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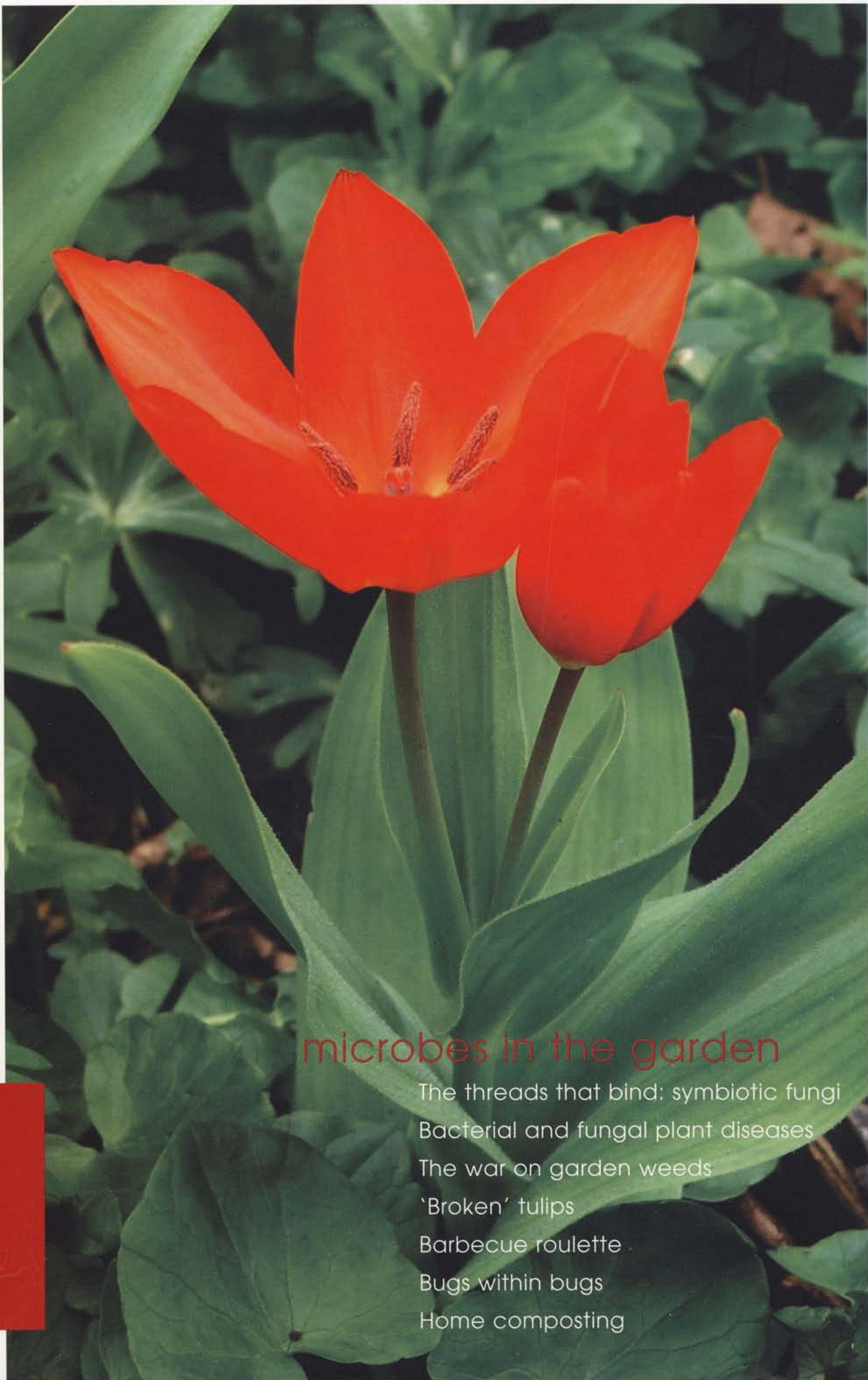

microbes in the garden

- The threads that bind: symbiotic fungi
- Bacterial and fungal plant diseases
- The war on garden weeds
- 'Broken' tulips
- Barbecue roulette
- Bugs within bugs
- Home composting

contents

vol32(2)

regular features

other items

articles

Cover image Red tulips (cultivar unknown). *Ian Atherton, SGM*

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Microbiology Today in bloom

Without micro-organisms it is unlikely that gardens as we know them would exist. Although ornamental plants and fruit and vegetables are subject to assault from a range of bacterial, fungal and viral diseases, they still depend on microbes to break down organic matter in the soil to provide vital nutrients and to form essential symbioses such as those of mycorrhizal fungi with their root systems. Other more esoteric relationships exist, some of which are explored in this issue of the magazine with its focus on 'microbes in the garden'.

The theme was planned before we heard the good news that the Society's application for a stand in the lifelong learning exhibition at the Royal Horticultural Society's Chelsea Flower Show had been successful. The display will feature mycorrhizas, showing the wide variety of plants that rely on fungi for essential nutrients in exchange for a supply of sugars. Alastair Fitter's article on p. 56 covers this topic in some detail.

The Chelsea Flower Show runs from 23 to 28 May and so we are taking the opportunity to hand out copies of *Microbiology Today* to the visitors. We hope that these enthusiasts will enjoy learning about the largely unseen role of different micro-organisms in their gardens. A warm welcome is extended to these new readers of the magazine. We also hope to see some SGM members on the stand!

60 years on: SGM 1945–2005

The Society for General Microbiology celebrated its diamond jubilee recently. The inaugural meeting of Original Members, at which the Society was formally launched, took place on 16 February 1945, although discussions leading to the decision to form the Society had started in 1943, and continued throughout 1944. The governing body was elected at this gathering, the rules approved and the annual subscription set at 1 guinea. Due to wartime paper shortages it was not yet possible to publish a journal. Original Members numbered 241 and SGM held its first scientific meeting later that year in Cambridge in July.

By coincidence the 322nd meeting of SGM Council took place on 18 February this year, presenting an ideal opportunity to celebrate the Society's birthday. Current President, Hugh Pennington, cut a cake decorated with a portrait of the SGM's first President, Sir Alexander Fleming, which was enjoyed by staff and Council members. The Society's health was also toasted in champagne, with a wish for many more successful years in the future.

Information on SGM's history is available on the website (www.sgm.ac.uk/about/history.cfm).

▲ *Ian Atherton, SGM*

◄ *Faye Jones, SGM*

Bug's life at Royal Society

Sheffield University's project to teach students at inner-city Chaucer School about microbiology has been chosen for display in the prestigious Royal Society Summer Exhibition. Funded jointly by the SGM, a Royal Society Partnership award and the University, **Professor Jeff Green** and his colleagues gave more than 100 year 10 and 11 students the opportunity to do some practical work and learn about microbial growth, as well as the important role of micro-organisms in our daily lives. The exhibition will be open to the public from 4 to 8 July 2005. See **www.royalsoc.ac.uk** for details.

Fred Brown Memorial Meeting

Dave Rowlands (Leeds), would like to thank SGM formally for supporting the tribute to **Fred Brown** held at the Royal Society in November. Around 150 people attended, including family, younger scientists and an amazing number of Fred's older friends and colleagues. The scientific programme was wide ranging but reflected Fred's personal interests. The event finished with a tribute by his eldest son Roger and was followed by a dinner attended by many who had been associated with Fred over the years.

Microbiology Today hits the headlines

The Comment article on MRSA in the February magazine provoked a good deal of interest in the media. **Mark Enright**'s piece put paid to the idea, current in the popular press, that poor hospital hygiene lies at the root of the problem. Although this is an important factor in resolving the MRSA crisis, the issue is far more complex than generally perceived. Journalists honed in on the news that the emergence of two particularly transmissible genotypes in the UK coincided with increases in hospital-acquired MRSA bacteraemia, along with the more alarming fact that other strains were beginning to affect healthy people in the community.

As a result the issue was aired on the *Today* programme on BBC Radio 4 and other news bulletins before being eclipsed by the announcement that day of the engagement of Prince Charles and Camilla Parker-Bowles! Despite this interruption, the story was taken up by the printed media over the next few days, with some very responsible reporting. Mark Enright gave several interviews and was able to highlight the lack of government funding into basic MRSA research. John Reid, the UK Health Secretary, and other government officials were provoked into responding. Gratifyingly, MT was identified as the source of the story in both printed and broadcast media.

Keeping up the good work

SGM works on many fronts to raise important microbiological issues to policymakers and opinion-formers. The MT Comment on MRSA achieved this objective as described above. However, to make good progress we depend on members who are willing to alert us to potential topics, write on controversial subjects and feel comfortable talking to the press.

The Public Affairs Office keeps a database of experts on all aspects of microbiology who have agreed to respond to enquiries. More people are always needed to help with our efforts to promote microbiology responsibly. Please contact Faye Jones (**e** f.jones@sgm.ac.uk) if you are interested.

SGM Council

February meeting highlights

Industrial Liaison Officer

The search for an SGM Industrial Liaison Officer is ongoing. In order to strengthen links with the commercial sector, it is hoped to recruit microbiologists working in industry as members of the committees of relevant SGM Special Interest Groups. Council heard that a second industrial members' forum was to be held at the Society's meeting at Heriot-Watt University in April where this particular issue will be discussed.

FIS Annual Conference

Council agreed that SGM, together with the Hospital Infection Society, the British Infection Society and the British Society for Antimicrobial Chemotherapy, would contribute to the support and organization of the Annual Conference of the Federation of Infection Societies.

SGM finances

The finances of the SGM activities in 2004 have been audited and Council was pleased to learn that all was in order and in compliance with UK Charity Regulations.

SGM strategy

The President, **Professor Hugh Pennington**, announced that the next strategy meeting would take place in March to enable a group of Council members and SGM staff to discuss Society activities and ways to develop them. The recommendations of this group will be debated in full Council.

Fighting infection

SGM continues with its endeavours to raise the awareness of microbiology and infection in the public eye. Council was informed of the arrangements for a presentation and discussion meeting on *Fighting infection* at the House of Lords on 1 March 2005. A large number of parliamentarians and members of the Upper House had accepted the invitation to attend. (See p. 96 for a detailed report.)

***Ulrich Desselberger**, General Secretary*

Annual General Meeting 2005

The Annual General Meeting of the Society will be held on **Tuesday, 13 September 2005** at the Society Meeting at Keele University. Agenda papers, including reports from Officers and Group Conveners, and the Accounts of the Society for 2004 will be circulated with the August issue of *Microbiology Today*.

Grants

Overseas schemes

International Research Grants

The grants allow scientists to travel to or from the UK and Republic of Ireland in order to carry out a defined piece of research in any field of microbiology. Applicants must be of postdoctoral level or above. Applications for 2005 are invited.

International Development Fund

The fund exists to provide training courses, publications and other assistance to microbiologists in developing countries. Applications for 2005 are invited.

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 all these schemes is **14 October 2005**.

Student scheme deadlines

Postgraduate Student Meeting Grants

Grants cover travel and accommodation expenses for attendance at **one** SGM meeting each year. Applications for a grant to attend the Keele meeting (12–14 September) must be submitted by **9 September 2005**. Applications for a grant to attend the joint SGM/Norwegian Societies meeting (27–30 September) must be received by **23 September 2005**. For allowances for travel and accommodation, contact the Grants Office or see the website.

President's Fund research visits

Open to Society members wishing to make a short research visit who are resident and registered for a PhD in an EU country or in their first postdoctoral position in an EU company. The second round of applications closes on **14 October 2005**.

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 **28 October 2005**.

SGM has a wide range of grant schemes to support microbiology. See **www.sgm.ac.uk/grants** for details. Any enquiries should be made to the Grants Office, SGM, Marlborough House, Basingstoke Road, Spencers Wood, Reading RG7 1AG (**t** 0118 988 1821; **f** 0118 988 5656; **e** grants@sgm.ac.uk). Check out the current schemes, to ensure that you don't miss any deadlines.

News of Members

Observer accolade

SGM President **Professor Hugh Pennington** has been voted into the *Observer Food Magazine*'s 'Hall of Fame' 2005. He received the Judge's Award, resulting in three pages of discussion on a wide variety of food safety-related topics in the Sunday paper, accompanied by a gory picture of Hugh in a slaughter house.

2005 Feldburg Foundation Prize

Congratulations to **Professor Geoffrey L. Smith** FRS of Imperial College London and Editor-in-Chief of *Journal of General Virology*, who has been awarded the 2005 Feldburg Foundation Prize in recognition of his research into poxviruses. The Prize is awarded each year to one British and one German scientist, to promote Anglo-German friendship in medical and biological science. Professor Smith will deliver a prize lecture at Würzburg and three additional lectures in Germany.

Scottish honours

Congratulations also to the following members who have been elected Ordinary Fellows of the Royal Society of Edinburgh:
Alistair Brown (Aberdeen), **Anne Glover** (Aberdeen), **Anthony Nash** (Edinburgh) **James Prosser** (Aberdeen)

Deaths

The Society notes with regret the deaths of **Professor W.G. Armstrong** (member since 1954), **Dr J. Cohen** (member since 1990), **Professor C.E. Hormaeche** (member since 1981 and Council member 1995–1999), **Professor R.F. Middleton** (member since 1986), **Professor D.A.A. Mossel** (member since 1950) and **Dr W. Stannard** (member since 2002).

Staff News

Lesley Hoyles, Senior Staff Editor on IJSEM, left in March to take up a research post at the University of Reading. We are very grateful to Lesley for her contribution to the success of the SGM journals over the past 4 years, particularly the work she put in on JGV in 2004 during a difficult period. We wish Lesley every success in her career back in the lab. **Melanie Scourfield** will be taking over the IJSEM Senior Staff Editor role.

A warm welcome to new Staff Editor **Karen Rowlett**, who started work in April. Karen comes to SGM with a wealth of scientific editing experience, both as a freelance and through her work at CABI Publishing.

SGM Prize Lectures and Awards

A range of prestigious awards is made by the Society in recognition of distinguished contributions to microbiology. The award panel will consider the submissions in the autumn and their recommendations will be taken to November Council for approval. The outcome will be announced in the February 2006 issue of *Microbiology Today*.

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

Fleming Award

The Fleming Lecture is awarded annually for outstanding research in any branch of microbiology by a young microbiologist in the early stages of his/her career. The award is £1,000. The recipient gives a lecture based on his or her work to a meeting of the Society and the text will be published in whichever of the Society's journals is the most suitable.

Marjory Stephenson Prize Lecture

This is the Society's principal prize, awarded biennially for an outstanding contribution of current importance in microbiology. The winner receives £1,000 and gives a lecture on his/her work at a Society meeting. The 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 including universities, the general public, school pupils or professional groups. The winner receives £1,000 and gives a lecture on a topic of his or her choice at a Society meeting.

Nominations are now sought for the 2006 prize lectures. Please complete the form and send it, together with the supporting documents, to **Dr Ulrich Desselberger**, c/o SGM HQ. Dr Desselberger will be pleased to discuss the criteria for nominations, should any queries arise (**e** ulrich.desselberger@cb241x.fsnet.co.uk).

The closing date for all nominations is 30 September 2005.

Undergraduate Microbiology Prizes

The prizes aim to encourage excellence in the study of microbiology by undergraduate students and to promote scholarship in, and awareness of, microbiology in universities.

The prizes are awarded annually to the undergraduate student in each qualifying institution who performs best in microbiology in their penultimate year of study for a Bachelor's degree. Each winning student will be awarded £100, a certificate and a free year's undergraduate membership of the SGM.

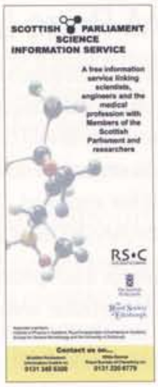
One prize is available to each university in the UK and Republic of Ireland offering a degree course with a significant content of microbiology. The university chooses the assessed microbiological work for which the prize is awarded. The submission should be supported by formal marks, not an informal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

Universities are now invited to nominate a student for a 2005 SGM Undergraduate Microbiology Prize. Submissions can only be accepted on the form which has been sent to all institutions. The full rules and further copies of the form may be downloaded from the SGM website or obtained from the Grants Office at Marlborough House.

The closing date for nominations is **31 August 2005**.

◄ Professor Andrew Weightman, Cardiff School of Biosciences, presents Laura Thomas with her SGM Undergraduate Microbiology Prize in 2004. *Dr Stuart Davies*

Scottish Parliament Science Information Scheme (SPSIS)



This scheme was set up in 2002 to provide MSPs with access to impartial advice and information on scientific topics. With a base at the Royal Society of Edinburgh, co-sponsors of the scheme with the Royal Society of Chemistry, the University of Edinburgh and the Scottish Parliament Information Centre, 52 Topic Co-ordinators were found who were willing to swiftly identify experts in their field to assist with enquiries. SGM was invited to be an associate of SPSIS to act as a conduit to expertise in microbiology. Our existing experts in Scotland agreed to be involved. Following a review after its first year of operation, the scheme will continue and SGM has been asked to participate again. SPSIS will be re-launched in the early summer and will be heavily promoted to MSPs.

BBSRC reviews the microbial science it funds

The Biotechnology and Biological Sciences Research Council will shortly be reviewing its considerable research portfolio in the Microbial Sciences, and is inviting views from the research community and others.

The review will cover research on viruses, bacteria, archaea, fungi and protists. It is part of a series of reviews and consultations providing information that helps BBSRC to set its research priorities and plan its activities in the light of stakeholders' views. Recent reviews have covered research in *Sustainable Agriculture* (2002), *Crop Science* (2004) and *Farm Animal Genomics* (ongoing).

The *Microbial Sciences* review will:

- review current research sponsored by BBSRC through responsive mode, core strategic grants to institutes and other funding relevant to microbial science.
- analyse research strengths and weaknesses in the context of a medium- to longer-term (i.e. 5–10 years) strategy for microbial research.
- consider how BBSRC's research priorities in this area relate to those of other Research Councils and Government Departments, in particular to MRC, and those of industry and other stakeholders, in an international context.
- advise BBSRC on priorities for future research in microbial science and how the high priority areas should be developed and to recommend options that
  - (a) promote collaborations as appropriate
    - (i) within and between BBSRC institutes
    - (ii) between BBSRC institutes and the universities
    - (iii) between BBSRC and other funders nationally and internationally;
  - (b) incorporate the most appropriate funding and training arrangements/mechanisms to support microbial science research in institutes and universities;
  - (c) optimize the transfer of the outputs of basic research (including that of model systems and species) into application.

The review will be conducted by a panel of experts drawn from the main stakeholder groups, which, following the formal, open consultation, will submit a report and its recommendations to BBSRC's Strategy Board. A report will be considered by the BBSRC Council later in 2005.

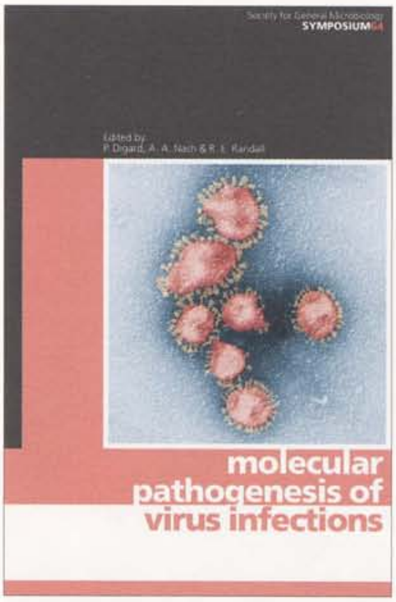
The consultation document will appear shortly on BBSRC's website at **www.bbsrc.ac.uk**. All interested parties and individuals are strongly encouraged to participate and submit their views.

Professor Nigel Brown, Director of Science and Technology at BBSRC (and long-time member of the SGM) said '*We would particularly value the views of practising microbiologists. The SGM membership includes a variety of experts, working within and outside the BBSRC's scientific remit. It is important that we obtain as wide a series of views as possible.*'

The Review Secretary, **Dr Jef Grainger**, is happy to answer any questions about the review process (**e** jef.grainger@bbsrc.ac.uk).

bbsrc
biotechnology and biological sciences research council

sgm symposium 64



Molecular Pathogenesis of Virus Infections

Edited by P.E. Digard, A.A. Nash & R.E. Randall
Published by Cambridge University Press (2005)
£30.00/US$50.00 (members)
£75.00/US$125.00 (non-members)
pp. 339 ISBN 0-52183-248-9

This is an impressive symposium volume. Besides being 'bang up-to-date' the contributions provide a compendium of well written and interesting chapters in keeping with the excellent reputation of this series.

This field is moving so fast that very few scientists can hope to keep in tune with all the complexities of the molecular pathways being revealed – this volume is therefore very well timed and should be a valuable asset for both virologists and molecular pathologists.

One's immediate reaction on reading it is to admire the ingenuity of viruses in combating the host defence mechanisms. The strategies adopted are varied and are critical to an understanding of the disease outcome.

There are 16 chapters, some of which provide a comprehensive review (e.g. an excellent dissertation on HIV immunity) and others which examine more general concepts (e.g. adaptive immunity, gene silencing initiated by iRNAs and cellular restriction factors). A striking feature of many of the contributions is the multiplicity of appropriate recent references. Indeed, in the chapter on influenza pathogenicity where the possibility of an avian influenza pandemic is real, this is particularly pertinent. The chapter on haemorrhagic diseases caused by dengue virus infection illustrates the direct importance of the T cell responses and antibody enhancement in disease aetiology. In many of the chapters the key roles of virus gene products in regulating apoptosis and the interferon response are discussed in considerable detail. Thus in many persistent RNA virus infections the virus is able to thwart apoptopic pathways successfully. In the case of hepatitis C infections there are around 10 million cases in the USA and with no viable vaccination strategies and no adequate therapies; the case for unravelling the molecular pathways is compelling. The chapter describing progress on this problem illustrates the complexities of the interacting pathways of interferon signalling and T cell responses. With the more recent emergence of SARS infection the short chapter on feline coronaviruses provides an update on a model which is more amenable to *in vivo* investigation.

Papillomavirus infections are quite widespread and have (because of lack of good *in vitro* systems) only been studied in any depth relatively recently. The presentation describing the basic events leading to the variety of disease outcomes characteristic of this family makes fascinating reading and illustrates the ability of a small virus genome to employ many different strategies to disrupt cell cycle controls. In another chapter, infection by Ebola and Marburg viruses where the disease usually overwhelms the host via efficient suppression of the host defences is described in some detail.

The characteristics of the responses to infection by members of the herpes family are described in two chapters. One of these is targeted very specifically on the role of CD8 T cells in the regulation of HSV-1 latency and the other provides a broader perspective of gamma herpesvirus pathogenesis based on murid herpes virus 4.

The larger viruses are covered by chapters on pox viruses and African swine fever viruses and show that in addition to the strategies employed by their smaller cousins, these viruses can even produce gene products which can act as decoys to subvert the defences of the host.

It is interesting that the Editors have decided to include a contribution on prion diseases. The agents responsible are apparently not viruses and our knowledge of the molecular pathways leading to the spongiform encephalopathies, in stark contrast to the descriptions in other chapters, is almost minimal. Nevertheless, its inclusion is a sharp reminder that nature can quite often even subvert the intrusions of the molecular biologist!

Professor Willie Russell
University of St Andrews

An order form for Symposium Volume 64 (and earlier volumes) is available on application from the SGM Membership Office (members@sgm.ac.uk)

The threads that bind: symbiotic fungi in the garden

▲ Fruiting body of the ectomycorrhizal fungus *Thelephora terrestris*. *Robert L. Anderson, USDA Forest Service (www.forestryimages.org)*

Most people think of fungi and plants in terms of disease, but as **Alastair Fitter** explains, certain fungi are essential to plant growth. They form mycorrhizas – mutually beneficial associations with plant roots. Without this symbiosis our gardens would not be so green.

Everyone knows that a plant has leaves and flowers, and below ground its roots branch and explore the soil. Yet that picture misses an essential component as virtually all plants live with a fungus in a symbiosis called a mycorrhiza (from the Greek, meaning 'fungus root') that is essential to both partners. The plants get phosphate and some other nutrients from the fungus, and the fungus gets all its sugars from the plant. Plants gain other benefits too from the symbiosis and sustainable farming, forestry and gardening will all increasingly rely on understanding how it behaves.

Meet the ancestors

To explain why they are mycorrhizal, we need to go back to when plants first colonized the land more than 400 million years ago, in the Ordovician and Devonian periods. The first land plants had no roots; their coarse, branching rhizomes lay on or near the surface of the ground. The obvious problem for these plants was getting water, but in practice they probably grew in wet places where water may not have been the challenge. A greater difficulty was getting phosphate. The aquatic ancestors absorbed it from the water, where it was present, although very dilute. On land, a new problem emerged: phosphate ions form extremely insoluble compounds with elements such as iron, aluminium and calcium (think of bone), all of which are abundant in rocks and soil; hence phosphate ions diffuse extremely slowly into soils, taking days to move a few millimetres. Phosphate would not therefore move to the plants, and with no roots, the plants could not forage for phosphate in the soil. Instead they formed a symbiosis with fungi, whose growing network of threads (the mycelium) allowed them to explore the soil and forage for phosphate. In return the plant provided the fungus with organic compounds.

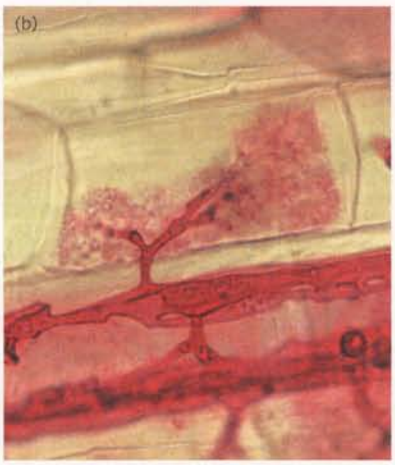
Three lines of evidence support this story: first, molecular evidence shows that this group of fungi originated at or before that distant time; second, we find plants that form this type of mycorrhiza in all branches of the evolutionary tree of land plants, showing that they must all have shared a common mycorrhizal ancestor; and most convincingly, there are fossils from Devonian rocks nearly 400 million years old that contain the fungal structures (Fig. 1a) and older Ordovician spores that are unequivocally from the group. This ancestral type is known as an arbuscular mycorrhiza, after the tiny structures called arbuscules that develop inside the cells of the root and branch like trees (Fig. 1b). The arbuscule is where the plant obtains phosphate from the fungus. Surprisingly, we still do not know where the fungus gets sugars from the plant, but it may be in the intercellular spaces where the fungal hyphae proliferate inside the root. The plant is the only source of organic carbon for the fungus, which apparently cannot grow solo; no-one has yet cultured these fungi without a plant.

Thoroughly modern mycorrhizas

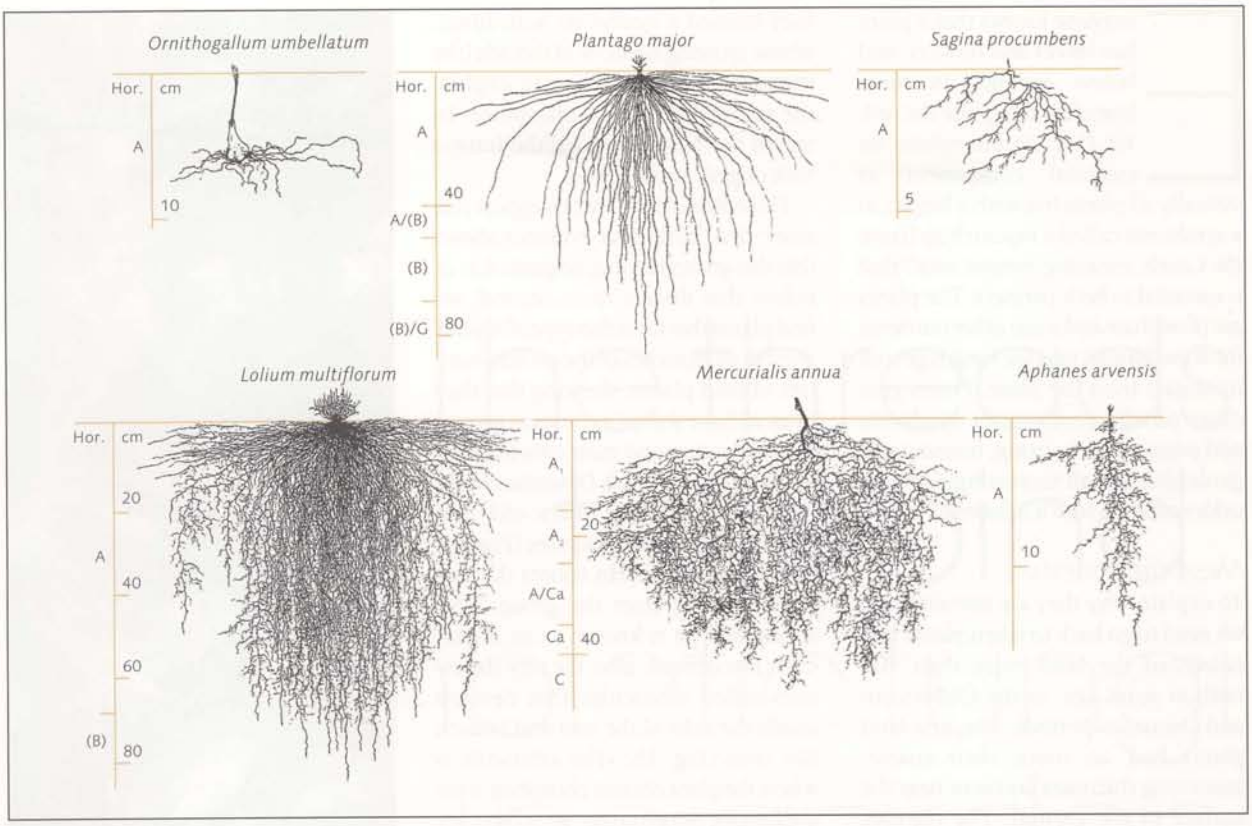
The reasons for the origin of this symbiosis do not, however, explain why about two-thirds of modern plant species form arbuscular mycorrhizas. Most modern plants have well developed root systems and can obtain phosphate themselves: they can grow in pots of sterilized soil. However, the root

▲ Hyphae (white) of a fungus (phylum Basidiomycetes) growing on the roots (brown) of the strawberry tree (*Arbutus unedo*). *Dr Jeremy Burgess / Science Photo Library*

◄ Fig. 1a. Arbuscule in a fossil rhizome of *Aglaophyton major*. The arrow points to the dichotomously branching hypha that gives rise to the arbuscule, as also seen in the modern root. *Reprinted with permission from Taylor et al. (1995) Mycologia* **87**, *567*



◄ Fig. 1b. Arbuscules of an arbuscular mycorrhizal fungus (Glomeromycota) in a modern root of *Hyacinthoides non-scripta*. *J. Merryweather*



systems of plants display enormous variation in form: grasses have densely branched root systems with very fine roots (Fig. 2, bottom row), whereas plants with bulbs and corms (snowdrops, crocuses, onions) have coarse, unbranched root systems (Fig. 2, top row). Plants with dense, fine roots rely on the fungus for phosphate only in very infertile soils, whereas the bulbs and other thick-rooted species may be wholly dependent on the symbiosis except in the most heavily fertilized soils. In modern agriculture, biological solutions to problems that could be solved technologically have been unfashionable, and little attention has been paid to the potential benefits of this symbiosis. However, phosphate fertilizers are all mined unsustainably, and farmers and gardeners may therefore need to rely more on their fungal partners in future.

Modern plants with fine root systems still form mycorrhizas, even though they can often acquire phosphate themselves, because the fungi do more than forage for phosphate: they can acquire other nutrients from soil, especially the less soluble and hence less mobile ones such as zinc; they can protect roots from other fungi that may be parasitic or pathogenic; and they can bind roots to soil so improving their drought resistance. There are other functions, too, for which the experimental evidence is less strong, but even this list shows that mycorrhizal fungi are powerful partners. Consequently, they have profound impacts on plant communities, and can determine the competitive hierarchies amongst plant species.

Amazing fungi

The fungi themselves are remarkable. Their separate phylum, Glomeromycota, has only about 150 described species. However, since the taxonomy is entirely based on spore features, this paucity almost certainly hides greater diversity: again, molecular evidence points to that. They are apparently asexual, but their unique spores contain thousands of nuclei that appear to be genetically diverse, so that a single fungal mycelium may be the genetic equivalent of a population of individuals (or even possibly a community of species!). We are only just beginning to understand the basic biology of these organisms, even though they are among the most abundant creatures on earth.

Ectomycorrhizas

There is no way to tell whether a plant is symbiotic with an arbuscular mycorrhizal fungus just by looking at it. You need to stain the roots to reveal the fungal structures, though under a microscope you can also see hyphae around the root. However, this is not the only form of mycorrhiza. Later in evolution, a new mycorrhizal symbiosis emerged: this one is visible to the naked eye, because the fungus changes the way the roots develop, and the resulting stubby, often branched root tips, coated with fungal hyphae, are very distinctive, hence the name ectomycorrhiza (Fig. 3). The ectomycorrhizal symbiosis seems to have evolved at least twice, in each case with woody plants – first with pines and their relatives, and later with woody flowering plants, such as oaks, beeches and birches (Fagales). The same fungi are involved in each case, and they are very different from those that form arbuscular mycorrhizas. Ectomycorrhizal fungi are almost all Basidiomycota or Ascomycota, often forming well known and distinctive fruiting bodies: fly agaric (*Amanita muscaria*) is an ectomycorrhizal associate of birch and pine.

Ectomycorrhizas function similarly to arbuscular mycor-

> *Virtually all plants live with a fungus in a symbiosis called a mycorrhiza that is essential to both partners*

◀ Fig. 2. Variation of root system architecture displayed by root tracings of a range of species. *Reproduced with permission from L. Kutschera (1960) Wurzelatlas mitteleuropäischer Ackerunkräuter und Kulturpflanzen (Frankfurt: DLG)*

▲ Fig. 3. An ectomycorrhizal root of pine, colonized by *Lactarius* sp. The roots are stunted and branch dichotomously; the sheath of fungal hyphae surrounding the root is clearly visible. *F. Martin*

▶ Fig. 4. The achlorophyllous orchid *Epipogium aphyllum* growing at one of its last British sites in 1966; it is now apparently extinct in Britain. The plant has no leaves and virtually no roots either, and is wholly reliant on a mycorrhizal fungal partner for all its nutritional requirements. *A. Fitter*

rhizas: the fungus explores soil and obtains nutrients that it exchanges for sugars with the plant. However, ectomycorrhizal fungi can be grown in pure culture, without a plant, because they can decompose and obtain nutrients – especially nitrogen – directly from organic materials. Without this direct access to nutrients, plants rely on other fungi and bacteria to break down the materials and release them, for which they must compete with other microbes. The ectomycorrhizal symbiosis seems to have evolved as an adaptation to growing in ecosystems where plant litter accumulates because decomposition (and hence the nitrogen cycle) is slow, leading to nitrogen deficiency. As far as we know, arbuscular mycorrhizal fungi cannot directly breakdown organic matter, and are not heavily involved in increasing the uptake of nitrogen, of which the ionic forms, nitrate and ammonium, are generally quite soluble in soils. Nowadays, ectomycorrhizal plants dominate forests in the temperate and boreal zones, whereas trees with an arbuscular mycorrhizal symbiosis are found in most tropical forests, where decomposition and nitrogen cycling are rapid and litter does not accumulate.

Other symbioses

These two types of mycorrhiza are the commonest and most important, whether in natural communities or in managed systems, such as farms, forestry and gardens. However, there are many other root–fungus symbioses, generally confined to particular groups of plants, which suggests that they have evolved recently. One is with heathers and their allies (Ericales). This symbiosis is with a group of fungi that are especially effective at breaking down organic materials for nitrogen. Heathers grow typically in soils where peat forms, which shows that decomposition has almost ceased and that the nitrogen cycle has also ground to a halt. Again, the symbiosis works as an exchange: the heather gets nitrogen and the fungus gets sugars.

Orchids too form their own mycorrhiza, but a very odd one: the orchid is parasitic on the fungus, shown most clearly in orchids that form no chlorophyll (Fig. 4). Once described as saprophytes, suggesting that they live off dead organic matter, these plants obtain all their nutrition (mineral and organic) from their fungal partner. Nobody has yet found anything that the fungus gets from the orchid. How orchids trick their fungal partners (some of which are parasites on other plants) into entering this one-sided relationship is a mystery.

In conclusion

Mycorrhizas are ubiquitous: most plants exist in symbiosis. There are several distinct types with unique ecological properties. In natural ecosystems mycorrhizal fungi appear to control the diversity of the plant community and the speed of the carbon cycle; in managed systems, except in some types of forestry, their potential has yet to be exploited and will not be until we understand better the biology and ecology of the organisms involved.

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Bacteria, and more especially fungi, damage most garden plants. They tend to attack at the most vulnerable stages of plant development: germination, the rooting of cuttings, rapid foliar growth, flowering and fruiting. Many pathogens only attack one of these susceptible phases.

Seeds and seedlings

Germinating seeds and seedlings are at the greatest risk. The main reason is that seedlings are fleshy and juicy whereas seeds contain reserves of carbohydrates and other stored food reserves used in germination. Many seedlings are either killed or incapacitated by a mixed group of micro-organisms which cause damping-off and foot rots. The protozoan oomycete 'pseudofungi', in the genus *Pythium*, are often the chief culprits, causing damping off. The disease is worse in damp or wet soils. The closely related oomycete *Phytophthora* spp. behave similarly, but also attack the fleshy newly emerged roots and stem collars on much more mature plants, including a number of trees. Oomycetes need water for their zoospores to penetrate and spread through the soil and so can be limited if soils are made more free draining by the incorporation of gravel or compost. The true fungi *Rhizoctonia solani* and *Alternaria* spp., and species of *Pseudomonas* bacteria, attack both seedlings and also more mature roots. While the soil-borne fungi spread by a network of strands known as the mycelium, the bacteria have to rely on films of water to move to new hosts. *Rhizoctonia solani* causes 'wirestem' as it attacks and emaciates the collar region of seedlings of the cabbage family by means of hyphae which often emanate from tightly packed bundles of mycelium called pseudosclerotia.

◄ Hawthorn fire blight (single flower truss infection with spread into pedicels) caused by *Erwinia amylovora*. *DEFRA*

► White root rot (*Rosellinia necatrix*) on a Narcissus bulb. *DEFRA*

Bacterial and fungal diseases of garden plants

Pathogenic fungi and bacteria are always in the environment, ready to attack garden plants when the opportunity arises. **Roland Fox** describes some of the diseases that can affect plants at various stages of development.

Roots

Even after plants become established they can be attacked by root rots (*Pythium* spp., *Phytophthora* spp., *Rhizoctonia solani*, *Thielaviopsis basicola*, *Fusarium* spp., *Nectria radicicola* syn. *Cylindrocarpon destructans* and *Phoma chrysanthemicola*). Even trees and shrubs are killed by honey fungus root rot (*Armillaria mellea*) and white root rot (*Rosellinia necatrix*). Both also attack some herbaceous plants and the latter destroys bulbs. Foliage on trees infected by *Armillaria mellea* usually turns yellow, then brown, branches die back and growth is reduced. The roots of infected conifers often become heavily caked with resin, soil and mycelium. Deciduous trees occasionally develop sunken cankers beneath loose bark often permeated with gum and other exudates.

Armillaria

Armillaria mellea is considered the most damaging fungal root rot as its hosts include the coarse roots and lower stems of trees, shrubs, vines, and some herbaceous plants. In addition to *Armillaria mellea* which is largely a temperate species of root pathogen, there are many other closely related *Armillaria* species worldwide, but most live as saprophytes on dead woody material. In Britain, *Armillaria mellea* is often known as the bootlace fungus because of the hard compacted threads known as rhizomorphs which allow it to reach new hosts. Between the wood and the bark over infected areas are white fan-like mats of mycelium and flattened, reddish black-brown rhizomorphs. The latter resemble the thin string-like rhizomorphs it produces in soil. For a few weeks in autumn clumps

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of the honey-coloured mushrooms often appear around the bases of heavily infected trees and stumps. *Armillaria mellea* causes a white rot of infected wood. Initially this is light brown and water-soaked, then white, often with black lines. Mycelium can survive for decades in this food source before spreading through the soil inside rhizomorphs to colonize living hosts, leaves or dead wood. The rhizomorphs continue to grow until they at first contact, then entwine round and penetrate healthy roots. Infection of uninfected roots may also result if they touch or graft onto infected roots. Control is difficult, but all dead stumps and roots should be removed from heavily infected areas.

Stems

The stems of mature plants such as roses, bulbs, corms, carnations, lilies and tomatoes are affected by a variety of stem rots (*Botrytis cinerea*, *Sclerotinia sclerotiorum*, *Rhizoctonia solani* and *Alternaria* spp.). Inside the stems of tomatoes, carnations and other plants there may be Fusarium wilt/corm rot (*Fusarium oxysporum*) or Verticillium wilt (*Verticillium albo-atrum*). These enter via the roots and form long-lived resting propagules as does bulb rot (*Sclerotium tuliparum*). *Sclerotium tuliparum*, like the causal agent of white rot of onions, *Sclerotium cepivorum*, is long-lived in soil as sclerotia; these are highly compacted balls of mycelium with an impermeable rind not unlike that covering the strands inside rhizomorphs. They have the same protective function against other fungi and exposure to adverse environments.

The bacterium responsible for crown gall (*Agrobacterium tumefaciens*) also spreads in the soil like *Pseudomonas* spp., the cause of bacterial basal crack, black blotch or wilt. Affected plants affected by develop a large gall at ground level. Crown gall is particularly prevalent on roses, but can occur on plants as diverse as gladiolus and oak.

Leaves

The leaves of many garden plants are pocked by spots caused by the fungi *Ascochyta*, Alternaria leaf spots (*Alternaria alternata* and other species), and *Phyllosticta antirrhini*, Phlox leaf spot (*Septoria drummondii*), Iris leaf spot (*Didymellina macrospora*) and bacteria like those responsible for Antirrhinum leaf spots (*Pseudomonas syringae* pv. *antirrhinum*). Ring spot (*Mycosphaerella dianthi*) results in a somewhat more complex spot. The downy mildews (e.g. *Peronospora parasitica*) and the cause of ray blight (*Didymella chrysanthemi*), by contrast, produce blight symptoms where the pathogen enjoys unrestricted growth compared to the leaf spots whose colonial tendencies are promptly inhibited by the host's defence mechanisms. Other common leaf pathogens include the powdery mildews (like *Erysiphe polygoni*, various *Oidium* and *Sphaerotheca* spp.) which grow superficially over the leaves, but feed undetected by the host via specialized hyphal structures called haustoria sunk into their epidermal cells. Often powdery mildews develop when host plants are shaded. The rusts (*Puccinia horiana* and other spp., *Uromyces* spp.) have adopted an extensive intercellular mode of colonization. The distorted growth caused by *Corynebacterium fascians* depends on environmental and chemical factors. In violet smut (*Urocystis violae*) the petiole of the leaf is also swollen and distorted by the production of spores.

◀ 1. Delphinium black blotch caused by *Pseudomonas syringae* pv. *delphinii*.

2. Fuchsia rust (*Pucciniastrum epilobii*) on the upper surface of a detached leaf.

3. Gladiolus crown gall (*Agrobacterium tumefaciens*).

4. Bay laurel leaf spot (*Phyllosticta lauri*).

5. A severely affected stem base of a pelargonium with leafy gall caused by *Corynebacterium* (*Rhodococcus*) *fascians*.

6. A cyclamen plant with cyclamen grey mould (*Botrytis cinerea*) and crown rot.

7. A single bloom of a chysanthemum with grey mould (*Botrytis cinerea*).

8. Fruiting bodies of the honey fungus, *Armillaria mellea*.

DEFRA (1–7); Roland Fox (8)

Fire blight of apples, pears, *Cotoneaster*, *Sorbus*, *Pyracantha*, hawthorn and related trees is caused by *Erwinia amylovora*, imported to southern England from the Americas in the 1950s. This destructive disease has now spread to most of Europe, the Near East and New Zealand. Other bacterial foliar diseases in the garden are the bacterial leaf spots caused by *Pseudomonas* and *Xanthomonas* spp. In particular, if unchecked, the bacterial leaf spots on cherry leaves caused by *Pseudomonas syringae* usually develop into the symptom known as shotholes. If this is not treated it can spread from the leaves to the twigs and from there into the branches and the trunk where it causes gummosis and ultimately premature death. A number of *Xanthomonas campestris* pathovars occur in the garden. *Xanthomonas campestris* pv. *campestris* causes a black rot of cabbage and related plants.

Flowers

During flowering plants can exhibit a range of diseases. Probably the most serious is damping and spotting caused by *Botrytis cinerea*. Sclerotinia rot (*Sclerotinia sclerotiorum*) and Alternaria flower spot (*Alternaria* spp.) are also frequent. On chrysanthemum, petal blight or flower scorch (*Itersonilia perplexans*) and ray blight (*Didymella chrysanthemi/Mycosphaerella ligulicola*) are damaging along with stunt (Chrysanthemum Stunt Viroid) and flower distortion/aspermy (Tomato Aspermy Virus). After flowers have been harvested and put in a vase, the water may become contaminated by cut flower rot bacteria (*Pseudomonas* spp.)

Disease versus decay

Plants are at risk from infection by various pathogens at different stages of their lives. It is common knowledge that micro-organisms can spoil harvested fruits and vegetables. Some of these pathogens produce powerful toxins and so it is wise to eat only sound produce. Interestingly it has been suggested that these poisons evolved to discourage ourselves and other animals from devouring the food that moulds need. However, when we eat edible pathogenic fungi like *Armillaria* and even truffles (not virulent pathogens but they do stunt trees) we can make some amends! Even after the death of plants, many soil-borne facultative pathogens and saprophytes compete for their remains in the soil. If they did not our world would soon resemble a gigantic compost heap! Finally, it is also worth considering the incredible adaptations pathogens have evolved on several occasions in order to survive and thrive at our expense.

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Soil microbes and the

Weeds are a big problem to all gardeners and growers, especially if they do not want to use chemical herbicides. Robert J. Kremer explains how microbes can provide an effective, alternative means of control.

Weeds have been associated with human activity from the very beginnings of society, when man evolved from a hunter-gatherer mindset and began to domesticate plants and animals and cultivate the land on which he settled. Why have weeds continued to persist as problems in our gardens, lawns, fields, meadows, and roadsides to this day? What is the nature of weeds that causes them to be opportunistic in almost any environmental situation and pose problems ranging from competition with man's desirable plants, to production of allergens, production of complex chemicals often toxic to man and animal, contamination of foods, feed and fibre, and harbouring other pests? In today's society it seems to be easier to find a 'quick fix' for problems rather than try to understand why the problem exists and derive a management plan based on knowledge.

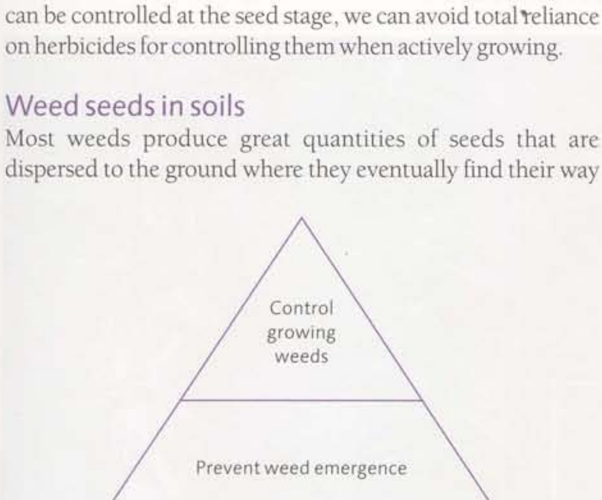
Because estimated costs of losses due to weeds are likely to exceed \$10 billion annually, the simplest way to get rid of them is treat with herbicides and the problem disappears – for this year – only to return again the following spring. The majority of farmers, gardeners and others involved in land management only see the growing plant that needs control; they do not realize the dynamics of the entire life cycle of a weed. The larger and fundamental part of the

war on garden weeds

weed problem lies in the soil as resident and viable seeds or other vegetative propagules (e.g. bulbs, rhizomes, etc.). In fact a total weed management approach is based on preventing seed production to relieve pressure on stopping weed emergence and control of the growing weed (Fig. 1). If weeds can be controlled at the seed stage, we can avoid total reliance on herbicides for controlling them when actively growing.

Weed seeds in soils

Most weeds produce great quantities of seeds that are dispersed to the ground where they eventually find their way into the upper few centimetres of the soil. These seeds have physiological traits that allow them to persist in a viable state (dormancy) in the soil for 50 years or more. Not all of them germinate every year, so weed problems can continue even if one manages to control seed production of weeds for several years! Why do weed seeds persist in soil without being attacked and decayed by the millions of micro-organisms typically inhabiting the soil? Based on many trials involving tedious retrieval of weed seeds from soil and culturing the associated micro-organisms, we found that many weed seeds possess elaborate mechanisms for avoiding microbial attack.



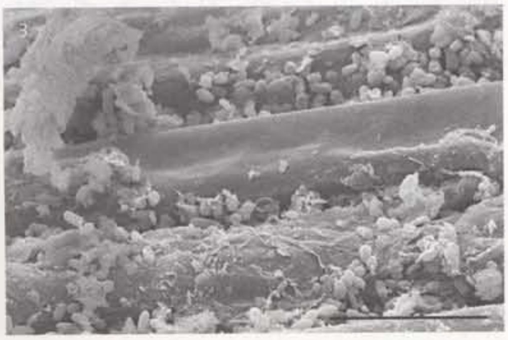
◄ Opposite page. Fumitory (*Fumaria* sp.), a beautiful flower, but an annoying weed for many gardeners. *Ian Atherton, SGM*

▲ Remains of the flower heads of a species of thistle, a common field weed. *Ian Atherton, SGM*

◄ Fig. 1. The three-part total weed management programme for crop or garden production systems, based on critical phases during the life history of a weed. *Reproduced with permission from R.J. Aldrich & R.J. Kremer (1997) Principles in Weed Management (Ames, IA: Iowa State University Press)*

Seeds with hard and dark-coloured coats (such as mallow), pose not only a physical barrier to attack by micro-organisms, but can also release toxic chemicals from their coats in soils at an optimum water content that repel or even kill soil micro-organisms. We have also found that some weed seeds harbour bacteria on or in the seed coat that are antagonistic to soil microbes.

Selection of 'seed-attacking' micro-organisms, therefore, would be a difficult task considering the nature of weed seed structure and chemistry. Some scientists have suggested that other organisms such as surface-dwelling insects might pierce seeds during feeding and allow entry of micro-organisms for attack. This strategy may work for only a few weed species and it is



Soils managed in a sustainable manner have more potentially weed-suppressive bacteria than soils managed under conventional systems that rely on high inputs of chemicals

▲ Fig. 2. Inhibition of velvetleaf (*Abutilon theophrasti*) seedling growth by inoculation with deleterious rhizobacteria (left). Note the much more extensively branched root system of the non-inoculated plant (right). The inoculated plant also shows evidence of chlorosis in the newest leaves. *R.J. Kremer*

▲ Fig. 3. Root surface of a 2-week old velvetleaf root colonized by *Pseudomonas fluorescens* strain 239 cells (arrow) aligned in the intercellular spaces of root epidermal cells. Bar, 10 µm. *R.J. Kremer*

▶ Fig. 4. Suppression of weeds in sweetcorn plots after 2 years of compost amendments added to soil compared to no treatment (inset). Weed density and biomass of the composted plot was reduced by >50 %. *R.J. Kremer*

▶ Opposite page. Rosebay willowherb (*Chamaenerion angustfolium*) growing in a farmer's field. *Ian Atherton, SGM* difficult to maintain adequate numbers of such beneficial insects in the field or garden to have a significant effect on depleting the seed population in soil.

Weed seedlings are vulnerable

The germinating seed is a considerably more favourable target for microbial attack than the actual seed. We have selected numerous bacterial cultures from roots of weed seedlings that show excellent growth inhibition under favourable conditions (Fig. 2). It is critical that the bacteria recognize the weed seedling root via chemical signalling and establish high populations on the root surface through aggressive colonization (Fig. 3). Drawbacks to this approach have been that application of selected bacterial cultures in practical fields and gardens is hampered by adverse environmental conditions (moisture and temperature stress) and that while bacteria are adapting to the soil environment, the weed seedling simply outgrows any inhibitory effect. Also, it is nearly impossible to develop an inoculant able to attack the broad spectrum of weed species that often infest our fields and gardens.

Conservation biological control approach

Because it has proved difficult to select micro-organisms for release into fields and gardens to successfully attack weed seeds and seedlings, perhaps the resident microflora can be induced to suppress weed seedling growth? We know from previous reports that the application of aged composts or manures to soils often suppresses soil-borne diseases of our desirable plants. Using this strategy, we have found that soils that have been managed in a sustainable manner, such as in organic gardening, have more potentially weed-suppressive bacteria than soils managed under conventional systems that rely on high inputs of chemicals. We tested this observation by applying different composts and manures (12–15 Mg ha^{-1}) and mulches of cover crops such as hairy vetch and oats, and assessed microbial activity and weed density. We found that after 2 years, soil organic matter levels increased as well as several soil microbial enzyme levels, which were directly related to reduced weed density (Fig. 4). The important finding is that a farmer or gardener able to recognize that weed seeds reside in soil can control future infestations by using some simple practices that stimulate populations of weed-seed- and seedling-attacking micro-organisms. No added exotic microflora, no expensive, hazardous chemicals are required – just patience in conserving and nurturing the naturally occurring weed biological control agents that reside directly in their own soil.

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'Broken' tulips and *Tulip breaking virus*

▲ Illustration of 'Tulip cv. Semper Augustus' taken from *The Tulip Book* (circa 1630–1639). *Netherlands Economic History Archive*

▶ 'Broken' tulips, yellow and pink roses in a glass vase on a stone ledge, with a bottle of ink and a piece of paper identifying the tulips, by Jan Phillip van Thielen (1645–1650). *Reproduced with the permission of Richard Green Galleries*

Due to their beauty, range of colours and early flowering, tulips have remained popular as garden plants and cut blooms since they were first imported into Europe from Asia Minor and Persia more than four and a half centuries ago. Their introduction is usually attributed to Ogier de Busbecque who, in 1554, first sent tulip bulbs and seeds to Vienna. This, of course, was only a few years after the deaths of great historical figures such as Henry VIII, Martin Luther, Pope Clement VII and Francis I of France, and when Tsar Ivan IV (Ivan the Terrible) was at his most powerful. It is interesting that Busbecque, Ambassador of Ferdinand I, the Holy Roman Emperor, to the great Sultan Souleiman, the Ottoman Emperor (known to Europeans as the Magnificent and to his subjects as the Lawgiver), considered in such turbulent times the collection of plants new to the western world an important duty. After their introduction, tulips were immediately popular in Europe and, soon after, bulbs were distributed from Vienna to Augsberg, Antwerp and Amsterdam, and subsequently to other European cities.

Tulip breaking virus

Of the viruses now known to infect tulips and cause 'breaking', the best known is *Tulip breaking virus* (TBV) which induces leaf chlorosis and, in coloured cultivars, 'broken' flowers. Breaking, or rectification as it was also earlier known, describes the appearance of the flowers in which the petals, instead of being uniformly coloured, are variegated due to the irregular distribution of anthocyanin. Such 'broken' flowers are known to have occurred in tulips in Europe within a decade or so of their introduction and have since featured commonly in art and history. As early as 1585 Carolus Clusius, Professor of Botany in Leiden, described how some red-, yellow- and purple-flowered tulips in subsequent years produced flowers that became variegated (or, as later described,

It's hard to believe that in the 17th century people yearned to possess a diseased flowering bulb. Yet as **Alan Brunt** and **John Walsh** describe, tulips with variegated petals due a virus infection once commanded higher prices than works of art.

▲ Illustrations of 'Tulip cv. de geele Admiral de Man' (top) and 'Tulip cv. Candida' (bottom) taken from *The Tulip Book* (circa 1630–1639). *Netherlands Economic History Archive*

► Electron micrograph of potyvirus particles. *Colin Clay, Warwick HRI*

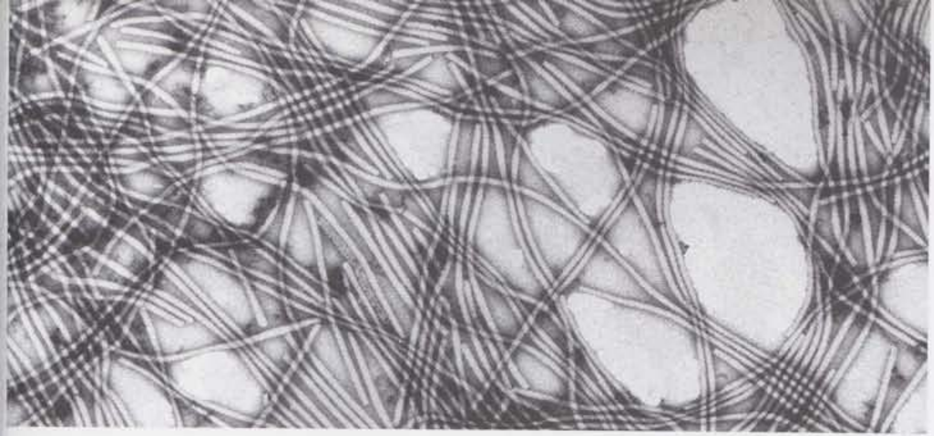
'broken'). The cause of breaking was then unknown and, not surprisingly in the absence of knowledge, was attributed to various causes, including an unsuitable planting depth for bulbs, applications of manure that were too high or too low, a soil that was too poor or too rich, or an inclement climate. Broken flowers produced by tulips in the year or two after becoming infected are undoubtedly beautiful, but thereafter the vigour and flower quality of infected plants decline markedly. Clusius first observed in 1585 that such plants slowly degenerated and this is well expressed, if rather grandiloquently, in his words '*...any tulip thus changing its original colour is usually ruined afterwards and so wanted only to delight its master's eyes with this variety of colours before dying, as if to bid him a last farewell*'. However, in the 20th century TBV was described occasionally as 'the benevolent virus', probably due to an inadequate literature search by the authors!

Tulip speculation in Holland

Although infected bulbs gradually degenerated, those producing broken flowers were very desirable and often sold for high prices, especially during the early 17th century. Financial speculation in such bulbs was then common; for example, some bulbs of cv. Semper Augustus, the most beautiful of broken red-flowered tulips, were each sold in Holland for 1,000 florins in 1623 when the average annual income was 150 florins. Two years later, each good Semper Augustus bulb sold for 2,400 florins, and in 1633 each bulb was valued at 5,500 florins. Speculation in tulips reached its peak from 1634 to 1637, and the mania is reported as affecting not only the wealthy, but also other citizens, including bricklayers, plumbers, swineherds, clergymen and teachers. The history of this period has been told repeatedly, but is worth restating briefly. In 1637, the year of so-called 'tulipomania', it is recorded that a bulb of Semper Augustus sold for 10,000 florins, this amount was then the price of a house, gardens and coach house in a very desirable location near the canal in central Amsterdam. However, this was also the year in which there were more sellers than buyers and eventually the market in tulips collapsed.

There are numerous contemporary satirical poems, essays, cartoons and paintings on the follies of the tulip speculators. As early as 1614 fun was made of those spending large sums on tulips; '*a fool and his money is soon parted*' appears on an engraving of two tulips by Claes Jansz, and in a painting by Jan Breughel the Younger, monkeys in contemporary clothing are depicted dealing in tulips. In a classic cartoon, tulip speculators are seen within an inn (which is in the shape of a fool's cap) named '*At the Sign of the Fool's Bulbs*' and, as a symbol of stupidity, has outside Flora sitting on a donkey. The cartoon has the caption '*A picture of the wonderful year 1637 when one fool hatched another and the idle rich lost their wealth and the wise lost their senses*'. A pamphleteer also satirically valued a tulip bulb as being equivalent to:

12 fat sheep	*1 silver goblet*
8 fat pigs	*1 full dress suit*
4 fat oxen	*1 bed (with linen)*
8 tons of rye	*2 hogsheads of wine*
4 tons of wheat	*4 barrels of beer*
1,000 lb of cheese	*2 barrels of butter*



In 1637, the year of 'tulipomania', it is recorded that a bulb sold for 10,000 florins, the price of a desirable house and gardens in central Amsterdam

It is also recounted that the Professor of Botany at Leiden (a successor to Clusius) developed such an intense hatred of tulips that he demolished any he saw with his walking cane.

Tulips in still life paintings

Due to the very high value of bulbs in the early 17th century, it cost less for some citizens to commission Dutch and Flemish artists to paint still life pictures which mainly featured broken tulips rather than buy bulbs. Paintings by Maria van Ooterwyck, Simon Verelst, Ambrosius Bosschaert, Jan Brueghel, Brussel, Hans Bollongier and many other artists are now exhibited in art galleries and museums worldwide. Pictures of 'broken' tulips were also commonly printed in herbals such as *Hortus Floridas*, engraved by C. van de Passe in 1614, which contains one of the earliest known illustrations of these flowers.

TBV was long thought from pictorial records to be the earliest recorded plant virus. However, it is now generally thought that the earliest reference to a virus-induced leaf chlorosis is described in a poem by the Japanese Empress Koken in AD 752: '*For, the plant I saw in the field of summer the colour of the leaves were yellowing*'. It is speculated that the described disease was possibly caused by *Tobacco leaf curl virus*, which is known to occur and cause similar symptoms in infected plants in Japan.

Recent history

Although 'broken' tulips have occurred in Europe for over four centuries, the cause of breaking was not established unequivocally until almost 50 years ago. Immediately after the end of World War I, breaking was thought to be virus-induced by analogy with other plant diseases; some evidence for this was produced during the following decade when in 1927 it was shown to be sap-transmissible (although in the early 1600s it was shown that breaking could be transmitted mechanically by 'grafting' half a healthy bulb to half a broken tulip bulb) and in 1928 to be transmitted by aphids. It was not until the 1960s that TBV was shown to have flexuous filamentous particles mostly measuring about 12 × 750 nm and thus to be a virus. The genetic code of TBV has now been partially sequenced and the virus is recognized as a member of the genus *Potyvirus* (family *Potyviridae*). Like other members of the genus it is now readily detected and identified by serological and molecular techniques. Today broken tulips can be purchased that are the result of plant breeding, not virus infection. As TBV-infected bulbs gradually degenerate, this can be minimized by removing and destroying 'broken' bulbs quickly before aphids spread the virus to other bulbs and other hosts such as lilies.

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Useful contact

The Wakefield and North of England Tulip Society is dedicated to keeping older cultivars going, and breeding and showing new varieties. For further information contact Mr J.L. Akers, 70 Wrenthorpe Lane, Wrenthorpe, Wakefield WF2 0PT, UK (**t** 01924 375843).

At the first sign of sun, people dust down the barbecue, head out into the garden and start cooking. As **Martin Adams** and **Simon Park** describe, an enjoyable meal can easily be followed by a nasty dose of food poisoning.

▶ *The Image Bank*

Barbecue roulette

The increasing use of barbecues is a frequent omission from the catalogue of problems which forecasters predict will arise in the wake of global warming. Each year we see that as the hours of daylight lengthen and the temperature rises, some atavistic urge causes normally sane and sensible people to rush outside to cook. But away from the relatively well controlled environment of the domestic kitchen there lurk increased risks from new and familiar hazards.

It is well known that the incidence of many types of bacterial food poisoning increases in the summer months. A recent study of *Campylobacter* infection in England and Wales between 1990 and 1999 found that increased rates of infection correlated with temperature. This may, of course, be the result of several different factors, but the increased predilection for barbecues is probably one of them. One certainly doesn't have to be a very diligent searcher of the literature to turn up numerous reports of outbreaks associated with barbecued foods. There have been

outbreaks of *Salmonella*, *Campylobacter* and *Staphylococcus aureus* food poisoning caused by barbecued food reported recently from Australia, Germany, the Netherlands, Norway, the United States and the UK.

These outbreaks can arise from a variety of causes, as we will outline below, but a risk factor unique to the barbecue is that the cook is frequently not the usual household food handler; the person who by reason of experience is likely to be the most organized and the most knowledgeable in matters of food hygiene. While 'amateur nights' can be commendable exercises to discover new talent in many areas, when it comes to barbecuing it may be at some cost.

Cooking outside will increase the chances of contamination from sources such as birds (a known reservoir of *Campylobacter*) and flies, but the principal problems are likely to come from the increased risk of familiar hygiene failures such as undercooking, inappropriate storage and cross contamination.

Straight from the cow (or chicken)

Many of the raw foods used in barbecues, particularly meat and poultry, may be contaminated with bacterial pathogens. The incidence of *Salmonella* on chilled and frozen chickens produced in the UK has been monitored periodically for a number of years and a steady decline has been noted from 79 % in frozen poultry in 1984, to 41 % in 1994, to a figure of 6 % quoted by the Food Standards Agency in 2001. The incidence of *Campylobacter* has also declined from around 90 % in the late 1990s, but remains very high with a currently

cited figure of 50 %. Occasional studies report much higher levels, especially in imported chickens. Cattle and sheep are natural reservoirs of verotoxin-producing *Escherichia coli* (VTEC) and meat derived from these animals can become contaminated during the slaughtering operation. Its incidence on raw meat is much lower than that of *Salmonella* or *Campylobacter* on poultry – surveys usually report figures between 0 and 3 % – but the severity of the illness it causes in vulnerable groups such as the young and the elderly makes it a very important hazard to consider.

Turning up the heat

With a high likelihood that raw meats will contain bacterial pathogens, control measures available during the final preparation are critically important to assure safety. *Salmonella*, VTEC or *Campylobacter* do not have any marked heat resistance, so adequate cooking should ensure their elimination. With intact cuts of meat, such as steak, undercooking is less of a concern since the interior of muscle from a healthy animal is likely to be sterile and the surface contamination should be eliminated quite quickly by the heat on a hot barbecue. However, with irregular shaped products such as chicken pieces or products formed from comminuted meats such as burgers or sausages, thorough cooking throughout may be more difficult to achieve. This is particularly so when faced with the uncontrollable searing heat of a barbecue which is rapidly carbonizing the outer surfaces of the product and sending billowing clouds of acrid smoke into the eyes of the inexperienced (and possibly slightly drunk) chef. At high temperatures potentially carcinogenic heterocyclic amines and benzo[a]pyrene can also form inside and on the surface of red meat and these have been linked with an increased risk of colorectal cancer. Wise is the practitioner who microwaves first and then finishes off on the barbecue.

Spreading it around

Though thorough cooking is an effective control measure, it will all be for nought if the product is then subject to cross contamination. Numerous studies have demonstrated how effectively pathogens can be distributed around the environment and back on to food in the absence of strictly observed hygiene. Key rules such as washing hands after handling raw foods and the use of different utensils for raw and cooked products may be less scrupulously observed away from the ordered calm of the kitchen.

Something on the side

While the association of pathogens with raw meats might attract most attention, the potential for other common ingredients of the *al fresco* meal to cause illness should not be overlooked. There have been a number of outbreaks here and abroad related to fresh produce used in salads, such as lettuce, tomatoes and bean sprouts, caused by pathogens such as *Salmonella*, *Shigella* and VTEC. There is probably no greater risk associated with barbecues than with conventional food preparation, although extended inappropriate storage may be more likely if food is prepared well in advance of a barbecue function. Improper storage of potatoes baked in foil has caused three outbreaks of botulism in the United States. In the largest of these, which affected 30 people, the potatoes were cooked for 2 hours in an oven, then left at ambient temperature for 18 hours. Heating in foil was not sufficient to kill the *Clostridium botulinum* spores which were then able to grow in the anaerobic environment and produce toxin during subsequent storage. As a result of these outbreaks the USFDA classified baked and boiled potatoes as a 'potentially hazardous food'.

Microbes don't cause all the problems...

It is far from our intention to give an unbalanced picture, overemphasizing the microbiological hazards so, by way of redress, it is also worth noting some evidence of non-microbiological problems associated with barbecuing. There was, for example, the 10-year retrospective study conducted at Stoke Mandeville hospital which found that burn injuries from bonfires and barbecues accounted from 2·16 % of admissions, the regrettable incident of cadmium poisoning when someone used a refrigerator shelf as an improvized

barbecue grill, the arsenic poisoning that resulted when wood impregnated with copper-chrome-arsenate was used on a barbecue, the asthma attack triggered by a barbecue, the carbon monoxide poisoning caused by a barbecue grill, 'Backyard barbecue syndrome' caused by steak impaction in the oesophagus and finally the fatal stab injury caused by a skewer at a barbecue!

Bon appetit!

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▲ *Cartoon Pattie Hendrie*

▼ & ▶ *Ian Atherton, SGM*

Bugs within bugs: symbiotic bacteria in garden insects

Many insects are garden pests, and wreak havoc on both ornamental plants and crops. **Angela Douglas** reveals the unseen role of microbes in helping garden insects to survive.

Why is your garden green?

Macrobiologists would give a microbe-free answer to this question. The animals consuming garden plants – mostly insects – are kept in check by a combination of plant defences which make the plants unpalatable or downright toxic, and natural enemies such as ladybirds and other predatory beetles, parasitic wasps and fungal pathogens. This approach neglects a key weapon of phytophagous (plant-feeding) insects in their fight back against the near-inedible plants and army of natural enemies: symbiotic micro-organisms.

Many of the microbes requisitioned by phytophagous insects in their unending war with plants and natural enemies cannot be cultured by traditional laboratory methods. However, the recent development of molecular techniques to study unculturable forms is permitting many new discoveries to be made about these micro-organisms.

Why symbiotic micro-organisms are used by phytophagous insects

Micro-organisms are metabolically versatile, while animals are metabolically impoverished. This difference is key to understanding why symbiotic micro-organisms are exploited by phytophagous insects. Much plant material is deficient in nutrients that these insects cannot synthesize, including essential amino acids and vitamins. It may contain poisonous secondary metabolites that insects cannot detoxify. These metabolic deficiencies can be made good by forming symbioses with micro-organisms possessing these capabilities. Microbial symbioses in insects vary widely in their intimacy, from complex and ever-changing microbial communities in the gut lumen to highly specific relationships involving single bacterial taxa restricted to particular insect cells.

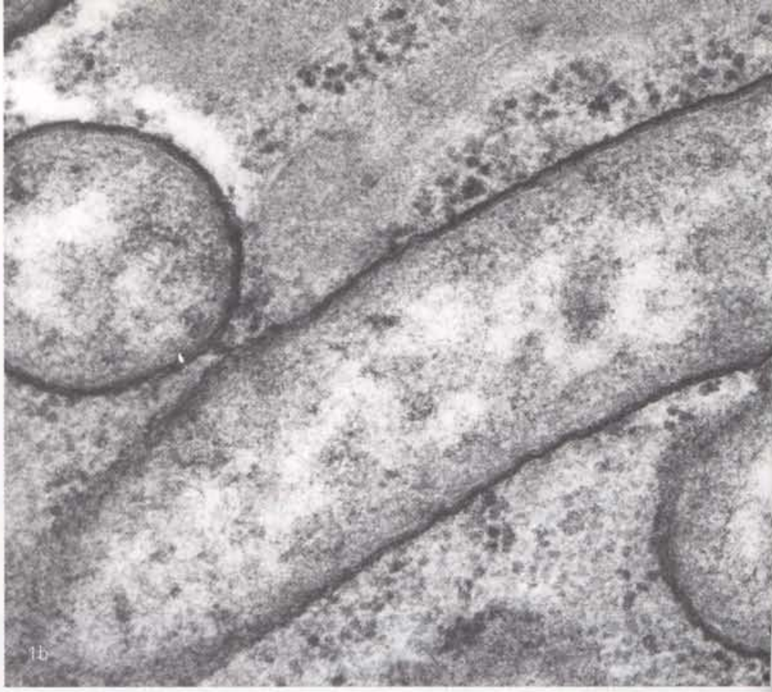
Insect herbivores can be divided into two functional groups: the 'chewers', such as caterpillars, grasshoppers and leaf beetles, which consume plant tissues wholesale; and the 'suckers', such as whitefly, aphids and spittlebugs, which imbibe plant sap. I will consider these two groups separately.

The microbiology of chewing insects: why caterpillars are not mini-cows

The traditional, but inaccurate, perception of microbial symbioses in chewing insects comes from our understanding of microbial associations in cows and other vertebrate herbivores which have cellulose-degrading bacteria in their guts. Wood-feeding lower termites – I trust absent from gardens in the UK – conform broadly to this paradigm (although their cellulolytic micro-organisms are protists rather than bacteria), but among phytophagous insects symbiotic cellulose degradation is exceptional. Some insects produce

▲ North American lupin aphids, *Macrosyphum albifrons*, feeding on a lupin stem. The large female on the left is giving birth to a live nymph. *Vaughan Fleming / Science Photo Library*

◄ A caterpillar on a blueberry leaf. *Derek Shimmin / Science Photo Library*



▲ Fig. 1. Bacterial symbiosis in weevils. (a) A weevil of the genus *Sitophilus* feeding on grain. (b) The symbiotic bacteria in *Sitophilus*, informally known as SOPE, are located in the cytoplasm of special insect cells, known as bacteriocytes. *G. Febvay and A. Heddi*

► Fig. 2. Bacterial symbiosis in aphids. (a) The aphid *Macrosiphum euphorbiae* colonizes potato plants and many garden plants. (b) Its symbiotic bacteria, assigned to the genus *Buchnera*, are restricted to insect cells, bacteriocytes, in the aphid body cavity. In this section of an adult reproductive female aphid, the *Buchnera* are localized using a *Buchnera*-specific FITC-labelled probe (green). Bar, 200 µm. *A.C. Darby, S.M. Chandler and A.E. Douglas*

their own cellulase enzymes. Others appear to be cellulase-free herbivores that eat lots of plant food, digest the starch, protein, etc., and void the greater part of the plant material as frass (faeces).

The biosynthetic capabilities of symbiotic micro-organisms are, however, exploited by some chewing insects, especially those feeding on 'tough', slowly growing plant tissues of low nutrient content. The micro-organisms are believed to provide the insects with essential amino acids and vitamins, supplementing the supply from their plant diet. The main focus of recent research on this type of relationship is the *γ-Proteobacteria* required by the economically important weevil pests, *Sitophilus*, of grain stores. The symbiotic micro-organisms with biosynthetic functions in the many other chewing phytophagous insect pests are a 'rich seam' for future microbial research.

The microbiology of sucking insects: symbioses without parallel

Insects feeding on the phloem or xylem sap of plants include whitefly, aphids, spittlebugs, leafhoppers, jumping lice (psyllids), scales and cicadas. They are major garden pests, depressing plant growth and flower production, transmitting plant viruses and producing unsightly sticky honeydew that is substrate for sooty moulds and other fungi. Without exception, these insects bear micro-organisms, usually bacteria, in cells separated from the gut. The bacteria are *α*-, *β*- or *γ-Proteobacteria*, varying between insect groups.

The best studied of these associations is between the *γ*-proteobacterium *Buchnera* and aphids. *Buchnera* provide the aphid tissues with essential amino acids, which are deficient in plant phloem sap. The association is very ancient, originating some 200 million years ago. In other words, *Buchnera* has been transmitted from mother to offspring through the generations of aphids since the early Mesozoic and perhaps earlier. The genome of *Buchnera* in three aphid species has been sequenced completely, and their genomes are tiny, about 650 kb, with gene complements that are a subset of the genes in the more familiar, related *γ*-proteobacterium *Escherichia coli*. Gene loss has been substantial, including all of the energy-producing TCA cycle apart from the gene for *α*-ketoglutarate dehydrogenase (required for synthesis of the essential amino acid lysine), many genes required for the cell envelope (e.g. no capacity to synthesize lipopolysaccharides), and most transcriptional regulatory sequences. Despite this, *Buchnera* has retained the genes for essential amino acid biosynthetic pathways, and there is strong evidence that they can synthesize these compounds, releasing 50 % or more to the aphid tissues.

It is widely assumed, but has not been demonstrated, that the relationship of phloem- and xylem-feeding insects generally is similar to the aphid–*Buchnera* symbiosis. These symbioses are without parallel, because the animal hosts, all hemipteran insects, are the only animals that can utilize plant sap as sole food throughout their life cycle; and the repeated evolution of symbioses with micro-organisms has been crucial to this lifestyle.

Microbiology and chemical warfare in the garden

Chemical warfare is rife in the garden. Plant secondary compounds deter or are toxic to phytophagous insects, and some phytophagous insects are chemically protected against natural enemies. Micro-organisms associated with phytophagous insects have been suggested repeatedly to detoxify plant secondary compounds or synthesize secondary compounds effective against natural enemies. To date, the evidence has been slight. Perhaps the best example is the rove beetle *Paederus*, with bacteria allied to *Pseudomonas aeruginosa* that protect the beetle with a polyketide informally known as pederin.

There are, however, indications that bacteria may intervene in aphid interactions with plants and natural enemies. The bacteria, informally known as secondary bacteria, are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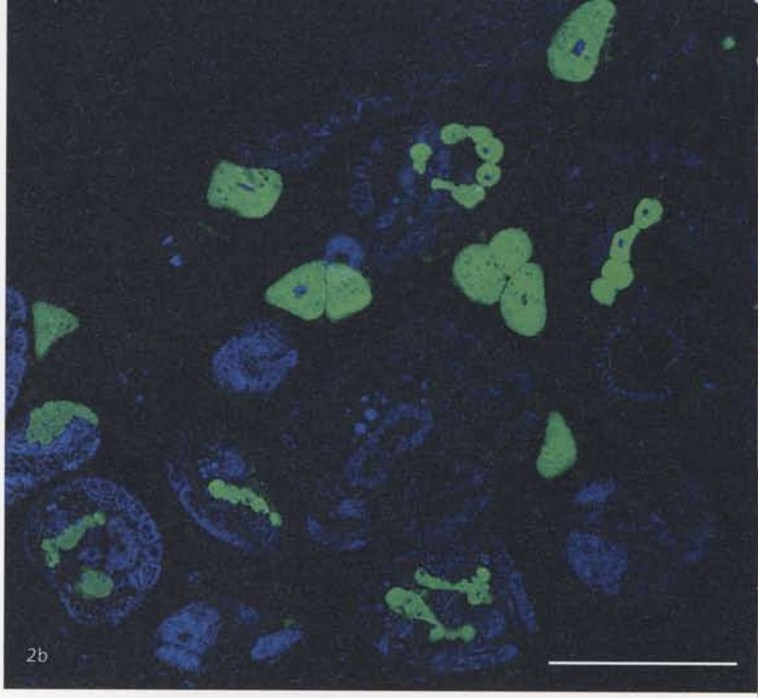
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There are indications that bacteria may intervene in aphid interactions with plants and natural enemies

γ-Proteobacteria distinct from *Buchnera*, and not present in all aphids. They promote aphid resistance to parasitic wasps, perhaps by producing chemicals that kill the parasitoid eggs deposited into the aphid body, and can alter the range of plants utilized by aphids. The general implication is that these horizontally transmissible bacteria not required by the insect may have a dramatic impact on the outcome of aphid interactions with other macro-organisms in terrestrial communities, including the growth rate and persistence of aphid colonies on garden plants. It is not known if other phytophagous insects have comparable microbial relationships.

Plant defences revisited

So far, I have not specified the mode of action of plant chemical defences against phytophagous insects. Many of the known ones are exploited in chemical insecticides that target the nervous and digestive systems of the insects. However, for the many insects dependent on microbial symbioses, there is a further crucial target – the symbiotic micro-organisms and their interactions with the insect. Research on plant defences with symbiotic micro-organisms as the primary target is in its infancy, but there is now evidence that the *Buchnera* symbiosis may be targeted by factors in certain plants, causing reduced essential amino acid production, disrupted regulation of the *Buchnera* population, and depressed aphid performance. Further research is required to establish the symbiosis-active compounds, the incidence of such plant defences and the insect/microbial gene products that are targeted. This approach may offer the opportunity to replace the relatively non-specific chemical insecticides, widely used in gardens despite the great collateral damage to natural enemies, by precision insecticides targeted to specific microbe–insect relationships.

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Useful website

- www.york.ac.uk/depts/biol/units/symbiosis/intro.htm

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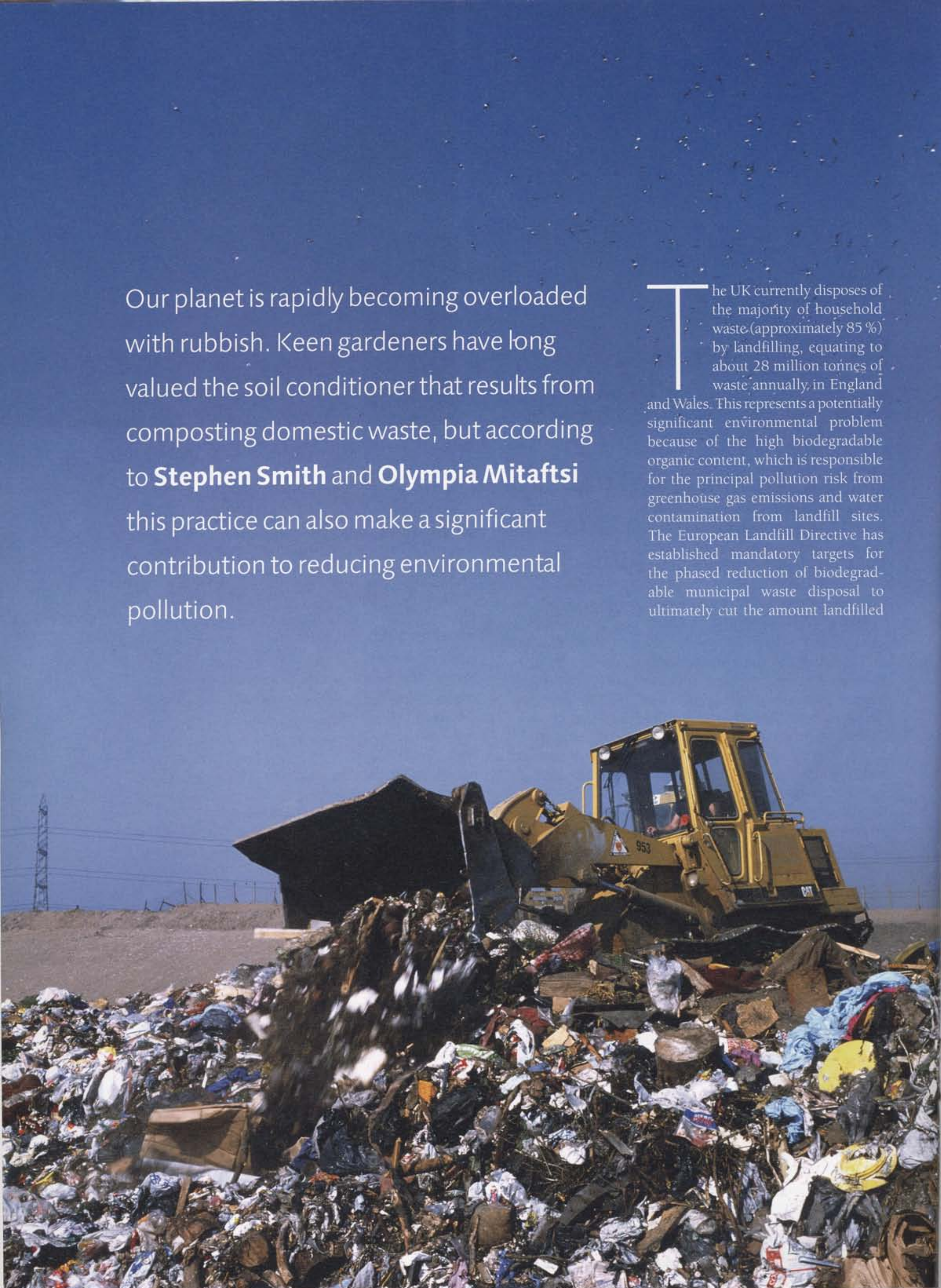

Our planet is rapidly becoming overloaded with rubbish. Keen gardeners have long valued the soil conditioner that results from composting domestic waste, but according to **Stephen Smith** and **Olympia Mitaftsi** this practice can also make a significant contribution to reducing environmental pollution.

The UK currently disposes of the majority of household waste (approximately 85 %) by landfilling, equating to about 28 million tonnes of waste annually, in England and Wales. This represents a potentially significant environmental problem because of the high biodegradable organic content, which is responsible for the principal pollution risk from greenhouse gas emissions and water contamination from landfill sites. The European Landfill Directive has established mandatory targets for the phased reduction of biodegradable municipal waste disposal to ultimately cut the amount landfilled

Home composting and its role in waste management

to 35 % of that produced in 1995. In England and Wales, the Government and National Assembly have also set targets to recycle or compost at least 25 % of household waste by 2005, increasing to at least 33 % by 2015.

Natural waste treatment

Composting is the aerobic microbial degradation of bulky organic waste, which usually generates heat, to produce a stabilized residue with significant value as a soil conditioner. The advantages of this natural process for treating biodegradable waste have placed it in a priority role for delivering the Government's target reductions in household waste disposal to landfill. Many householders with horticultural interests have traditionally composted and re-used their garden waste (Fig. 1). Encouraging and developing participation in home composting schemes also has major potential advantages in providing a low-cost approach to waste management and facilitating the sustainable recycling of biodegradable organic waste (Fig. 2). However, there is uncertainty about the effectiveness of home composting as a method of diverting organic waste from landfill disposal in practice, and the treatment and stabilization of waste in small capacity composting systems has received little scientific investigation or optimization.

Testing the value of home composting

Research at Imperial College London has quantified the amount of waste deposited in home compost bins by householders, which is therefore diverted from landfill disposal, in a study trial within the suburban setting of Runnymede Borough Council (RBC), Surrey. The microbiological activity in home compost bins in relation to organic waste degradation processes in these systems was also studied.

Sixty four households within the study area were approached to participate in the 2-year research project. A statistically designed trial was established with the co-operation of participating householders to quantify the potential reductions in domestic waste disposal to landfill by home composting. Householders were offered a subsidised compost bin for purchase and were supplied with experimental equipment to record the amounts of kitchen, paper and garden waste placed in the compost bins. Treatments were assigned in factorial combinations by dividing the group

◄ A landfill site in the UK. *Simon Fraser / Northumbrian Environmental Management Ltd. / Science Photo Library*


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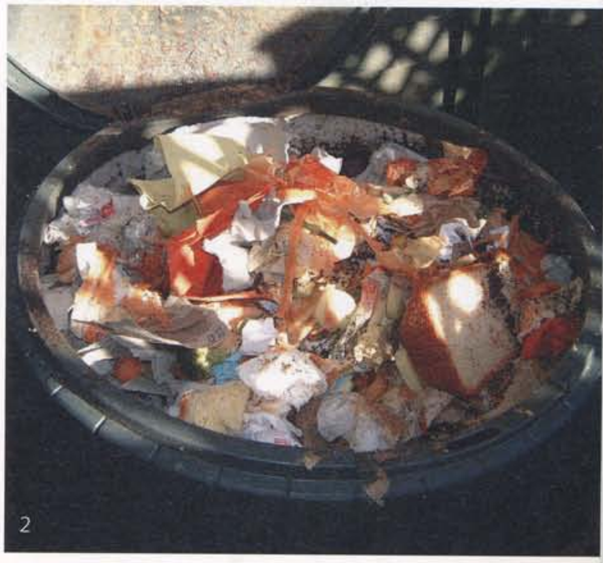
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► Figs 1 & 2. Composting biodegradable household and garden waste using a home compost bin. *Stephen Smith*

Table 1. Waste inputs to home compost bins for the period May 2000 – March 2002

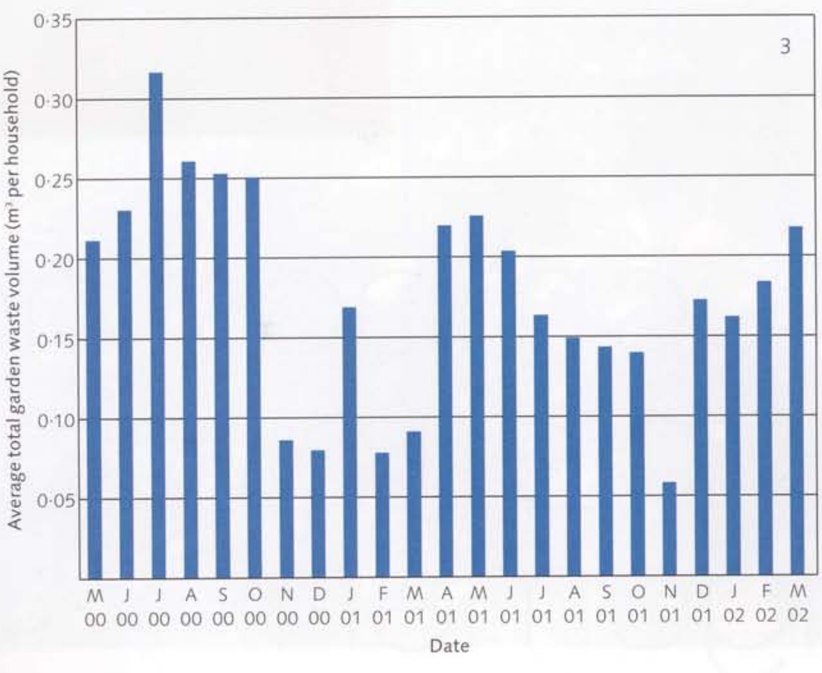
	Kitchen waste	Paper waste	Garden waste*	Total
Monthly mean, kg (Total no. of possible monthly deposits, *n*=1472; none deposits set to zero)	9	0·8	24	34
Monthly 95 percentile	27	4·0	88	103
Monthly mean recorded deposit, kg (None deposits omitted)	11	1·6	39	39
Frequency of actual monthly deposits (*n*)	1205	736	909	1275
Frequency (%)	82	50	62	87
Total annual deposit, kg	108	9·5	290	410
Input (percentage of total)	26	2	72	100

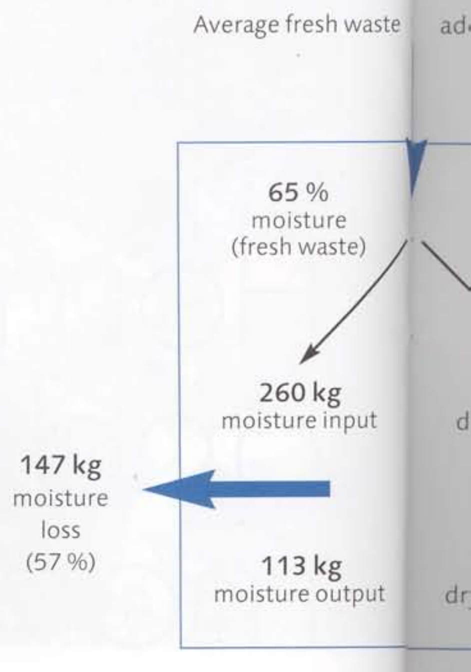
*Estimated from the density of grass clippings, 200 kg m^{-3}.

into large and small garden size classes. Additional treatments were randomly assigned within each garden size class and included: ± mixing, ± proprietory accelerator, ± earthworm inoculation.

A mass balance was produced for each compost bin at the end of the first and second year (May 2001 and 2002) of the trial. Materials in each compost bin were collected and weighed in buckets using a hanging scale. Material recovered from the bins was divided into three distinctive layers based on the extent of decomposition [fresh (A), semi-decomposing (B) and compost (C)] and the mass of each of these components was measured. Representative composite samples from each layer were collected to determine the moisture content and material from Layer C was subjected to a more extensive suite of chemical analyses.

Monthly and annual total waste inputs to the compost bins per household are summarized in Table 1. The total average annual input was approximately 400 kg, which is considerably larger than the default value assumed for home composting of 100 kg y^{-1} per household. The average monthly recorded deposits of kitchen and garden wastes were 11 and 39 kg, respectively, although, as would be expected, there was a seasonal trend in garden waste inputs (Fig. 3). The relative contribution of kitchen, paper and garden waste to the total waste input was 26, 2 and 72 %, respectively. The average moisture and dry matter mass balance for the bins determined from the 2-year study is illustrated in Fig. 4. The results showed that approximately 60 % of the fresh matter deposited in the bins was removed through moisture and volatile solids losses during the microbial composting





Home composting clearly offers a highly effective approach to processing and stabilizing domestic biodegradable waste

process, equivalent to 147 kg (37 %) and 84 kg (21 %) of the total input mass, respectively. Home composting clearly offers a highly effective approach to processing and stabilizing domestic biodegradable waste.

The potential benefits

The RBC Home Composting Study indicated that home composting could potentially divert up to 10 % of the domestic solid waste stream from landfill disposal on the basis that approximately 20 % of households in the community become engaged in the activity. This level of participation would achieve about 35 % of the waste diversion required to fulfil the immediate target set by the Government of composting or recycling 25 % of household waste by 2005. Cost savings to be gained by the waste disposal authority are also potentially considerable and were estimated as almost £82,000 in RBC on the basis of the diversion rates measured during the study. Therefore, home composting can provide a significant contribution to household waste diversion from landfill disposal and should be included as an integral part of an overall strategy for the collection, treatment and disposal of biodegradable waste.

Biological activity

Temperature and gas measurements of materials undergoing decomposition were taken to indicate the nature of the biochemical processes operating within the home compost bins and the rate of microbial activity. Participants in the RBC study were supplied with a soil/compost temperature probe (0–80 °C) and recorded the temperature of material in the compost bins (Fig. 5). This was complemented with more detailed monitoring of temperature conditions and gas profiles using an electronic thermometer and gas sampling probe (Fig. 6).

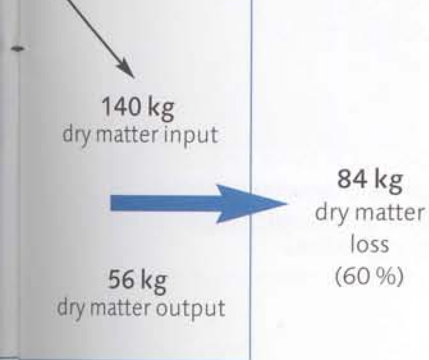
Temperatures recorded by householders were highly variable, but there was an underlying seasonal trend relating to ambient temperature conditions (Fig. 5). Temperature profiles generally varied between 6 and 50 °C and were usually above ambient in the psychrophilic (0–20 °C) to mesophilic (20–45 °C) ranges, indicating active biological degradation. The warmest conditions were generally found in recently deposited waste, associated with high rates of microbial activity in this layer, and temperatures declined with increasing depth in more stabilized material. Oxygen concentrations were typically close to ambient values and showed that waste degradation was predominantly by aerobic processes. Only traces of methane were occasionally found so home composters are not an important source of this greenhouse gas.

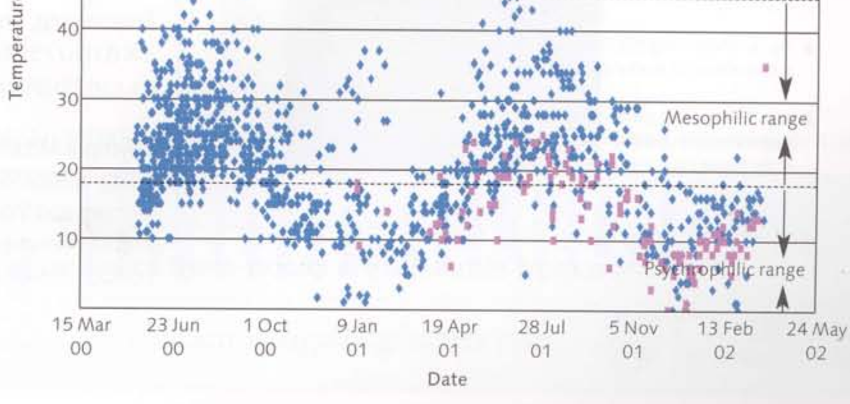
The stabilization of frequent inputs of small amounts of mixed organic residues in small-scale composters does not follow the normal ecological progression observed with conventional batch-operated, industrial-scale

◀ Fig. 3. Mean monthly garden waste inputs to home compost bins, May 2000–March 2002. *Stephen Smith*

◀ Fig. 4. Average mass balance of waste processed in home compost bins during May 2000–March 2002. *Stephen Smith*

▼ Fig. 5. Compost temperature recorded by participants in the RBC Home Composting Study, May 2000–March 2002. ◆, temperature in bin; ■, ambient temperature. *Stephen Smith*





▲ Fig. 6. Measuring microbial activity based on interstitial gas composition in home compost. *Stephen Smith*

▲ Fig. 7. Preparing garden, food and paper waste samples in a field experiment investigating waste biodegradation processes in small-scale home compost bins. *Stephen Smith*

composting systems. Waste treatment in small-scale units is highly biodynamic and organic matter is present at different stages of decomposition, which depends on microbial activity as well as invertebrate animals, particularly earthworms. Regular small inputs of complex mixtures of different waste types (kitchen, paper and garden waste) to small-scale composting systems provide a stable and well buffered environment for the biodegradation of putrescible household solid waste.

What next?

The direct measurement of waste diversion rates from landfill disposal by home composting and other household waste recycling methods is a principal objective of a further phase of research at Imperial College London, supported by The Norlands Foundation and RBC. This will be achieved using an automatic weighing apparatus fitted to the refuse collection vehicle to determine the effects of home composting and kerbside collection on the residual waste produced from a large sample of properties in the Borough. The project represents the first application of advanced weighing technology to quantify the impacts of household waste management practices on diversion rates in a statistically designed investigation and will establish the fundamental relationship between the distribution of home compost bins in the community and the extent of waste diversion from landfill disposal. A controlled field experiment is also assessing the extent of potential waste throughput by small-scale home composters and is further quantifying the rates of microbial activity during the biodegradation of organic waste in these systems (Fig. 7).

Acknowledgements

This programme of research is funded by The Norlands Foundation and is in collaboration with Runnymede Borough Council.

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International Development Fund report

Rebuilding microbiology education in Iraq

Basrah University was established in 1964 near the Arabian Gulf coast in Iraq's second largest city. It was once the envy of the Arab world and Middle Eastern higher education. A large number of papers was published every year, and students from around the region flocked to its graduate research programmes. As early as 1977, while studying there for my Masters degree in marine biology, I was already using online services: I could order documents and papers electronically straight from the Library of Congress, an innovation lacking in many western universities even a decade later.

Three major wars and 13 years of harsh sanctions have left an estimated 80 % of Iraq's 22 universities and 43 vocational colleges almost totally damaged. One campus in Basrah is just a shell and piles of rubble. The estimated rebuilding costs are \$1·2 billion. When I contacted Professor Salman in Basrah 3 months after the fall of the previous regime to find out his needs, he replied, *'we are not talking about libraries and laboratories right now; we need chairs, blackboards, and chalks!'*

Last spring, when Congress budgeted \$87 billion for Iraqi reconstruction, only \$8 million was allocated to higher education. In the following summer, the newly appointed Minister of Higher Education, Dr Taher Al-Bakaa went to the World Bank and asked for \$120 million for the first year. The response was negative. The most substantial American aid to Iraqi higher education came from the US Agency for International Development (USAID), which offered \$20 million in grants to five American universities to set up partnerships with Iraqi universities. The programme was slow to get off the ground because of security concerns. The British Council and individual UK universities have done a brilliant job in encouraging exchange programmes, sponsoring many workshops, seminars, and meetings in Britain and Iraqi neighbouring countries to rebuild higher education in Iraq.

In summer 2003 I visited Basrah University and other Iraqi institutions to evaluate their requirements. The Chancellor of Basrah University and some of his staff then came to the UK and highlighted up-to-date microbiology and biotechnology as being in urgent need of reintroduction to the university curricula. The microbiology syllabus being taught in Basrah University was decades old. I approached SGM to sponsor a 2-week training course in new techniques in microbiology. This was successful, although my visit was postponed twice due to the security situation.

I ran an intensive training programme on *Microbiology Techniques and Biotechnology* for 47 staff and postgraduate students from different colleges. They participated with enthusiasm and dedication, despite the limited resources.

The course included basic and advanced microbial identification techniques and demonstrated the use of ILT to compensate for the unavailability of chemicals and equipment. Among CAL programmes generously donated from SGM funds were PCCAL Packages for Educational Institutions; Hyperclinic (Interactive case studies in Microbiology); Microbes in Motion; Bacterial Growth 3; Identibacter interactus (simulation of bacterial identification);

SGM helps microbiologists in developing countries through this fund, usually by supporting training courses and other small technology transfer projects. See **www.sgm.ac.uk** for the rules. The closing date for 2005 applications is **14 October**.

Introduction to Recombinant DNA Technology; and the EIBE CD on fermentation.

Traditional teaching methods are dominant in the university and I described alternatives such as using models and video tapes to facilitate the teaching and learning process, PBL, case studies and debating. I gave talks on biotechnology applications in medicine, agriculture, and pharmaceutical products and how Iraq can benefit from such applications given the status quo!

I delivered four seminars on various topics to different institutions, together with a general seminar on the current global efforts to restore the Hammar Marshes. I actually visited these marshes to witness the cooperative role between the indigenous people and the Marine Science Centre in the restoration process, which looks promising. A sample of marsh water was taken for microbiological testing.

The Technical College and Basrah Technical Institute suffered heavy losses during the war and I met their Deans and staff to see the ongoing efforts between them and the British authorities to rebuild and restore these institutions. They were very grateful for the co-operation of colleges in UK, the British Council and British authorities in the south for their dedicated work.

The Higher Education and Scientific Research Ministry in Baghdad expressed their keen interest in spreading this programme to other universities once the security situation improves.

The University Chancellor and Council invited me to a special dinner to thank me for my time at the university and presented me with an appreciation certificate and thank-you letters to SGM and my college. The feedback from the participants on the evaluation forms has put a huge moral responsibility on my shoulders to spare some time and share my knowledge with our deprived friends and colleagues. I found there is a great hunger to learn about new technologies. However, I should emphasize the risks involved, as security is on most Iraqis' minds, let alone those of people from abroad!

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Further information

See '*The poor condition and high hopes of university life in Basrah today*' at http://www.public.iastate.edu/~mariposa/hamid1.htm

◄ Students on the course and the current state of Basrah University. *Hamid K. Ahmed*

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**

A. tumefaciens – friend or foe?

In keeping with our garden theme, **Dariel Burdass** takes a look at crown gall, a harmful tumour on trees and shrubs caused by bacteria. She explains how DNA from the bacteria get into the plant genome and stimulate the gall formation, a process that can be exploited by plant biotechnologists.

Agrobacterium tumefaciens

The soil bacterium *Agrobacterium tumefaciens* is mainly found living in the rhizosphere, the area of soil that surrounds the roots of plants. Some strains contain a large plasmid known as the Ti (tumour-inducing) plasmid. A plasmid is a small circular piece of DNA that is separate from the bacterial chromosome. It is these strains that are pathogenic and can infect a wide variety of broad-leaved plants, including fruit trees and shrubs, e.g. pears, apples and roses, causing a tumour-like growth known as crown gall.

Crown gall

The crown of the plant is the area at the base of the stem just before it joins the roots; the majority of crown galls occur here. They vary in size, from 1 to 30 cm, with the majority being around 5 cm across. In the early stage the gall appears as a small round white swelling that is rough and spongy. As it matures it becomes dark brown in colour, hard and woody. The galls can obstruct the movement of nutrients and water through the plant tissue causing the infected plant to become stunted and unhealthy. These plants are also less resilient to changes in temperature.

There is no cure for the infected plant. This has huge financial implications for commercial growers as diseased plants have to be destroyed.

Entering a plant cell

A. tumefaciens can only enter plant cells through a wound. Phenolic compounds such as flavonoids are secreted from damaged tissue. The bacteria are attracted to these signalling molecules by chemotaxis and move towards the wound. *A. tumefaciens* then binds to the plant cell and is ready to transfer its Ti plasmid.

Plants can become damaged during cultivation processes such as grafting and pruning, by soil insects and by the effects of weather such as freezing temperatures and wind abrasion.

The role of the Ti plasmid

The bacterium causes tumours by transferring a small section of the Ti plasmid called T-DNA into the plant cell where it becomes integrated into the plant genome. This process resembles bacterial conjugation. The Ti plasmid carries genes which are responsible for the transfer of the T-DNA. These genes are switched on by the phenolic compounds secreted from the wound. The T-DNA carries genes which encode enzymes that cause the overproduction of the plant hormones auxin and cytokinin. These hormones stimulate the uncontrollable and rapid growth of plant cells, leading to the formation of a tumour. T-DNA also induces the plant cells to produce opines (amino acids) which are used as a food source by the bacterium.

Biotechnology applications

Although *A. tumefaciens* is a plant pathogen, its abilities can be exploited by scientists for beneficial purposes. It is widely used as a vector for transferring genetically engineered DNA into the genome of plant cells. For example, the genes that encode tumour production on the T-DNA section of the Ti plasmid are replaced in the laboratory by genes that encode a desirable trait such as herbicide tolerance. These engineered genes then become incorporated into the plant genome.

◀ Crown gall on *Euonymus* sp. *Geoff Kidd / Science Photo Library*


Weed management

If weeds are poorly controlled then this affects both the quantity and quality of the crop that is harvested. This is because weeds compete with the plant for food, light and water. The herbicide glyphosate is used to control weeds in fields where soya beans are grown. Glyphosate rapidly breaks down on contact with the soil, reducing its effect on the environment and making it more desirable to use than other more persistent chemicals. Unfortunately, glyphosate is non-selective and does not discriminate between weeds and crops. It can only be applied to the weeds before the soya plants emerge from the soil.

Genetic engineers have developed transgenic soya plants that are tolerant to the herbicide glyphosate. This means that the weeds can be sprayed even after the crop has started to grow.

How is this done? Restriction enzymes are used to cut out the T-DNA. The sequences at either end of the T-DNA are necessary for the transfer of the genetic material and remain. The foreign gene encoding the herbicide-resistant trait is inserted between these two end sections. A marker gene is also incorporated into the plasmid to identify plants that have accepted and expressed the foreign gene. This recombinant plasmid is then transferred back into *A. tumefaciens*.

The next stage in the process is the infection of the soya plant with the engineered plasmid and the integration of the foreign gene into the plant genome. Transgenic soya plants are generated containing the foreign gene, making them resistant to the herbicide glyphosate.

Useful resources

Madigan, M.T., Martinko, J.M. & Parker, J. (2003). *Brock Biology of Micro-organisms*, 10th edn. New Jersey: Pearson Education.

http://helios.bto.ed.ac.uk/bto/microbes/crown.htm

SGM supports training boost for student biology teachers

This event was supported by a grant from the SGM Public Understanding of Science Fund. See www.sgm.ac.uk/grants

Last session, every trainee teacher of secondary biology across Scotland attended a 3-day *Biotechnology for Scotland* residential school, hosted by the University of Aberdeen. The aim was to bring them up-to-date with recent developments, in recognition of the need for a teaching force that is well informed about the rapidly changing field of biotechnology. Delegates took part in lectures, laboratory sessions, industry visits and other activities. The programme built on the experiences from a pilot event run in Glasgow in 2003. Parts of it were intended to help the students raise, with their own pupils, some of the societal issues related to the new technologies.

The SGM grant helped to run the practical microbiology sessions where the students gained hands-on experience of activities suitable for use with pupils in the school laboratory. The procedures included examples of bioremediation with the fascinating use of *Photobacterium phosphoreum* as a biosensor and of soil micro-organisms to degrade hydrocarbons.

'Microbiology made easy' consisted of experimental work designed to engage early secondary pupils. It is hoped that this will help pupils to more readily understand the science behind everyday issues of hygiene and other directly relevant applications of microbiological principles. All of the participants were provided with a full set of practical support materials and resources such as SGM's *Microbes and Food* posters.

This event resulted from collaboration between the five Initial Teacher Training Institutes in Scotland and was facilitated by the Scottish Institute of Biotechnology Education and the Science and Plants for Schools Biotechnology Scotland Project (SAPS Scotland).

Dr Peter Shand, a lecturer in the School of Education at Aberdeen said, '*The event has allowed teacher training institutes to develop closer links with each other and with the various organizations involved in biotechnology education*'. Professor Ian Booth of Aberdeen was closely involved with the development of the programme. He also gave a talk about harmful and beneficial micro-organisms which was of direct relevance to the Scottish school curriculum. The university provided first-class laboratory facilities and identified speakers. Other microbiology-based activities included a visit to the Glendronach distillery and the development of resources on the role of micro-organisms in waste management.

Feedback from the attendees was very positive. '*I really enjoyed the week. I thought the resources and facilities were excellent. I feel more confident now about delivering biotechnology in the future. It is good to know that there are people and resources available to help.*'

Plans are well underway for a third residential event for PGCE Biology students in Scotland. For the first time other science subject specialists will join the biologists. At least one of the sessions will provide microbiology activities.

Kath Crawford

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gradline

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

Life science commercialization

If you are coming to the end of your PhD and are interested in business then you might want to consider working in the booming area of life science commercialization.

The government has recently been encouraging the transfer of knowledge and technology from the academic to the commercial sector. Universities have received funding to build-up teams of staff to promote knowledge transfer activities. Many institutions have developed existing research support or business development offices, but some universities and the MRC have created technology transfer companies to commercialize their research (e.g. Manchester, Imperial, Cambridge and Oxford). Within this sector are a number of roles open to life science PhDs.

Research support – gathering and disseminating information on potential sources of funding to academics. Staff may be science specialists or perhaps focus on funding from Europe.

Research development – helping academics attract new sources of external research funding. Once this has been identified, a research development officer might help to draft applications and draw up contracts.

Business development/commercial services – creating links with businesses and other organizations; developing local networks of universities, biotechnology companies, etc.

Technology transfer – liaising with scientists who have a commercially valuable idea, assessing its potential and, if necessary, managing the patent process.

Some of the roles overlap and job titles may vary. However, looking at relevant web pages will give you an idea of the scope of these positions.

A career in technology transfer is by no means restricted to working in the UK, as Canada-based SGM member Alain Richard explains opposite.

A job in . . .

Name Alain Richard
Age 39
Present occupation
Director of Commercialization, Life Sciences, Valeo Management, L.P., Montréal, Québec, Canada
Previous employment
Technical support management – Genomics One Corporation, Laval, Québec, Canada (2000–2002); Quantum Biotechnologies, Montréal, Québec, Canada (1996–2000); Postdoctoral researcher – Laval University, Québec, Canada (1995–1996)
Education
Laval University: PhD Microbiology and Immunology (1995); MSc Microbiology and Immunology (1990); BSc Microbiology (1988)

Q *What does your company do?*

Valeo Management is a limited partnership that commercializes technologies from four Québec universities. We concentrate on promoting ideas with a solid business case that meet important industry needs. Most of the company's current activities involve technology transfer under licence and we work in close collaboration with the research bureau from each university. Income is given back to the universities and the inventors. Valeo Management has also helped to create spin-off companies, including two in biotech-pharma.

Q *Why is this important?*

We ensure sustainability in development and commercialization of university research and the spread of promising discoveries into society via business. We also set up and fund proof-of-concept experiments that greatly increase the value of a technology. Without these

Technology Transfer

experiments, potential licensees often do not consider the technology, rendering its commercialization difficult.

What prompted you to leave research?

During my graduate studies, I quickly realized that I enjoyed giving seminars. I also wanted to be in contact with other people, communicating and presenting technologies, which I preferred to working at the bench.

How did you find the transition from university-based research to the commercial sector?

I actually found it smoother than I had expected. Maybe this was because I began in a start-up company where everyone had to multi-task – we were all in the same boat! I did find, in the private sector, there is a greater emphasis on complying with deadlines to meet market needs ('time-to-market' concept).

What skills from your research career were applicable to working in technical support management?

My clients were scientists working in private or public labs, so the years I spent in the lab prepared me adequately to understand their needs; resulting in an efficient service.

What new challenges did your current post bring?

The main challenge has been to develop my business flair and not to spend too much time evaluating the commercial potential of a technology. The dynamics of business are not based on crystal-clear facts but on taking risks and using instinct. Another challenge has been finding ways to tell some scientists that their research cannot be commercialized for reasons such as intellectual property issues, production costs, competitors, lack of a market, etc.

What advice can you offer to others thinking of a career in life science commercialization?

I would recommend technology transfer, which is undergoing a very exciting and rapid evolution. Technology transfer and commercialization of research are by essence multi-disciplinary and the variety offered by a degree in microbiology is definitely an excellent preparation for this career path. Also, many projects involve microbial processes, such as protein production. I believe that an MSc or PhD degree in a relevant field can be an asset, helping in the interaction with the scientists who feed the technology pipeline.

Further information

Office of Science and Technology – **www.ost.gov.uk/enterprise/index.htm**

UK Science and Technology – **www.ukssciencetech.com**

Valeo Management LP – **www.valeosec.com/index.html**

Valorisation-Recherche Québec (VRQ) (in French) – **www.vrq.qc.ca**

Licensing Executives Society (USA and Canada) – **www.usa-canada.les.org**

Association of University Technology Managers (AUTM) – **www.autm.net**

Taking UK science to Parliament

Monday, 14 March 2005

Britain's top younger researchers visited the House of Commons to present their work recently. Over 540 applications were received from scientists, engineers and technologists for the 270 places at this annual event which aims to showcase UK research and R&D in National Science Week. Both poster judges and visiting MPs commented on the wide range of work displayed and the very high quality of the presentations and the enthusiasm of the presenters.

Sponsoring MP **Dr Brian Iddon** commented that these unique events brought real UK science and younger researchers to Parliament and were a central feature of the Parliamentary 'science' year and much appreciated by members, peers and others. About 70 MPs called in to visit the posters.

The traditional lunchtime reception, now in its seventh year, covered all areas of SET. Congratulations to SGM member, **Dr Clare Lanyon**, a postdoctoral research associate in the School of Biology, Newcastle upon Tyne University, who won a £250 commendation for her poster presentation in this session. It was entitled *Does the immune system play a role in the community structure of commensal micro-flora and associated chemosensory individuality?*

An innovation was an evening reception focusing on Biosciences, sponsored by relevant organizations including the Biosciences Federation. It is hoped to hold this every year from now on.

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 fight against blight – a potential viral solution

Hacker, C.V., Brasier, C.M. & Buck, K.W. (2005). A double-stranded RNA from a *Phytophthora* species is related to the plant endornaviruses and contains a putative UDP glucosyltransferase gene. *J Gen Virol* **86**, 1561–1570

Researchers think that they have found an RNA virus that may affect pathogenicity in one species of *Phytophthora*. All members of this genus are plant pathogens. The most famous caused potato blight in Ireland in the 1840s. Chemical control is not always effective, so researchers continue to look for new ways to control these pathogens. Some phytophthoras contain virus-like double-stranded RNA molecules that may have potential as biocontrol agents. Ken Buck and Caroline Hacker from Imperial College in London, UK, together with Clive Brasier from the Forest Research Agency, have studied one of these RNAs from a phytophthora infecting a Douglas fir tree. The viruses most closely related to this novel piece of RNA were in the genus *Endornavirus*, which affects plants such as rice and beans, although *Phytophthora* is not a plant. This is therefore the first non-plant member of the *Endornavirus* genus and has been given the name phytophthora endornavirus 1 (PEV1).

The RNA contained a single gene that appeared to encode several proteins joined together. All endornaviruses have a single gene that encodes one very large protein. From comparisons with other proteins, there were regions that should act as enzymes to synthesize the RNA molecule. Researchers assume that a proteinase enzyme cuts it up into functional proteins.

◄ Coloured scanning electron micrograph of the potato blight fungus *Phytophthora infestans*, emerging from a potato leaf. *Andrew Syred / Science Photo Library*

The interesting new feature of PEV1 is that it contains a region that looks like a glycosyltransferase, an enzyme that attaches a glucose sugar molecule onto a lipid sterol. When the researchers went back and looked more closely at the sequence of the polyprotein from other endornaviruses, they spotted regions similar to this enzyme in two of them. This is the first time a glycosyltransferase gene has been seen in an RNA virus.

This enzyme exists in some DNA viruses, especially ones that infect insects. Researchers think that the gene must benefit the virus and have been acquired from the host organism at some point in the evolution of the virus. The glycosyltransferase in PEV1 was not particularly similar to the gene in *Phytophthora* protists. Indeed, it was as closely related to the gene in bacteria, fungi or plants, suggesting that it was acquired by an ancient endornavirus before the separation of bacteria, fungi and plants. That would explain why it appeared in a similar place in two other endornaviruses from rice that the researchers examined. The benefit of glycosyltransferase to, for example, baculovirus is that infected insects remain as caterpillars and increase the yield and spread of the virus. Although the researchers do not know what happens in *Phytophthora*, some fungal pathogens need a similar enzyme as part of their pathogenicity mechanism, and the endornavirus might therefore affect pathogenicity. The researchers are therefore quite excited that they may have discovered a new way to investigate, and maybe control, the potential for disease caused by this important group of pathogens.

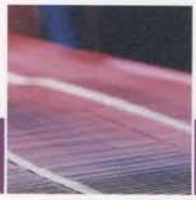
A novel soil bacterium and antibiotic-resistant TB

Cook, A.E., le Roe, M. & Meyers, P.R. (2005). *Actinomadura napierensis* sp. nov., isolated from soil in South Africa. *Int J Syst Evol Microbiol* **55**, 703–706

Tuberculosis (TB) is a serious health problem in South Africa, exacerbated by low success with treatments, an increase in the level of strains resistant to current medication and the high incidence of co-infection with HIV. Indeed, TB is the leading cause of death among people who are HIV-positive in the country. New treatments are needed to tackle the antibiotic-resistant strains of *Mycobacterium tuberculosis* (the bacterium that causes TB).

Ironically, many antibiotics originate from compounds secreted by bacteria. The group of bacteria called the actinomycetes is the leading producer of antimicrobial compounds of biological origin. Researchers keep on looking for new species of actinomycetes as sources of new antibacterial compounds that can be developed into treatments for TB and other bacterial diseases.

Researchers led by Paul Meyers at the University of Cape Town have therefore been searching for new actinomycetes and testing them for new antibacterial compounds. One strain isolated from soil was particularly interesting. The appearance of the bacterial cells and the cell wall composition, along with the sequence of a characteristic gene, identified it as an actinomycete from the genus *Actinomadura*. It was sufficiently different to be named as a new species, *Actinomadura napierensis*, indicating that it came from the town of Napier (in the Western Cape province of South Africa). It secreted an antibacterial compound which the researchers managed to partially purify. Bioassays showed that the compound killed several species of bacteria, although unfortunately not *M. tuberculosis*.



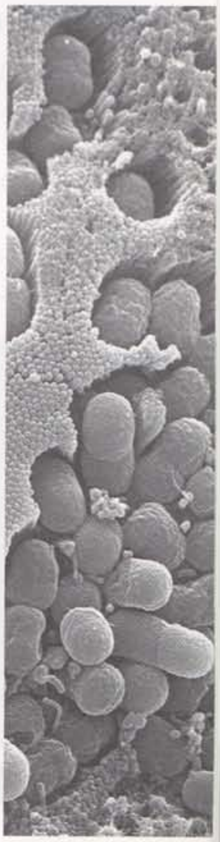
The flexible *E. coli* genome

Hejnova, J., Dobrindt, U., Nemcova, R., Rusniok, C., Bomba, A., Frangeul, L., Hacker, J.H., Glaser, P., Sebo, P. & Buchrieser, C. (2005). Characterization of the flexible genome complement of the commensal *Escherichia coli* strain A0 34/86 (O83:K24:H31). *Microbiology* **151**, 385–398

Harmless commensal strains of *E. coli* frequently inhabit the human colon. However, other strains are distinctly pathogenic, causing serious enteric and diarrhoeal disease. Now that all the genes in several strains of *E. coli* have been sequenced, detailed comparisons may indicate how particular ones are linked to disease symptoms. Researchers have focused on pathogenic strains, learning about specific subsets of genes associated with virulence or the ability to thrive in a particular environment. These genes are frequently associated with others that permit them to move between bacterial cells. Researchers have therefore developed the idea that *E. coli* has a core set of genes found in all members of the species and a flexible gene pool that allows a strain to live in a particular environment or have a particular type of pathogenicity.

However, the difference between strains is surprising. One comparison of the entire collection of genes in three strains showed that only 39·2 % of them were the same. A multinational collaborative project has focused on identifying the features of one strain of *E. coli*, called A0 34/86 (serotype O83:K24:H31), that makes it positively beneficial. It is used routinely as a live oral vaccine in the Czech and Slovak Republics. The strain was originally isolated from pig faeces, but for over 30 years A0 34/86 has protected premature and newborn infants at risk of diarrhoeal infections. Colonization with A0 34/86 probably displaces pathogens and allows the normal gut flora to redevelop. In the longer term, A0 34/86 seems to make the children significantly less prone to repeated infections and developing allergies. Obviously, it would be good to know exactly what makes this strain so beneficial.

The collaborators used a number of techniques and came up with information that challenges the current view of what makes *E. coli* a pathogen. To their surprise, only about 5 % of its genes were specific to A0 34/86, and many usually described as virulence factors were present. It even had genes for adhering to cells and synthesizing toxins characteristic of strains causing urinary tract infections. The researchers tested how well A0 34/86 colonized the gut of piglets to discover exactly why it was exceptionally good at colonizing a host. One group of genes, which included ones that helped other bacteria adhere to cells and cause infections, also seemed to be important for successful colonization of the piglets. It looks as if these genes are also the reason why A0 34/86 is so good at colonizing the gut and providing protection from infections. Researchers have clearly got more to learn about the relationship between pathogenic and commensal strains of *E. coli*.



▶ Cultured human small intestinal mucosa infected with enteropathogenic *E. coli*. *Stuart Knutton, University of Birmingham*

Getting attached

Rubinsztein-Dunlop, S., Guy, B., Lissolo, L. & Fischer, H. (2005). Identification of two new *Helicobacter pylori* surface proteins involved in attachment to epithelial cell lines. *J Med Microbiol* **54**, 427–434

Hans Fischer and his colleagues at Lund University in Sweden and Aventis Pasteur in France have come up with a new way to identify bacterial proteins that can cling to human cells. Pathogenic bacteria have to be able to hang onto the cells of their host, whether the host is an unwilling human, animal or plant. Understanding how this happens could lead to new antibacterial treatments. However, it is not always easy to identify the features of bacterial and host cells that lead to a close attachment. The authors of this paper have invented a way to test whether any particular protein plays a role.

The bacterium *Helicobacter pylori* causes chronic gastritis and peptic ulcers. The infections can also lead to some types of cancer. However, since *H. pylori* inhabits the stomach of at least half the human population, researchers would like to know why it makes only a few people ill. One factor must be the interaction between the surfaces of the bacterial and human cells in the stomach. Researchers have already identified one protein that helps *H. pylori* adhere, but know that there must be more.

The DNA sequence containing all the genes in *H. pylori* has already been worked out. The researchers compared regions of unknown function with other bacterial genes to work out whether any had the characteristics for a protein on the cell surface. They picked out five genes, synthesized the corresponding proteins and attached them to microscopic beads to produce something that mimicked a bacterial cell.

The researchers mixed cultured human cells with the protein-coated beads to test whether there was the same attachment response as between human and real *H. pylori* cells. None of the human cells attached to the beads alone, but two out of the five unknown proteins allowed some types of human cells to cover the beads entirely within 24 hours. The strongest interaction was with cells that originally came from the lining of the stomach, although cells from the surfaces of the large intestine and kidney also attached to the pseudo-bacteria. Even cells derived from the bladder and small intestine surfaces showed a small amount of attachment. This small-scale trial has proved that the method can identify proteins that are important in attaching bacteria to surfaces, and in the process the researchers have provided a role for the products of uncharacterized genes. In addition, the human stomach cells remained alive and thrived on the beads, so this might be a useful way to study the carcinogenic effects of *H. pylori*.

Faye Jones, Public Affairs Administrator, describes some SGM Microbiology Awareness Campaign activities which aim to raise the profile of microbiology to politicians and opinion-formers.

Microbiology Awareness Campaign 2005

Fighting infection

SGM's Microbiology Awareness Campaign gathered momentum on Tuesday 1 March when microbiologists went to Westminster to inform Peers and MPs that new and re-emerging infectious diseases could spell trouble if not tackled soon.

More than 40 MPs and Peers gathered on The Terrace at the House of Lords to hear a series of presentations on infection issues. It was followed by a drinks reception where the guests were able to talk to expert microbiologists.

In his introductory speech, our host, **Lord Soulsby of Swaffham Prior**, expressed concern about the closures and cutbacks in many research centres, in spite of '*science funding being assessed as secure*'. He was followed by **Professor Sir John Arbuthnott** who summarized the problems of infection and described what SGM is helping to do about them.

▲ Lord Soulsby of Swaffham Prior and Dr Ian Gibson, MP in conversation with SGM Professional Affairs Officer Geoffrey Schild at the House of Lords event. *Ron Fraser, SGM*

Professor Adrian Hill, University of Oxford, explained that tuberculosis infections are increasing in the UK and that we are constantly under threat from malaria. New vaccines are desperately needed to protect people worldwide from these ancient diseases. Professor Hill amazed the audience by revealing that tuberculosis has killed more adults than any other pathogen and that more children die from malaria than any other infectious disease.

Sexually transmitted infections were also on the programme and again, the incidence is increasing, with the biggest threat coming from HIV/AIDS. According to **Professor Robin Weiss** more people have died of HIV since 26 December 2004 than because of the Asian tsunami on that day.

Other presentations included one on the importance of educating the public about microbiology from SGM Education Officer, **Dr Susan Assinder** and a run-down by HPA Board Chairman, **Professor Sir William Stewart** of what the Health Protection Agency is doing to control infections.

A spirited discussion followed, chaired by **Dr Ian Gibson, MP**, with the speakers fielding widely ranging questions. Some of the answers were uncompromising. The audience was informed that without targeted government funding for microbiological research, serious health and economic problems would lie ahead.

The attendees were also treated to displays from various groups and organizations working to understand, prevent and treat many key infectious diseases of humans and animals. Among these was **Dr Jodi Lindsay** of St George's Hospital Medical School in London, who emphasized the economic and health costs of treating MRSA infections in the UK. She stressed that as MRSA is becoming more dangerous and more resistant, with no new drugs or vaccines available, ring-fenced funding for research was essential. '*The current number of MRC, BBSRC, Department of Health and Wellcome Trust grants currently active on MRSA is zero and seven years after the National Audit Office highlighted the lack of research funding for antibiotic resistance, little has changed*', she said.

Other displays were on diagnosis and surveillance of disease in farmed livestock and wildlife by the Veterinary Laboratories Agency; the Food Standards Agency's strategy to reduce the incidence of food-borne disease; the Wellcome Trust's efforts at fighting malaria; animal health research by the Institute for Animal Health; and influenza by the National Institute for Medical Research, National Institute for Biological Standards and Control and the Health Protection Agency.

The staff at SGM Headquarters would like to take this opportunity to thank all of those involved in putting together the exciting programme for this event.

Faye Jones
Public Affairs Administrator

reviews

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

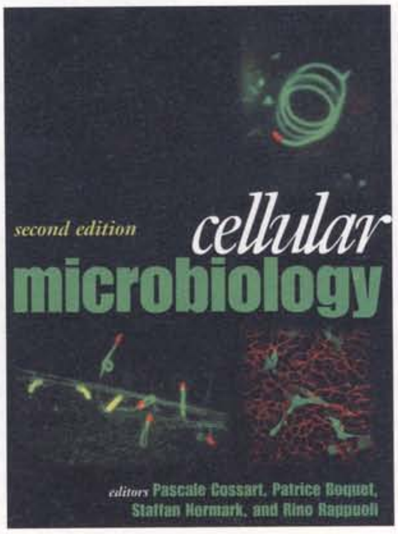
Cellular Microbiology, Second Edition

Edited by P. Cossart, P. Boquet, S. Normark & R. Rappuoli
Published by American Society for Microbiology Press (2004)
US$119.95 pp. 636
ISBN 1-55581-302-X

The discipline of cellular microbiology has grown rapidly in the last 10 years with the creation of new journals, regular scientific meetings and the acceptance of the term as the merger of cell biology and molecular microbiology. The Editors of this book have been some of the key players in this field and have the potential to bring together the most important and exciting new researchers to review the progress of cellular microbiology up to the end of 2004.

The book starts with review and introduction chapters to provide background to the subject – some microbiology for cell biologists and some cell biology for microbiologists! However, I felt this was not edited in the best way and there was far too much duplication in the material presented. For example, the first chapter, an 'Overview of microbial pathogens', not only suffered from providing too much detail for uninitiated molecular microbiologists, e.g. '*downstream effects of Pyk2 include activation of Src and subsequent phosphorylation of p130Cas, which complexes with Crk, leading to Rac1 activation*', but also was followed by another chapter listing all the same pathogens again, but in the context of the properties of their genome sequences. A single chapter with less of the cell biology detail would have sufficed. The cell biology chapter was better and explained the basic concepts important later in the book, but suffered from lack of figures and that the key figure, which was important to illustrate most of the main features of the cell structure, was a 'colour plate' which was in the middle of the book, resulting in constantly having to flick back and forth between the text and the figure.

After the mixed introductory section, the organization and quality of the chapters improves as they describe more specific aspects of the subject. These tend to alternate between a chapter on a particular aspect of cell biology, like the actin cytoskeleton, and then an ensuing chapter describing the ways in which bacteria exploit these components during infection. Subsequent chapters gave good coverage of adhesion, type III and type IV secretion systems, bacterial toxins and their use in cell biology research and interactions of microbes with the immune system. The book then concludes with some very topical chapters on new post-genomic methods for virulence gene discovery and an interesting chapter on the use of simple non-vertebrate hosts, like the nematode worm, to model mammalian pathogenesis. Amongst these, David Russell's chapter on 'Where to stay inside the cell: a homesteader's guide to intracellular parasitism' is a particular highlight. While the book has a heavy focus on bacterial pathogens, there is a chapter dedicated to the cellular microbiology of viruses, but this seems rather to have been included as a comparator to the bacterial chapters rather than a comprehensive review of the cell biology of viral infections.



The book would function clearly as a resource for a cellular microbiologist coming from either a cell biology or a molecular microbiology background. Apart from the poorly edited early chapters, the book provides in-depth, up-to-date and well referenced chapters covering all aspects of cellular microbiology and is to be recommended as a core text. Coming 5 years on from the first edition of this book, there is plenty of new material to justify buying this edition.

There is one thing that bugs me about 'cellular microbiology' as it is defined in this book – why only focus on pathogens? There are many bacteria that live intracellular lifestyles that are not pathogens and there is much we can learn about the nature of these associations from such organisms. To see a review of bacterial genomes in which only pathogens are mentioned is like taking the population of a city and just listing the criminals – comparing these to the free-living and symbiotic intracellular relatives is an important method of identifying what has made these organisms the bad guys!

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

Fungal Disease Resistance in Plants: Biochemistry, Molecular Biology, and Genetic Engineering

Edited by Z.K. Punja
Published by The Haworth Press (2004)
US$39.95 pp. 266
ISBN 1-56022-961-6

This timely volume covers areas of current research interest in fungal disease resistance in plants. Seven chapters have been contributed by established specialists. Major topics have been comprehensively covered, i.e. signal transduction in plant defence responses; the cellular expression of resistance; the role of the hypersensitive response; fungal virulence factors and pathogenesis-related proteins; mechanisms of induced resistance and their application to crop protection. A final chapter usefully reviews the current status of genetic engineering of plants and its role in the enhancement of resistance to fungal pathogens. The volume provides useful overviews, together with in-depth treatment of areas of specific interest to the authors. All chapters are well referenced. There are few illustrations and figures so it is unfortunate that the quality of reproduction is low, especially for the digital images. However, it is a useful and informative volume, to be recommended for researchers in the field.

***Susan Isaac**, University of Liverpool*

The Living Soil: Fundamentals of Soil Science and Soil Biology

By J.-M. Gobat, M. Aragno & W. Matthey
Published by Science Publishers (2004)
£27.20/US$49.50 pp. 626
ISBN 1-57808-210-2

This book, aimed at both students and researchers of soil science, emphasizes the balance between chemistry, physics and biology. There is a lot in it for microbiologists not least in providing a perspective of how it all fits together. Translated from French, there are the occasional confusing terms, e.g. 'insufflation', and 'structuration', that are no longer used, but the benefit is that the French language literature gets a deserved airing. This is especially true of peat microbiology that is well informed. The chapters on composting, bioremediation and food chains are also particularly good. Photographs, figures and tables are good quality, used effectively and distributed liberally, making it eye-catching and interesting. A distinctive style of the book is the mix of 'linear' and 'modular' reading. Margins are used to explain concepts and methods and make summary comments. These notes can be confusing in their purpose as they are sometimes headings, notes or occasionally simple quizzical and quirky comments. The authors should be congratulated for trying something different and although this style may need some refining, I liked its originality and readability. The title is similar to a very early book by Sir John Russell, but soil microbial diversity is more than ever a very modern and popular topic and I would recommend this book as a good complementary read.

***Colin Campbell**, Macaulay Land Use Research Institute*

Plant–Pathogen Interactions: Annual Plant Reviews, Vol. 11

Edited by N.J. Talbot
Published by Blackwell Publishing (2004)
£89.50 pp. 264
ISBN 1-40511-433-9

'*The Irish potato famine … is absolutely not limited to a historic reference*' state West & Vleeshouwers in this book when cataloguing the economic and social impact of the 60-odd species of *Phytophthora*.

Although part of a series, this is a stand-alone volume that does a remarkably good job in providing a comprehensive overview of micro-organisms that cause diseases in plants of economic significance. This is no mean task, given the involvement of agents as diverse as viruses, bacteria and the eukaryotic groups of fungi and oomycetes (*Phytophthora infestans*, the infamous cause of the Irish potato famine, now in a distinct kingdom, the Straminopila).

Each of these groups employs distinct infection strategies and the eight plant/pathogen examples selected for inclusion are sound choices. Inclusion of the chapter on the bean pathogen *Pseudomonas syringae* provides an outstanding example of how the environment is fundamentally significant in epidemic disease. Excellent value for institutional purchase and seriously recommended reading for all researchers in this field.

***Alan Vivian**, University of the West of England*

Reviews on the web

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

The GMO Handbook: Genetically Modified Animals, Microbes and Plants in Biotechnology

Cases in Human Parasitology

Testing of Genetically Modified Organisms in Food

Parasite Genomics Protocols. Methods in Molecular Biology, Vol. 270

Color Atlas of Medical Bacteriology

Genomics, Proteomics, and Clinical Bacteriology: Methods and Reviews. Methods in Molecular Biology, Vol. 266

The Hygiene Hypothesis and Implications for Home Hygiene. A Report Commissioned by The International Scientific Forum on Home Hygiene (IFH)

Problem-orientated Clinical Microbiology and Infection: Second Edition

Handbook of Microbiological Media, Third Edition

Viral Fitness: The Next SARS and West Nile in the Making

Marek's Disease: An Evolving Problem. Biology of Animal Infections Series

The Bacterial Chromosome

comment

plant pathogens on the move

Being green does not make a plant environmentally friendly. **Béatrice Henricot** and **Caroline Gorton** take a look at the risks of introducing new pathogens into the UK on imports of garden plants.

Despite increasing public awareness of our impact on the natural environment there has been very little discussion of the threats posed by the importation of exotic pathogens on garden plants. The volume of plant movement has never been greater, and the risk of introducing novel and ecosystem-shaping diseases is at an all-time high. The pressure to enable free movement of goods is unlikely to decrease and so we need to examine the protocols in place in the UK to detect and eradicate unwanted organisms.

Epidemics caused by introduced plant pathogens are not new and infamous examples include potato blight in the 19th century and Dutch elm disease in the late 1960s. However, attention has only recently been focused on the inadequacies of our plant health protection system by publicity about the imported fungal disease known as 'sudden oak death'. More appropriately called 'ramorum dieback', it is caused by *Phytophthora ramorum*. Whilst surveying for it, another new pathogen, *P. kernoviae*, was discovered, with the potential to be even more destructive. In the March issue of the RHS journal *The Plantsman*, Clive Brasier covers the biological, economic and social weaknesses of the plant health protection system and urges for drastic changes. He estimates that 80% of potentially high-risk pathogens are not listed as quarantine organisms and that more efforts should be made to identify them before they escape from their natural environment. However, with so many potentially threatening pathogens, detailed analysis of them all is virtually impossible. It would also be impractical to account for those which cause no damage in their native environment but might pose a risk if transferred to a different ecological niche.

The fungus *Cylindrocladium buxicola*, which causes defoliation and die back of box, illustrates the ease with which novel organisms can become established. It was introduced by a nursery in the UK in the mid-90s and has had a devastating impact on the nation's garden heritage. Incorrectly identified for several years as a related fungal species already known here, it was eventually recognized as a new pathogen to the UK. Despite having all the characteristics of an introduced organism (homogenous genotype, no close genetic relationship to any described species of the same genus and causing great damage to its host where it has been introduced), it was not classified as a quarantine organism. It soon became established in gardens and the wild, including Box Hill where it threatens the rare native habitat.

The first failing was not identifying the intercepted organism as a new species. Sadly, the required mycological skills are now rare as few postgraduates are entering the jobs market with training in plant pathology these days. The second problem is our inability to value the British flora and fauna as an asset to be protected. Countries such as New Zealand and Australia have procedures to limit the damage caused to their wildlife by non-native organisms. The UK does not, perhaps because the long history of importing material from its colonies makes people think that the majority of the plants growing in Britain are not native. And finally, the problem has been compounded by the use of suppressant fungicides. There is a strong argument to support limiting products that are available to professionals. Many commercial products that are legally approved for crops can also be used on ornamental plants in nurseries, but no data are available on their efficacy or the appropriate dosage to control specific diseases. Consequently, symptoms can be suppressed in the nursery and unwitting gardeners introduce diseased specimens to their own plots. Brasier calls this the 'Trojan Horse' method of transmitting disease. It is the prime reason for the spread of both *Cylindrocladium* and *Phytophthora*!

If plant movement was controlled as strictly as that of animals, there would be a dramatic reduction in the opportunities for new diseases to spread. By permitting the import of certified tissue cultures which were propagated at the ultimate destination, that country's horticultural sector would benefit. At present the lack of a 'polluter pays' approach to pathogens means that it makes economic sense to ignore the environmental cost, but consumers could have a significant effect, by being more aware of the origins of the plants they buy. We must never forget that plants are not sterile objects, but potentially entire ecosystems.

▲ Box (*Buxus sempervirens*) parterre affected by box blight. *Sir E. Harper*

Béatrice Henricot & **Caroline Gorton** are plant pathologists at RHS, Wisley, Woking, Surrey GU23 6QB, UK (**e** beatricehenricot@rhs.org.uk)

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