17 May 2013

Society for General Microbiology Consultation Response

Department for Business, Innovation and Skills – Key priorities for the research base and interactions between the research base and the wider innovation ecosystem

Introduction

We are pleased to respond to the BIS consultation on key priorities for the research base and interactions between the research base and the wider innovation ecosystem.

We have divided our response into five sections: (1) key points; (2) the Society for General Microbiology and its role in UK microbiology; (3) the structure of the UK's research base in microbiology; (4) priorities for the microbiological research base; and (5) interactions between the microbiology research base and the wider innovation ecosystem.

We hope this information is useful to you as you work on your review. Please do contact us for further information. With our national reach, and deep knowledge of our discipline, we can provide case studies and other data on UK microbiology and its impacts.

1. Key points

- The UK's microbiological research base supplies knowledge and skilled personnel for the chemical manufacturing, healthcare, food, agriculture, and forestry sectors of the economy.
- BIS is encouraged to continue engagement with synthetic biology and systems biology since this frontier research area is expected to have major economic impact in industrial biotechnology.
- In the healthcare field BIS should consider closer working between the Research Councils, Technology Strategy Board, and the National Institute for Health Research, particularly on areas such as antimicrobial resistance and antibiotic discovery.
- Knowledge Transfer Networks are useful but could engage more effectively with younger researchers and researchers unused to working with industry.
- Open governance of research should be encouraged to allow all parts of the innovation ecosystem, including learned societies, to participate fully.

2. About the Society for General Microbiology

The Society for General Microbiology (SGM) is a membership organisation for scientists who work in all areas of microbiology. It is the largest learned microbiological society in Europe with a worldwide membership based in universities, industry, hospitals, research institutes and schools. The SGM publishes key academic journals in microbiology and virology, organises international scientific conferences and provides an international forum for communication among microbiologists and supports their professional development. The Society promotes the understanding of microbiology to a diverse range of stakeholders, including policy-makers, students, teachers, journalists and the wider public, through a comprehensive framework of communication activities and resources. Further information about SGM is provided in Appendix 1.

3. The UK's research base in microbiology

Microbiology research is concerned with advancing:

- Prevention and cure of infection in people, crops and livestock
- Industrial fermentation processes to manufacture chemicals, biofuels, pharmaceuticals and bio-therapeutics
- Safe and efficient food production; food and drink manufacturing
- Responsible innovation in frontier fields such as synthetic biology, industrial biotechnology, bio-nanotechnology and green energy
- Pollution control and the safeguarding of water quality

Based on extrapolation from our membership numbers, plus a rough scoping exercise, we would estimate there are about 10,000 microbiologists in the UK engaged in training and research, across basic, medical, agricultural, environmental, and industrial fields. Researchers are employed in hospitals, universities, research institutes, third sector and private firms (food industry, supermarkets, chemicals, pharmaceuticals, biotech and other sectors), as well as in niche areas such as the military (counter-bioterrorism). Researchers will generally have completed, or be working towards, a PhD (infectious disease specialists may also have a dental, medical, or veterinary degree).

Our own survey indicates that there are about 90 undergraduate courses and 60 taught Master's courses with microbiological content in UK universities, hospitals and colleges. This taught system sits alongside research training up to PhD level. Although comprehensive national statistics are unavailable, we estimate that there are over 1,000 PhD students with an interest in microbiological research in the UK.

Good microbiology is inherently interdisciplinary, spanning from the very small (biomolecules, a viral particle, or single bacterial cell) – to the very large (e.g., how and why people and populations become infected with a disease). It transcends short, medium and long-term agendas – from immediate practical uses (e.g., disease diagnosis and food safety), to frontier research (e.g., synthetic biology). There is, accordingly, considerable overspill between microbiologists working in basic research and practical application, and the subject is focussed on the solution of real-world problems.

Key academic centres for microbiology research are the universities and the research institutes (e.g., National Institute for Medical Research, Pirbright Institute, Rothamsted Research, John Innes Centre, Moredun Research Institute, etc.); additionally there is considerable microbiological research in

Government research establishments (AHVLA Weybridge, Dstl Porton Down, etc.). Microbiological teaching and research are found in all major universities; the greatest concentrations are in the London colleges and institutes. Funders are BIS (primarily through BBSRC and MRC), Department of Health, Defra, the Ministry of Defence, Technology Strategy Board (TSB), Wellcome Trust, and industry. The HIV and cancer charities also fund microbiology research (cancer can have infectious causes).

Microbiological know-how (and skilled microbiologists) makes a significant impact on UK GDP in the chemicals, pharmaceuticals, healthcare, food and beverage (bread, cheese, yogurt, probiotics, beer, whisky, etc.) and agriculture/forestry/horticulture (silage, biological control agents, disease control) sectors.

There has been a huge increase in microbiological research within traditional chemicals manufacturing firms. Their priority is to develop synthetic biology-based bioprocesses to convert renewable feedstocks to biofuels, chemicals and biomaterials, as an alternative to using oil to manufacture chemicals. Firms involved range from the very large (BP, Shell, Invista Intermediates, Lucite International, and Ineos Bio), to SMEs (Biome Bioplastics, Green Biologics, TMO, BioSyntha, and Plaxica).

In pharmaceuticals, there are UK-based biotech start-ups working on anti-infectives; these include: Absynth Biologics, Aquapharm, MGB Biopharma, Novacta Biosystems, and Procarta Biosystems. The large firms – GlaxoSmithKline and AstraZeneca – participate in the EU's Innovative Medicines Initiative to develop new antimicrobial drugs.[1]

Like many of the sciences, microbiology is international, with a global community in most topics. The UK is an active and well-known part of this community. The most high-profile international work concerns infectious disease control and surveillance, focused on influenza pandemic preparedness, and cutting rates of HIV, tuberculosis and malaria.

4. Priorities in microbiology research

Healthcare sector

- Research to tackle antimicrobial resistance

Recently the Chief Medical Officer (CMO) highlighted the urgent nature of antimicrobial resistance. In extremis, it could return surgeons to the days of Lister, with no means of post-operative infection control. At the least, it could escalate the financial cost of treating even minor infections. The CMO's announcement was not news to the microbiology community. We had already flagged antimicrobial resistance as a critically important challenge (and opportunity) for future research and innovation in the healthcare sector.

The research solutions to antimicrobial resistance will probably lie with new diagnostic devices (to rapidly identify resistant infections), and new antibiotics. Neither of these, unfortunately, has been

[1] http://blogs.nature.com/news/files/2012/05/GlaxoSmithKline-AstraZeneca.pdf

forthcoming in the UK, given the reduction in funding for our medical diagnostics sector, and the limited funding for concerted innovation for new antibiotics. Undoubtedly, the solution to antimicrobial resistance is a complex, and international one (e.g., the EU's Innovative Medicines Initiative), but we also believe the issue is tractable given sufficient research effort; with the right approaches, it can be solved.

Now is the time for the UK research community to develop a cross-sector antimicrobial research strategy that builds on existing initiatives and UK research excellence to find a way forward. SGM will be issuing a policy briefing on this topic later in the year, and would be delighted to discuss antibiotic and diagnostic device research with BIS; in our view, these are as much industrial and innovation policy issues, as they are health concerns.

- Preparing for emerging (and resurging) infectious diseases

Infectious diseases can suddenly emerge, or resurge, and have serious consequences for human health and the economy over extended periods. Examples from medical practice over the last forty years include HIV/AIDS, SARS/Coronavirus, and pandemic influenza.

The Society for General Microbiology is currently conducting a study of research policy around sexually-transmitted infections (STIs), due for publication later in the year. We argue that our sexual health – long-described as 'The Cinderella of Medicine' – risks missing out on the dramatic advances in basic scientific research now shaping other medical fields. STIs, which include HIV/AIDS, chlamydia, gonorrhoea and syphilis, are a serious public health problem in need of new diagnostic tests, drugs and vaccines. This need is particularly acute given increasing infection rates in Europe, the USA and in emerging economies in Asia (witness the current, and tragic, syphilis epidemic in China), coupled to the global problem of antimicrobial resistance (see also above).

Similar arguments can be made for the other emerging and/or resurging infectious diseases, particularly the viral infections like pandemic influenza, SARS/Coronavirus, and viral links to cancer. We need our research base to retain the depth of skills, research capacity, wisdom, and adaptability to respond to unexpected threats.

Industrial biotechnology

Chemicals manufacturing is intrinsic to the quality of 21st century life, providing pharmaceuticals, healthcare products, textiles and clothing, packaging, cleaning materials, food ingredients and a whole host of other consumer products (e.g. cars, computers, TVs). The chemicals industry is one of the most productive and profitable industrial sectors in the UK, with a turnover of £57bn, 180,000 direct employees and 5.1 million employees in end-user industries.[2] These numbers emphasise the UK's strength in chemicals.

It is estimated that over 30,000 different chemicals are now in commercial use. Since the period after WWII, chemicals manufacturing has largely depended on oil-derived starting materials, but unstable

[2] http://www.cia.org.uk/Newsroom/TheChemicalIndustry.aspx; http://www.soci.org/Chemistry-and-Industry/CnI-Data/2010/19/Chemistrys-boost-to-GDP

oil prices – and emerging green technologies – are prompting a transition towards alternative, renewable starting materials. This transition could be revolutionary and has the potential to restructure the chemical industry, with new manufacturing centres emerging.

The new, renewable, feedstocks are much harder to process using traditional chemistry, and microbial processing frequently provides the only realistic option. Synthetic biology can now be used to engineer micro-organisms to produce almost any type of current, commercial chemical product, or to produce new types of intermediates and biomaterials. Emergence of this new biorenewables industry will depend on several key research priorities:

1. Using synthetic biology to develop micro-organisms for efficient utilisation of wastes from agriculture, food processing, or industrial processes (including waste gases), or even municipal waste
2. Engineering artificial metabolic pathways in micro-organisms to form a wide range of industrial chemicals at high yields
3. Innovative bioprocesses to form chemical products in high yields at industrial scale
4. Integrating microbial fermentation processes with traditional chemicals processing to elaborate the microbial products to >30,000 chemical products

Ultimately this new area of synthetic biology and industrial biotechnology is predicted to contribute £4-12bn to the UK economy by 2025.[3] The BBSRC and EPSRC initiatives in this area – including the new BBSRC/TSB-funded Industrial Biotechnology Catalyst (to be launched in 2014) – are therefore valuable.[4] We believe that microbiological research lies at the heart of this exciting new opportunity for the UK chemicals industry.

Food, agriculture and forestry sectors

In 2011, SGM produced a policy report on the contribution of microbiology research to food security and safety.[5] This report argued for the importance of multidisciplinary teams; microbiology research programmes (including the necessary resources required to deliver the proposed research); training and development of skilled microbiologists; and high-quality research facilities, including those needed to study crop or environmental systems in practice (rather than in surrogate laboratory-based models). The report also advanced arguments for the following key research areas:

- Soil health and nutrient cycling

The soil microbial community is largely uncharacterised, but is vital for agricultural productivity. Soil microbes are responsible for decomposition of organic material and biogeochemical cycling to provide plant nutrients, capture and release of essential minerals, and maintenance of soil structure. Further research into the soil community and its role in nutrient cycling will lead to increased yields of crop plants, with a significant impact on global food production.

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[3] https://connect.innovateuk.org/c/document_library/get_file?p_l_id=79343&folderId=169208&name=DLFE-1715.pdf

[4] http://www.bbsrc.ac.uk/news/industrial-biotechnology/2013/130125-n-industrial-biotechnology-catalyst.aspx

[5] http://www.sgm.ac.uk/en/all-microsite-sections/food-security-and-safety/index.cfm

- Plant-microbe dynamics

Microbial interactions are vital for plant growth, across agriculture, horticulture and forestry. Uptake of atmospheric nitrogen and several inorganic minerals by plants are dependent on micro-organisms. Research is needed to enhance beneficial plant-microbe interactions around the root and on the leaf surface.

- Crop, livestock and forestry pathogens

In the last decades, devastating infectious threats to our crops, livestock and forestry included BSE in cows, Schmallenberg in sheep, amoebic gill disease in farmed salmon, fungal disease in wheat and potatoes, and ash dieback and sudden oak death in forests.

As an example, crop diseases lower output and reduce the quality of produce; in 2012, wet weather and fungal disease knocked back UK wheat yields to 1980s levels (5 tonnes per hectare) in some areas, according to the ADAS Harvest Report. The year 2012 was also severe for late blight in potatoes, due to warm, damp weather, with a high potential for disease predicted for the current season.[6]

We need to better exploit new crop and pathogen genomic data to identify crop resistance traits; and to use computer-based models to predict the impacts of changes in climate and agricultural practices on crop disease.

- Food wastage

Microbial contamination and spoilage is a major cause of loss of food and feed, including fruit and grain. Research is needed to minimise this.

- Recycling organic wastes

We need to improve production of cell-wall-degrading enzymes from microbial sources for the commercial breakdown of plant structures, allowing us to better convert waste into usable energy and fertiliser.

New research frontiers

- Synthetic biology

Synthetic biology enables the rational design of new microbial cells to perform functions relevant to industrial biotechnology, e.g.: make platform chemicals, high value intermediates, biomaterials, biofuels and pharmaceuticals. For example, a major project to synthesise an anti-malarial drug (artemisinin) shows the potential of the technology in pharmaceutical manufacturing.[7]

[6] Analysis prepared by Glyn Harper, AHDB Potato Council, for SGM, based on data from the 'Fight against Blight' survey 2012.
[7] http://www.ncbi.nlm.nih.gov/books/NBK1717/

UK support for synthetic biology should be continued and expanded, since the topic is a national research strength.[8] Microbiology is central to synthetic biology, since much of the research aims to re-engineer microbial cells for useful purposes. Bacteria and yeast are the most commonly used hosts for engineered components.

Industrial Biotechnology and synthetic biology overlap considerably but there are many other applications of synthetic biology. These include novel biosensors, bacterial nanowires, bacterial fuel cells, and bacteria that record/count digital information. Design of artificial genetic circuits functioning in human cells will deliver gene therapy tools to combat incurable diseases such as cancer; virology is vital here. Efforts to completely rewrite whole genomes have been successful (e.g. synthetic *Mycoplasma mycoides*), heralding the way to 'design and build' organisms for specific purposes. Other approaches aim to alter the genetic code to allow the incorporation of artificial amino acids into proteins to alter their activities or to generate new scaffolds for chemical synthesis.

- Systems biology

Systems biology integrates state of the art experimental techniques with mathematical and computational modelling to study how the behaviour of the living cell emerges from interactions between its molecular components. Systems biology underpins both basic science and more applied research in medicine and synthetic biology, by providing fundamental information about the functionality of cells and their molecular components. The concepts of systems biology stemmed from pioneering work on model micro-organisms such as *Escherichia coli* and *Saccharomyces cerevisiae*, much of it in the UK. Microbes still constitute important platforms for systems biology. Currently, systems biology offers tools, models and approaches that are applicable to the identification of vulnerabilities in bacterial pathogens and thus has high potential to deliver a new generation of antibiotics.

5. Interactions between the microbiology research base and the wider innovation ecosystem

Knowledge Transfer Networks

Knowledge Transfer Networks (KTNs) can be useful for making introductions between academics and companies and helping academics to showcase their work at industry workshops. KTNs are currently most effective when assisting established academics with prior experience of working with industry. There is, however, a huge gap in provision for early career academics or academics trying to take the first steps into industry-relevant/impact-driven research. This group of academics need to learn (a) how industry works and (b) the research priorities for industry. It would be an excellent development if the KTNs would consider how they might address this unmet need for early-career academics.

[8] Multidisciplinary Synthetic Biology Research Centres – http://www.bbsrc.ac.uk/funding/opportunities/2013/synthetic-biology-research-centres.aspx

Role of the Research Councils

The Research Councils play a critical role within academic research in the UK. There are good and strong relationships with other funders, including companies, charities, Government departments and the Higher Education funding bodies. Mechanisms are in place to minimise duplication and promote dialogue. Organisations such as the MRC, the Wellcome Trust and the Bill and Melinda Gates Foundation fund specific areas of microbiological research concerned with infectious disease. The particular strength of the BBSRC and EPSRC is their support for microbiology beyond its medical aspects, and their broad, cross-cutting focus which allows work across subjects and disciplines. Ring-fencing of research budgets is valuable for strategic planning.

Cross-department, and cross-sector, action on infection research

A diversity of research projects is important, and we should encourage this, as we will need a diverse range of good ideas to underpin future science and healthcare innovation (drugs and vaccines, medical devices, and new ways of working). The National Institute for Health Research (NIHR) and the Research Councils make contributions to our infectious disease research portfolio.

Funding directed through NIHR appears considerably higher than through the individual Research Councils (MRC and BBSRC).[9] There must be a better way of identifying synergies between the various funders of medical research (government, philanthropic, and private sector), and of joining-up research funding, regulatory agencies, and end-users (health professionals and patients), to produce better outcomes for public health, and the economy.

Our forthcoming report on research policy around sexually-transmitted infections, due for publication later in the year, will develop ideas in this area.

Industrial links

UK businesses and policy-makers are represented on Research Council committees and boards, and there are specific schemes to bring research outputs to businesses (e.g. Biosciences Knowledge Transfer Network). As the Research Councils may routinely devolve intellectual property to the research institution, industrial access to the research base often occurs at institutional level.

Industrial biotechnology is a major interest for members of the Society for General Microbiology. One key barrier everyone identifies is communication and knowledge exchange between academia and industry. In this context, the BBSRC Networks in Industrial Biotechnology and Bioenergy (NIBB), which may then lead to funding opportunities, seem to be a good idea, and BBSRC have specifically invited SGM to engage in this initiative.

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[9] NIHR (2011/12): £931.1 million; MRC (2011/12): £763.3 million; BBSRC (2011/12): £542.5 million. Sources: http://www.nihr.ac.uk/files/Publications/NIHR%20Annual%20Report%202011-12%20final.pdf, p. 56; http://www.mrc.ac.uk/Utilities/Documentrecord/index.htm?d=MRC008776, p. 156; http://www.bbsrc.ac.uk/web/FILES/Publications/bbsrc_annual_11_12.pdf, p. 46.

UK microbiology's 'civil society' – the learned societies and ad-hoc professional groups

There are at least two learned societies and 13 professional groups active in UK microbiology, and the Society for General Microbiology is the largest of these. These societies and groups are in the closest contact with the needs of researchers, and play crucial but often overlooked roles in funding research ('pump-priming' funds and training grants), supporting knowledge dissemination, generating awareness and providing advice. The individual strengths and expertise of all the organisations involved in UK science need to be harnessed in pursuit of high-quality research. To aid interactions, the Research Councils could do more on open governance.

Society for General Microbiology – President & Chair of the Policy Committee:

- Professor Nigel Brown, Emeritus Professor, University of Edinburgh

Society for General Microbiology – Policy Committee:

- Professor David Blackbourn, University of Birmingham
- Professor Martin Cranage, St George's, University of London
- Professor Colin Harwood, Newcastle University
- Professor Maggie Smith, University of York
- Professor Gill Stephens, University of Nottingham
- Dr Jeremy Webb, University of Southampton

The Policy Committee additionally sought the views of Professor Andrzej M. Kierzek (University of Surrey) in preparing this response.

Contact point for further information:

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Appendix 1

Vision

A world in which the science of microbiology provides maximum benefit to society.

Mission

To promote high-quality microbiological science, both nationally and internationally, to a diverse range of stakeholders.

Rationale

The potential socio-economic benefits arising from microbiology are substantial. They include:

- A healthier future (for humans, animals and plants) and a better quality of life, within the context of a sustainable natural environment.
- The development of biotechnology products (such as food, drinks, biopesticides, biofuels and medicines), which generate wealth and employment, and so support growth and innovation.
- The advancement of scientific knowledge, as a benefit in its own right, and to allow us to plan for the future and contribute to international solutions for global challenges, such as climate change, the burden of disease and food security.

Strategic priorities

To achieve its Vision and Mission, the Society will work towards the strategic priorities below.

- Publishing: to contribute to the science of microbiology through high-quality publications.
- Scientific conferences: to hold international scientific conferences to disseminate research knowledge and provide a forum for communication between microbiologists and to grow and support communities among them.
- Raising awareness: to inspire and educate people about microbiology, and allow them to make informed decisions which recognize the importance of microbiology and its advances.
- Influencing policy: to ensure that appropriate scientific information and expert opinion are made available to policy- and decision-makers and that the improvement of resources and infrastructure for microbiology is supported.
- Professional development: to promote microbiology as a career from school level onwards and support career and professional development of microbiologists.

The Society is a Charity registered in England and Wales (No. 264017) and in Scotland (No. SC039250) and a Company Limited by Guarantee, registered in England and Wales (No. 1039582).

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