hot springs of Yellowstone Park are teeming with life! However, I would put the study of microbial life in extreme conditions, beyond the 1940s, and back to the early years of the 20th century, when Arrhenius suggested his version of panspermia and Macfadyen was proving that bacteria can survive at extremely low temperatures.

To conclude then, the term astrobiology, although etymologically imprecise, is extremely useful in that, under its umbrella, we can have astrobiology societies and journals and bring together interested parties at astrobiology conferences. When we eventually find life beyond the stratosphere, we will have a science up and running to further exploit what will be the most important discovery in the history of mankind. We can then toast the fact that events have overtaken etymology, and that at last the word astrobiology means something; at this point anyone disposed towards pedantry will be able to sleep soundly in their beds!

Milton Wainwright
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Further reading

Gilmour, I. & Sephton, M.A. (eds.) (2003). *An Introduction to Astrobiology*. Cambridge: Cambridge University Press.

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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** (j.westwell@sgm.ac.uk)

Careers in scientific publishing

If you are nearing the end of your PhD you are probably considering your career options. For those who want to continue in research, decision making can be fairly simple. But, if you know your future lies away from the bench, it can be hard to find a new direction.

As your supervisor will have told you (possibly many times!) publishing and disseminating research findings are essential to the success of all academic scientists. What s/he may not have mentioned is the range of career opportunities that publishing offers to scientists with a PhD.

Scientific publishing falls into three main categories: books, journals and periodicals. All of these can include an element of e-publishing. Scientists tend to find a role either as a commissioning editor for a book publisher or as an editor in the production of books and journals.

Commissioning editors are usually employed full-time by a publishing house and their responsibilities include researching future topics, identifying suitable authors and supporting them and the book throughout the process. Most commissioning editors attend conferences to keep up-to-date with recent research and make contacts. They may also sell books on conference exhibition stands.

Staff editor, copy-editor, desk editor and production editor all relate to the people involved in preparing books and journals for printing. They are responsible for getting the book or submitted articles from 'raw material' to a finished product. This includes checking spelling and grammar, making sure units of measurement are the same throughout the document, that tables and illustrations are integrated with the text and ensuring that references are consistent with the house style. Editors also look at the style and clarity of the writing and may need to make changes, such as re-wording sentences or dividing long sections into shorter paragraphs. In the past, much of this work was carried out on hard copy, but the vast majority of journals now accept online submissions and most copy-editors work on-screen. Dealing with authors at this stage can require tact and diplomacy, especially if you are proposing significant changes to their writing. Editors may also be involved in other preparations for printing, e.g. allocating page numbers and checking proofs. More specialized posts may require electronic typesetting skills, using software such as Quark Xpress, or the creation of web pages.

Most editing posts are full-time, but there are opportunities for experienced copy-editors and proofreaders to work freelance.

If you love your science but don't want to remain in active research, a career in scientific editing can be a good choice. It offers the chance to stay up-to-date with cutting edge science, keeps you in contact with the research community and offers you the opportunity to apply the transferable skills (e.g. project management, writing) and specialist knowledge developed during your PhD. A good eye for detail and a grasp of English grammar are essential. If you are still not sure about this career and have the financial resources, there are one-day taster courses available and also distance-learning courses in proofreading and copy-editing. If you know that you want to work in publishing it is a good idea to get some relevant experience, such as editing student or departmental publications.

Jobs in publishing are advertised weekly in Monday's *Guardian* (www.jobs.guardian.co.uk) and in *New Scientist* (www.newscientistjobs.com).

Further information

SGM journals (www.sgmjournals.org).

The Association of Learned Society and Professional Society Publishers (www.alpsp.org).

The British Society for Immunology website (http://immunology.org/careers/p5.htm) features a profile of a commissioning editor.

The Publishing Skills Group website (www.workinpublishing.org.uk) contains extensive information and downloads on book, journals and magazine publishing, with links to other organizations and jobs pages.

The Publishing Training Centre at Book House (www.train4publishing.co.uk) provides information on publishing careers including higher education courses. Book House also offers distance learning courses in proof reading and copy editing in addition to its open courses.

The Society for Editors and Proofreaders (www.sfep.org.uk) offers accreditation and registration to editors and proofreaders – useful for freelancers. It also offers training.

Trevor Horwood, an established freelance copy-editor and author of *Freelance Proofreading and Copy-editing: A Guide* (ISBN 0-95239-747-1), hosts www.copyediting.co.uk which includes a range of FAQs for the potential editor.

A job in ... journal publishing

Name Natalie Wilder
Age 28
Present occupation
Senior Staff Editor *Journal of General Virology*
Previous employment/ relevant work experience
Staff Editor *International Journal of Systematic and Evolutionary Microbiology / Journal of Medical Microbiology*
Education
University College London: PhD Viral Molecular Genetics (2003); Oxford University: MBiochem (4-year first degree in Biochemistry) (1999)

Q What attracted you to an editorial post rather than pursuing a research career?

I first started thinking about publishing as a career when I was in the final year of my biochemistry degree, but I wasn't sure, so I decided to do a PhD because it opened up a lot of different avenues. When I finished my PhD, I knew that I wanted to stay in science, but research wasn't for me – I got frustrated with the repetitive nature of lab work and the 'nanofocus' of working on one specific project. Journal publishing seemed like an interesting prospect, as you stay at the forefront of scientific research in several diverse areas. So, while I was writing up my thesis, I sent off my CV 'on spec' to several publishers and applied for any publishing jobs that were advertised.

Q How did you find the transition from lab-based to office-based work?

I was asked this at my interview at SGM for the Staff Editor post! I didn't find it a problem at all – I had been writing my thesis for several months and analysing data for a while before that, so I was already completely comfortable working at a computer, rather than in the lab. I also don't miss working with smelly and toxic reagents! A lot of skills that you learn during a PhD are very transferable into a publishing job – for example, time management, writing style and good presentation.

Q What does your current job involve?

Working on *JGV* is great, because every manuscript is different – I could be editing a paper about an HIV vaccine one day, potato viruses and famine the next, then Creutzfeldt–Jakob disease the day after that! Copy-editing is the 'nuts and bolts' of my job – this involves checking accepted manuscripts for spelling, grammar, scientific consistency and readability. The standard of authors' writing varies enormously and there's something very satisfying about editing a manuscript where the science is fascinating, but badly written, and turning it into something that people find interesting to read. The other tasks that I spend varying amounts of time doing include sorting out graphics for the figures, preparing issues of the journal (allocating page numbers, etc.), checking proofs, dealing with correspondence from authors, editors, freelances and printers, helping to select cover pictures for the journal, updating web pages and preparing monthly and annual statistics. I also attend national and international meetings and conferences to represent *JGV* and SGM.

Q How do you see your future?

At the moment, I'm very happy in my current position. Senior Staff Editor is my first managerial post, so I'm gaining confidence in managing *JGV* and its employees, as well as building up experience in the publishing industry as a whole. I definitely plan to stay in journal publishing in the long term – I really think that I've found my niche and a job that I love. I'm quite ambitious, so in the future, I'd like to increase my responsibilities and move up the career ladder in publication management.

Q What advice can you offer people looking for a similar career?

You need to be very precise in your written work, and to have a good 'eye' for spotting errors and inconsistencies. Any experience that you gain will help – for example, checking other people's work (particularly those who are not native English speakers), entering essay competitions or preparing your own papers for publication. Think carefully about whether it is editing or writing your own material that you enjoy, as these are two complementary, but separate, career choices. Some journals do offer scope for copy-editors to write articles, so check job descriptions carefully. You must be able to work to deadlines without sacrificing standards, and to deal politely and tactfully with members of the scientific community. My final advice, if you feel that this is the career for you, is to go for it – I find my job hugely rewarding and satisfying.

hotoffthepress

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

Family affairs

Lee, K.-B., Liu, C.-T., Anzai, Y., Kim, H., Aono, T. & Oyaizu, H. (2005). The hierarchical system of the '*Alphaproteobacteria*': description of *Hyphomonadaceae* fam. nov., *Xanthobacteraceae* fam. nov. and *Erythrobacteraceae* fam. nov. *Int J Syst Evol Microbiol* **55**, 1907–1919.

Classifying bacteria has always been tricky. They look very similar, so microbiologists have enthusiastically adopted methods based on the sequence of bacterial DNA. The genes that encode parts of the ribosome have changed very slowly during evolution because ribosomes have a vital role in the cell. Sequences of the 16S rRNA gene from hundreds of bacteria have now accumulated, so researchers in Japan have used them to review one class of bacteria, the '*Alphaproteobacteria*'. The bacteria within this class have diverse lifestyles, including photosynthetic and non-photosynthetic species as well as ones that require oxygen and others that can do without it.

The researchers used a computer program to compare the sequences of 16S rRNA genes from 249 species to produce a robust phylogenetic tree. The tree indicated that the natural relationships among the bacteria made them fall into five major clusters. When the researchers studied which species were in each cluster, it was obvious that more taxonomic work was needed before firm conclusions could be drawn about some of the groupings. For example, the *Rickettsiales* cluster included a few species that spend their entire lives within protozoa.

In some regions, however, the relationships were so clear that the researchers recommended the creation of three new bacterial families to record this fact. One was the new family *Hyphomonadaceae* for a series of marine genera such as *Hyphomonas*, *Maricaulis* and *Oceanicaulis*. The second was *Erythrobacteraceae* for genera like *Erythrobacter*, *Porphyrobacter* and *Erythromicrobium* that all contain distinctive lipids and pigments. A third new family, *Xanthobacteraceae*, for genera such as *Xanthobacter*, *Azorhizobium*, *Labrys* and *Starkeya* within the cluster of the '*Rhizobiales*', contained the most diverse collection of species.

Yeast as a human model in *E. coli* research

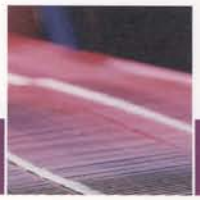
Rodriguez-Escudero, I., Hardwidge, P.R., Nombela, C., Cid, V.J., Finlay, B.B. & Molina, M. (2005). Enteropathogenic *Escherichia coli* type III effectors alter cytoskeletal function and signalling in *Saccharomyces cerevisiae*. *Microbiology* **151**, 2933–2945.

EPEC strains of the intestinal bacterium *Escherichia coli* cause life-threatening diarrhoea in children. These strains latch onto the cells of the gut and inject specific proteins into the human cells, altering their shape and severely damaging the intestinal surface, resulting in diarrhoea. The genes for these proteins lie together on the *E. coli* chromosome at the locus of enterocyte effacement (LEE). Researchers in Spain and Canada have been collaborating to exploit the similarities between ordinary brewer's yeast, *Saccharomyces cerevisiae*, and human cells to learn exactly what LEE proteins do.

As well as providing information about the function of each bacterial protein, the ease of genetic and mutational testing in *S. cerevisiae* means that researchers can check their ideas much more easily than using human cells. The researchers ensured that each LEE protein was synthesized in a series of yeast cells and looked for any effects on growth or shape. *S. cerevisiae* cells divide by forming a bud at one end in a process that requires well-organized activity of skeletal proteins and division of the cell nucleus. One bacterial protein, Map, interfered with many steps in these processes to alter cell shape, division and intracellular signalling. This suggests that it affects several regulatory steps. The researchers created mutations that showed the toxic effects were attributable to one end of the protein.

Other proteins accumulated in particular spots within the yeast cells. Patches of EspF associated with the few buds that formed in yeast cells expressing this *E. coli* protein. Another protein, EspD, accumulated within the intracellular membrane system. Proteins EspG and EspH are transported into intestinal cells by EPEC strains. EspH activated a yeast intracellular signalling pathway, although it had no effect on yeast cell growth. EspG was distributed throughout the yeast cell and resulted in a loss of co-ordination of budding with division of the nucleus, strongly inhibiting growth. Overall, the data from these studies will help to clarify the role of these proteins in human disease.

◀ Visualization of the microtubular apparatus by immunofluorescence with anti-tubulin antibodies (green) in yeast cells defective in budding as a consequence of the expression of the *Salmonella* virulence factor Map (red). The nuclei were stained with DAPI (blue). *Maria Molina, Madrid*



Gut flora and autism

Parracho, H.M.R.T., Bingham, M.O., Gibson, G.R. & McCartney, A.L. (2005). Differences between the gut microflora of children with autistic spectrum disorders and that of healthy children. *J Med Microbiol* **54**, 987–991.

As well as their social and communication problems, many children with autistic spectrum disorder (ASD) are reputed to suffer from digestive problems. Parents often say that relieving these problems improves the child's behaviour, but there is little clinical evidence to support this. The bacteria that live in the gut have a major role in its activity and health, but knowledge of what constitutes a 'normal' intestinal microflora is still in its infancy because of the difficulty in measuring the large number and diversity of bacteria in the gut.

Nevertheless, researchers at the University of Reading have made a start on understanding the gut microflora associated with autism. They recorded the numbers of selected bacterial groups in faeces from children with ASD and from two healthy control groups, namely the non-autistic siblings of children diagnosed with ASD and a group of unrelated, healthy children. The researchers used a questionnaire to assess the nature of any digestive problems experienced by each child, what they ate and their history of antibiotic intake.

It turned out that almost all the children with ASD had digestive disorders, along with a quarter of the non-autistic sibling group, but none of the unrelated healthy children recorded any symptoms. Many of the autistic children were on a gluten- and/or casein-free diet as this has been associated with reduced digestive problems. A further contrast was that none of the unrelated healthy children took probiotics, while these were taken by over half of the children with ASD and 40 % of healthy siblings. Several children had been prescribed antibiotics, but one-third of those with ASD had received more than six courses.

Considering all these factors, it was interesting that only two differences were found in the number of bacteria from the three groups. All the children harboured the groups of bacteria that were monitored, but there was a significant difference in the number of *Bacteroides* between the two healthy groups of children. The other, and perhaps more significant, difference was that the children with ASD contained the highest number of the *Clostridium histolyticum* subgroup that the researchers had ever seen. However, a further analysis of the figures indicated that there was no significant difference between the numbers in the sibling subgroups (ASD and healthy) as both these subject groups harboured intermediary levels of the *C. histolyticum* subgroup. This suggests that genetics, as well as diet and living conditions, may determine the composition of the gut microflora. In addition, since certain strains of *Clostridium* can sometimes produce powerful neurotoxins, it suggests a further line of research that is worth investigating.

A tale of two clades

Likos, A.M., Sammons, S.A., Olson, V.A. & 14 other authors (2005). A tale of two clades: monkeypox viruses. *J Gen Virol* **86**, 2661–2672.

The orthopox viruses cause diseases like smallpox and monkeypox. Naturally occurring smallpox was eradicated over 25 years ago following a campaign of vaccination and public-health surveillance. Monkeypox was first described as an infection of non-human primates, but between 1970 and 1986, smallpox surveillance programmes turned up 10 cases in humans in West African countries such as Sierra Leone and Liberia, and 394 cases in the Congo Basin. The fatality rate was ~10 %, but previous smallpox vaccination appeared to be protective. There was concern that this disease might replace smallpox, but it became apparent that monkeypox transmission could not be sustained indefinitely between humans without its zoonotic host(s).

In May 2003, monkeypox leapt to the attention of the American Centers for Disease Control and Prevention (CDC) because of reports of a new illness characterized by a rash and fever. The origin turned out to be a consignment of about 800 small mammals imported into Texas from Ghana. Some species carried the monkeypox virus, which then infected pet prairie dogs from which people had contracted the disease. The disease symptoms appeared to be less severe than in the earlier African cases and the outbreak was contained. At the same time, more cases were reported in young people in the Republic of Congo, with the difference that people became very seriously ill and infection was transmitted from person to person.

Inger Damon and collaborators at the CDC, together with colleagues working in public health in Africa and USA, as well as from the WHO, have been comparing details of the patients and viruses. They focused on cases from the Republic of Congo between 1981 and 1986 and the USA in 2003, where they had comparable information about patients. The researchers thought that the youth of patients, and not having been vaccinated against smallpox, all contributed to more severe disease and mortality. However, the statistical analysis showed that the illness was more transmissible, serious and lasted longer among African than USA case patients, regardless of their age or vaccination status.

After analysing the virus genomes, they realized that the viruses, rather than the patients' circumstances, were likely to be the reason for these differences. The researchers examined the sequence of all the genes in three strains of virus isolated from African patients and virus isolated from US human and prairie dog cases, and found some differences that could affect the efficiency of the virus in causing severe, human-to-human transmissible disease. These features have been conserved in the African strains for over 30 years. The Congo Basin type had a feature that may diminish the body's efforts to remove the virus from the bloodstream, while the West African type that infected the Americans contained a new component that could facilitate recognition and clearance of the virus by the immune system.

Microbiology Awareness Campaign

SGM members will read about some of the more high profile activities that take place to raise the awareness of our discipline, but much more goes on behind the scenes, as **Faye Stokes** reveals in her update.

The Society's Microbiology Awareness Campaign (MAC) rolls inexorably on. It was set up to raise awareness of the importance of microbiology in everyday life and the roles of microbiologists to parliamentarians, opinion formers, policy makers, the media and the public. Because of the Society's charitable status, it has to remain politically impartial, but we can still get our microbiological message across in a number of ways.

Parliamentary events

In March this year we held an event at the House of Lords, hosted by Lord Soulsby of Swaffham Prior, where peers and MPs were informed by leading microbiologists that new and re-emerging infectious diseases would spell trouble for the UK if not tackled soon (see the May 2005 issue of *Microbiology Today*, p. 96). The *Fighting Infection* event was very popular and attended by over 40 MPs and peers. It generated a lively debate between the attending parliamentarians and scientists.

These events take the form of short presentations by expert microbiologists, followed by questions and discussion. Microbiologists from widely varying subject areas are invited, as well as parliamentarians and civil servants. A buffet lunch is then served when informal dialogue can take place. There are also displays on relevant topics that are invited from institutions involved in microbiology.

Following the success of the events held at Westminster and in Edinburgh in 2004 for Members of the Scottish Parliament (MSPs), the external relations team is now planning to take MAC to the Welsh Assembly in 2006 and Ireland in 2007.

Parliamentary publications

We also have an on-going programme of presenting microbiological information in publications that are read by MPs, peers and their advisers. In May, the Society published an article in the Whit 2005 issue of *Science in Parliament*, the journal of the Parliamentary and Scientific Committee. This body provides a liaison between parliamentarians and scientific organizations, industry and academia. It highlights scientific and technological issues to members of both Houses of Parliament that are relevant to matters of public interest and to the development of policy.

We find that microbiological topics attracting public attention are also of the greatest interest to government. They desperately need to know the real facts behind the hype. Hence our two-page spread reinforced the theme of fighting infection and described the problems caused by MRSA and avian influenza, as well as potential solutions, pointing out that only well trained microbiologists can help to provide these. The journal is distributed to members of the House of Commons, House of Lords, the members of the Parliamentary and Scientific Committee (scientific, industrial and academic),

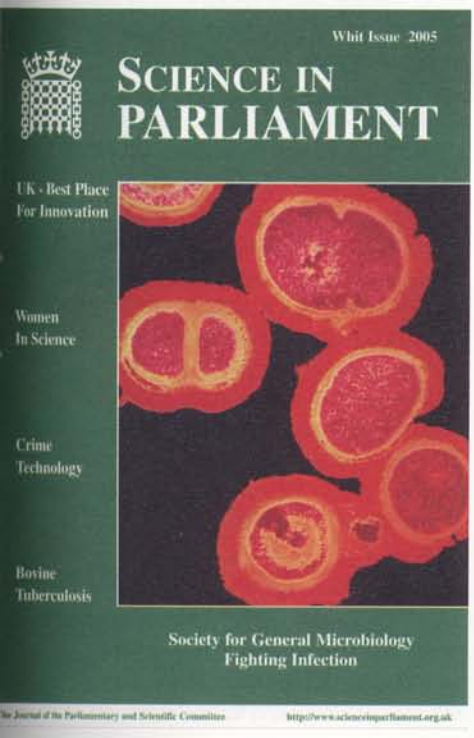
Committees in the European Parliament, science attachés in UK embassies abroad and foreign embassies in London (www.sciencein parliament.org.uk/sip.asp).

SGM also places full-page adverts in magazines such as the *Parliamentary Monitor* and *The House*, usually in special issues devoted to science. The most recent one dealt with MRSA, but earlier advertisements covered zoonoses such as foot-and-mouth disease and BSE, and general public health (www.epolitix.com/EN/ Publications/).

As well as including articles and adverts in journals read by parliamentarians, SGM also regularly distributes *Microbiology Today* to over 500 MPs, peers, MSPs, AMs and MLAs.

Scottish Parliament Science Information Service (SPSIS)

As an affiliated organization of the SPSIS, SGM is also helping to get accurate information about microbiology to MSPs. This service was set up to ensure that they have access to reliable, rapid and impartial facts on science, engineering and technology to help enlighten parliamentary debates on scientific issues, raise the profile of science in the parliament and ensure MSPs are informed by appropriate, knowledgeable experts. A number of SGM members are SPSIS experts for the Scottish Parliament.



Press releases

The Society's efforts to publicize microbiology research and innovations to the public via the media have also had great success this year. Press releases are prepared for scientific research presented at SGM spring and autumn conferences, as well for every issue of *Microbiology Today* and for interesting articles in the Society's four journals. Not only have the releases from the meetings been generating worldwide interest, with references to the publicized research cited in *Nature*, by the BBC, in many local newspapers and trade magazines, not to mention an exhibit at the Science Museum in London, but the press release for Dr Mark Enright's *Comment* article on MRSA in the February 2005 issue of *Microbiology Today* led to a sensible discussion of the problem on BBC Radio 4's *Today* programme (www.sgm.ac.uk/ news/media_releases.cfm; www.bbc. co.uk/radio4/today/listenagain/ zthursday_20050210.shtml).

Experts

Other efforts to ensure sensible reporting of microbiological issues in the press involve the SGM Experts Database. We are always looking to expand this service, as it has been useful when putting journalists in touch with leading experts in many areas of microbiology. Recently, Dr Keith Jones commented on hotel hygiene for *You and Yours* on BBC Radio 4, Dr Susan Assinder explained the dangers of 'grow your own bacteria kits for kids' to the *South Wales Argus* and a number of experts on plague, biomining and tetanus contributed to the latest series of *The Good, the Bad and the Ugly* on BBC Radio 4.

Consultations

The same database is also used by the External Relations Office to identify members willing to comment on policy documents. Recent SGM responses have included the Government Chief Scientific Adviser's guidelines on scientific analysis in policy making, DEFRA's proposed EC directive on controls for avian influenza and FSA's draft biosecurity guidance booklet *Biosecurity on the Poultry Unit* (www. sgm.ac.uk/news/consultations.cfm).

You can help

All of these activities have helped in one way or another to improve the basic understanding of microbiology by non-experts. *E. coli*, *Salmonella* and MRSA are commonly spoken about (and not quite so often referred to as viruses!), and journalists are sometimes even using the terms bacterium and bacteria correctly. Every contribution is valuable and if you wish to influence science policies in the UK by providing comments for consultations or want to get the right microbiological message across to the media and so to the public, please join our expanding database of experts.

Is there a burning issue that you consider should be raised?

Suggestions for topics for parliamentary briefing papers and advertisement spreads are always welcome. Or maybe you would like to write a *Comment* feature for this magazine. Don't forget that it goes to hundreds of opinion-formers and decision-makers, as well as your fellow microbiologists.

Any comments and requests for an Experts Database form should be sent to pa@sgm.ac.uk

Faye Stokes
SGM Public Affairs Administrator

Jeff Green and **Mark Wentworth** receive a PUS grant from the SGM to help promote microbiology to a local school, but the project reached a wider audience than they ever imagined.

A bug's life

A microbiology masterclass with Chaucer School in partnership with the University of Sheffield

Background

The aim of the project was to develop a series of experiments, that whilst fitting within the science National Curriculum for Key Stage 4, would teach local school students about the importance of microbiology in modern society. It also allowed them to get hands-on experience of experimental techniques and equipment that they don't have access to in school, with the hope that it might stimulate them to continue their scientific studies beyond GCSE.

Our project

The project was funded by grants from the SGM and the Royal Society's Partnership Scheme. It was divided into three sections: part one taught students the social and economic importance of micro-organisms. The second part was the microbiology master class given at the University of Sheffield. Finally, the students used the knowledge and techniques they had learnt to develop and carry out a research project in school, the results of which were written up and presented as posters.

The microbiology masterclass

The masterclass took place over 3 days in our teaching laboratories. Sixty students from both year 10 and 11 participated in the event. The masterclass itself comprised nine experiments, making it an intensive learning experience which taught students the basic techniques used by microbiologists.

Students were taught aseptic technique, how to work safely with *E. coli* and how to culture it on plates. They then moved on to use serial dilutions to calculate the number of bacteria in a solution. Students were introduced to the importance of hygiene and found out that bacteria live on our skin and in our throats. They discovered how different conditions affect the growth and viability of *E. coli*. The students also investigated how antibiotics control and kill bacteria, using plates containing different antibiotics to identify resistant strains. They were also taught about multiple antibiotic resistance and determined which antibiotics a multiply resistant strain of *E. coli* was sensitive to. Finally, students discovered how rapidly bacteria can divide and constructed growth curves by measuring the change in turbidity of *E. coli*; they then used an electron microscope to find out what the individual bacteria looked like.

The research projects

Back at school students set to work planning their research project with help from university staff. They aimed to determine the factors that affected how fast *E. coli* could divide, such as pH, salt concentration and temperature.

Students prepared posters to present their findings to staff and invited guests at a special open evening.

Reflections on *A Bug's Life*

This is the second year we have run *A Bug's Life* and once again it has had a huge positive impact on the aspirations of the students and their confidence and enjoyment of science. Many of them said that they would be thinking about going to university in the future, and that they wished that all their science lessons could be more hands-on, like the microbiology practicals.

Taking *A Bug's Life* to the Royal Society's Summer Science Exhibition

Each year the Royal Society showcases leading research from around the country at its summer science exhibition in London in July. This year there were 25 stands, 24 representing cutting edge science from some of the best labs in the UK, while the final exhibit was one of the exceptional projects funded by the Partnership Grants Scheme. Our project was selected to put on a display to represent this category.

The exhibit

The team was made up of six year 10 students from Chaucer School (Gareth, Ismet, Katie, Laura, Lauren and Zoe) along with their teacher Dr Aitken, and two members of university staff (Dr Wentworth and Professor Green).

During the day time the exhibition was opened to the public and school parties, and the team were kept busy explaining about microbiology and their project. On Tuesday evening the event was open to teachers and other people in education, all of whom were very impressed with the work we had done and the achievements of the students. Many people were surprised that the students manning the stand were only in the first year of their GCSEs. On the Wednesday morning the exhibition was visited by the Duke of Kent who spent some time talking to the students about their display and what they would like to do in the future.

The highlight of the event though was the black tie soirées which took place on the Wednesday and Thursday evenings. These events were expressly for Fellows of the Society and their VIP guests; all the exhibitors and the guests were dressed in their finest and the students got to wear their evening gowns and suits. Guests included eminent scientists, MPs, members of the House of Lords and FRSs.

Over the 4 days there were around 4,000 visitors, and we found ourselves constantly busy with people eager to find out about our project and what could be achieved by students with a little help from higher education institutions like Sheffield University.

This was a once in a life-time experience for all those involved. However none of this would have been possible without funding from the SGM or the Royal Society, whom we would like to thank for their support.

Jeff Green and Mark Wentworth
Molecular Biology & Biotechnology, Sheffield University, Western Bank, Sheffield S10 2TN, UK (e mark_wentworth@blueyonder.co.uk)

Further information

For details of SGM PUS grants, see www.sgm.ac.uk/grants

For Royal Society Partnership Awards see www.royalsoc.ac.uk/funding

▲ 1. The team dressed for a soirée at the Royal Society's Summer Science Exhibition. *M. Wentworth*
2. The Duke of Kent visits the *Bug's Life* stand. *M. Wentworth*
3 and 4. School students learning microbiological techniques at the university labs. *M. Wentworth*

reviews

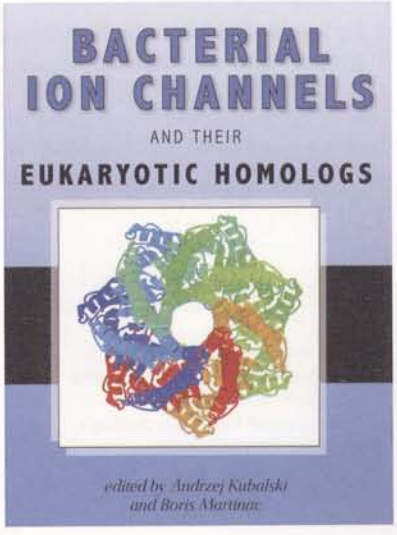
If you would like your name to be added to our database of book reviewers, please complete the book reviewer interests form on the SGM website. A classified compendium of reviews from 1996 to the present is also available on the website.

Bacterial ion channels and their eukaryotic homologs

Edited by A. Kubalski & B. Martinac
Published by American Society for Microbiology (2005)
US$115.95 pp. 358
ISBN 1-55581-328-3

The topic for this book is an exciting one, and one that a decade ago would have made a rather slim volume. Channels were things that those other people in your department worked on, who would go on about 'voltage gating' and 'patch clamping' until your eyes glazed over. However, bacteria have channels too and ironically these proteins have provided the first structural data that has advanced knowledge of eukaryotic channels way beyond what was achievable using traditional physiological methods alone.

The first homologue of a eukaryotic channel was identified in *E. coli* in 1994, when some fortuitous sequencing revealed a coding sequence homologous to eukaryotic potassium channels. However, this potentially dogma-breaking discovery languished in the literature for a long while – mainly because a deletion of the gene, *kch*, had no discernable phenotype in *E. coli*. While studies on this protein and other channels, notably the mechanosensitive channels, continued steadily in the bacterial community, the world of channels was turned upon its head when Declan Doyle and Roderick Mackinnon solved the first structure of a potassium channel in 1998. Suffice to say that this was from a bacterial source; the KcsA protein from the *Streptomyces lividans*, which more than anything else made the scientific community realize that bacteria have channels.



This book aims to review our knowledge of bacterial channels 7 years after the momentous paper from Mackinnon's group and in the wake of 10 years of bacterial genome sequencing. It is edited by Andrzej Kubalski and Boris Martinac, who both hail from the mechanosensitive channel field, and contains chapters covering all different types of channels that are known in bacteria. The early chapters focus heavily on the structure and function of the full spectrum of potassium channels as these have received the most impetus from the wave of new structures from bacterial sources that followed from KcsA. These are well written from a bacteriological standpoint, especially the chapters on voltage-gated and inward rectifier channels. They are followed by strong chapters on molecular modelling and simulations of channels, and a general chapter bringing together information on the molecular mechanisms of bacterial channels. The book then branches out with chapters on glutamate-activated channels and sodium channels.

The title of the book, while focusing on bacterial channels, has the subtitle '*and their eukaryotic homologs*', and the weighting is sometimes skewed heavily towards the subtitle, no more so than in the chapter on chloride channels. The only two structures of chloride channels are from *E. coli* and *Salmonella enterica* proteins and, in addition, the molecular properties and physiological role of the *E. coli* protein has been elucidated. This appears to act as a sodium/chloride antiporter in *E. coli* and functions in acid resistance. Hence, these proteins could be an exciting evolutionary intermediate form between a channel and a transporter. However, the bacterial chloride channels only get a passing mention in this chapter, which essentially covers eukaryotic channels. It is very disappointing that this exciting new work is not discussed: in fact the bacterial proteins are actually discussed more in other chapters that are not even directly about chloride channels!

Despite this one poor chapter, the rest of the book is excellent. There are two chapters on mechanosensitive channels, which have been studied almost exclusively in bacteria, and these chapters collate and describe the properties of these pressure-sensitive proteins in some detail, bringing together the full suite of knowledge from genetics, sequence, molecular biology, electrophysiology, structure and simulation. The final chapter then ties all this information on channels together in considering their roles in bacterial physiology. For channels like the mechanosensitive channels this is well known, but for others, like the voltage-gated sodium channels, their cellular roles are still rather unclear. What is clear is that the bacterial world is offering much new information about the structure and evolution of channels in biology.

Overall, this book is an inclusive and timely introduction to the bacterial world of channels and is a real first of its kind. Although the book lacks material from some of the top names in this area (Mackinnon, Gouaux and Miller spring to mind), it still has many excellent chapters and will serve as a very useful reference book to a wide range of microbiologists with interests in transport, physiology and protein structure and function.

***Gavin Thomas**, University of York*

Bacterial Spore Formers: Probiotics and Emerging Applications

Edited by E. Ricca, A.O. Henriques & S.M. Cutting
Published by Horizon Bioscience (2004)
£95.00/US$190.00 pp. 244
ISBN 1-90493-302-5

This book gives the impression of preaching a message about the significance of the ecological and applied aspects of this bacterial group and the way in which our increasing molecular information is being deployed to extend existing practical uses and develop new ones.

Section I, comprising the first seven chapters, provides the basic background: the general features of the *Bacillus* spore; taxonomy of the aerobic spore-formers; ecology of *Bacillus* spp. in soil; *B. anthracis* and related pathogenic species; *B. subtilis* sporulation, mainly from a molecular viewpoint; the spore coat; and the spore surface.

Section II deals with spores as probiotics: it begins with safety aspects, moves to the fate of spores in the gut following ingestion and continues with transfer of antibiotic resistance (mainly via conjugative transposons) in the GI tract. Next come four chapters on various aspects of spore-formers and their spores as probiotics for both humans and animals, a chapter on potential for *Bacillus* spp. in sports turf management, and one on ecology of spore formers in the gut.

The final section is on spores as vaccine vehicles and in therapeutics. Two chapters describe how antigen-encoding sequences can be spliced into spore-coat protein genes, thus permitting the use of spores as oral vaccines; the third and final chapter describes the use of clostridia in a novel form of cancer therapy, clostridial-directed enzyme prodrug therapy (CDEPT), whereby genes for prodrug-converting enzymes are spliced into a clostridial genome; the spores are injected, following which they can only germinate in the hypoxic environment of the tumour; and finally a prodrug is applied which is only activated by germinated clostridia within the tumour.

The book brings together ecological and molecular approaches in a novel and refreshing way, and is also unusually diverse in the locations of the contributors (which may help to explain the previous point!). It also has a commendable emphasis on applications, especially of our molecular genetic knowledge, and looks for these in both the developed and developing worlds. The chapters on controversial subjects such as probiotics, oral vaccines and CDEPT set out to make a case, but are reasonably balanced and judicious in their conclusions. The book has been well edited and is attractively produced. It makes interesting and useful reading for professional microbiologists at all levels, and could be used to get undergraduate and postgraduate classes thinking more widely about the uses to which science can be put.

***Simon Baumberg**, University of Leeds*

SAGE: Current Technologies and Applications

Edited by S.M. Wang
Published by Horizon Bioscience (2005)
£95.00/US$190.00 pp. 376
ISBN 1-90493-307-6

This book is a thorough treatment of SAGE (Serial Analysis of Gene Expression). SAGE can provide quantitative measures of gene expression, based on the sequence of mRNA-derived fragments, or SAGE tags; this can be more than 10 times as sensitive as EST for transcript identification. Although there are difficulties with this method (discussed in helpful detail in the first chapter), the potential power is worth the careful work necessary to achieve the results. The 18 chapters in this book cover a range of applications, for example, comparing transcriptomic differences in brain territories, developmental studies in *Drosophila*, plant gene expression studies, and statistical analysis of SAGE data. The last chapter (*Reverse transcriptome: identification of novel transcripts through novel SAGE tags*) discusses using SAGE to identify the full set of transcripts, including those of low abundance (which contains the largest fraction of different genes, since only a few genes are highly expressed).

***David Ussery**, Technical University of Denmark*

Reviews on the web

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

Food Microbiology: An Introduction

Bacterial Protein Toxins: Role in the Interference with Cell Growth Regulation

The Proteomics Protocols Handbook

An Atlas of the Clinical Microbiology of Infectious Diseases

Handbook of Media for Environmental Microbiology

Handbook of Corynebacterium glutamicum

Natural Products: Drug Discovery & Therapeutic Medicine

Principles and Techniques of Biochemistry and Molecular Biology

Revenge of the Microbes: How Bacterial Resistance is Undermining the Antibiotic Miracle

Bioremediation: Applied Microbial Solutions for Real-World Environmental Cleanup

Biomedicine and the Human Condition: Challenges, Risks and Rewards

Structural Biology of Bacterial Pathogenesis

Zoonoses and Communicable Diseases Common to Man and Animals, 3rd edn. Vol. I: Bacterioses and Mycoses. Vol. II: Chlamydioses, Rickettsioses and Viroses. Vol. III: Parasitoses

Bioinformatics Basics Applications in Biological Science and Medicine, 2nd Edn

Petroleum Microbiology

Methods in Yeast Genetics 2005 Edn

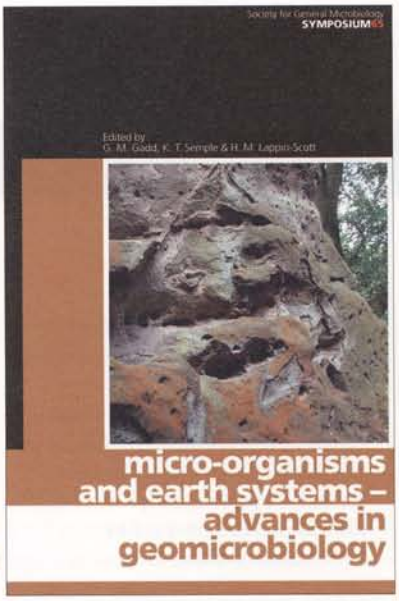
Antifungal Agents: Methods and Protocols

Structural and Functional Relationships in Prokaryotes

Fungal Biology, 4th Edn

Rust Diseases of Willow and Poplar

sgm symposium65



Micro-organisms and earth systems – advances in geomicrobiology

Edited by G.M. Gadd, K.T. Semple & H.M. Lappin-Scott
Published by Cambridge University Press (2005)
£30.00/US$50.00 (members)
£75.00/US$125.00 (non-members)
pp. 376 ISBN 0-521-86222-1

Since Vernadsky published *Biosfera* in 1926, it has been accepted that the face of the Earth results from the intense interactions between the biosphere and the lithosphere, between living organisms and mineral matter. Although they have been in large part identified, the processes involved in these interactions are still poorly understood and conceal numerous challenges for biogeoscientists. This is particularly true when micro-organisms are concerned. We have to keep in mind that it is the micro-organisms that constitute the main agents in the wide variety of the Earth's biogeochemical cycles, due to their numerous metabolic pathways, their ability to conquer all types of environments, and by their sheer numbers. To emphasize this point, Stephen J. Gould refers to the 'bacterial mode' when speaking about the diversity of life. *Micro-organisms and earth systems* presents the state-of-the-art of our knowledge on these complex and challenging interactions and proposes a thorough investigation of the role of micro-organisms in shaping the terrestrial epidermis.

First, the authors have been chosen from amongst the world's top specialists for each topic. The book is extremely well documented by these authors, who provide first-hand scientific results. The high level of the scientific content is not at the cost of the clarity of the book's purpose, which should be to reach the widest possible audience. The quality of the illustrations makes it very didactic and, even if one is not a specialist in a particular subject, the content is so well explained that it brings the reader up to the required level.

Micro-organisms and earth systems deals with a wide range of micro-organisms – bacteria, cyanobacteria, fungi – involved in an equally wide range of biogeochemical cycles and environments. For example, several papers discuss the cycles involving carbon, silica, sulfur, iron, nitrogen and various heavy metals in both terrestrial and marine environments. However, many of the papers concern not only basic research, but also applied research. For example, the preservation of stone buildings or toxic metal remediation are some of the subjects dealt with in the book. The potential involvement of micro-organisms in global change is also tackled through the study of their role in various biogeochemical cycles of greenhouse gases, such as CO_2 and CH_4. In addition, the challenges posed by extreme environments are presented in studies of Antarctic dry valleys, the deep ocean, and caves. Also treated are environments with toxic components and extreme pH values.

For curious readers, this book goes beyond the state-of-the-art and explores frontiers of the living world and the way we perceive it. It includes a contribution on the deep intraterrestrial biosphere, and discusses the consequences of what we learn from the Earth's micro-organisms for exobiological purposes.

Although descriptions of micro-organisms' metabolic pathways and their roles in biogeochemical cycles constitute the body of the book, methodology is not ignored. The reader can find the most recent techniques involving high performance equipment, from molecular ecology to nanomicroscopy. Many of the methods used during the authors' investigations are described in detail or useful references are provided, making the book helpful for lab work.

This book constitutes a milestone in the emerging field of biogeosciences and will interest not only microbial ecologists and geomicrobiologists, but also all scientists working with a multidisciplinary perspective and approach to understand the Earth's biogeosystem. This book is imperative reading for Masters and PhD students, as well as advanced researchers involved in biogeosciences. Personally, I will use this book intensively not only as a reference both for information and as inspiration, but also as a textbook for my Masters students.

Eric Verrecchia
Institut de Géologie, University of Neuchatel, Switzerland

An order form for Symposium Volume 65 (and earlier volumes) is available from the SGM Membership Office (members@sgm.ac.uk)

comment

Clostridium difficile

MRSA is often in the news, but now a different hospital-acquired infection is hitting the headlines. As increasingly virulent strains of *Clostridium difficile* are discovered, **Ian Poxton** wonders what can be done to beat this pathogen.

Bacillus difficilis was first reported in 1935 as a component of the faecal flora of new babies. Renamed *Clostridium difficile*, this Gram-positive, strictly anaerobic spore-former received little coverage in the literature. Until 1976 it was regarded as harmless, but by 1977 it was recognized to be a dangerous pathogen, the major cause of pseudo-membranous colitis (PMC). *C. difficile* was subsequently identified as the main cause of hospital-acquired antibiotic-associated diarrhoea, a lesser form of the rarer PMC. Over the next decade, several outbreaks of *C. difficile*-associated disease (CDAD) occurred throughout the developed world.

The pathogenic mechanisms are now reasonably well understood. The major virulence factors, two large exotoxins, A and B, act on rho and other small GTP-binding proteins, resulting in the breakdown of the cytoskeleton of gut epithelial cells. Immunopathological mechanisms are also triggered and the resulting cellular damage and infiltration of neutrophils give rise to the pathology. Symptoms range from mild to serious diarrhoea and life-threatening PMC, megacolon and possible perforation. It was thought that the two major toxins worked in concert, but recently cases caused by Toxin A-negative strains have been found. Genetic approaches for studying pathogenesis have proved extremely difficult – the organism living up to its specific name!

During the 1990s, CDAD increased almost exponentially. It is now endemic in many hospitals, where it survives as resistant spores after dissemination by often explosive diarrhoea. It is especially common in wards for the elderly and in other areas where antibiotics are widely used. About 30% or so of patients in geriatric wards carry it, and up to half of these can be symptomatic. It imposes a huge financial burden on the health services because of the increased length of stay of patients and the more intensive patient management required.

Most hospital staff are well aware of CDAD and recently it has overtaken MRSA in incidence and prevalence in some hospitals. Public awareness of the disease is only recent. During 2004 in parts of North America there was a noticeable increase in incidence and severity, with more deaths attributable to the disease. The causative strain was more virulent than those previously seen, now identified as a hypervirulent clone – ribotype 027. It has a deletion in the gene which encodes the negative regulator of the toxins; therefore, toxins are produced at higher levels than normal. It is also resistant to the commonly used quinolone antibiotics. In June 2005 this strain hit the UK headlines by causing problems in several hospitals, including Stoke Mandeville. There are also several current outbreaks in The Netherlands.

Most patients become colonized with the bacterium because the normally protective colonic microbiota has been disrupted by antibiotics. Subsequent susceptibility to disease is probably due to an inability of the host to mount a protective immune response to the organism and its toxin(s).

Although treatable with antibiotics (usually metronidazole or vancomycin), relapses or re-infections occur in up to 30% of patients. The unpleasantness of the disease has meant that improved therapies are desperately required. Re-establishing the gut microbiota is a sensible approach to prevention or treatment, and the use of certain probiotics has been advocated. The euphemistically known 'faecal transplants' are more unusual. They involve repopulating the gut with healthy faeces usually donated by a close relative. Other treatments include the use of agents that bind the toxins in the gut and prevent their uptake, and passive immunotherapy to supplement antibody deficiencies.

What is certain about *C. difficile* is that it is now endemic in most of our hospitals and will remain so while the sick are being treated with antibiotics. Despite Herculean attempts to get rid of the spores by cleaning, it seems efforts are failing. The best short-term hope is that the disease is kept in check by a combination of 'infection control' procedures, judicious use of antibiotics and the development of more successful treatments. But now a 'super strain' has arrived...

▲ Coloured SEM of *C. difficile*. *D. Phillips/ Science Photo Library*

Professor Ian R. Poxton
Medical Microbiology, Centre for Infectious Diseases, The Chancellor's Building, Edinburgh EH16 4SB, UK
(e i.r.poxton@ed.ac.uk)

Further reading

Special issue on *C. difficile* (2005). *J Med Microbiol* **54**, part 2 (Feb).

Riley, T.V. (2004). Nosocomial diarrhoea due to *C. difficile*. *Curr Opin Infect Dis* **17**, 323.

Voth, D.E. & Ballard, J.D. (2005). *C. difficile* toxins: mechanism of action and role in disease. *Clin Microbiol Rev* **18**, 247.

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