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bugs get everywhere

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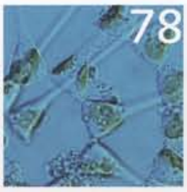

Cover image Looking through the clear, frozen surface of Lake Vanda, Antarctica. The liquid water 65 m below teems with bacterial life. *George Steinmetz / Science Photo Library*

Contributions are always welcome and should be addressed to the Editor c/o SGM HQ, Marlborough House, Basingstoke Road, Spencers Wood, Reading RG7 1AG Tel. 0118 988 1809 Fax 0118 988 5656 email mtoday@sgm.ac.uk web www.sgm.ac.uk

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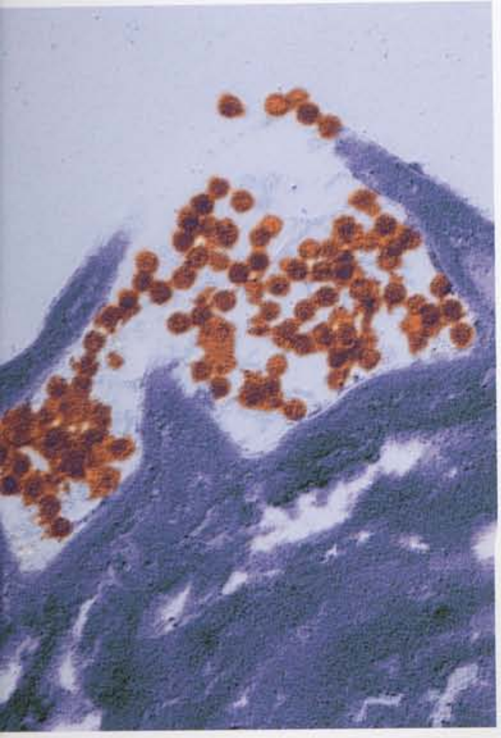
news

Microbiology Today Editorial Board

With the resignation of Professor Iain Hagan from Council due to pressures of work, the editorial board has lost one of its valued members. We are all very grateful to Iain for his input over the past few years and especially for being the lead in the well-received issue on 'microbes and cancer'.

In his place we welcome **Paul Hoskisson**, a lecturer at the University of Strathclyde whose speciality is actinomycetes and who has already contributed an article to the magazine on his favourite micro-organisms.



▲ Coloured electron micrograph of human papillomaviruses (ultrathin section) being shed from a human wart. *Klaus Boller, Paul-Ehrlich-Institute, Langen, Germany*

A new initiative in Virology!

www.gla.ac.uk/faculties/vet/research/postgraduatestudy/

The University of Glasgow is offering a new cross-faculty Masters programme for individuals who wish to pursue a career in virological sciences. The one-year Masters of Research in Virology is largely hands-on, with two research projects each lasting up to 20 weeks, in addition to advanced taught modules.

This new initiative augments the highly successful Honours degree in Virology. These courses are the only stand-alone degrees in virology on offer in the UK. Dr Stephen Dunham (s.dunham@vet.gla.ac.uk) is the course co-ordinator of the MRes degree.

Microscopy and microbes

SGM/RMS joint meeting

24 June 2008, Excel London

Don't forget to register for this exciting one-day event which will focus on the cellular aspects of infection and the important role microscopy has in furthering our knowledge of this field. Both cell invasion processes and the tussle that takes place once a pathogen has started to replicate within the host cell and fight back will be considered. Eminent international speakers include: Mark Jepson (Bristol), Urs Greber (Zurich), Michelle Swanson (Michigan) and Timo Hyypiä (Finland).

The event takes place at Microscience 2008, the RMS's flagship microscopy conference and exhibition. The registration fee for the session is £45 for SGM and RMS members, which will also entitle delegates to visit the exhibition. For further details contact Paul Monaghan (paul.monaghan@bbsrc.ac.uk) and to register see **www.microscience2008.org.uk**

People

Michael Bushell, Professor of Microbiology, University of Surrey, has been appointed to the Advisory Committee on Novel Foods and Processes of the Food Standards Agency.

Deaths

The Society notes with regret the death of **Dr Ken Sargeant** (member since 1964).

An obituary of **Dr Norbert Pfennig**, an Honorary Member who joined SGM in 1958 and who died in February, will be published in a future issue of *Microbiology Today*.

Well-known American scientist, **Professor Joshua Lederberg**, has died aged 82. He won the 1958 Nobel prize in physiology or medicine for his work on the genetics of bacteria that laid the foundations for modern molecular genetics. His work was wide-ranging, he advised several US Presidents and he received many honours, including foreign membership of the Royal Society. Interestingly, in view of the theme of this issue of the magazine, Lederberg was a member of the US National Academy of Sciences Space Science Board 1958–1974 and recommended that spaceships should be sterilized before takeoff and astronauts quarantined on return from their missions.

Professor Dennis L. Knudson (joined SGM in 1972) died on 2 March, 2008.


SGM Council

February Meeting Highlights

Sir Howard Dalton, FRS

Council held a minute's silence to honour the memory of former **President Howard Dalton**, who died on 12 January. An obituary appears on p. 100.

Bovine TB

Professors Barer and **Penn** reported on the progress of the independent inquiry into bovine TB research that the Society is carrying out for Defra. The working group has met twice since November Council and are approaching the review under several subject headings. The various chapters will be collated into a report due to be delivered to the Chief Veterinary Officer and Chief Scientific Adviser at the end of April.

ESCV

Council members were pleased to learn that the transfer of administrative and financial support services for the European Society for Clinical Virology to SGM headquarters was progressing well. The renewal invoices for 2008 membership subscriptions will be sent out soon, once the euro bank account is up and running.

Research Council

The President, **Robin Weiss**, and the Executive Secretary, **Ron Fraser**, spent an hour recently with the new Chief Executive of the MRC, Sir Leszek Borysiewicz. Issues relating to learned society publishing and open access were discussed and Council's concerns about the perceived problems of research in academic medical bacteriology were raised. It was also noted that the BBSRC Director of Science and Technology, Professor Nigel Brown, is attending the SGM's forthcoming meeting in Edinburgh in order to talk to delegates, particularly those working in virology.

SGM Journals

Funder-mandated open access policies continue to be monitored and it appears that the earlier burst of author payments, mainly to *JGV*, has declined recently. Most of this money related to research funded by the Wellcome Trust. Overall, it appears that authors are being placed in confusing positions by funders.

SGM Finances

Council members heard that the audit of the SGM 2007 accounts had successfully taken place. The financial situation of the Society at the end of the year was healthy. The policy decision to diversify the investment portfolio in the year had proved to be a wise one.

FIS Conference 2007

SGM both hosted and provided the organizing secretariat for the 2007 Conference of the Federation of Infection Societies (FIS). This was a very successful meeting, being well attended and financially viable.

Meetings

The new meetings organization system is now in operation and the Scientific Meetings Committee had met the week before Council to plan the scientific sessions for the event at Harrogate in Spring 2009. The theme of the meeting will mark 80 years since Fleming's discovery of penicillin, considering the progress in microbiology since then. The Executive Secretary tabled the draft revision of the bye-laws that must be approved by Council to accommodate the new arrangements. The two remaining scientific meetings under the old Group system are in Edinburgh and Dublin this year and the Scientific Meetings Officer reported that both are progressing well.

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

He did a DPhil in virology under the supervision of Tom Tinsley in Oxford between 1970 and 1975 and was a professor at Colorado State University, specialising in Infectious Diseases, Genomics and Bioinformatics at the time of his death.

SGM staff

Congratulations to Senior Staff Editor, **Natalie Wilder**, who gave birth to baby Alexander John McGuire on 17 March. He weighed in at a bouncing 8 lbs 11 oz. Mum and baby are doing well. Natalie's role on *JGV* is being covered by **Ashreena Osman**.

Welcome to new Staff Editor, **Rachel Walker**, who is just completing her PhD from Liverpool University on the characterization of the role and regulation of secreted proteins of *Enterococcus faecalis*. Rachel's first degree was also at Liverpool in Microbial Biotechnology.

Annual General Meeting 2008

The Annual General Meeting of the Society will be held on Tuesday, 9 September 2008 at the Society Meeting at Trinity College Dublin.

Agenda papers, including reports from Officers and Group Conveners and the Accounts of the Society for 2007 will be circulated with the August issue of *Microbiology Today*.

SGM Prize Lectures and Awards

A range of prestigious awards is made by the Society in recognition of distinguished contributions to microbiology. Nominations are now sought for the 2009 prize lectures. The award panel will consider the submissions in the autumn and take their recommendations to November Council for approval. The outcome will be announced in the February 2009 issue of *Microbiology Today*.

Prize lecture rules and a nomination form are on the SGM website: **www.sgm.ac.uk/about/prize_lectures.cfm**

Fleming Award

This is awarded annually for outstanding research in any branch of microbiology by a microbiologist in the early stages of his/her career.

The winner receives £1,000 and gives a lecture based on his/her work to a Society meeting. The text is usually published in a Society journal.

Colworth Prize Lecture

This is awarded biennially for an outstanding contribution in an area of applied microbiology. It is sponsored by the Colworth Laboratory of Unilever Research.

The winner receives £1,000 and gives a lecture based on his/her work to a Society meeting. The text is usually published in a Society journal.

Fred Griffith Review Lecture

This is awarded biennially in recognition of long and distinguished service to microbiology.

The winner receives £1,000 and gives a personal overview of an area of microbiology to a Society meeting. The text is usually published in a Society journal.

Peter Wildy Prize for Microbiology Education

This is awarded annually for an outstanding contribution to any area of microbiology education.

The winner receives £1,000 and gives a lecture on a topic of his/her choice at a Society meeting.

Completed nomination forms, together with the supporting documents, should be sent to Dr Ulrich Desselberger, c/o SGM HQ.

The closing date for nominations is **30 September 2008.**

▲ Nicola Kennerley, University of East Anglia, receiving a 2007 Undergraduate Microbiology Prize earlier this year.

Undergraduate Microbiology Prizes

The prizes aim to encourage excellence in the study of microbiology by undergraduate students and to promote scholarship in, and awareness of, microbiology in universities. The prizes are awarded annually to the undergraduate student in each qualifying institution who performs best in microbiology in their penultimate year of study for a Bachelor's degree. Each winning student will be awarded £150, a certificate and a free year's UG membership of SGM.

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

Universities are now invited to nominate a student for a 2008 Prize. Submissions can only be accepted on the form which has been sent to all institutions. The full rules and further copies of the form may be downloaded from the SGM website or obtained from the Grants Office at SGM HQ. The closing date for nominations is **29 August 2008**.

Grants

Scientific Meetings Travel Grants

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

International schemes

International Development Fund

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

President's Fund for Research Visits

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

The Watanabe Book Fund

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

The closing date for applications to these schemes is **26 September 2008**.

Student schemes

Postgraduate Student Meeting Grants

Grants contribute towards travel and accommodation expenses for attendance at ONE SGM meeting each year. Applications for a grant to attend the Dublin meeting (8–11 September) must be submitted by **5 September 2008**.

GRADschool Grants

Awards to contribute the full course fees of a UK GRAD national (personal or career development) residential course. Applicants must be resident and registered for a PhD in the UK.

Elective grants

These enable UK/Ireland medical, dental or veterinary science undergraduates to work on microbiological research projects in their elective periods. The second round of applications closes on **26 September 2008**.

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

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

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

Wellcome Trust International Engagement Awards

www.wellcome.ac.uk/doc_WTX036603.html

These new awards of up to £30,000 support projects that aim to achieve some or all of the following:

- to strengthen the capacity of people in developing countries to facilitate public engagement with health research
- to stimulate dialogue about health research and its impact on the public in a range of community and public contexts in developing countries
- to investigate and test new methods of engagement, participation, communication or education around health research
- to promote collaboration on engagement projects between researchers and community or public organizations
- to support Wellcome Trust-funded researchers in developing countries in engaging with the public and policy makers.

Applicants must be based in certain developing countries or in the UK working with partners in developing countries. See the website for full details. The next deadline for receipt of applications is **24 October 2008**.

Science for humanity

http://scienceforhumanity.net/

This new initiative, supported by NESTA, brings together scientists, international development agencies and local social enterprises to develop workable, science-based solutions to specific problems in developing countries. Issues around water, energy, disease diagnosis and treatment, environmental sustainability and agriculture will be the main focus.

microshorts

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

Vietnam bans hamsters

Vietnam's Ministry of Agriculture is handing out fines of 30 million dong ($1,900), almost double the average annual wage in Vietnam, to people who are caught in possession of hamsters, which are believed to be spreading disease. The pets have been growing in popularity, partly thanks to this year being Chinese Year of the Rat. As a result, hamsters are being traded illegally from China and Thailand, avoiding proper licensing and epidemiological controls. The authorities are concerned about the increasing sub-culture of hamster forums and hamster clubs.

http://news.bbc.co.uk/1/hi/world/asia-pacific/7283299.stm

Blooms like it hot

Worldwide water quality is likely to be affected by an increase in cyanobacterial blooms, especially during heat waves, according to new research that shows the world proliferation of cyanobacteria is linked to climate change. Scientists at the University of North Carolina, USA, and the University of Amsterdam, The Netherlands, have been looking at the behaviour of cyanobacteria in lakes. As the surface temperature of a lake increases, the warm water floats on top of the colder water, leading to stratification in the lake. Cyanobacteria like stratification. They make small gas vesicles, which make them buoyant so they float up to the warmer surface waters. Eventually, blooms of cyanobacteria form in the lake and block out light to other aquatic organisms, such as plankton.

Science **320**, 57–58, 4 April 2008

Antibiotics from alligators

Alligators have vicious fights in swamps teeming with pathogenic microbes, so how do they heal so quickly and resist infection? Researchers at Louisiana State University in Baton Rouge and McNeese State University in Lake Charles, Louisiana, USA, puzzled over this question and have found that a protein in the alligators' blood could be the answer. The peptide, which is now being sequenced, is believed to strengthen the reptiles' immune system. It is also found in the skin of

Ancient cellulose 'next best thing to a close encounter'

The search for life on other planets may benefit from looking for ancient cellulose in salt deposits, according to scientists at the University of North Carolina at Chapel Hill. The researchers found 'remarkably intact' cellulose microfibres in pristine salt deposits 2,000 feet under the New Mexico high desert. The cellulose was found at the US Department of Energy's Waste Isolation Pilot Plant (WIPP), where radioactive waste is placed thousands of feet underground. Cellulose is one of the most abundant materials on Earth. Prehistoric forms of the molecule were made by cyanobacteria, which dominated the Earth up to 2.8 billion years ago. Scientists estimate the age of the cellulose found in the salt deposits to be 253 million years old, pushing back the earliest direct evidence of biological materials on Earth by 200 million years.

Astrobiology **8**, 215–228, 1 April 2008 (DOI: 10.1089/ast.2007.0196)
www.liebertonline.com/doi/abs/10.1089/ast.2007.0196

frogs and toads, Komodo dragons and crocodiles. A serum containing the peptide successfully killed 23 different strains of bacteria, including some that are resistant to antibiotics. A similar serum made from human blood killed only 8 of the bacterial strains. The researchers hope the peptide may be used to develop new antimicrobial treatments, particularly for burn victims and people with diabetic foot ulcers. However, more research is needed as the peptide can be toxic to humans in high concentrations.

http://news.nationalgeographic.com/news/2008/04/080407-alligator-blood.html

▲ American alligator (*Alligator mississipiensis*). This large reptile is native to the south-eastern United States. *Clay Coleman / Science Photo Library*

◀ Golden hamster. *Ray Coleman / Science Photo Library*

◀ Water of a lake discoloured by a bloom of the blue green alga *Cyanophyceae*. *Dr Jeremy Burgess / Science Photo Library*

▶ Precipitation from a rain cloud. *Photos.com / Jupiter Images*

Biofilms should be protected, say conservationists

Biologists are calling for the protection of biofilms that coat a tidal flat just south of Vancouver, Canada, after researchers discovered that half the world's population of western sandpipers feed on the bacterial community. The birds, which weigh just 30 grams each, eat 20 tonnes of biofilm every day during the spring migration. 'Snot feeding,' says Environment Canada biologist Bob Elner, 'adds a whole new dimension to avian life.' Bacteria and diatoms settle out of the sea and secrete mucus that binds them to the mud, so they are not washed away with the tide. The birds have hairy tongues and beaks that are perfectly adapted to suck up the biofilms.

Ecology **89**, 599–606, March 2008 (DOI: 10.1890/07-1442.1)

Bacteria call clouds home

Microbes have long been used by the ski industry to make snow at warmer temperatures, but scientists now believe bacteria have a greater effect on precipitation than we thought. Researchers from Louisiana State University, with scientists from Montana and France, sampled clouds directly and found that bacteria are present in all locations, from France to Antarctica. Although not all of them are 'rain-making' bacteria, it is probable that microbes capable of encouraging precipitation are distributed widely in the atmosphere. Snow forms when water molecules join around ice nuclei, small particles that allow ice-like structures to form at slightly higher temperatures. Some bacteria, such as *Pseudomonas syringae*, can act as ice nuclei. *P. syringae* is also a plant pathogen, and encouraging precipitation may be an important part of its infection cycle. Bacteria can become aerosolized, reaching the clouds where they make snow to transport them back to the ground. By doing this, pathogenic microbes can move around and infect different crops.

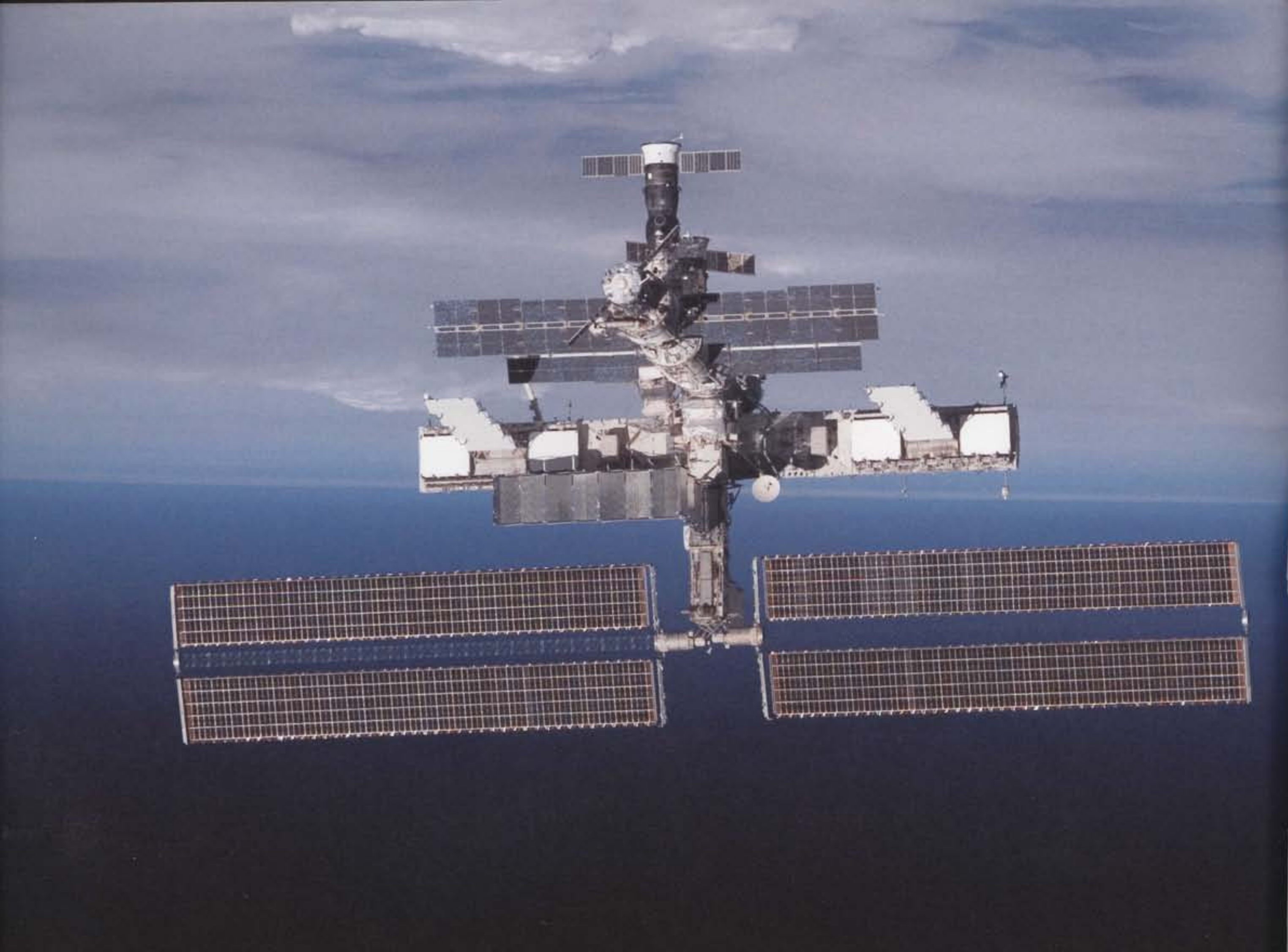
www.newscientist.com/channel/life/dn13396-airborne-bugs-may-trigger-rain-to-get-home.html?feedId+online-news_rss20

Science **319**, 1214, 29 February 2008

'Corpus' museum opens

A game that allows visitors to become immune cells features in a new museum in The Netherlands. *Corpus: Journey Through the Human Body* is an interactive museum that opened in March 2008. The building consists of a 115-foot high seated human figure and the interior is modelled from fibreglass to resemble the inside of a human body. Visitors are taken on an escalator into the body via a wound in the calf. They travel through the digestive system, following a cheese sandwich, then visit the heart, lungs, mouth, nose, ear and brain. On the way back down, there are games, including one that involves throwing beanbags at giant bacteria on a big screen to knock out invading pathogens. Businessman Henri Remmers secured $31 million private funding for the project, which has been endorsed by the Dutch Health Ministry.

www.corpus-experience.nl/index.php?refresh=true



Space bugs!

On Earth, microbes get absolutely everywhere. Indeed, there seem to be very few completely sterile natural environments. But what about microbial colonization of locations beyond Earth? In this article we'll explore the realm of space bugs. There is a great deal of interest in the microbiology of the closed artificial environments created for human exploration of the cosmos, such as the International Space Station (ISS), as well as in minimizing the risks of inadvertently transporting terrestrial contamination elsewhere, and even the possibility of a natural mechanism spraying life between worlds over the history of the solar system.

Dirty spaceships

Although limited microbiological research was carried out before the launch of the *Apollo* spacecraft that flew astronauts to the Moon and back in the late 1960s and early 1970s, the first extensive in-flight studies of microbial diversity were carried out on the Russian space station *Mir*. *Mir* was humanity's first long-term inhabited outpost in space, launched in 1986 and consisting of a five-port docking hub with connected resupply ships and habitation modules. Over the course of the station's almost 15 years of service, numerous studies were conducted on the biota surviving in different regions, such as the dining area, sleeping quarters and hygiene facilities. Widespread bacterial colonization was noted, but fungal levels typically remained low throughout space missions, probably due to the low humidity of the recycled air.

A unique discovery was made in 1998 when a NASA mission to the space station found several large free-floating blobs of water caught behind the service panels of one of the habitation modules. These had formed as water vapour in the air condensed into tiny droplets and coalesced in the microgravity environment of the station into sizeable drops. Samples from these 'free-floating condensates' were syringed into sterile bags and returned to the ground for extensive analysis.

The condensate samples were noted to be a cloudy white or brown colour, and culture studies were run to identify the micro-organisms inhabiting this unique wet environment. The bacterial isolates were predominantly Gram-negative and included many *Enterobacteriaceae* such as *Escherichia coli* and *Yersinia* species. These contaminants were almost certainly supplied by the human occupants of the station. Alongside the bacterial biota, fungi, amoebae and ciliated protozoa were recovered from the free-floating condensate, and even dust mites. Perhaps most worrying, however, the researchers isolated several opportunistic pathogens and what they suspected to be a *Legionella* species, although this identification could not be confirmed as subculturing failed. Some species

Does life exist outside our planet? **Lewis Dartnell** explores the likelihood of microbes being out there somewhere.

of this genus cause Legionnaires' disease, an often fatal infection.

More recently, the ISS has been sampled for microbial abundance. Many contaminants from human occupation have been found, such as *Staphylococcus epidermidis*, which are also commonly found in other closed environments like nuclear submarines. On the whole, though, the ISS carries a much lower bioload than other space platforms. This has a lot to do with the lessons learned from previous missions, such as the installation of HEPA filters on air handling systems and a robust housekeeping programme of weekly cleaning and biweekly disinfection. Over its operational lifetime, *Mir* witnessed numerous crew exchanges, re-supply deliveries and biological experiments. More importantly, *Mir* had also suffered numerous malfunctions that led to raised temperatures and high humidity: ideal conditions for microbial growth. *Mir* was also much older when sampled, and the progression of microbial colonization of the ISS will be closely tracked.

The problems of microbial infection are particularly acute aboard space missions. Prolonged exposure to cosmic radiation and microgravity is believed to have a negative effect on the immune system, and disease transmission is enhanced within the closed environment of recycled air and water. Studies report that diseases, mainly respiratory infections, occur in a quarter of space shuttle flights. But the problem is not limited to that of infection, and adverse microbial effects also include allergies, toxicity of air and water supply, and biodegradation of critical spacecraft components.

For longer missions, such as the habitation of the Moon or a return trip to Mars, it will simply not be possible to supply sufficient consumables from Earth. Ingenious biologically based regenerative life support systems are being proposed, relying on plants and micro-organisms to provide food, oxygen production, waste recycling and water purification. In this case, a microbial outbreak might not only affect crew health, but crash the life support systems and endanger the viability of the entire mission.

It is clear then, that wherever man boldly goes his microbial fauna is sure to follow. As discussed above, if this is allowed to get out of control it may pose serious problems on long-term space missions. But in terms of our responsibility as explorers, perhaps even more serious is the possibility of inadvertently spreading our terrestrial contamination to the extraterrestrial locations we visit.

◀ International Space Station (ISS), seen from the Space Shuttle *Discovery* as it leaves towards the end of mission STS-121. Photographed on 15 July 2006. *NASA / Science Photo Library*

▼ Astronaut Terrence W. Wilcutt transports a water bag from the space shuttle *Atlantis* to the *Kristall* module of Russia's *Mir* space station. Photographed on mission STS-79 (6–26 September 1996). *NASA / Science Photo Library*

Planetary protection

Preventing the spread of microbial life between worlds of the solar system has been a top priority of NASA, and the other space agencies of the world, for decades now. This effort is known as planetary protection, and aims to not only limit the possibility of transporting terrestrial life to places like Mars, but also accidentally bringing something back home. Although the risks of this back contamination are decidedly minimal, they are not negligible, and even the *Apollo 11* astronauts were placed in quarantine for 3 weeks after returning from the 'magnificent desolation' of the Moon.

Sterilizing robotic probes before launch is a relatively simple measure. The *Viking* landers sent to the Martian surface in the late 1970s were baked in an autoclave for over 2 days. This is a prohibitively expensive enterprise, however, and is especially problematic for the delicate modern instruments, so in general only the parts of spacecraft expected to come in contact with potentially inhabitable regions are sterilized so thoroughly. For example, NASA's latest Mars probe, the *Phoenix* lander, will touch-down in the Arctic plains this May and dig beneath the frozen surface to hopefully make the first ever direct measurements of Martian water and organic molecules. The robotic arm will excavate up to 50 cm underground and deliver samples to a suite of analysis instruments atop the lander. To guarantee the cleanliness of this arm, and thus the validity of any organic detection, it has been enclosed in a biobarrier bag – effectively an interplanetary condom – and will only be unsheathed once on the Martian surface.

Once the political will arises to send the first human pioneers to Mars, however, such biological containment will be nigh-on impossible. As we've seen already, humans and the inhabitable sections of our spaceships are inherently dirty, and once we arrive to plant flags and footprints in the rusty soil, our microbial entourage will inevitably begin leaking out onto Mars. Terrestrial life may not survive the hazards of the Martian surface for long, but it can be spread far and wide by winds. Once humans have visited the red planet, how could we ever be totally certain that any subsequent biological discoveries weren't simply signs of our own dirty sleeves?

There is the increasing realization, however, that our best efforts at planetary protection may never ensure the biological isolation of the planets – there may exist a natural process that has been transporting life between neighbouring worlds since the birth of the solar system.

Spreading the seed of life

The idea that life can spread between different planets and moons to ensure a constant cross-fertilization of worlds, known as panspermia, has been knocking around for well over a century now, but has been recently gathering a great deal of momentum with mounting evidence.

There are essentially three main hurdles that must be passed in order for life to be expelled from one world and arrive safely upon the surface of another. The first is in ejection from the home world. Encouragingly, studies show that lumps of surface rock could quite easily be flung off a planet fast enough to escape its gravity by the shock wave of a near-by asteroid strike. Secondly, microbial stowaways within these exiled meteorites must survive the ravishes of the space environment for an interplanetary voyage lasting perhaps several million years. The major hazards include desiccation by the hard vacuum, the sterilizing glare of solar ultraviolet light and the constant trickle of cosmic radiation. But again, combinations of modelling and experimental research suggest that provided microbes are buried deep enough within the protective interior of their host boulder they could persist for substantial periods of time. Finally, life must survive the heat blast of re-entry into the atmosphere of the destination planet and the shock of slamming into the ground, essentially the mirror image of the original ejection process.

Some researchers believe they have already found fossilized microbial emigrants from another world – signs of Martian nanobacteria within the meteorite ALH84001 – although this remains a hotly contested claim. The theory of panspermia is rapidly gaining support, and this cross-fertilization mechanism may even explain the apparently rapid emergence of life upon our own planet as soon as conditions became appropriate, perhaps from Venus or Mars.

One recent study has produced exciting results demonstrating just how plausible panspermia really is. Earlier this year, researchers at Humboldt University in Berlin tested the feasibility of microbial cells surviving being ejected off a planet's surface by the shock of a nearby asteroid impact. Three types of micro-organism, *Bacillus* spores, *Chroococcidiopsis* (a cyanobacterium) and *Xanthoria* (a lichen), were loaded into pellets of rock and fired from a specially adapted gun. This generated an enormous pressure pulse in the life-laden rock and temperatures briefly approaching 1,000 °C – recreating the conditions that microbes would be subjected to if blasted off their home planet by a nearby asteroid strike. The surprising outcome was that under these conditions, significant proportions of all three test organisms survived, showing that such organisms really could survive forced departure from their home world.

Lewis Dartnell
CoMPLEX (Centre for Mathematics and Physics in the Life Sciences and Experimental Biology), University College London, Wolfson House (2nd Floor), 4 Stephenson Way, London NW1 2HE, UK (e l.dartnell@ucl.ac.uk)

Lewis Dartnell researches the possibility of life on Mars at University College London. His new book, Life in the Universe: A Beginner's Guide, *is reviewed on p. 98 of this issue.*

There are probably no little green men on Mars, but **Charles Cockell** would not be surprised to find micro-organisms on the red planet.

It is not often apparent to microbiologists or members of the public that we know for certain that there has been life on Mars. Since the crash of the Soviet's *Mars 2* lander on the surface of the planet in 1971 (Fig. 1), a diversity of landed and crashed probes of various kinds, many of them not sterilized, have been delivered to the surface of Mars by the world's space-faring nations. Only the *Viking* spacecraft (Fig. 2), which landed in 1976, were completely heat sterilized to kill spores. Many of these spacecraft have delivered an inventory of spores found in spacecraft assembly facilities, including *Bacillus* species.

A fascinating scientific question is whether there is, on the surface of Mars today, a viable spore hidden and shielded from Mars' intense UV radiation in one of these various contraptions. There seems to no reason why a spore, cooled to Mars' average temperature of –60 °C should not have survived since the 1970s. So on the face of it the answer to the question I was asked to address is likely to be 'yes'.

Are the conditions suitable for microbial life?

Aside from this perhaps slightly facetious and tangential answer to the intended question is another, longer running, question of whether the planet Mars has or does harbour

Is microbial life

▲ A true colour image from the panoramic camera on NASA's Mars exploration rover *Opportunity* of exposed rock in Victoria Crater. The ridge in the foreground is known as Cape Verde (28 September 2006). *NASA / JPL / Cornell / Science Photo Library*

► Fig. 1. A Soviet stamp from 1972 depicting the *Mars 2* lander. The first lander on Mars crashed on 27 November 1971, delivering its (unintended) inventory of microbial spores within its interior equipment and wiring to the surface of Mars.

► Fig. 2. A model of a *Viking* lander. The US *Viking 1* lander landed on Mars on 20 July 1976 and was the first spacecraft to be deliberately autoclaved to destroy its inventory of contaminant micro-organisms. *NASA / Science Photo Library*

habitable conditions for indigenous life. This question is a simple microbiological puzzle, which unfortunately has been hijacked by sensationalism, claims and counterclaims such that many people are fearful of engaging in any meaningful discussion of its answer.

Many remarkable facts are now known about the planet Mars. We know from the early *Viking* orbiter images that early Mars hosted standing bodies of liquid water. Empirical evidence for these water bodies, in the form of sedimentary rocks with well-defined stratigraphy, has been forthcoming from the recent Mars exploration rovers (Figs 3 and 4). We also know that the surface of Mars, one dominated by volcanic basalts, has many of the key nutrient requirements for life, just as many volcanic terrains on the Earth provide nutrient rich soils.

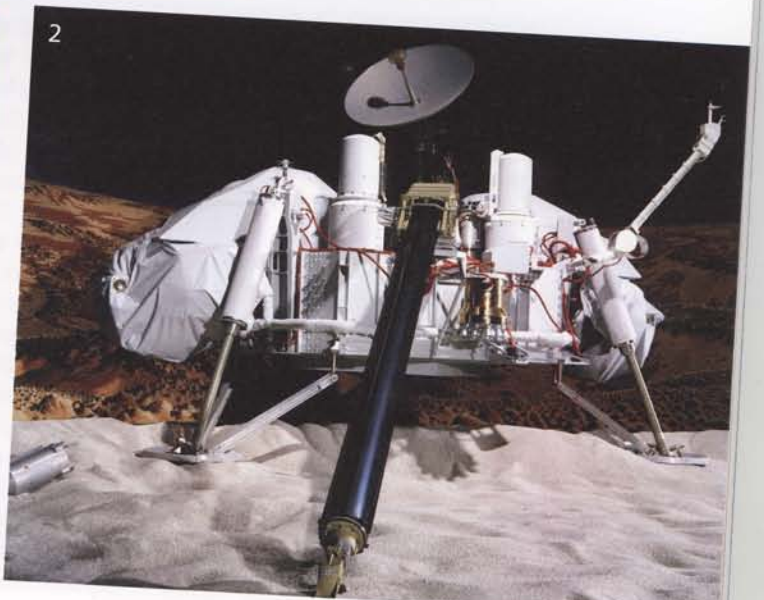
Abundant carbon is present in the 97 % carbon dioxide atmosphere. Sulfur is to be found in the widespread surface sulfate deposits. There is phosphorus in the form of apatites and the volcanic rocks contain many potential micronutrients such as manganese. The presence of abundant reduced and oxidized iron on the surface shows that a half reaction for iron oxidation and reduction exists for energy acquisition, although the potential for electron acceptors, such as nitrates and oxygen, seems more limited. Nitrogen may be one of the most important limiting nutrients, although the atmosphere contains nitrogen gas.

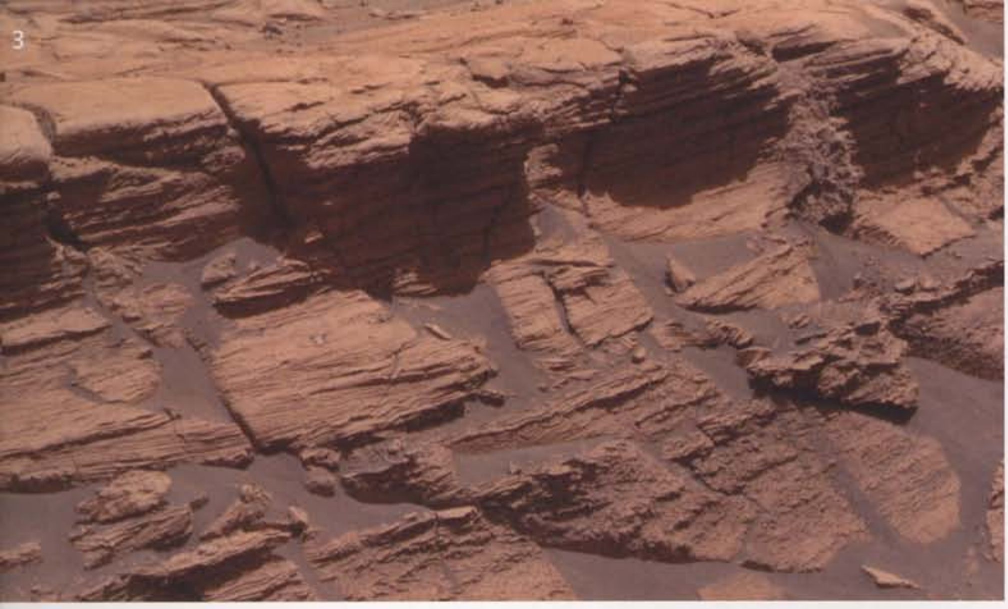
Possible sources of microbes

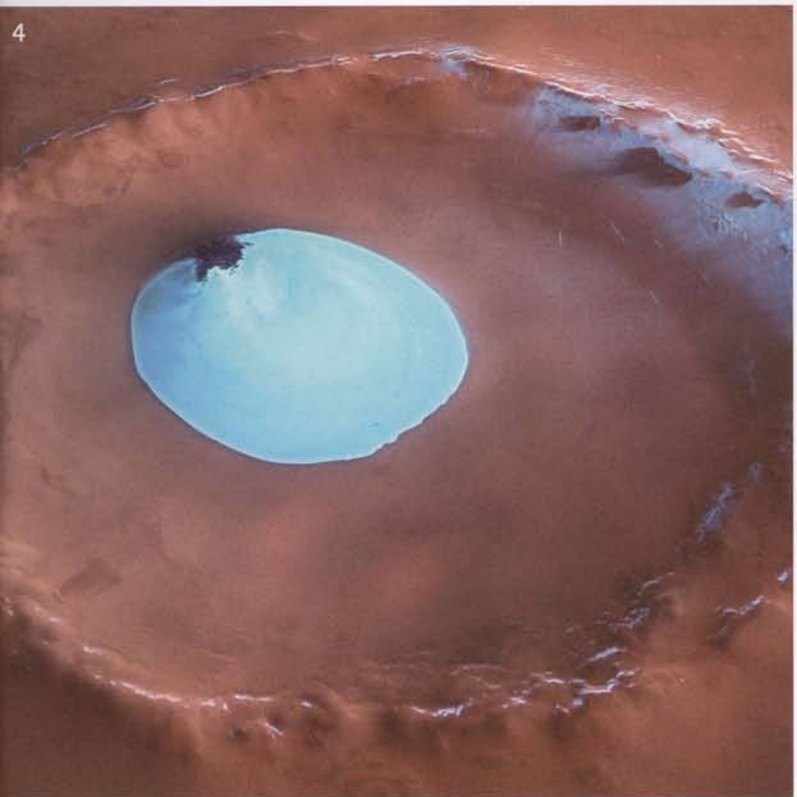
Where would life come from to take advantage of any such habitable conditions? One answer would of course be Mars itself. As we know so little about the biochemistry necessary for the first self-replicating organisms to emerge, it is not possible to say whether Mars was an environment conducive to an origin of life. A second possibility is the transfer of life from Earth to Mars. The presence of abundant liquid water on Mars in its past coincides with a period when geobiologists think that life on Earth was emerging. There is good evidence for fossil life on Earth at about 3.5 billion years before present, probably just after the period when Mars began to desiccate and freeze, suggesting that Mars and the Earth shared many environmental features in common at a key period during the Earth's very early biological evolution.

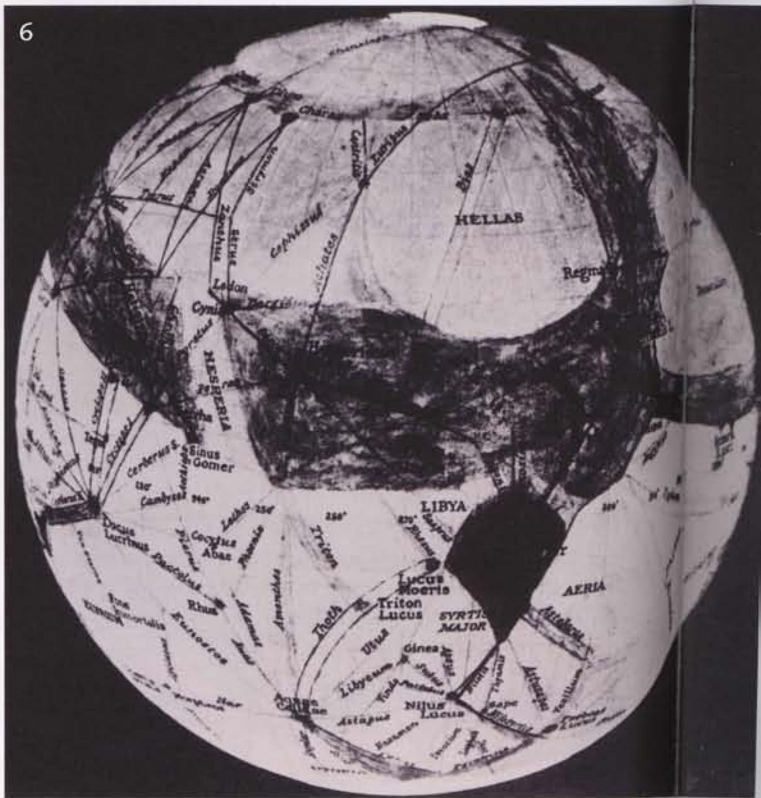
It is known that Earth and Mars are not isolated with respect to the exchange of materials. Modelling suggests that about half a tonne of Mars lands on the Earth each year; most of it

on Mars possible?







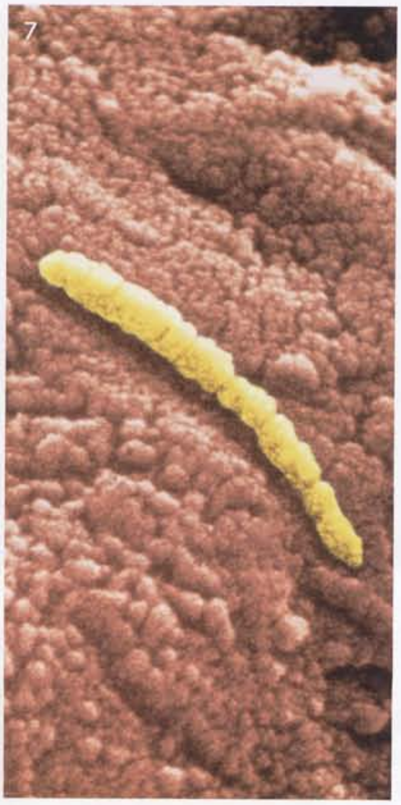


will disappear into the oceans and uninhabited regions, but some of this material is collected by meteoriticists. There are over 20 rocks collected that are known to have a Martian origin. Less material will reach Mars from the Earth because it must move against the Sun's gravity, but it seems clear that as occurs today, Mars and Earth exchanged a lot of rocky material ejected by asteroid and comet impact events in their early history.

An intriguing question is whether rocks ejected by asteroid and comet impacts could transport life, or even complex prebiotic molecules, from one planet to another. This is an interplanetary extrapolation of an old question in biogeography, which is covered in some detail in Lewis Dartnell's article on p. 62. Mineralogical evidence in the interior of Martian meteorites suggests that rocks can be ejected by impact events whilst still retaining temperatures in their interior below 100 °C. A vital question, however, is whether micro-organisms or organic compounds could survive the interplanetary journey, with extremes of desiccation, low temperatures and cosmic radiation exposure. Modelling calculations show that the shortest duration trips for some rocks travelling from Mars to Earth is a decade, with many taking millions of years.

Could microbes exist on Mars?

The title of this essay belies yet another subtlety. 'Is microbial life on Mars possible?' is a very different question from 'is there life on Mars?' for the reason that it is quite plausible to have a sterile planet that harbours habitable conditions. On the Earth the vastly productive photosynthetic biosphere generates so much organic carbon that not only are micro-organisms pervasive in most environments, but most bodies of water, even the most transient ones, become colonized by organisms using exogenous contaminants. It is not difficult to imagine a situation on Mars, for instance, where an asteroid or comet impact into its extensive permafrost deposits would generate a transient body of liquid water which lacked any surrounding microbiota to take advantage of it (Fig. 5). We would say of such a body of water that microbial life within it might be possible, but does not occur. It is one



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◀ Fig. 3. Martian sedimentary rock layers exposed on the 'Payson' ledge on the western edge of Erebus Crater. Sedimentary rocks on Mars provide evidence for sustained bodies of liquid water on Mars – were they sterile? This image was obtained by the Mars Exploration Rover *Opportunity* on 3 March 2006. *JPL / Cornell / NASA / Science Photo Library*

◀ Fig. 4. An impact crater at 70°N on Mars (Vastitas Borealis) containing ice. Immediately after an impact the heat generated from the collision would have melted Martian permafrost generating circulating hydrothermal systems. Such environments could potentially represent locally habitable conditions on Mars. *ESA / DLR / FU Berlin (G. Neukum) / Science Photo Library*

◀ Fig. 5. Infrared and visible light composite image showing the region south of the Mawrth Vallis on Mars. This and the Mawrth Vallis area hold special interest because of the presence of phyllosilicate minerals. These phyllosilicates (orange) attest to a time when aqueous rock weathering occurred on Mars. *NASA / JPL / Univ. of Arizona / Science Photo Library*

◀ Fig. 6. The possibility of life on Mars has attracted some unfortunate attention. A map drawn by astronomer Percival Lowell of canals which he thought had been constructed by a dying desiccating civilization. *Science Photo Library*

◀ Fig. 7. A claimed Martian 'microfossil'. These images, much loved by the media, should not distract from the fact that the search for habitable conditions on Mars underpins a fundamentally sound scientific question. *NASA / Science Photo Library*

thing to have a planet that has localized conditions where microbial life, from a thermodynamic and kinetic point of view, is theoretically possible, but it is quite another to have a planet where there is actually a biota that can use these conditions. Mars might be a sterile, but locally habitable world.

The implications of answering the question

It is important to remember that the search for life on Mars is just a test of a scientific hypothesis, and that either outcome will be quite stunning. The discovery of life on Mars would open up an entirely new field of microbiology. As terrestrial micro-organisms have occupied microbiologists for almost four centuries, a new planet harbouring a biota, even one related to life on the Earth, would yield new research vistas in microbiology, biophysics, biochemistry and other related fields.

Demonstrating that there is no life on Mars is rather more difficult, but if all plausible habitats were searched and no life was found, one might conclude that Mars was and is lifeless. It would not only inform us that the Earth is a biogeographical island and that the cross-inoculation of planets with micro-organisms is unlikely, but it would also raise the question, 'what was missing on Mars that allowed an origin of life on the Earth when both planets shared very similar early conditions?'

Reality and imagination

The question of life on Mars reaches beyond the purely scientific realm and enters into sociological territory. The Siren-like draw of this question and the power it exerts over the imagination of the public and scientists alike makes it an irresistible calling to cranks, egotists and those just caught up in a tide of optimism. Percival Lowell saw canals (Fig. 6), in their place some scientists see microfossils (Fig. 7), which whether real or not, nevertheless rest on controversial evidence. So great is our desire to prove we are not alone that the evidence for life is pushed to its limits. This state of affairs should not distract from the simple fact that on the surface of Mars, or in its deep subsurface, there remains an uncontroversial and empirical answer to a fundamentally sound microbiological question: 'Is microbial life on Mars possible?'

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Antarctica: a last frontier for microbial exploration

▲ Microbial mats in ice from behind the Seuss Glacier near Lake Hoare. *Amy Chiuchiolo, Montana State University*

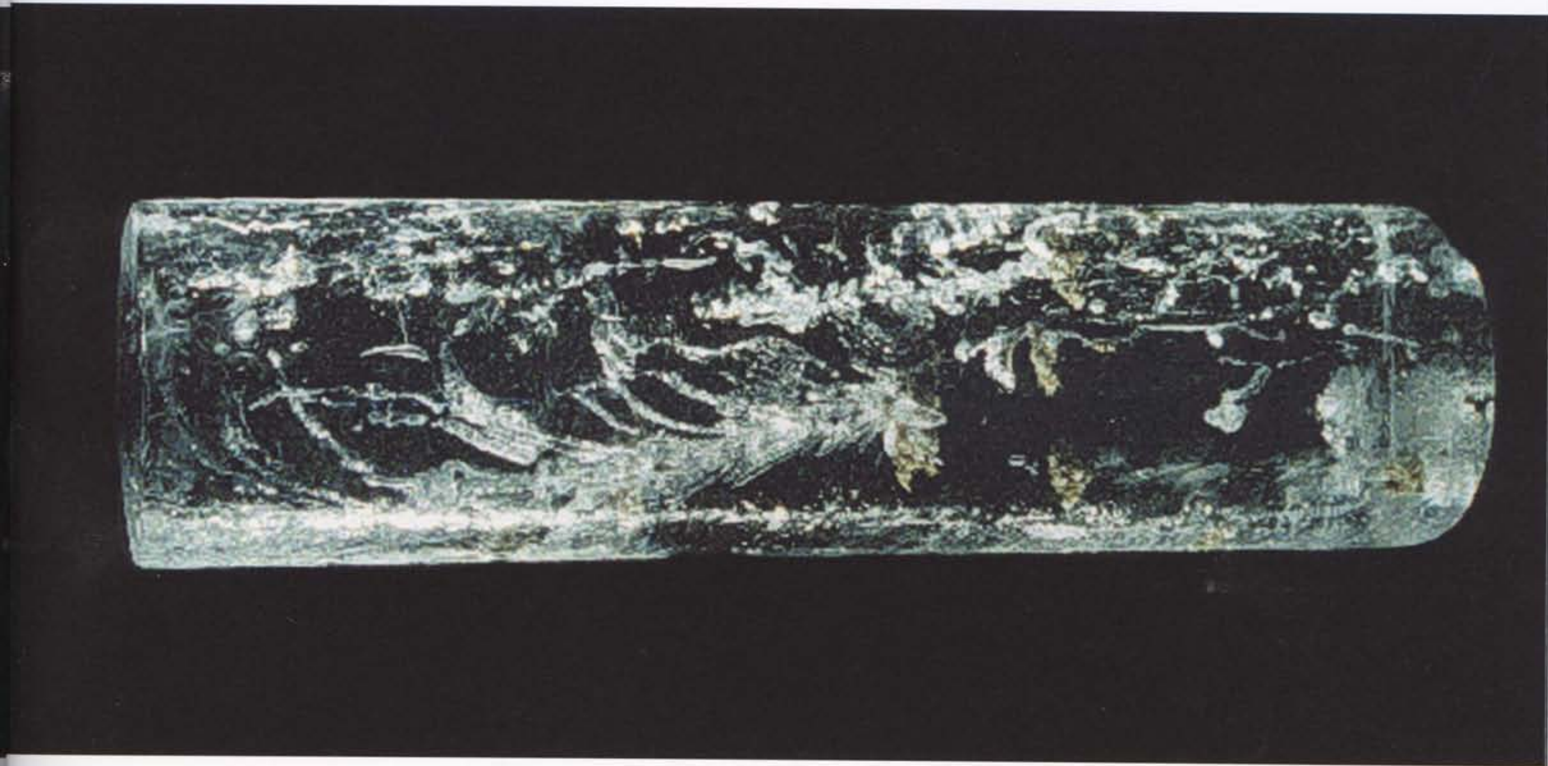
► A lake-ice core sample containing sediment and ice bubbles. *John Priscu*

Deep under the Antarctic ice lie huge bodies of water. **Brent C. Christner** and **John C. Priscu** believe that these lakes may contain some of the most unusual, extreme microbial ecosystems on Earth.

The realization that there was life on the Antarctic continent, other than that associated with the marine system, did not come to light until the seminal investigations initiated by the International Geophysical Year (IGY) in the late 1950s and early 1960s. These important pioneering studies reshaped our understanding of the potential for life in the coldest and driest desert on Earth. Research since these early IGY studies has revealed that large numbers of micro-organisms thrive in environments previously thought to be uninhabitable. Microbiological investigations conducted on deep ice cores and subglacial environments now support the notion that the Antarctic cryosphere may harbour some of the most unusual and extreme microbial ecosystems on our planet.

Lake Vostok

Subglacial Lake Vostok is by far the largest of the more than 140 subglacial lakes that have been identified thus



far, with a surface area of more than 14,000 km^2, a depth in excess of 800 m, and a volume of ~5,400 km^3, making it one of the largest freshwater lakes on Earth. Despite surface air temperatures averaging –60 °C, the base of the East Antarctic Ice Sheet is near the pressure melting point of water (~–3 °C) owing to the combined effect of Earth's outward heat flux, the insulating properties of the overlying ice, and a reduced pressure freezing point resulting from the weight of the overlying ice sheet. The first indication that a lake existed beneath the East Antarctic Ice Sheet was based on anecdotal reports in the early 1960s by pilots with the Soviet Antarctic Expedition, who noted an extremely flat area near Vostok Station that could represent ice floating on water. These airborne observations were later confirmed by seismic data, radar profiles, and ice cores collected from the overlying ice.

The lake consists of a northern basin (water depth of ~500 m) and a larger southern basin (~800 m), which are separated by a bedrock sill. The variation in ice-sheet thickness between the north (~4,200 m) and south basins (~3,900 m) of the lake produces a 0.3 °C difference in the pressure melting point of water. This gradient results in glacial ice melting into the lake in the north, and refreezing (i.e. accretion) to the bottom of the ice sheet in the south, which has important repercussions to both horizontal and vertical circulation within the lake. Although lake water from Lake Vostok has not been directly sampled, the Russian Antarctic Expedition plans to penetrate the lake within the next 5 years. To date, all information on the microbiology of Lake Vostok is based on analysis of the basal portion of an ice core drilled at Vostok Station, which has provided seminal data to predict limnological conditions in the lake's surface waters. This ice, referred to as accretion ice, is comprised of water from the lake that has frozen to the bottom of the ice sheet.

Possible microbial life in the lake

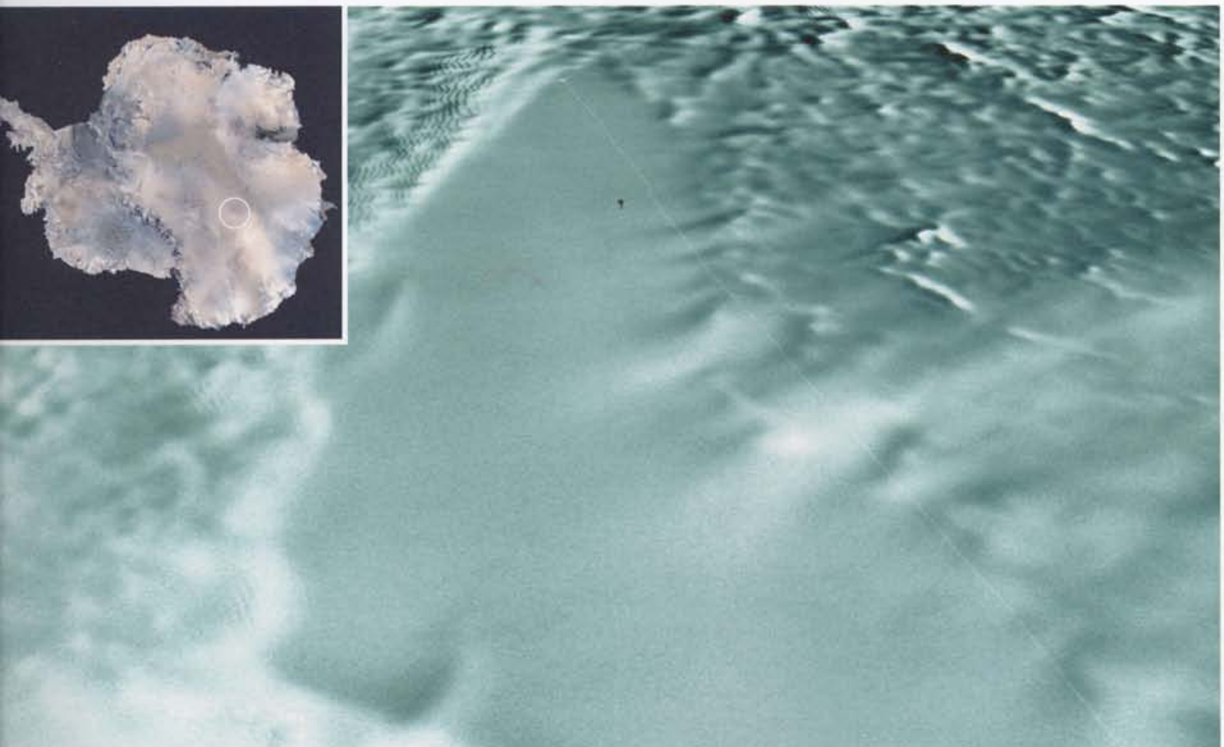
While viable micro-organisms from the overlying glacial ice and in sediment scoured from bedrock adjacent to the lake must be regularly seeded into the lake, the question remains whether these or pre-existing micro-organisms (i.e. organisms that existed before Antarctica became glaciated about 13 million years ago) have established a flourishing community within Lake Vostok. Heterotrophic activity has been reported within melted samples of the accretion ice and amplification and sequencing of small subunit (16S) rRNA genes from extracted DNA and isolated cultures imply the lake is inhabited by bacteria related to the *Alpha-*, *Beta-*, *Gamma-* and *Deltaproteobacteria*, *Firmicutes*, *Actinobacteria* and *Bacteroidetes*. The average concentration of dissolved organic carbon, prokaryotic cells, and total dissolved solids in surface waters of the shallow embayment and open lake are predicted to be 86 and 160 µM, 150 and 460 cells ml^{-1}, and 1.5 and 34 mM, respectively. The input of organic carbon from the ice sheet has been estimated to be insufficient to support reproductive growth of the entire lake community, and a sustained ecosystem would require a supplemental chemical energy source residing in iron, sulfur and hydrogen redox couples.

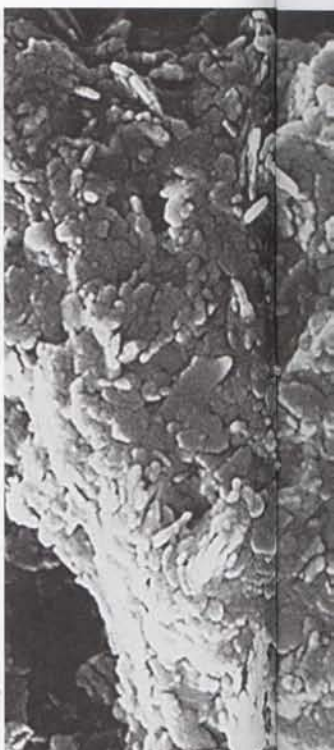
Meltwater that enters the lake from the overlying ice sheet has about 10 times more gas than the accreted ice that leaves the lake, resulting in supersaturated gas concentrations within the lakewater itself. Calculations have revealed that Lake Vostok may have a dissolved oxygen concentration 50 times higher than that in the open ocean and contains much more oxygen in the form of air hydrates. Alternate electron acceptors, such as nitrate, are continually introduced into the lake through the melting of basal ice and sulfate is produced through the chemical weathering of sulfide minerals in the bedrock. Glacier flow results in the comminution of mineral matrices in the underlying bedrock, releasing carbonate, sulfide, iron and organic matter into the subglacial environment. Geochemical evidence implies that the microbial oxidation of metal sulfides in glacial flour occurs in oxic and anoxic glacier bed environments. Under oxic conditions, sulfide oxidation and heterotrophic activity will consume oxygen, eventually creating anoxia. Sulfide oxidation with Fe(III) as an oxidant can occur in the absence of oxygen, and sulfate reduction and methanogenesis are potential biogeochemical pathways for the anaerobic mineralization of organic matter. Thus, abiotic glacial geochemical processes may be sufficient to provide an energy source to microbes existing in Lake Vostok.

There has been speculation regarding geothermal energy input from high-enthalpy mantle processes or seismotectonic activity, which could introduce significant amounts of thermal energy and support an ecosystem similar to those found in deep-sea hydrothermal vents. However, since documented geophysical, glaciological processes could supply subglacial lake ecosystems with nutrient and redox couples for microbial metabolism, the search for viable subglacial communities need not be exclusive to environments with geothermal fluid or gas input.

Recent findings from subglacial environments

Knowledge of microbial life in subglacial ecosystems is limited due to sparse data resulting from the technological, financial and environmental challenges associated with sampling such cold and remote subsurface environments. Considerable progress has been made over the last 10 years in the exploration and study of subglacial environments, permitting a glimpse of the microbial life that exists under conditions of high pressure, cold temperature, low nutrient input and no sunlight. Estimates of the number of cells and





organic carbon content in the Antarctic ice sheets and subglacial environs (4×10^{28} cells and 11×10^{15} g C) exceed that reported for the Earth's surface freshwater lakes and rivers (1.3×10^{26} cells and 1.2×10^{15} g C). These tentative estimates imply that the deep cold biosphere in Antarctica contains a previously unknown, but globally relevant pool of prokaryotic cells and associated organic carbon.

What next?

Future research of microbial ecosystems in subglacial lakes depends on a plan in which water samples are collected and returned to the surface. The overriding and limiting issues of this entire strategy are environmental concerns and the control of contamination in both forward and return excursions into the lakes. As such, it is of prime importance that environmental stewardship precedes all scientific endeavours. To this end, the Scientific Committee on Antarctic Research (SCAR) has established an international body of specialists to outline a detailed plan for eventual lake entry and sample return. This plan calls for the establishment of a network of instruments that gather limnological data continuously, collection of water samples for return to the surface, and recovery of deep sediment cores that can be used to reconstruct paleoclimatological, geological and microbial records for Antarctica. The next decade should prove to be an interesting time of microbial discovery for Antarctic science, one that follows the Antarctic tradition of melding interdisciplinary and international science. We can expect subglacial lakes to be at the forefront of such discovery since they remain one of the last unexplored frontiers on our planet.

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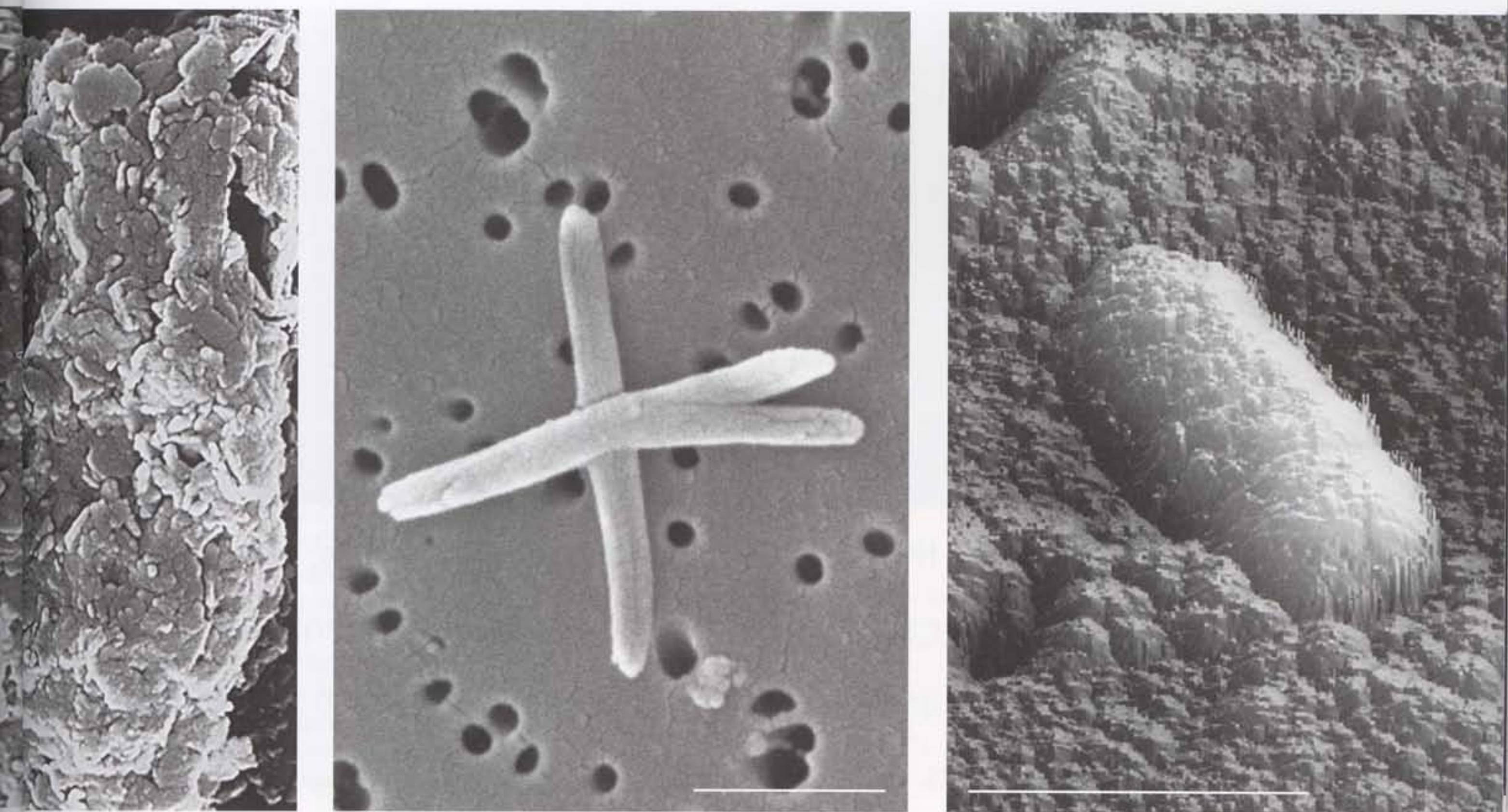
◄ Radar satellite image of the ice over Lake Vostok, Antarctica. The ice smooths out over the lake (centre), contrasting with the rough terrain of the ice over the surrounding mountains. The inset shows the approximate location of Lake Vostok. *Canadian Space Agency / Radarsat / NASA / Science Photo Library (inset NASA)*

▼ Scanning electron micrograph (left, centre) and atomic force micrograph (right) of microorganisms from Lake Vostok accretion ice samples from a depth of 3590 m. *John Priscu (left; Bar, 1 μm); Brent Christner (centre; Bar, 1 μm); John Priscu (right; Bar, 0.5 μm)*



Antarctic lichens: life in the freezer

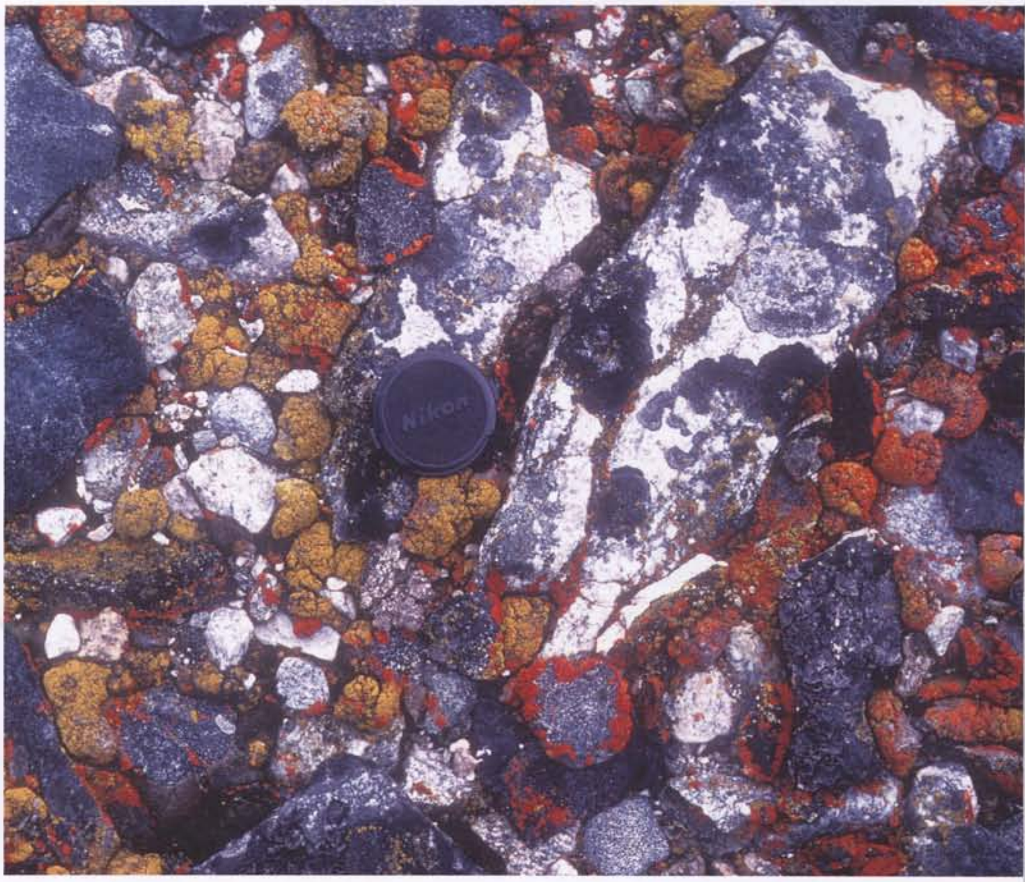
Amongst the sparse life that exists in Antarctica, as **Paul Dyer** and **Peter Crittenden** explain, lichens show the most amazing ability to survive and grow in the harsh conditions.

Antarctica is one of the most environmentally extreme locations on Earth, being the coldest, driest and windiest continent. The vast majority of Antarctica is covered by ice sheets, averaging over 1.6 km thick, which are effectively lifeless zones. However, approximately 2 % of mostly coastal terrestrial surface is annually ice-free, allowing the survival and growth of certain animal, plant and microbial life forms. And dominating the terrestrial vegetation, both in terms of biomass and biodiversity, are one of the ultimate examples of life in the freezer – the Antarctic lichens.

Living together in the cold

Lichens are symbiotic organisms composed of two microbial partners: a fungal partner, thought to recruit nutrients and water and provide environmental shelter, and a photosynthetic partner, normally a green alga (or occasionally a cyanobacterium) that provides a carbohydrate source for growth. The partners come together to form a characteristic lichen 'thallus', which may have a flattened (crustose), leafy (foliose) or shrubby (fruticose) growth form. The symbiosis allows lichens to survive and grow in environmentally stressed habitats where there is little competition for resources, with lichens found worldwide in areas subject to low nutrient supply, extreme temperatures and low water availability.

In the case of the Antarctic, over 350 species of lichens have been reported from continental and maritime regions. Lichens are found particularly in coastal areas where they occur on various rock surfaces and skeletal soils, especially those near to bird colonies that receive nutrient input from aerosols. Certain *Usnea* species may form extensive stands covering several hectares in maritime Antarctica. However, lichens can also be found inland where ice-free rocky outcrops known as 'nunataks' occur. Indeed, lichens hold a world



◄ Adelie penguin rookery at Cape Hallett, Ross Sea, East Continental Antarctica.

▲ Top Dark grey-black coloured crustose thalli of *Buellia frigida*, together with foliose *Umbilicaria deccusata* growing on rocks near Rothera Station, Antarctic Peninsula. The dark pigmentation may confer resistance to elevated UV-B radiation and promote thallus warming.

▲ Bottom A colourful show of lichens, including species of *Caloplaca*, *Candelariella* and *Xanthoria*, growing on nutrient enriched rocks and soil at the site of a former penguin rookery near Casey Station, East Continental Antarctica.

Photos Peter Crittenden

record for the most southerly discovery of macroscopic life on Earth, with thalli of *Carbonea*, *Lecidea* and *Sarcogyne* species found at a latitude of 86° 29′ South within continental Antarctica.

Adapting to the cold

Conditions for survival and growth in Antarctica are really not pleasant. The Antarctic winter is bad enough. In regions where lichens are found, there are extended periods of darkness in the depths of winter and temperatures may plunge to between –20 and –50 °C. This may be alleviated somewhat by snow cover, which may buffer the most extreme cold. However, even the brief Antarctic summer provides its own challenges. Air temperatures may rise to just above freezing during the day, but substrata and their accompanying lichens may become much warmer as they are heated by the sun and may reach in excess of 30 °C. With night temperatures dropping to well below freezing, lichens can be exposed to a daily change of temperature in excess of 40 °C combined with a freeze/thaw process. Quite a challenge to any physiology! In addition, lichens are exposed to potentially damaging levels of solar radiation, especially given the depletion of ozone cover over the Antarctic during the past 30 years, and significant areas of Antarctica are in effect deserts due to very low rates of precipitation.

Given these extreme conditions, a number of physiological adaptations have been identified in Antarctic lichens which may allow them to survive the harsh winter and sustain growth for brief periods during the Antarctic summer when favourable conditions occur. First, lichens are able to survive extended periods of freezing in a dormant state. Second, some lichens have been shown to remain physiologically active at temperatures well below freezing, with photosynthesis shown to occur at temperatures as low as –24 °C, albeit at very slow rates. Third, they are able to survive in a desiccated state, and then rapidly rehydrate when exposed to water such as snow melt or humid air. Some *Xanthoria* species can even begin to photosynthesize within 5 minutes after rehydration! Furthermore as a probable response to elevated UV-B levels and as a possible adaptation to allow warming, several lichens species have dark-coloured or black thalli. Indeed, levels of the pigment usnic acid in *Usnea* species have been shown to vary according to season and incoming UV-B levels.

Nutrients such as nitrogen and phosphorus are also in very short supply over much of terrestrial Antarctica, which can limit lichen growth. Indeed, large animal colonies such as penguin rookeries have a major influence on lichens. Recent work by the Nottingham group in collaboration with CEH Edinburgh and Antarctica New Zealand has shown that ammonia released from the breakdown of penguin faecal matter and other debris can influence lichen chemistry and physiology at distances up to tens of kilometres from a rookery. Closer to rookeries, at distances of 10 to several hundred metres, is a highly eutrophicated zone in which distinct lichen communities are found, typified by yellow and orange species of *Xanthoria*, *Candelariella* and *Caloplaca*. It is tempting to speculate that responses of Antarctic terrestrial plant and microbial communities to climate warming will be most evident within the relative hot-spots of nutrient availability surrounding animal colonies.

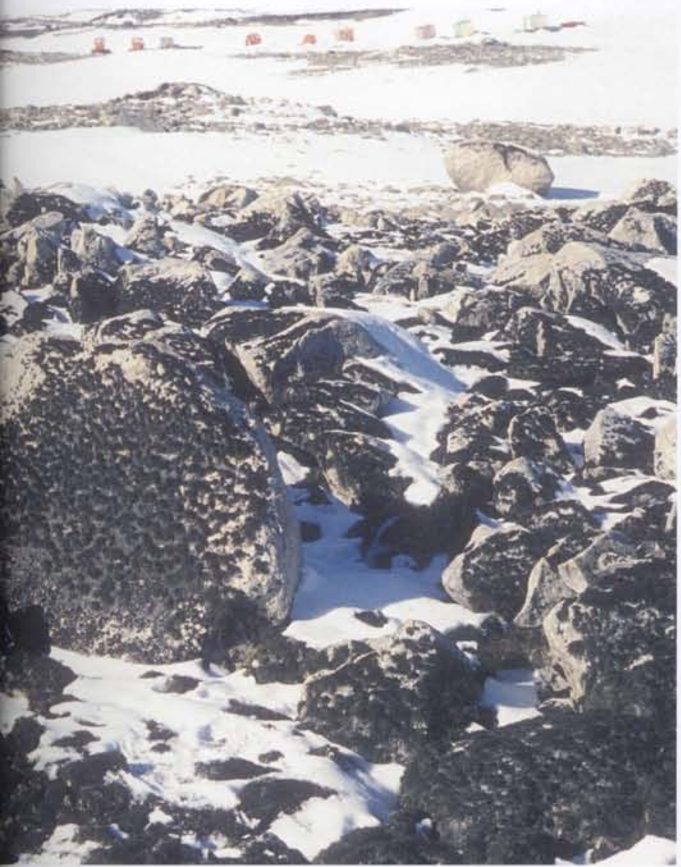
Life in the rocks – extraterrestrial clues?

In addition some lichens have adapted a very unusual lifestyle, resorting to living within the surface of soft rocks such as sandstone, thereby gaining shelter from the harsh external environment. These 'cryptoendolithic' symbionts have been found growing at depths up to about 2 cm within translucent, porous rocks found in arguably the most

▲ Top The widespread and locally abundant fruticose lichen *Usnea sphacelata*, growing near Casey Station, East Continental Antarctica. Note the presence of the yellow pigment usnic acid.

▲ Bottom Lichen-dominated rock field near Casey Station, East Continental Antarctica. Note especially the presence of black-coloured fruticose *Usnea sphacelata*.

Photos Peter Crittenden



extreme environment on Earth – the intensely cold, ice-free 'McMurdo Dry Valleys'. Indeed, these Antarctic environments may provide the closest terrestrial equivalent to conditions on Mars. Intriguingly, the lichen *Xanthoria elegans* has been shown to survive exposure to outer space, on a recent space shuttle mission, and the predicted pressures of meteor impact. This has led to speculation that lichens may even be able to colonize planets via transport on meteorites. Could the fact that many lichens have the same orange colouration as Mars be in any way connected?

Some unique features

Antarctic lichens also have other specialized features. Some species exhibit the phenomenon of 'gigantism', referring to the presence of unusually large growth forms, often in stable but harsh environments. Exceptionally large thalli of *Buellia* and *Placopsis* species greater than 50 cm in diameter have been discovered. Although little is known of their growth rates, it is estimated that these may be from 500–5,000 or more years old. Another unusual feature is the specificity of the symbiotic interaction. In many temperate environments the fungus–photobiont interaction is very specific, requiring the involvement of particular species of symbiont. However, in the Antarctic this specificity appears to be relaxed, with the fungal partner able to establish a lichen symbiosis with a range of photosynthetic partners. This has been interpreted as an adaptation to ensure that the lichen symbiosis can occur given the restricted availability of potential partners.

Finally, lichens found in Antarctica may represent a key component of global lichen diversity. Certain species, such as the widespread *Buellia frigida*, are endemic to the Antarctic, meaning that they are only found in this region. Other Antarctic lichens have a bipolar or more widespread worldwide distribution. However, our ongoing work has revealed that although lichens such as *Xanthoria elegans* and *Ochroloechia frigida* from the Antarctic might appear morphologically identical to other specimens from around the world, they in fact have distinct genetic and physiological features. Thus, they might represent novel ecotypes, adapted to the harsh environmental conditions of the Antarctic.

Looking to the future, lichens are well established as biological monitors of environmental conditions. Given that the Antarctic appears to be particularly vulnerable to climate warming, changes in the populations of Antarctic lichens might provide a timely warning that we are defrosting the freezer at our own peril.

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Ship ballast tanks: how microbes travel the world

As the international shipping fleet travels the oceans, it carries with it hidden cargoes of microbes. **Fred C. Dobbs** explores the hazards posed and describes what can be done to counteract them.

Engines rumbling at low r.p.m., every commercial ship chugging into every port in the world inadvertently carries with it stowaways. No romantic adventure or piratical skullduggery at work here – these stowaways are micro-organisms entrained with water deliberately brought within the ship's hull and held in its ballast tanks. Such tanks are designed to hold enormous quantities of water – each has a capacity of hundreds, even thousands of metric tonnes – and are crucial to ships' cargo operations and safety at sea. By pumping water in or out of these tanks and adjusting the ship's waterline, the crew can compensate for cargo loading, increase propulsion efficiency and maximize the ship's stability in rough waves.

Huge amounts of ballast water are transported every day as the global fleet plies its trade. Any organisms that have

◀ A cargo ship in port at Gustavia, St Barts, West Indies. *Photos.com / Jupiter Images*

▶ Scientists sampling residual water inside a ship's emptied ballast tank. *Fred C. Dobbs / Old Dominion University*

survived since 'coming on board' are liable to be released when ballast water is next discharged. Unfortunately, we know all too well that many non-native (also called 'non-indigenous') invertebrates and plants have been introduced to new environments in this manner. Some of these introduced species proliferate, their populations released from control by predators, parasites or other factors. When they out-compete and deleteriously affect native organisms, we further classify them as 'invasive species'. In some spectacular cases, such as the zebra mussel in North America and the comb jelly in the Black Sea, invertebrates introduced by ballast water have fundamentally altered the ecosystem to which they were delivered. Such drastic ecological changes have also precipitated significant economic expenditures, e.g. to remove attached zebra mussels from industrial water-cooling systems, and in the Black Sea, wholesale collapse of fisheries.

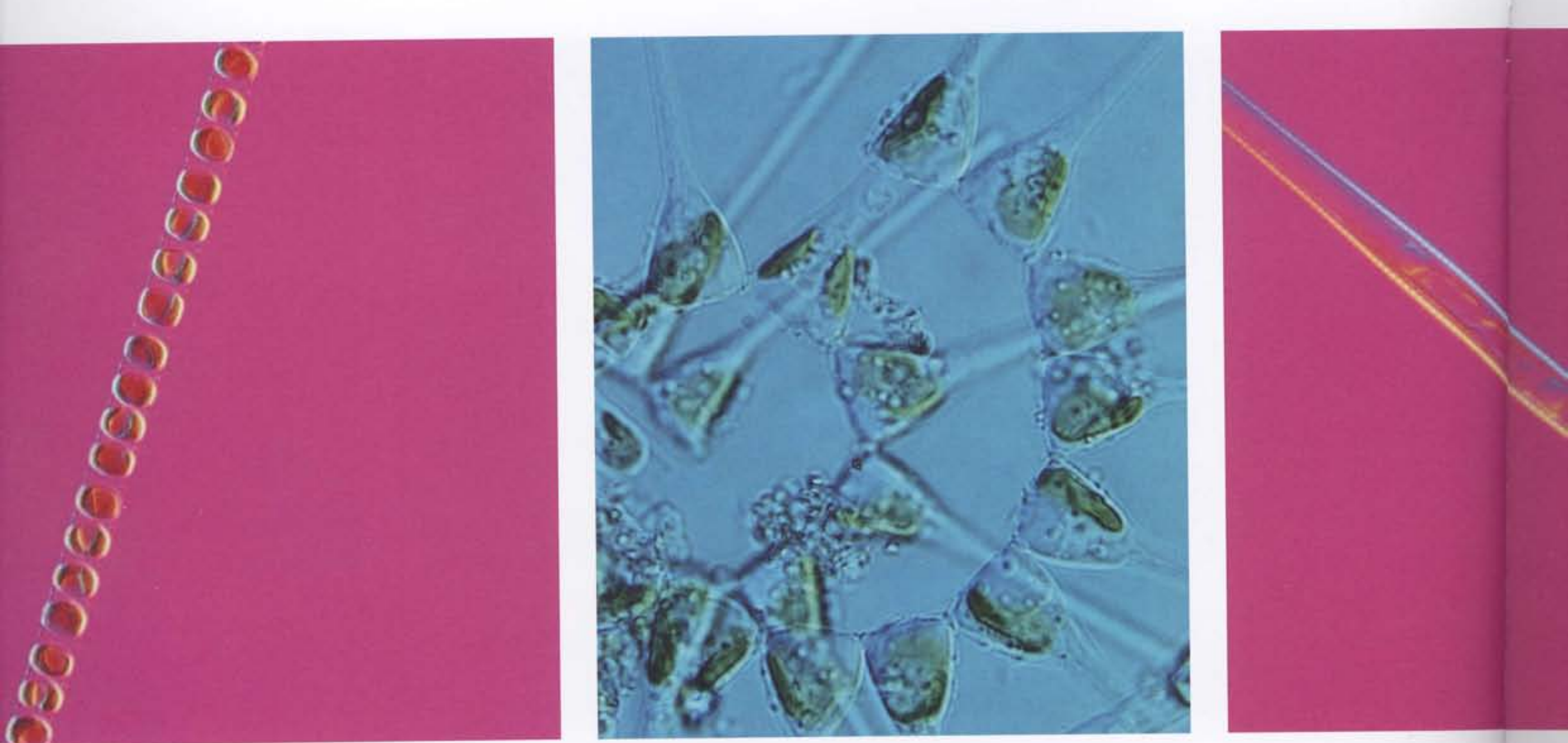
In a parallel sense, are there inimical consequences to transporting and disseminating aquatic micro-organisms in ships' ballast tanks? We are certain only that scenarios envisioned by some have been sufficiently of concern to promulgate regulations concerning ships' handling of ballast water. What are those scenarios and how have they contributed to regulations facing global shipping?

Micro-organisms in ballast water – can they be 'non-indigenous'?

For more than 20 years, scientists have reported a variety of large, easily recognized phytoplankton (e.g. dinoflagellates and diatoms) and protozoa (e.g. ciliates and foraminifera) in ballast water. On the other hand, the diversity of smaller, less readily discerned forms, especially bacteria and viruses, is nearly unknown. We do know something, however, about their abundance. In lakes and oceans, every millilitre of surface water contains about 10^2 protists, 10^6 bacteria, and between 10^7 and 10^9 viruses. It is inevitable, therefore, that hundreds of trillions of micro-organisms enter a single ship's ballast tanks during normal operations.

Although the overwhelming majority of these aquatic micro-organisms is not harmful to humans, some species in ballast water do indeed represent potential risks to public health, notably pathogenic bacteria such as *Vibrio cholerae*, the aetiologic agent of human cholera, and dinoflagellates, some species of which are responsible for harmful 'red tides'. Other pathogens and faecal-indicator micro-organisms reported from ballast tanks include: enteroviruses, *Escherichia coli*, enterococci, *Cryptosporidium parvum* and *Giardia duodenalis*. Reported harmful algae species include: *Pfiesteria piscicida*, *P. shumwayae*, *Aureococcus anophagefferens*, *Microcystis* spp. and *Anabaena* spp. While to the best of our knowledge, no outbreaks of disease have been associated with ships' ballasting activities, it is only on very, very rare occasions that ballast tanks are sampled for their microbiological inventories.

Are there microbes discharged with ballast water that could be classified as non-indigenous species? The answer is not as clear as it is for invertebrates, and microbial ecologists debate the biogeographic distribution of microbes. Some argue free-living bacteria and protists must be distributed worldwide, simply because their small size facilitates their dispersal. If micro-organisms indeed are ubiquitous in their distribution, then they cannot be considered to be non-indigenous. Another school of thought disagrees and contends some microbes clearly do have a biogeography. Many examples support this contention, among them inter-oceanic transfers of marine phytoplankton species. The English Channel and coastal European seas, for example, have in the past century experienced introductions

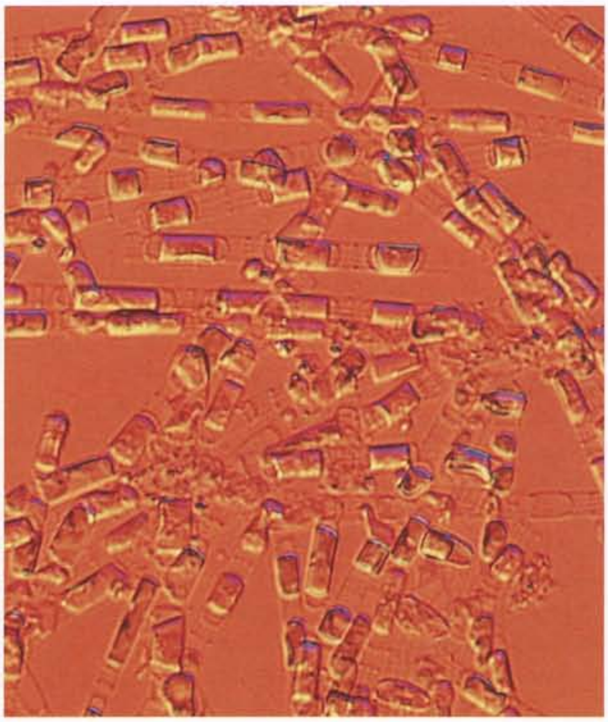


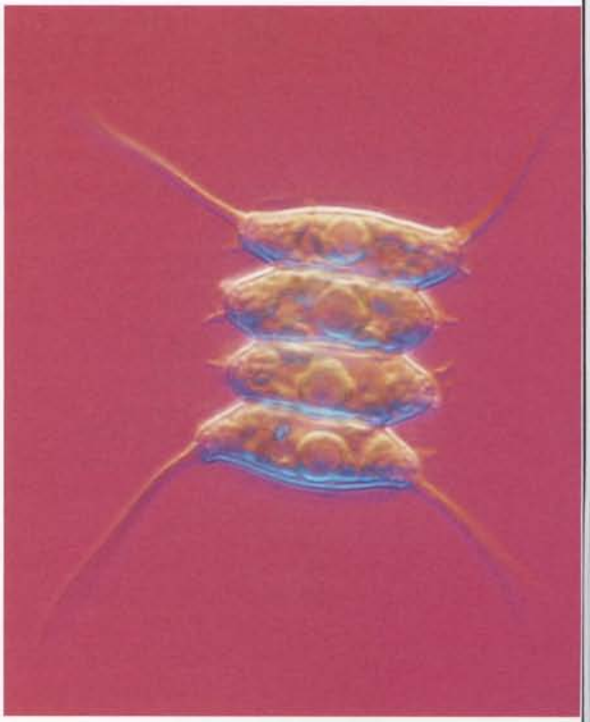
▲ A range of phytoplankton such as those found in ship ballast water. From left to right: unidentified chain-forming centric diatom; *Asterionellopsis glacialis* (diatom); unidentified pennate diatom; *Skeletonema costatum* (diatom); *Scenedesmus* sp. (colonial green alga). *Lisa A. Drake / United States Coast Guard Academy*

of two diatom species, *Odontella sinensis* and *Coscinodiscus waelesii*, phytoplankton previously known from the East China Sea and North Pacific coasts, respectively. If the second group of scientists is correct, then aquatic micro-organisms can be non-indigenous, are therefore potentially invasive, and their presence in ballast water is indeed of concern.

Regulations and technological solutions

While microbial ecologists have not resolved the biogeography argument, many government and international agencies have, in a sense, already decided for themselves. Consider microbiological mandates proposed by the International Maritime Organization (IMO), which sets rules and standards for the global shipping industry. The IMO has issued an 'International Convention for the Control and Management of Ships' Ballast Water and Sediments', now being considered for ratification by its member states. It reads in part: '*Ships conducting ballast water management shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 µm in minimum dimension and less than 10 viable organisms per ml less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension…*' Numerous species of aquatic micro-organisms, notably fresh- and saltwater phytoplankton and protozoa, fall into these size-predicated limits, particularly the smaller one. While the IMO Convention has no specific call-outs for total numbers of bacteria, it does stipulate maximum concentrations for *V. cholerae*, *E. coli* and intestinal enterococci.





In the United States, there are no similar federal regulations and in their absence, several states are enacting their own. California, for example, has issued standards for discharged ballast water that call for orders-of-magnitude reduction in total bacteria and total virus numbers relative to their natural concentrations.

How will ships reduce the number of micro-organisms discharged with their ballast water? The past decade has seen a flurry of technological development in this regard, and a cornucopia of techniques has been tested in the laboratory and in full-scale, land-based installations. In a few cases, treatment units have already been installed on ships. Proposed technologies range widely in their mechanisms, from filtration to biocides, ultrasound to ultraviolet irradiation, and more. It is imperative, of course, that the treatment does not corrode the steel ballast tanks, and furthermore, it must yield water that meets any chemical discharge standards for harbours. What a challenge it will be for technologies to effect such low numbers of micro-organisms in enormous volumes of discharged ballast water! And what an equally daunting challenge for scientists to measure those numbers accurately!

Playing Johnny Appleseed?

There is a folk legend in the US about a character named Johnny Appleseed, who, as he roamed the mid-western portions of the country in the first half of the 19th century, sprinkled apple seeds wherever he went. The result – apple trees proliferated and the region was characterized by an abundance of orchards. Are we playing Johnny Appleseed with aquatic micro-organisms as global shipping inadvertently spreads them around the world in discharged ballast water? And if so, need we be concerned that some of those microbes are harmful? Certainly these questions are ones of considerable interest to microbial ecologists, but given the context, are pertinent to water-quality managers and regulatory agencies as well. Our understanding of the issues involved will increase as additional and more sophisticated studies are performed, especially those employing the tools of modern molecular biology.

Fred C. Dobbs
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Further reading

Dobbs, F.C. & Rogerson, A. (2005). Ridding ships' ballast water of micro-organisms. *Environ Sci Technol* 39, 259A–264A.

Ruiz, G.M. & others (2000). Global spread of micro-organisms by ships. *Nature* 408, 49–50.

www.europe-aliens.org/index.jsp
DAISIE – Delivering Alien Invasive Species Inventories for Europe. Inventories of alien species in Europe, many of which represent ballast-water introductions.

www.imo.org/home.asp – International Maritime Organization

meetings

Autumn08 | Trinity College Dublin

8–11 September 2008 | 163rd Meeting

Plenary

Behaviour of biofilm bacteria: from cooperation and communication to control

8–9 September 2008

Organizers: G.M. Gadd, P.S. Handley, P.R. Langford, H.M. Lappin-Scott, M.M. Tunney, M. Upton & J. Verran

Speakers

Biofilm basics

J. Verran Manchester – *Prologue – setting the scene*

H.M. Lappin-Scott Exeter – *The role and significance of biofilms in nature, infection and industry*

A. McBain Manchester – *Laboratory models for biofilm maintenance and growth-rate control*

M. Upton Manchester – *Exploring biofilms using molecular techniques*

A.H. Rickard USA – *Microscopic analysis of biofilm community structure*

J. Verran Manchester – *Resources for biofilm education*

Bacterial biofilm structure and organization

P.B. Rainey New Zealand – *Evolution of species interactions in a biofilm community*

P. Stoodley USA – *Forces affecting biofilm structure and organization*

K. Sauer USA – *Temporal gene expression in biofilms using proteomic approaches*

J. Webb Southampton – *Dispersal in biofilms*

H.K. Flemming Germany – *Extracellular polymeric substances in biofilms*

T. Tolker-Nielson Denmark – *Extracellular DNA in bacterial biofilms*

Biofilm communication, resistance and control

S. Molin Denmark – *Adaptation and evolution of* Pseudomonas aeruginosa *to a biofilm lifestyle in the CF lung*

M.R. Parsek USA – *Intercellular signalling and biofilm development*

P. Kolenbrander USA – *Community composition and communication in biofilms – species interactions*

D.A. Spratt London – *Metagenomic analysis of bacterial communities*

G. Seymour New Zealand – *From dental plaque to periodontitis and cardiovascular disease – why worry about biofilms?*

M. Givskov Denmark – *The future of biofilm control using quorum sensing inhibitors*

P. Gilbert Manchester – *Mechanisms of bacterial biofilm resistance to antimicrobials and the 'Persister' theory of resistance*

Other symposia

Innate immunity systems

10–11 September
Cells & Cell Surfaces/Microbial Infection Groups
Organizers: I. Henderson & A. Cunningham

Biofilm infection of medical devices

10 September
Clinical Microbiology Group
Organizers: D. Mack & M.M. Tunney

Makeover for SGM meetings

From 2009, Society meetings will have a new look. The scientific sessions over three and a half days will cover the latest topics in modern microbiology, within a framework of fewer parallel sessions in the mornings, standalone keynote lectures and afternoons packed with workshops, debates, demonstrations and mini-symposia catering for all areas of microbiological science. Poster-viewing will take place over a drink in the evenings. Career development and microbiology education will also be covered. The ever-popular Gala Dinner will retain its Tuesday evening slot.

Spring09 | Harrogate International Centre

30 March–2 April 2009

Legacy of Fleming – 80 years since the discovery of penicillin

80 years after Alexander Fleming discovered penicillin, our scientific sessions will consider the latest developments in the diagnosis, prevention, control and treatment of infectious diseases. Topics include: Impact of medical intervention on evolution of microbes / Multidrug-resistant TB / Production, formulation and delivery of antimicrobials / New antibiotics / Infection control / Novel therapeutics / Susceptibility to infection and disease / Mechanisms of resistance / Staphylococci / Bedside diagnostics / Molecular evolution of virus pathogens.

Related events are on: Lessons in history – the microbiology of war wounds / The human microbiome

Other sessions will focus on: Molecular virology / Environmental microbiology / Metagenomics / Food preservation.


Infective endocarditis

11 September
Clinical Microbiology Group
Organizers: S. Lang & D.R. Ready

Industrial bioremediation: from contamination to clean-up

10–11 September
Environmental Microbiology Group / Irish Branch
Organizers: C. Whitby & E.M. Doyle

Packaging of nucleic acids

10–11 September
Eukaryotic Microbiology Group
Organizers: M.L. Ginger, A.S.H. Goldman & S.K. Whitehall

Fuels and chemicals from renewable feedstocks

9 September
Fermentation & Bioprocessing Group
Organizer: G.M. Stephens

Microbial adhesion to food matrices

10 September
Food & Beverages Group
Organizers: C.E.D. Rees

Sealed membranes: the structural basis of transport and energetic processes

10–11 September
Physiology, Biochemistry & Molecular Genetics Group / Irish Branch
Organizers: F. Sargent & G.M. Fraser

Annual General Meeting

9 September

Young Microbiologist of the Year Competition

9 September

Abstracts

Deadline for receipt of titles and abstracts for offered presentations: **9 May 2008**.

Accommodation

For this event, overnight accommodation is not available through the Society. Instead it can be booked directly via Conference Partners:

www.conferencepartners.ie/sgm2008/
t +353 (0)1 296 8688
e lisa@conferencepartners.ie

There is an All Ireland Gaelic football match in Dublin w/c 8 September, so please book your accommodation early to avoid disappointment.

Autumn**09**

Translational microbiology

Heriot-Watt University, Edinburgh – 7–10 September 2009

Abstract**Book**

EICC meeting, Spring 2008 – Now available as PDF on the SGM website.

Irish**Division**

Spring 2009

Innovative models and systems for studying microbial pathogenesis
University of Cork, Ireland

For further details, contact Evelyn Doyle (e evelyn.doyle@ucd.ie).

Other**Events**

SGM/Royal Microscopical Society joint meeting

Microscopy and microbes
Excel, London – 24 June 2008
www.microscience2008.org.uk

Biochemical Society/SGM

Molecular biology of Archaea
St Andrews – 19–21 August 2008
www.biochemistry.org/meetings/programme.cfm?Meeting_No=SA079

Federation of Infection Societies Conference

Cardiff City Hall – 2–4 December 2008
www.fis2008.co.uk

Registration

Registration is through the SGM website (www.sgm.ac.uk/meetings).

Registration fees per day (*incl. all refreshments, conference literature, welcome reception*)

Earlybird (up to 8 August 2008)	
Ordinary Members*	£40
Student/Associate Members*	£20
Non-members	£110
Retired/Honorary Members	Free
Full (after 8 August 2008)	
Ordinary Members*	£50
Student/Associate Members*	£30
Non-members	£120
Retired/Honorary Members	£10

**Please note: to qualify for earlybird rates, 2008 membership fees must be paid by the deadline of 8 August.*

Meetings on the web

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

Meetings organization

The organization of SGM meetings programmes is co-ordinated by the Scientific Meetings Officer, **Professor Hilary Lappin-Scott**. Suggestions for topics for future symposia are always welcome.

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

Abstracts

Titles and abstracts for all presentations are required in a standard format and should be submitted through the SGM website. Deadlines apply. For further information contact the Events Administrator.

schoolzone

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

Medicines from fungi

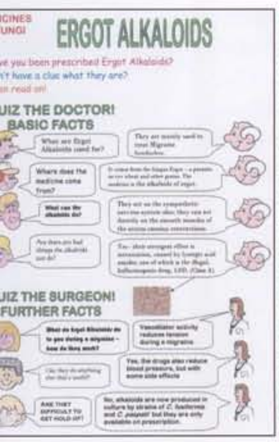
Wednesday 9 April saw the judging of the ever-popular annual competition run by the Microbiology in Schools Advisory Committee (MiSAC). This year it was sponsored by the British Mycological Society with the theme of 'medicines from fungi'. It aimed to increase awareness of the wide range of pharmaceutical products that are derived from fungi.

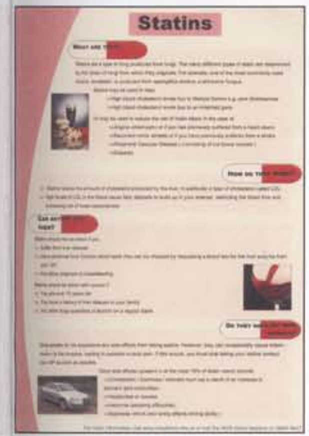
The brief was to design a patient factsheet about a drug of fungal origin and the breadth of drugs researched was impressive (even some of the judges learned a thing or two!). Penicillin was a popular choice and many students showed high levels of understanding of key concepts, including penicillin's mode of action, antibiotic resistance and the ineffectiveness of antibiotics against viral infections.

77 schools took part with a total of 584 entries (412 at Key Stage 3 and 173 at Key Stage 4). A special mention goes to the Vasile Alecsandri High School which submitted students' work all the way from Romania. The overall standard of entries was pleasing, with work that was informative, imaginative and beautifully illustrated (although some entries featured gruesome images of fungal infections!). There are certainly some budding science communicators and medical writers in our midst.

Judging of the Key Stage 3 category was difficult and the first prize was chosen due to its clarity of information combined with creative presentation. This winning entry, a 'Quiz the Doctor' factsheet about the use of ergot alkaloids to treat migraines, was created by Sian Deasy of Hounsdown School in Southampton. Second prize went to Nadia Fernandes of Sheffield High School whose fact file on statins was professionally presented. Robyn Lawrence of Diss High School was awarded third prize for his detailed work on penicillin. Entries from Dawn Buchanan of Edgbaston High School, Jack Linley of Kirkham Grammar school and Alice Elliot of The Mount School, York were all highly commended.

The short listed Key Stage 4 entries were extremely good and choosing between them was demanding. First prize was eventually awarded to Holly Emms of the King's School Ely for her fact sheet on statins that was so concise, accurate and well presented that it could easily have passed for a real NHS patient leaflet! Lizzie Vale of St Nicholas' School was awarded





second prize for her eye-catching work on the role of griseofulvin in treating athlete's foot. Third prize went to Ushna Qureshi of Rugby High School for her well organized work on statins. The judges were all impressed by the work of Bea Xu and Sandra Fahmy whose excellent cartoon strip was awarded a commendation for creative design. The work of Tessa Gwart and Kirsten Wilkinson of George Heriot's School, Edinburgh and Vivek Murthy of King Henry VIII School, Coventry was also highly commended.

The competition continues to be a great success, not only with themes that remain relevant to the science curricula, but with tasks that help students develop valuable skills, for example the ability to carry out independent research, select and explain appropriate scientific information and present it in a style appropriate for a target audience. We look forward to next year's competition which will be sponsored by SGM and focus on the role of microbes in the topical issue of climate change.

Gemma Sims, SGM

▲ Some of this year's judges inspecting the entries. From left to right: Martin Adams (SfAM), Maurice Moss (BMS), Anthony Whalley (BMS), Margaret Whalley (BMS), Lucy Goodchild (SGM) and Gemma Sims (SGM).

◀ Opposite page KS3 winners (from left to right, 1st, 2nd and 3rd) and the KS4 creative design award winner.

◀ This page KS4 winners (from top to bottom, 1st, 2nd and 3rd).

Science education in flux

www.qca.org.uk/qca_13575.aspx

www.ltscotland.org.uk/5to14/about5to14/curriculumforexcellence/introduction.asp

The whole UK education system has been experiencing a vast amount of change. In England and Wales the Key Stage 3 National Curriculum has been under review and changes to it will be implemented from September. Current Year 11 students, who will be sitting their GCSEs imminently, are the first cohort to complete the new GCSE science courses launched in September 2006, such as OCR's *Science in the 21st Century* and Edexcel's *360° Science*.

This academic year science teachers have been furiously attending courses to help them get up to speed with the changes to the new GCE AS and A2 science specifications, due for launch in September 2008. In addition, Ed Balls, the Secretary of State for Education, announced in October 2007 that a new Science Diploma would be introduced in 2011 (a decision originally rejected by his predecessor, Alan Johnson). Diplomas in other subjects, such as IT and Engineering, will be launched in September 2008 and are expected to be available alongside GCSEs and A levels. It is claimed that these new qualifications will allow students to develop functional skills (for example in ICT and numeracy), thinking skills and enhance personal learning, as well as acquire subject-specific knowledge. Diplomas will also contain compulsory work experience and project work. It is not known what the content of the new Science Diploma will be and at the time of writing the government has no plans to replace GCSEs and A levels with diplomas, although some education commentators are predicting the opposite.

In Scotland the 3–18 curriculum is also under a review called a *Curriculum for Excellence*. The Scottish Government regards science education as important and is putting a lot of money into developing new resources.

Whatever happens, these changes will have an impact on the transition from school to university and admissions tutors could find it hard going to stay up-to-date in the rapidly evolving scene.

Projecting microbiology

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

The Nuffield Foundation offers 1,450 funded places a year, in two separate schemes, for aspiring young scientists. The schemes provide summer project opportunities in leading scientific industries, research institutes and UK universities. The SGM has its own vacation studentship grants for microbiology undergraduates, but we are very pleased to fund 10 Nuffield Schools and Colleges Bursaries each year, which are aimed at students in the first year of an advanced or higher level STEM course. They are able to join a real research project with practising scientists. Projects run for 4–6 weeks in the summer vacation and students receive a £75 a week bursary. In our case, once Nuffield has received our sponsorship they contact the Regional Co-ordinators who organize the placements and ask if they have any students specifically seeking a microbiology project. The SGM money then goes towards these placements.

After completing their projects, students attend local events where they display them to an invited audience of teachers, other students and representatives from industry, universities and research institutes. Many receive prestigious BA CREST Awards as a result and some go forward to compete in the BA CREST National Science Fair.

Listed below are examples of some of the microbiology projects that students carried out in 2007:

Project provider	Project title
GlaxoSmithKline	Cloning and characterization of a fungal gene
John Innes Centre	Crystallization of DNA gyrase from *Mycobacterium tuberculosis*
John Innes Centre	Bionanoscience: exploring the virus-chemistry interface
Scottish Association for Marine Science	The vitamin requirements of two microalgal species
Division of Infection & Immunity, University of Glasgow	Producing inactive kinase enzymes to aid the study of cytokinesis in *Trypanosoma brucei*
Agri-Food and Biosciences Institute, Belfast	Detection of DNA from harmful bacteria in foodstuffs
Queens University, Belfast	Food microbiology
Mourne Country Meats Limited	Cooking/cooling against microbiological levels in cooked ham
Dept of Civil & Environmental Engineering, UCL	Sources and flux of microbiological pollutants in air in urban environments
BPL	Developing a method for the examination of microbiological bio-burden of detergent solutions
NIMR	How mouse malaria affects the stem cell progenitors of blood cells
Health Protection Agency	Stabilization of recombinant anthrax vaccine

The Nuffield Foundation is always seeking project supervisors, so if you are interested in offering a placement, do contact the National Co-ordinator, Sharmila Banerjee (s.banerjee@nuffieldfoundation.org).

A website to support practical biology

www.practicalbiology.org

The SGM is providing sponsorship for a project being initiated by the BioSciences Federation (BSF) in partnership with the Nuffield Curriculum Centre (NCC).

The new website will support teachers in delivering practical work in schools, along the lines of the already well-established sites the NCC runs with the Institute of Physics (www.practicalphysics.org) and the Royal Society of Chemistry (www.practicalchemistry.org). The site will list practical ideas to support biology teaching by topic, and it will be easily searchable. The activities will be presented in a standard format, to include health and safety considerations as well as suggested teaching approaches and questions for the students.

The website is currently in development, but member organizations of the BSF will be invited to contribute practical investigations, which will be moderated by the NCC and put into the standard format if approved. SGM will, of course, be submitting some tried and tested microbiology experiments for consideration.

Further information will be provided in Schoolzone once the site is live.

gradline

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

Getting

For many researchers in the middle of experimental work or about to tackle their theses, publishing doesn't really make it to the top of their priority list. However, many of their supervisors will be looking for publishing opportunities – why the contrasting approaches? **Charles Penn**, Editor-in-Chief of *Journal of Medical Microbiology* shared his perspective (as editor and author) with early career microbiologists at the SGM Spring Meeting in April this year.

There is no doubt that publication is used as a measure of research output and success. Researchers can only enhance their career prospects if they publish early in their careers. However, there are a number of factors to consider.

Before you start

Bear in mind that some research output is inherently unpublishable on its own. Raw data such as sequences and survey results need a biological context and a research ethos. Mainstream, high-impact journals mainly (but not exclusively) publish hypothesis-driven research.

If at all possible, experiments should be designed with publication in mind, considering factors such as controls and the importance of multiple lines of evidence. You should also rule out all alternative explanations for your observations. Sometimes it can help to outline your papers at the early stages of your experiments. Publishing strategy is also important – do you want one high-impact paper or several smaller papers? Aiming for a big paper is tempting (and can bring great rewards), but it does require better evidence to tell a complete story, which takes longer to gather. Lesser observations that don't fit together well are better suited to publication as several small papers.

You should be aware of potential competition from other research groups. By keeping up to date with the literature you will know who is doing what. However, published research is at least several months old, so an informal ear (most often your supervisor's) to the ground can keep tabs on the activities of rival labs. If there are other researchers in your field, perhaps you can develop a unique line or niche to avoid duplication of work. Sometimes there is scope for collaboration, which can avoid conflict or limit damage.

If there is a risk of your research being scooped, you should consider your publication options. The first paper on a topic receives the most attention. Even if a second paper is more thorough, it may be less well noticed, so in this situation it might be wise to consider the likelihood of rapid publication once the paper is submitted.

When outlining your paper, early considerations are: what will be the paper's message(s) and where will you publish

published

it? Then you should look at the main lines of evidence; identify the section headings, select data for figures and tables, and decide on your discussion points. You should also be looking for any gaps in the data. If you can draft or write some of the paper ahead of finishing the lab work it can give you an opportunity to generate data to close the gaps.

Strategy is all

It is a good idea to have a publishing strategy. First of all, what type of paper are you writing? Do you have enough data (and the time) to write a primary research paper? Or do you have data from a side piece of work that would be better suited to publication as a note or letter?

Choice of journal is also important and this should be discussed with your supervisor. It is always good to aim for a journal with an excellent reputation and high impact factor since it will probably result in a high level of citation. But you do need to cast a realistic eye over your data. If there is a real risk of rejection by the big name journals and timings are critical, it might be better to target a less high-profile publication where you have a better chance of being accepted. In other words, don't waste time aiming for the impossible. This can be a difficult judgement to make and sometimes an objective eye from outside your group can be very useful.

Speed of turn-around is another consideration: some journals publish within a few months of initial submission, whereas there are a few where the editorial process can take over a year.

Getting down to writing

If at all possible, take the initiative and write the first draft yourself, preferably before you dive into thesis writing. If you leave it too late, the paper might never happen, either because you move on to other things or someone else publishes first. Supervisors do sometimes sit on drafts of papers for weeks or months so you may need to drive things on with gentle reminders. But don't expect an immediate turnaround either; your paper might be one of many items requiring input.

For publication in a journal (and to prevent your first draft coming back from an irate supervisor!), your writing should be clear, concise, easy to read and informative whilst not being too speculative (i.e. don't read too much into the data). It is important not to duplicate data – present them either as a table or a figure. Sometimes it is appropriate to include the results in the narrative rather than include too many tables and figures. Asking an experienced outsider to cast a friendly but critical eye over your writing can be very helpful at this stage.

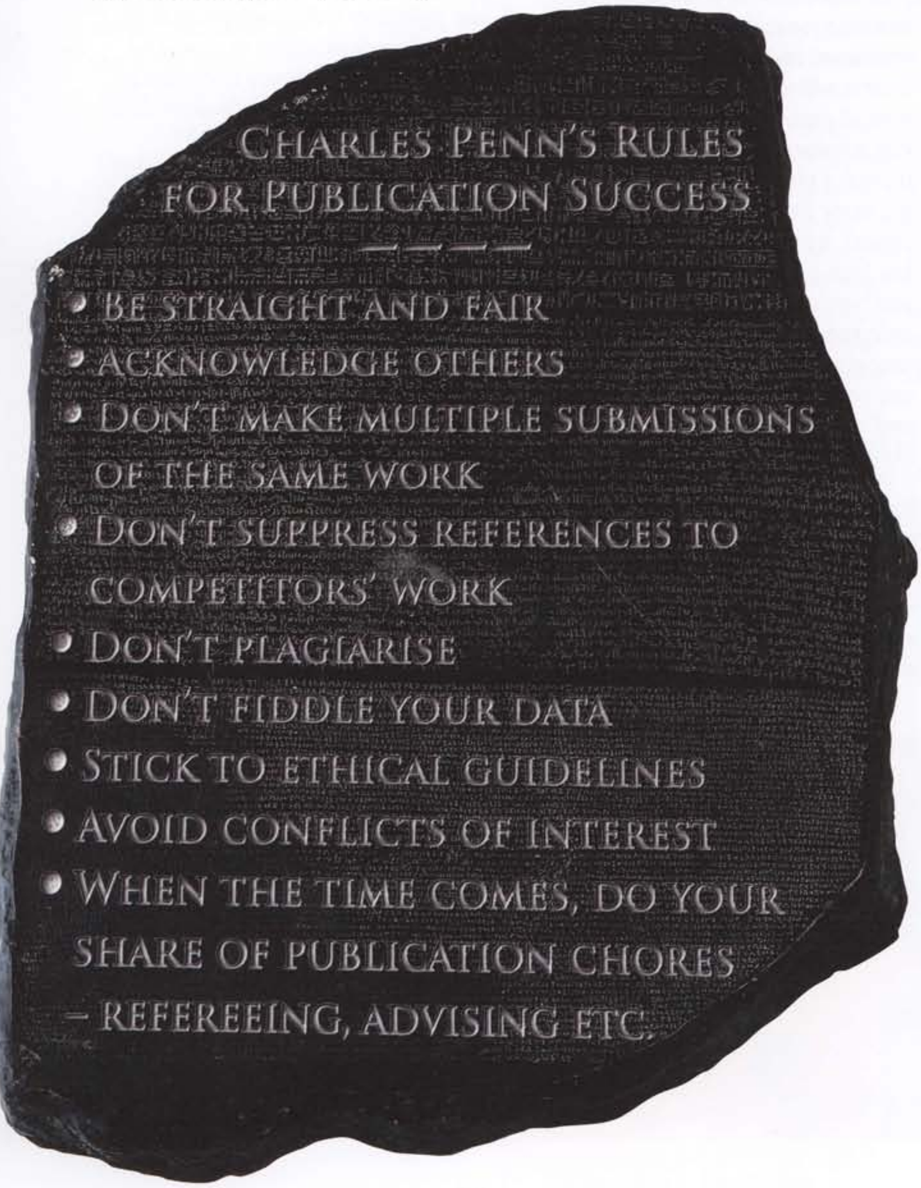
The finished paper

First impressions count, referees and editors are at best irritated by a poorly prepared paper. At worst, the quality of your research could be undermined by the lack of attention to detail in the presentation. You should aim for perfection – that means no spelling or grammatical errors and maintaining consistency in figures and table numbering. Using referencing software will help you avoid errors in your reference list. Don't forget to include acknowledgments and thanks to collaborators. Author inclusion can be tricky; generally speaking all should have contributed meaningfully to the work. Common convention is that the main worker's name should go first followed by significant helpers and the principal investigator's name should be at the end. Those who made a less significant contribution tend to appear in the middle of the list. Discuss this with your supervisor.

Submission

Once you are ready to submit your paper, read the journal's rules and advice. You should pay particular attention to the ethical and conflict of interest statements. Sometimes journals ask authors to suggest referees; this can be very helpful to the editors managing the peer-review process. You may be asked if you wish to exclude potential referees, this should not be done lightly and you should always give good reasons.

After submission, the editorial process begins. The handling editor must send the paper out for review and wait for the referees to return reports. If the reports are conflicting, editors may need to take their own view or send the paper out for another opinion. Once all comments are in, the editor usually composes an informative letter to authors requesting revisions. They then consider the revised paper, possibly sending it out again to referees. It is wise to remember that editors are usually unpaid and under pressure, so try not to upset them! On the other hand you should expect a reasonably prompt turnaround, so do remind them politely if months pass and you don't hear anything.



Dealing with the outcome

If your paper is rejected, try again with another journal. Decisions are not always fair and an element of luck can be involved.

Many papers are accepted following revisions. If you are asked to do this you should respond constructively to all points raised. If you can go along with recommendations you should do so, but you can argue your case on sticking points – editors will compromise. Importantly, no matter how you feel, respond calmly to the referees' comments which can be painful to read after all your hard work.

The joy and satisfaction of having a paper accepted is fantastic. But remember that many researchers experience rejection during their careers, so do not be disheartened if it happens to you. Finally – good luck!

| **Jane Westwell**, SGM

With thanks to Charles Penn for sharing his experience and knowledge.

hotoffthepress

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

The 'eyes' have it

Niesalla, H., McNeilly, T.N., Ross, M., Rhind, S.M. & Harkiss, G.D. (2008). Experimental infection of sheep with visna/maedi virus via the conjunctival space. *J Gen Virol* **89**, 1329–1337.

Sheep and goats can suffer a long-term and debilitating inflammatory disease, affecting their lungs, joints, udders and brains, that is eventually fatal. The condition is caused by one of several small ruminant lentiviruses, including visna/maedi virus (VMV). The virus targets lymphoid tissue and the circulating macrophages of the immune system. The EU has been supporting evaluation of a vaccination strategy against this condition in sheep. As part of this, a team in Edinburgh have been checking the transmission routes of VMV infection. The main ones are thought to be through milk for young animals, but via aerosols for adults. The infected animals exhale and cough a mixture of infected cells and free viral particles into the air. This fits with the fact that the lung and upper respiratory tract are efficient sites for contracting the infection. However, VMV infection has also been found in eyes. Even though the eye has several natural defences, including enzymes like lysozyme, many viral infections can start there. The researchers therefore set out to discover whether this disease could be caught from virus landing in the animals' eyes.

After infecting sheep with VMV, the authors checked for any disease symptoms or signs of the virus over 13 months. Virus was detected circulating in the blood in some of the animals within 2 weeks of infection, and in all of them within a month. The presence of antibodies, termed seroconversion, meant that the virus was not only present but active, and the sheep's immune system was attempting to counter any pathological effects. All of the sheep infected through the windpipe seroconverted, but only one of the four infected via the eyes did so, and then only 8 months after infection. A long delay between infection and evidence of virus activity was not unexpected because this is a well-known feature of infections with VMV and related viruses. Post-mortem examinations of the sheep showed that almost all the animals had inflammation in their lungs, typical of the early stages of the disease.

For a successful vaccination programme it is important to understand how the disease is transmitted and the full range of symptoms. These tests showed, for the first time, that VMV can infect through the eyes as well as through inhalation, and from quite low numbers of viral particles.

Novel bacterium from the whale-carcass ecosystem

Miyazaki, M., Nogi, Y., Fujiwara, Y., Kawato, M., Kubokawa, K. & Horikoshi, K. (2008). *Neptunomonas japonica* sp. nov., an *Osedax japonicus* symbiont-like bacterium isolated from sediment adjacent to sperm whale carcasses off Kagoshima, Japan. *Int J Syst Evol Microbiol* **58**, 866–871.

Sperm whale carcasses on the deep-sea floor form unique biological communities. A novel genus of marine worm, *Osedax*, has recently been discovered in such environments. These worms consist of a crown, trunk and root structure, and symbiotic bacteria exist in the root systems. Researchers from the Japan Agency for Marine-Earth Science and Technology have discovered a novel species of symbiotic bacteria in these worms during an investigation of a sperm whale carcass ecosystem off Kagoshima in Japan.

After running a battery of identification tests on the bacterium, it became obvious that it was closely related to other species of symbiotic marine bacteria, but different enough to warrant description as a novel species of the genus *Neptunomonas*, for which the name *N. japonica* was proposed. The only other known member of this genus had been found in creosote-contaminated sediment on the other side of the Pacific Ocean.

The genus *Osedax* is closely related to tubeworms, and it is thought that the method of acquisition of their symbiotic bacteria may be the same, i.e. horizontal transmission from the environment. *Osedax* worms are also known as zombie worms because of their ability to devour bones. The symbiotic bacteria are thought to help them digest the oils and fats in the bones.


Two pathogens with one drug

Zeidner, N.S., Massung, R.F., Dolan, M.C., Dadey, E., Gabitzsch, E., Dietrich, G. & Levin, M.L. (2008). A sustained-release formulation of doxycycline hyclate (Atridox) prevents simultaneous infection of *Anaplasma phagocytophilum* and *Borrelia burgdorferi* transmitted by tick bite. *J Med Microbiol* **57**, 463–468.

Ticks can transmit several diseases to wild and domestic animals, and people. The hard tick *Ixodes scapularis* carries *Borrelia burgdorferi* from its animal reservoir in the wild American white-footed mouse to people. This bacterium causes Lyme borreliosis (Lyme disease). There are 500–2,000 new cases of Lyme borreliosis in the UK each year, but it is the most common vector-borne disease in the USA with about 20,000 new cases annually. The effects on people vary considerably, from mild to very severe. The symptoms are numerous, ranging from feeling unwell with flu-like symptoms through tiredness with joint or muscle pains to a rash, digestive upsets, headaches and effects on the central nervous system. The best treatment is antibiotics over several months to kill the bacteria, starting as soon as possible after receiving an infected tick bite. Short courses of antibiotics have also been used to successfully treat Lyme disease.

However, *I. scapularis* can harbour other pathogenic bacteria. Human granulocytic anaplasmosis, caused by *Anaplasma phagocytophilum*, was first described in 1990 from the mid-western USA, but is now found increasingly along the north-eastern seaboard and the upper mid-western states. It is therefore possible to become infected simultaneously with *A. phagocytophilum* and *B. burgdorferi*. Doxycycline is the best antibiotic for treating acute infections of *A. phagocytophilum* and may also be effective against *B. burgdorferi*, although amoxicillin is usually the first choice.

Researchers at the CDC in the USA, in collaboration with QLT Laboratories, wanted to see whether doxycycline could also be used to prevent both infections. They compared the effectiveness of a single oral dose of doxycycline with one injection of a slow-release version of the same antibiotic. For the test, the researchers allowed bacteria-infected ticks to bite mice and then treated them with the two antibiotic formulations. The health of the mice was monitored for 3 weeks. The slow-release injection protected all the mice from both species of pathogenic bacteria. In comparison, over 70 % of the mice succumbed to infection when their therapy was a single oral dose of antibiotic, exactly the same result as in untreated mice. After this decisive result, the researchers wondered if this could be developed into a strategy to block or eliminate the bacterial infections in the wild animals and ticks, and as a basis to develop novel platforms to deliver doxycycline to people to prevent infection. As always, prevention of infections is preferable to devising cures. They are now evaluating field trials of novel doxycycline formulations to see whether this is possible.

Just say NO!

Mills, P.C., Rowley, G., Spiro, S., Hinton, J.C.D. & Richardson, D.J. (2008). A combination of cytochrome *c* nitrite reductase (NrfA) and flavorubredoxin (NOrV) protects *Salmonella enterica* serovar Typhimurium against killing by NO in anoxic environments. *Microbiology* **154**, 1218–1228.

Nitric oxide (NO) is a highly reactive gas encountered by microbes in many environments. Some bacteria encouter NO within animal tissues, where macrophage cells use it as a toxic molecule to repel the invaders. For every natural toxin, some bacteria have evolved methods to counter the effects. NO is no exception. It is known that bacteria can have several defences against NO, but it has not been clear if they are all important.

Salmonella bacteria are able to survive and even grow and divide within macrophages. They have at least three enzymes that can metabolize NO. Scientists from Norwich and Dallas, have now clarified how each enzyme protects the bacteria. They focused on *Salmonella* Typhimurium, which causes severe food poisoning. One enzyme, HmpA, was already known to detoxify NO in aerobic conditions. Indeed, some studies have indicated that it contributes to the virulence of *Salmonella* towards mice. There are two more enzymes that can handle NO: NorV is found in the bacterial cytoplasm; NrfA lies between the membranes and cell-wall polymers that surround and protect the cell. The advantages of this position are that the enzyme can detoxify NO before it enters the cell properly, and it can also channel some of the energy from this reaction into the energy-conserving system of the cell. NrfA therefore gives the cell the potential to use this toxin as fuel.

The researchers carried out a careful series of tests, measuring the growth of *S.* Typhimurium in aerobic and anaerobic conditions with different levels of NO gas dissolved in the growth media. They compared a series of bacterial strains that lacked the genes for one, two or all three of the enzymes. This, for the first time, showed that under anaerobic conditions NrfA protected the cells efficiently from NO, with NorV mopping up any NO that got into the cytoplasm. The cells could even boost the level of NrfA activity in response to NO in the growth medium. In addition, the importance of HmpA to counter NO under normal aerobic conditions was confirmed. By analysing the growth characteristics of an *S.* Typhimurium strain that lacked all three proteins, the researchers got a strong hint that there was at least one more NO-detoxifying system waiting to be discovered.

The advantage to the bacterium of these multiple methods to counteract one toxic molecule is that they give flexibility in the many environments in which the bacteria may find themselves exposed to this gas.

▶ Atomic force microscopy image of *Salmonella* Typhimurium. *Roy Bongaerts & Patrick Gunning, Imaging Partnership, Institute of Food Research, Norwich (www.ifr.ac.uk)*

◀ *Osedax* worms on a whale carcass. *Masayuki Miyazuki, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan*

goingpublic

SGM aims to promote microbiology to everyone. The latest Society meeting in Edinburgh provided a great opportunity to showcase some of the exciting new science in the programme to the world. Behind the scenes, **Lucy Goodchild**, was beavering away as press officer for the event. Here is her diary for the week.

SGM Hits the Headlines

This year's spring meeting, held at the Edinburgh International Conference Centre, was big. The enormous number of abstracts received was reflected in the number of delegates who attended, almost 1,400! It was the job of the external relations staff at Marlborough House to publicize the fantastic research being presented and the first step was to read over 200 abstracts, all fascinating, all newsworthy contenders. This was a long process. After a few rounds of elimination, and some difficult decisions, we arrived at a shortlist of 28 abstracts. Together with the authors, we worked on the press releases until everyone was happy. We ended up with 21 fantastic stories, covering everything from Greek food to contaminated soil in the Peak District. And this is where the publicity began.

Sunday 30 March

Our first success was with an exclusive I gave to *The Observer* on Sunday. 'Acid Bacteria Threat to Peak Beauty' shouted the headline – the meeting had started. But it didn't end there for author Patricia Linton, whose story was popular with the local papers and radio stations during the week. This was a great way to begin, and it provided some interesting reading on the plane up to Edinburgh!

Monday 31 March

Working with the Edinburgh Science Festival and Bernard Dixon, SGM carried out a survey that showed '*most people believe smallpox is not an extinct disease*'. Bernard's story (see opposite page) was a great success, and landed itself in about 20 regional newspapers!

Monday morning brought fresh enquiries about two stories in particular; Anthony Sanchez's research working towards a vaccine for the Ebola virus and an interesting study showing the positive effect of green tea on the efficacy of antibiotics, carried out by Mervat Kassem. There was a radio interview with David Richardson about nitrous oxide and newspaper articles on MRSA and microarrays.

Tuesday 1 April

Wary of April Fools' Day, I hoped our stories would be taken seriously; microbes in herring guts and 'alien' viruses that kill MRSA really do exist! Superbugs dominated the headlines, with the *Daily Mail* reporting Matthew Falagas' research on *Acinetobacter*, and Janice Spencer's success with bacteriophages in surgical stitches to prevent infection. It soon became apparent that research due to be presented by internationally renowned microbiologist Rita Colwell the next morning would be popular. I arranged for Rita to be interviewed live on BBC Radio 4's *Today* Programme and awaited Wednesday with excitement.

87% of public are unaware that smallpox was eradicated

Acid bacteria threat to Peak beauty

Wednesday 2 April

I was up with the sparrows, making sure I would be settled on the sofa to listen to Rita at 6.50am. Sure enough, John Humphreys interviewed her with interest. Rita's research into the use of satellite imaging to monitor sea surface temperature and predict cholera outbreaks is fascinating, and caught the attention of everyone listening (even causing a couple of friends and family to call me and ask questions about it!) This kicked off the Hot Topic session on microbes and climate change perfectly. There was international interest in Andrew Thomas's research in the Kalahari, and a local paper reported John Bythell's findings: that microbes could be the key to coral death.

A chunk of feta keeps tummies in fine fettle

FETA cheese can help prevent upset stomachs, a study suggests.

Thursday 3 April

Our two last press releases were a great success. Panagiotis Chanos was invited to Greece, to be interviewed on TV about the natural anti-food-poisoning properties of feta cheese made from raw milk. The story also appeared on page 7 of the *Daily Mail*, the *Herald Sun* in Australia and the *Independent* in Ireland. Jahangir Hossain was interviewed by a radio presenter at BBC Asian Network about the spread of Nipah virus through sweet food and domestic animals in Bangladesh. This story was very popular online, appearing on news websites from many different countries.

Lucy Goodchild
External Relations Administrator (e l.goodchild@sgm.ac.uk)

'Virus' dressings may beat superbugs

Warning over the superbug that resists safe antibiotics

Science writer **Bernard Dixon** is dismayed to find the level of ignorance about microbiology displayed by people on the streets of Edinburgh

Polling the public

There is widespread ignorance of one of the greatest achievements of medical microbiology – the eradication of smallpox from the world over a quarter of a century ago. A poll sponsored by the SGM, in conjunction with the Edinburgh International Science Festival, has revealed that 87% of 200 Scottish people interviewed in Edinburgh streets did not know that the disease is now extinct. It is, of course, almost certain that a survey conducted in London or elsewhere in the UK would have produced a similar result.

The finding inevitably prompts the question of whether opponents of immunization against today's other killer diseases, such as measles, are aware of the enormous impact which vaccines have made to our control of infectious disease. Smallpox killed 300–500 million victims during the 20th century (and left the faces of many 'lucky' survivors disfigured by pockmarks). As recently as 1967, 15 million people contracted this vile infection and 2 million of them died. Yet the successive achievements of 30 years of vaccination campaigns, masterminded by Donald Henderson and colleagues in his WHO team, meant that by 1979 the disease had been consigned to history.

For those of us fortunate not only to be unthreatened by smallpox but also to have been immunized against diphtheria, poliomyelitis and other fearful conditions, the twin lessons are crystal clear. Immunization is our most powerful and conclusive weapon to deploy against pathogens. And the risks of side-effects – whether real, as in the case of smallpox vaccine, or purely conjectural – in no way detract from the continued importance of immunization against our remaining killers. The SGM/ESF survey points very clearly to another continued need – to remind people, parents in particular, of the past successes of vaccination and its unceasing relevance.

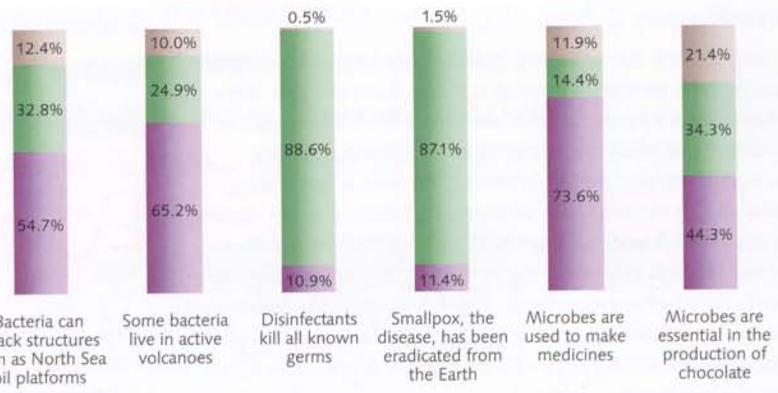
On the positive side, the Edinburgh study did show that many members of the public are conscious of the wide range of activities of micro-organisms, rather than simply their capacity to cause disease. Three quarters of interviewees knew that microbes are used to make medicines, while 65% knew that bacteria can live inside active volcanoes and 54% that they can attack North Sea oil platforms. About 44% were even aware of the involvement of microbes in chocolate making – one of their least familiar roles, even for scientists in other fields.

The survey, conducted in February and March this year by Scotinform, an Edinburgh-based polling organization, was based on a questionnaire designed to assess the level of public knowledge of micro-organisms and their functions. Experienced interviewers used the questionnaire to obtain answers from 201 individuals to multiple choice questions and 'true or false' statements. Age and gender data were also collected and the composition of the sample was adjusted to reflect the demographics of the general population. These data showed some significant differences in the knowledge of respondents in different age groups.

For example, 80% of people selected the true definition of microbes when given a choice of 'types of molecule', 'parts of a computer' and 'invisible forms of life such as bacteria and viruses'. In second place, 15% of respondents selected 'types of molecule'. But whereas over 90% of 45- to 64-year-olds answered correctly, the percentage fell to 70% for people of 65 or older and to 62% for 16- to 24-year-olds. Does this reflect an educational deficit in this cohort?

There was another age difference when interviewees were asked whether sunlight, microbes or water was 'most important in making compost'. Overall, 76% plumped for microbes. But 94% of the 65+ group chose this answer, versus only 56% of those aged 16–24. A generally upward trend in correct answers with increasing age presumably indicates growing awareness, particularly among gardeners, of the microbial basis of composting.

Knowledge of the efficacy of antibiotics was a second area where a significant disparity emerged. In response to the question 'Do antibiotics work against viruses, bacteria or both viruses and bacteria?', the percentages of correct replies overall were 21, 51 and 25%, respectively. However, while 64% of women stated that antibiotics act exclusively against bacteria, only 40% of men selected this answer.



▲ A small sample of the true/false questions used in the Edinburgh survey. Key: purple, true; green, false; brown, don't know.

Perhaps feedback from family doctors, in response to mothers requesting antibiotics for children's conditions such as sore throats, can account for this very pronounced difference. On this topic, the percentages of correct replies from both sexes among 16- to 24-year-olds and the 65+ group were only 29 and 43%, respectively.

Women tended to be more aware that viruses (rather than bacteria or 'cold and damp weather') are responsible for common colds, 79% selecting this option as against 72% of men. In terms of age, the proportion of correct answers rose steadily from 53% among 16- to 24-year-olds to 90% in the 65 or over category.

When asked whether bacteria can attack structures such as North Sea oil platforms, 57% of men said yes, compared with 52% of women. Overall, more participants (62%) agreed with the proposition that some bacteria can live in volcanoes than with the statement that bacteria can attack oil platforms (54%).

One of the 12 questions was quite different from all of the rest. It asked 'Who introduced penicillin as a life-saving drug?', with a choice of three names: Howard Florey in Oxford, Charles Rennie Mackintosh in Glasgow or Alexander Fleming in London. Unsurprisingly, perhaps, 88% of respondents opted for Fleming.

This question was included for its bearing on communication, since the results of the survey were to be presented in a session on *Communicating Microbiology* during the SGM's Spring Meeting. When, in 1942, journalists heard rumours of the first, seemingly miraculous cures of life-threatening infections by penicillin, they descended on the Sir William Dunn School of Pathology in Oxford to interview the leader of the team, Howard Florey. He immediately sent them packing. Florey did not like the media or publicity.

So the journalists made a few phone calls and found their way instead to St Mary's Hospital, Paddington. It was there, over a decade earlier, that Fleming had made the original observation of the inhibitory effect of something in *Penicillium* on staphylococci growing in a Petri dish. At St Mary's Hospital, Fleming gave the media a much warmer welcome than they had encountered in Oxford.

And that was the origin of the legend which portrays Fleming as the sole hero of the story of penicillin, with scarcely a mention of Florey and his Oxford team who purified the product and introduced it as a dramatically effective antimicrobial drug. As the Edinburgh survey shows, the legend remains alive and well. It is based not on effective communication, but on a failure of communication.

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reviews

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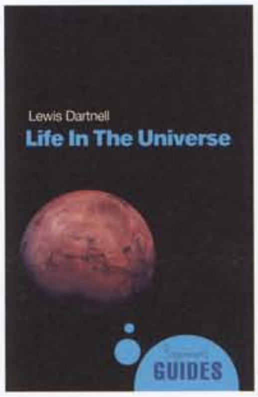

Life in the Universe: A Beginner's Guide

By L. Dartnell
Published by Oneworld Publications (2007)
£9.99 / US$14.95 pp. 202
ISBN 1-85168-505-9

It is difficult to describe this book. Interesting? Undoubtedly. Well written? Definitely. Easy to read? Yes. A good reference? A brilliant one. It is all of these things, and much more. In the preface, author Lewis Dartnell says the book 'has been written as both a popular science book and also as an entry-level primer for students starting a course in astrobiology.' I was intrigued by this and anxious to see how it would be achieved. I was not disappointed.

Astrobiology is a multidisciplinary, diverse, wide-reaching (quite literally) field. And it is a very young branch of science. As Lewis says, 'Astrobiology was not born to explain a particular discovery, as microbiology developed to explain sightings through the first microscopes, but is the offspring of more mature scientific disciplines as they overlap.' It is for this reason that astrobiological discoveries are often highly controversial and disputed, perhaps even disparaged, by scientists from other disciplines. I suggest those scientists read this book.

The book begins by looking at the fundamental question, 'What is life?' Lewis discusses the difficulty in using the MRS GREN definition of life (the one you get taught at school) and explores an alternative description. He is able to sit simple and complex ideas side-by-side seamlessly, going on to explain molecular chirality, the relationship between DNA and RNA, the importance of ATP and the final electron acceptor, respiration, photosynthesis and plausible alternatives to recognizable aspects of terrestrial biology. These ideas are put in context and they make sense. I couldn't put the book down.

As I read on, I got the wonderful impression that the author was just as fascinated by the subject matter as I was, reading it for the first time. A captivating chapter on extremophiles shows this perfectly, with descriptions of prokaryotic microbes that live in hot, cold, salty, acidic, alkaline and high-pressure environments, making eukaryotes seem like 'comparative wimps'. I read about cryptoendoliths that live in the cracks of rocks in the Antarctic dry valleys, and about SLiMEs in deep basalt aquifers. The information is very accessible, with analogies (household ammonia vs lemon juice) painting an understandable picture.

I knew a little about astrobiology before opening the book (although it would be just as good if you were starting from scratch) and one question that always played on my mind was how can scientists really believe in panspermia? The book tackles the difficulties of ejection (microbes leaving a planet), transit (microbes travelling through space) and re-entry (microbes burning through the atmosphere to land in a new world) brilliantly, answering my question once and for all.

One thing about life on Earth really stands out. It was incredibly improbable. For starters, there is the Goldilocks principle: that the conditions on Earth had to be just right. There is a measurable habitable zone around a star (stellar) and even in a galaxy (galactic). The size, temperature, life-span and luminescence of the star and the presence and size of the moon are important. The search for extrasolar, habitable planets is considered, as well as the investigation of potentially habitable bodies in our solar system, including Venus, Mars, Jupiter's moon Europa and Saturn's moon Titan.

Evidence of early microbial life on Earth, from stromatolites, for example, is as controversial and difficult to find as evidence for extraterrestrial life. According to Lewis, astrobiologists are 'doggedly searching' for this evidence, a pursuit that he describes as 'bewildering and frustrating'. But he is clearly enamoured with the subject, which is looking forward to a bright future. Lewis considers forthcoming developments in the field, impending missions and ambitious plans. He finishes by pondering what intelligent life might look like if it were to step off a flying saucer in front of the White House. I won't spoil the surprise.

Quite simply, this is a fantastic book. I read it in one go and I am half way through it again. It is set out in an accessible way that allows 'dipping' for information, it can be read section by section or all at once. It is a great reference, with no glaring mistakes, suitable for a curious layman or an astrobiology student. I recommend it for anyone with an interest in astrobiology in particular, biology in general, life, the universe and everything. And especially for anyone who needs a renewed interest in their work.

***Lucy Goodchild**, SGM*


Microbial Life, 2nd edn

By J.T. Staley, R.P. Gunsalus, S. Lory & J.J. Perry
Published by Palgrave Macmillan Ltd (2007)
£43.99 pp. 1066
ISBN 0-87893-685-4

Microbial Life represents a refreshing change of emphasis and style compared to more standard microbiology textbooks. It does, as its authors claim, have an emphasis on evolution throughout, and has authors who are still at the cutting edge of bacterial research and yet have found time to contribute to a text. This research activity shows throughout the book, and particularly in the 'Research Highlights' boxes which give a current topic in the style of a press-cutting relevant to chapters. Also in many of the illustrations, with the exception of the bacterial flagellum, more detail is shown than is usual in text books. This gives a hint of the immense structural information that is now available for microbial proteins. Examples of these helpful diagrams include ribosome and pilus structures, comparisons of the chemistry of archaeal and bacterial membranes, details of bacterial encounters with the human immune system. There is a good balance between environmentally, industrially and medically important micro-organisms in the book, and a very commendable Chapter 16 on microbial genomics which covers, in a concise way, much that students need to appreciate about the way genomics and transcriptomics inform and drive modern microbiology research.

Liz Sockett, *University of Nottingham*

Life in the Soil: A Guide for Naturalists and Gardeners

By J.B. Nardi
Published by University of Chicago Press (2007)
£15.00 / US$25.00 pp. 336
ISBN 0-22656-852-0

This compact volume (it is about the size of a Collins Field Guide) contains a wealth of information on soil and the life that lives in it, and is more than just a garden safari. In part 1, the exposition on soil formation and types in the introduction is masterly. Landscapes from around the world are described: (from rocky crag to temperate rain forest; desert to savannah) and the relationship between the soil type and structure, and the flora and fauna they support, clearly explained. Part 2 gives a fuller picture of life in and on the soil. Not just the usual 'litter critters' – the author starts with the microscopic, soil bacteria and protozoa, and finishes with the macroscopic; badgers and kangaroo rats. Each new entry is accompanied by a 'fact box' giving a quick reference guide to the organism, its classification, place in the food web, and impact on the garden. Part 3 turns to the gardener and his impact on soil through the use (or not) of fertilizers and compost, and the introduction of exotic species. There is an excellent final chapter on collecting and observing life in the soil, with notes on the construction of observation chambers and simple Berlese and Baermann funnels. The book finishes with a good glossary and an excellent reading list. The whole is illustrated with superb colour photographs and beautiful line drawings. Not just for gardeners and naturalists: this book would be excellent reading for the first year ecologist or environmental scientist.

A caveat: British readers should note that the author is an American and hence the 'robin' shown in photograph 47 is a thrush, and the 'Daddy longlegs' referred to on pages 105 to 107 is a harvestman (Class Arachnida, order Opiliones), not a cranefly.

Kit Brownlee, *University of Reading*

Reviews on the web

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

MycoAlbum CD Introductory Mycology Laboratory Review

Real-Time PCR in Microbiology: From Diagnosis to Characterization

Medical Mycology Cellular and Molecular Techniques

Effects of Herbs and Natural Products on Clinical Laboratory Tests

Animal Vaccination. Part 1: development, production and use of vaccines. Part 2: scientific, economic, regulatory and socio-ethical aspects

Methicillin-Resistant Staphylococcus aureus *(MRSA) Protocols*

Pichia *Protocols, 2nd edn*

Pseudomonas*: Genomics and Molecular Biology*

Genetic Variation: A Laboratory Manual

Poxviruses

Molecular Biology and Biotechnology: A Guide for Teachers/Guide for Students

Mims' Medical Microbiology, 4th edn

Clinical Microbiology and Infectious Diseases, 2nd edn

Salmonella *Methods and Protocols*

Chromosomal Mutagenesis

Reoviruses: Entry, assembly and morphogenesis

Myxobacteria: Multicellularity and Differentiation

Evolutionary Biology of Bacterial and Fungal Pathogens

High Pressure Processing of Foods

The Microbiological Safety of Food in Healthcare Settings

Handbook of Fermented Meat and Poultry

Nidoviruses

Food Biodeterioration and Preservation

Molecular Oral Microbiology

Epigenetics

Concepts in Genetic Medicine

Medical Microbiology for the New Curriculum A Case-Based Approach

The OIE Global conference on Aquatic Animal Health

The Mycobacterial Cell Envelope

Health, Risk and News. The MMR Vaccine and the Media

Pioneering Women in Plant Pathology

Sampling and Analysis of Indoor Microorganisms

Professor Sir Howard Dalton FRS

(08.02.1944–12.01.2008)

Howard was born in New Malden, Surrey, the son of a lorry driver. He was highly intelligent with an inquiring mind and his early interest in science was evident from his many exploits with cocktails of chemicals, which often had explosive consequences. Having survived many escapades with these early 'laboratory' experiments, Howard was eager to learn more and his mother was extremely proud of him passing the 11+ examination and attending Raynes Park Grammar School. Howard was awarded a place at Queen Elizabeth College, University of London, graduating in 1965 with a BSc in Microbiology.

His research career started when he undertook a DPhil with Professor John Postgate FRS at the ARC Unit of Nitrogen Fixation, University of Sussex, where he worked on nitrogen fixation in the soil bacterium *Azotobacter* and helped to elucidate how this aerobic soil bacterium protects its nitrogenase from oxygen damage by augmentation of respiration and conformational protection mechanisms. Howard then worked for 2 years as a postdoctoral fellow with Professor Len Mortensen at Purdue University, Indiana, on the biochemistry of nitrogenase in the anaerobic bacterium *Clostridium*.

Ever resourceful, while in the USA he avoided the possibility of being drafted to Vietnam by his ordination into the Universal Life Church, ironically on 1 April 1969!

Recognizing that electron spin resonance spectroscopic techniques were going to be of great importance in the study of metaloproteins, Howard returned to the University of Sussex in 1970 to work with Dr Bob Bray in the Department of Chemistry on two molybdenum-containing enzymes, nitrate reductase from *Aspergillus nidulans* and xanthine dehydrogenase from *Veillonella alcalescens*. The following year, Howard married Kira Rozdestvensky, whom he had met while living in the USA, and when Professor Roger Whittenbury persuaded Howard to take up a lectureship in Microbiology at the Department of Biological Sciences, University of Warwick in 1973, they settled in the village of Radford Semele near Leamington Spa. Roger recalls that Warwick in those days was hardly a magnet for microbiologists, offering only an abandoned chemistry laboratory containing just two pieces of equipment, a broken piano and a dartboard! A brief chat about his background and a promise that he would work on Roger's beloved methane-oxidizing bacteria and that was sufficient to initiate Howard's long and illustrious tenure at Warwick.

Howard built up a large research group at Warwick and pioneered work on two enzymes involved in bacterial oxidation of methane, a soluble, cytoplasmic methane mono-oxygenase (MMO) and a completely distinct membrane-bound particulate MMO. These remarkable enzymes can convert methane, a rather inert compound, into methanol. Howard and colleagues were able to purify and characterize them at the biochemical and molecular level, work which led to much of our current understanding of the structure and catalytic mechanisms of these MMOs. Howard also quickly realized that the soluble MMO had remarkable co-oxidation properties, which stimulated a longstanding interest in biocatalysis and biotransformations using MMO and other oxygenases. Through this research he also made extremely important contributions to research into the use of microbes to produce chemicals, work which was to stimulate his later interests in biofuels. He was consultant for the New Jersey company Celanese and then joined the Scientific Advisory Board for the spin-out biotechnology company Celgene, which gave him considerable insight into chemical and industrial aspects of microbiology that he used to good effect in his biotransformation research. All of this research at Warwick brought him a much-deserved international reputation, yielded many seminal publications in a career generating well over 250 scientific papers and opened up whole new research fields in the microbiology of one carbon (C1) compounds. Howard was awarded a Personal Chair at Warwick in 1983 and as his scientific career flourished, he and his colleagues were immensely proud of the accolades he received, especially his election as a Fellow of the Royal Society in 1993, his appointment as President of the Society for General Microbiology (1997–2000), the award of the Leeuwenhoek Medal Lecture at the Royal Society in 2000 and his knighthood in the New Year Honours list in 2007 for his services to science.

Howard also made significant contributions to the life of the University of Warwick. He was Chair of the Department of Biological Sciences (1999–2002) and held many positions in the University dealing with academic matters and other areas of University life. His enthusiasm for and extensive knowledge of Japanese gardens were also brought into play on campus, resulting in the creation of two fine gardens at Warwick.

In 2002, Howard was seconded to become Chief Scientific Adviser to Defra, a role in which he sought to instil scientific rigour into policy-making decisions based on sound scientific evidence. Howard led the scientific advisory team generating the UK contingency plan for dealing with avian influenza virus and was instrumental in raising the profile of climate change as a significant threat, delivering lectures on this and other topics such as biofuels and GM crops at many national and international meetings. He was a great communicator and he wrote a highly entertaining and popular blog describing his 2 week visit to the British Antarctic Survey in 2006 where he observed at first hand the effects of global warming on ice fields in Antarctica. Throughout his time at Defra, Howard maintained strong links with the University, returning each Friday to look after his research group. He returned full time to Warwick in October 2007 and in the short time before his death had already delivered some insightful and entertaining lectures on science policy to final year undergraduates with his usual passion and engaging style.

Howard had an immense zest for science and life in general and was a fine sportsman in every sense of the word. In his early days at Warwick he was a regular in the Rowington Village cricket side; a fiery fast bowler and very useful left-handed batsman. He was a lifelong Spurs supporter and a highly competitive member of the Biological Sciences football team, aptly named 'Biohazard'. In the 1970s Howard performed with distinction in the 'Biohazard' team that played a friendly match with the Saudi Arabia national team, thereby adding to his illustrious international career. A great passion of Howard's was real tennis and he was a member of Leamington Real Tennis Club where his competitive spirit, guile and ability won him many tournaments. It was here, while playing in a friendly doubles tournament, that he tragically collapsed and died on 12 January 2008. He had just returned from a month in The Gambia assisting his wife Kira in her extensive humanitarian work, setting up new schools and medical centres there. This work will now be assisted through generous contributions made to the African Oyster Trust in his memory. He was also excited by the prospect of advising the Gambian government on a number of important environmental issues.

Howard was a down-to-earth, self-effacing man, outgoing and witty and in the 1980s was a 'leading light' at gatherings of the staff of Biological Sciences at Warwick in weekly socials at local pubs (code-named 'Choir-Practice'!). He also enjoyed the occasional 'poker-night' with selected colleagues who invariably relieved him of his hard-earned cash. Howard's penetrating questions and insightful comments at national and international scientific meetings always made for lively and stimulating debate and discussing science with him was always immensely rewarding. He was extremely generous of his time with well over 100 PhD students and postdoctoral researchers, and it was a real privilege for me to work with him as a PhD student and then as a colleague for nearly 30 years. Above all else, he made science fun and was an inspirational mentor, a much-loved colleague and a dear friend. He will be very sorely missed. Howard is survived by his wife Kira and children (Christopher, Eric, Jeremy and Amber).

Colin Murrell, University of Warwick

John Grainger writes...

I first worked with Howard when he joined the committee of the then SGM Teaching Group. We were full of trepidation when we learnt that he was to become the next Council rep on the group, expecting by reputation for him to appear only occasionally at committee meetings and then bronzed and with his leg in plaster from a skiing incident, or some similar scrape. But we were totally wrong – he was absolutely excellent and put in 100 % attendance. I have an abiding memory after one of our meetings at an SGM conference of him pushing his way to the bar and coming back with two handfuls of empty glasses. The Fermentation Group had had a symposium sponsored by a drinks firm and their officers couldn't carry all the unused bottles back to Scotland by train. Hearing of their predicament, Howard had taken the excess off their hands for the sole benefit of the Teaching Group Committee! He was always very supportive of my work with schools and particularly influential when he was President.

Some SGM connections – Janet Hurst

Howard was always a great supporter of the SGM, joining in 1964 whilst still an undergraduate student. He was an elected member of Council (1985–1989), the period alluded to by John Grainger, before becoming President 10 years later. SGM staff have fond memories of Howard – he was great to work with and chaired Council meetings humorously but well. He was a bon viveur who always seemed to know a good restaurant in the locality of a scientific meeting, providing us with a welcome change from university fare (but at a cost much to the treasurer's disapproval). Particularly memorable was a ceilidh at Heriot-Watt, where Howard's anarchic refusal to follow the caller brought complete chaos to the dance. Howard was involved with the Society right up to the end. He was a keynote speaker in the plenary at the Edinburgh meeting in September 2007 and instrumental, in his Defra role, in commissioning SGM to carry out the independent inquiry into bTB research currently being completed. He will be sadly missed.

▲ A *Culex quinquefasciatus* adult, a few days post-mortem, treated with the fungus *Metarhizium anisopliae*. Anita Gordillo

comment

Fungi as biological controls of insect disease vectors

As our climate changes, the threat from insect-borne disease may increase in the more temperate parts of the world. **Nancy Beckage** and **Anita Gordillo** discuss how, in the future, fungi may be used to control these insect vectors.

Entomopathogenic fungi have been exploited as agents for biological control of insect pests for decades. Two highly effective fungal pathogens are *Metarhizium anisopliae* and *Beauvaria bassiana*. The spores (conidia) come into contact with the insect body surface, germinate on the cuticle and move into the haemocoel, where the fungal hyphae proliferate. The host is killed due to production of toxins by the fungi. Strains have evolved to become host-specific, killing closely related species with minimal effects on non-target insects. Given appropriate conditions (temperature, humidity), the insect cadaver becomes encased in fungal spores as they erupt from the host, producing more conidia with potential to infect other individuals.

While several strains of *M. anisopliae* and *B. bassiana* have been employed as biological controls of insect pests in crop protection (e.g. 'Green Muscle' programme in Africa), their potential for controlling adult mosquito vectors of disease has only recently undergone evaluation. Implementation of *M. anisopliae* and *B. bassiana* in controlling adult *Anopheles gambiae* mosquitoes to reduce rates of transmission of malaria in Africa was described in 2005 (see Further reading). While microbial pathogens are widely used to control populations of mosquito larvae, they are not easily used for *A. gambiae*. The larvicide *Bacillus thuringiensis israeliensis* must be ingested to induce its mosquitocidal activity; *A. gambiae* develops rapidly as larvae in small pools of water following rainfall, thus making well-timed distribution of the pathogen difficult. Since physical contact of conidia with the mosquito cuticle is all that is necessary for infection, using *M. anisopliae* or *B. bassiana* as adulticides can be directed at the mosquitoes prior to their reproductive stage to reduce the number of potential offspring and the number of females that can potentially serve as disease vectors. Adult mosquito longevity decreases by >50% following infection, and female fecundity and egg production are significantly reduced within 48 h until the mosquito dies. Adult blood-feeding activity is also suppressed during this time frame, further contributing to a dramatic reduction in vector competence and decreased rates of disease transmission. *M. anisopliae* is also an effective biological control agent against other mosquito species such as *Culex quinquefasciatus*, *Aedes aegypti* and *Aedes albopictus*, which collectively are responsible for the spread of encephalitis viruses, West Nile Virus, filariasis, dengue fever and yellow fever.

Fungal efficacy is dependent upon the conidial concentration used to infect the mosquito, exposure time, medium in which they are administered and substrate to which the fungi are applied. The applications used thus far have used substrates on which the mosquitoes can be found resting following a blood meal, but targeting newly emerged adults prior to their initiation of blood feeding would be optimal to get the most significant reduction in disease transmission rates. Because of the multiple attributes of infection by these fungi that reduce the vector's ability to transmit disease, using fungi in biological control of adult stages of mosquitoes represents a new option in our vector management toolkit.

Current methods to control adult mosquitoes in impoverished countries are limited to indoor applications of residual chemical insecticides, or bednets treated with synthetic pyrethroids. Intensive use of pesticides globally since the introduction of DDT in the 1940s has resulted in major problems with development of vector resistance to insecticides, environmental pollution and adverse effects on non-targeted species. Moreover, changing rainfall patterns and increased temperatures associated with global warming are predicted to expand the range of many insect vectors that are currently confined to the tropics and subtropics, including the vectors of malaria, dengue and yellow fever. Global health burden will assuredly increase as a result of predicted changes in climate and environmental factors that favour the successful reproduction of insect vectors and the expansion of their ranges.

Genetically modified *M. anisopliae* expressing insect-specific toxins further enhances their virulence to mosquitoes, but their utilization in field-based mosquito control is controversial due to public concern regarding genetically modified organisms and regulatory issues. Regardless, the use of entomopathogenic fungi to control populations of adult mosquitoes clearly offers significant promise as a novel biologically based strategy to be integrated with other control measures to reduce global rates of vector-borne disease transmission.

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Further reading

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