

IN CONFIDENCE

**EVALUATION OF BBSRC ENGINEERING AND  
BIOLOGICAL SYSTEMS COMMITTEE RESPONSIVE  
MODE PORTFOLIO**

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This document represents the conclusions of a Review Panel of experts in engineering and biological systems.

The views expressed are those of the members of the Panel.

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## **Glossary**

AF.....	Agri-Food Committee
AS .....	Animal Sciences Committee
BMS .....	Biomolecular Sciences Committee
DIUS.....	Department for Innovation, Universities and Skills
EBS.....	Engineering and Biological Systems Committee
EPSRC.....	Engineering and Physical Sciences Research Council
GDB .....	Genes and Developmental Biology Committee
LSI.....	Life Sciences Interface
MRC .....	Medical Research Council
NERC .....	Natural Environment Research Council
PI.....	Principal Investigator
RA .....	Research Assistant
RAE.....	Research Assessment Exercise
TSB .....	Technology Strategy Board

## EXECUTIVE SUMMARY AND KEY CONCLUSIONS

This document sets out the views of a specialist Review Panel convened to provide an independent evaluation of the research supported in responsive mode through the BBSRC Engineering and Biological Systems Committee (EBS) since the Committee's inception in July 1996. The objectives of the evaluation were to assess the quality of the research supported and to identify major outcomes arising from it; to consider whether the EBS committee is currently funding the most appropriate areas of UK bioscience; and to identify ways to build on successes and address identified gaps and issues.<sup>1</sup>

The Panel's analysis was based on the results of questionnaire surveys of a sample of 201 current and past grantholders, 14 current and past EBS committee members, and one other UK funding organisation, and on the final reports for 137 sample completed grants.

### KEY CONCLUSIONS

#### Research quality

- EBS has supported some highly innovative and successful research in important multi- and inter- disciplinary areas. The quality of the portfolio as a whole was good and improved over time. Some of the research funded was high-risk, hypothesis-driven, and funding for this type of research must be continued.
- While continuing to ensure value for money from grants, EBS should not unnecessarily cut the amount awarded: evidence from the evaluation indicates that reduced awards underperform.
- To build on the outputs achieved, and to maintain its position internationally, the EBS community should be encouraged to consider how research in this area can best be translated into viable outcomes. BBSRC should play a role in facilitating this, particularly in relation to the use of new tools and technologies.

#### Research outputs

- The EBS portfolio has produced a good number of research papers and trained staff as well as an impressive number of new tools and technologies. This is despite the tensions which affect published outputs, including the need to protect IPR and the reluctance of some major, multidisciplinary journals to accept engineering papers.
- Over half the sampled PIs had established new contacts in the UK and/or overseas as a result of the EBS grant. However, only a few of these led to internationally co-authored papers, and there is scope for BBSRC to encourage further contacts, particularly in regions where relevant research is emerging strongly (e.g. India and Singapore).
- While recognising the comparatively high number of trained staff resulting from EBS grants, there is still a shortage of skilled researchers to sustain research within academia and industry in this important area. Recruitment of appropriate skills, in particular good numeracy skills, remains difficult.

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<sup>1</sup> In addition to funding responsive mode grants, the EBS Committee also funds research relevant to its remit via BBSRC-sponsored institutes, Interdisciplinary Research Centres and initiatives. These are evaluated separately by BBSRC and do not form part of this evaluation. For details of the EBS remit see Appendix 2 on page 31.

- The evidence suggests that some EBS grants have not contributed to the career development of the RAs working on the grants or to the flow of people between disciplines. The level of training provided varies between institutions and BBSRC should consider monitoring the information on funding options and career guidance given by HEIs.
- BBSRC's move to funding more Doctoral Training Grants, at the expense of targeted Committee studentships, appears to have disproportionately affected the availability of awards in the EBS area. More studentships should be funded in association with EBS research grants.

#### Balance and coverage of the portfolio

- Given the wide remit of EBS, and the quality of the research outputs, it is surprising that this area receives a lower proportion of BBSRC's responsive mode funding than other committee areas. As a result, the coverage lacks depth.
- EBS operates at several crucial research interfaces. The interface with other BBSRC committees needs to be monitored continuously to prevent gaps from developing as research initiatives move into mainstream funding.
- The most prominent interface is that with EPSRC's LSI and, while these linkages are clearly strong, there is uncertainty within the community about which Council to approach for funding. Roadshows should be arranged to address this. It is important that the research councils work together to ensure that no barriers exist which might hamper genuinely interdisciplinary research.
- A shift towards more translational research could be facilitated by increased dialogue in relation to the EBS area between BBSRC and MRC and by helping PIs to understand better the routes they can follow to obtain appropriate funding.

#### Economic and social impact

- The EBS portfolio has given rise to some notable industrial developments, including 14 spin-out companies. The overall level of interaction with industry is reasonable, particularly given the constraints within which PIs have to work (e.g. needs of the RAE, conflicting demands on their time). However, there is clear scope to increase such interactions, by facilitating a change in culture, particularly among academic researchers.
- BBSRC has a well-run central programme of activities to support PIs' public engagement activities. However, the level and range of activities reported by EBS PIs did not always match expectations. BBSRC should reconsider the current requirement for all PIs to carry out these activities and concentrate on encouraging those who show particular aptitude for them, by providing clearer direct incentives and increasing the rewards.
- The EBS portfolio has generated some important impacts in relevant research skills and training, and in relation to research for the public good - particularly research developments in biomedicine. It will be important to build on these developments by increasing the capacity of the EBS community to carry out translational research, by facilitating the dialogue at the BBSRC/MRC interface, and by raising the community's awareness of the potential impacts of their research.

## CHAPTER 1. BACKGROUND

### Introduction

1. The Biotechnology and Biological Sciences Research Council is one of seven Research Councils sponsored through the Department for Innovation, Universities and Skills (DIUS; formerly Office of Science and Innovation, OSI) of the UK government. Its principal aim is to foster a world-class biological science community in the UK. The mission of the BBSRC is to fund internationally competitive research, to provide training in the biosciences, to encourage opportunities for knowledge transfer and economic impact, and to engage the public and other stakeholders in dialogue on issues of scientific interest.
2. BBSRC supports research in a number of ways, including research grants, studentships, fellowships, and core strategic grants to BBSRC-sponsored research institutes. In the 2006-07 financial year, 36% of BBSRC research funding was spent via the 'responsive mode' scheme, whereby research grants are awarded to unsolicited high quality research proposals from eligible applicants in any area relevant to the mission of the Council.
3. For organisational purposes, the BBSRC research remit is currently divided into seven key areas each covered by a Research Committee: Agri-Food; Animal Sciences; Biochemistry & Cell Biology; Biomolecular Sciences; Engineering & Biological Systems; Genes & Developmental Biology; and Plant & Microbial Sciences.

### Evaluation context

4. Evaluation is of growing importance to BBSRC and, with its emphasis on evidence-based decision making, to the UK government. Evaluation plays a central role in:
  - justifying BBSRC funding allocation and contributing to the evidence that all Councils are required to submit to DIUS
  - informing internal funding decisions, providing evidence of progress and achievement, and facilitating the development of a strategic overview for future funding decisions
  - enabling BBSRC to account to government, the public, the scientific community and other stakeholders for the funds it allocates
  - helping BBSRC to improve its policy and practice, through informing policy decisions and the design of new schemes, programmes and processes; and through identifying good practice, lessons learned, and ways to improve processes.

Formal evaluation of research is currently conducted at a number of levels in BBSRC:

Grant	<ul style="list-style-type: none"><li>• Evaluation of final reports from individual grants</li></ul>
Scheme	<ul style="list-style-type: none"><li>• Evaluation of the responsive mode scheme, evaluating the portfolio of each Research Committee in turn</li><li>• Evaluation of research initiatives (time-limited research funding in strategically significant areas), 2-3 years after the grants have ended</li></ul>
Institution	<ul style="list-style-type: none"><li>• Institute Assessment Exercise, conducted every four to five years at BBSRC-sponsored Research Institutes</li></ul>

5. BBSRC's Evaluation Strategy<sup>2</sup> outlines the Council's approach to evaluation and methodology used. The BBSRC responsive mode portfolio is evaluated by Research Committee area on a rolling basis whereby two Committee portfolios are evaluated every year. EBS is the fifth Committee to be evaluated, following evaluations of the Animal Sciences, Biochemistry & Cell Biology, Genes & Developmental Biology, and Agri-Food Committee responsive mode portfolios carried out between 2005 and 2007.
  
6. This evaluation covers research grants supported in responsive mode through the EBS Committee which have been given a final report grade since 1996. The objectives of the evaluation were to:
  - assess the quality and international standing of research funded through the EBS Committee
  - identify the major outputs and, where possible, outcomes of the EBS Committee responsive mode portfolio over the past 10 years
  - identify strengths, weaknesses and gaps in the EBS Committee remit and the way it is structured
  - consult with the research community and other relevant funding bodies (government and non-government) to assess whether the EBS Committee is currently funding the most appropriate areas of UK bioscience
  - assess the economic and social impact of EBS-supported research
  - identify ways to build on successes, and ways to address identified gaps and issues.
  
7. BBSRC evaluations are evidence-based, and conducted by an independent Review Panel comprising scientists not closely involved with BBSRC, but who between them have expertise across the EBS Committee remit, who are asked to provide an independent scientific evaluation of the evidence presented (see Appendix 1 for Panel membership). This was:
  - **137** sample final reports (representing **59%** of all EBS Committee responsive mode grants that had been completed and graded at the time of sampling). See Appendix 4 for the full list of sample grants.
  - Questionnaires returned by **86** principal investigators (PIs) of completed grants (representing **37%** of all completed and graded EBS Committee responsive mode grants) and **41** current PIs (**39%** of all current EBS Committee responsive mode grants that had been underway for more than a year). For questionnaires see Appendix 3.
  - Questionnaires returned by **14** current and former EBS Committee members
  - Questionnaire returned by the Natural Environment Research Council, part of whose remit is relevant to that of EBS.
  - Additional information about the grants funded through the EBS Committee responsive mode drawn from BBSRC databases.

The sample final reports and PIs were chosen randomly from the point of view of the science, but in a structured way to be representative of the years and, where applicable, the final report grades achieved.

8. Further information on responsive mode funding in BBSRC, the evaluation objectives and methodology, and on the EBS Committee is given in the appendices.

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<sup>2</sup> [www.bbsrc.ac.uk/organisation/policies/reviews/funded\\_science/bbsrc\\_evaluation\\_strategy.pdf](http://www.bbsrc.ac.uk/organisation/policies/reviews/funded_science/bbsrc_evaluation_strategy.pdf)

## CHAPTER 2. RESEARCH OUTPUTS AND ACHIEVEMENTS

### Research quality

9. The general standard of the research funded by the Engineering and Biological Systems Committee in the sample grants assessed by the Review Panel was good, with some grants that were highly innovative and successful. Outputs from the most impressive grants are summarised on pages 13-17. Other grants were less inspired, but the quality of science and level of outputs appeared to have improved over time, with a marked step change around 1999. This was likely to be due to an increased understanding of the remit of EBS operating fully in responsive mode after the restructuring of BBSRC's committees and directorates, and an associated trend towards more genuine multidisciplinary and more applied approaches. Furthermore, some of the earlier grants had been reduced in length and value from the original application, which had clearly adversely affected the outcomes.
10. 79% of the final reports on EBS grants, submitted within three months of the end of the award, had been graded either A or B by EBS Committee assessors,<sup>3</sup> which was above average for BBSRC grants as a whole. Moreover, 80% of the PIs who had completed their grants and who responded to the questionnaire survey were of the opinion that their projects had been successful and had met their stated objectives; over 90% of current grantholders thought that their project was likely to achieve its objectives. This level of success was not always reflected in the sample of final reports reviewed by the evaluation Panel: some grants had been very focused and innovative, and had resulted in excellent outputs and outcomes, but others were less successful and had resulted in few outputs. However, it is important to note that EBS funds many hypothesis-driven grants which can be high-risk, and not guaranteed to be successful, and the Committee must be able to continue this practice.
11. The main reasons given by PIs for less successful grants were problems with recruiting and retaining staff, technical and methodological problems, and lack of resources, such as funding and equipment. Recruitment and retention in particular have been recognised as major issues across the biosciences in recent years; this is discussed in further detail below (paras 28-35).
12. Among the less successful grants were a number for developing instrumentation, and these grants might have benefited from a higher level of funding for a longer period of time, or from making greater use of sub-contractors to carry out aspects of the work, as RAs often do not have the necessary skills to take the technology forward.
13. There is also scope for EBS-funded researchers to make greater effort to translate research findings into viable outcomes. However, it should be recognised that PIs might not be aware of the options available to them or where to apply for funding for this type of work.

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<sup>3</sup> Reports are graded as follows:

A: Very high class work that has produced results of considerable scientific importance in a cost effective way and met all or almost all of the agreed or related key objectives

B: Work that has added significantly to knowledge in the field and met the majority of its agreed or related key objectives

C: Work that has fallen short of the contribution to knowledge or cost effectiveness expected from the original proposal even though it may have met some or all of its agreed or related key objectives

D: Work that has not added significantly to knowledge in the field and/or has failed to address the agreed or related objectives.

## Highlights

14. Of the 137 sample final reports assessed by the Panel, 40 grants were identified as being particularly successful and as having produced a high standard of outputs (29%); summaries of these are given on pages 13-17.
15. These projects were wide-ranging and included a number which focused on the development of new methodology and techniques. Many of the grants resulted in extensive new collaborations, both in the UK and overseas, and a reasonable amount of intellectual property, including patents and the establishment of spin-out companies. A good number of refereed publications has arisen from the selected projects and they contributed 291 of the total of 617 papers in refereed journals (47%). Several other grants were also worthy of note and summaries of these are given in Appendix 5.

## Research outputs

### Summary

16. Data for research outputs on completed grants were collected from final reports and questionnaire responses for the sample of 137 PIs. However, it should be noted that these figures are likely to be underestimates because they were compiled from final report forms for all 137 PIs, but from questionnaire responses for only 86 PIs (as the remaining 51 PIs did not return the questionnaire). As the final report is usually submitted too early for major outputs to have arisen, the Panel suggested that a system to capture these data annually during grants and for a significant period of time after they have finished be introduced to provide more reliable data for evaluation purposes.
17. Overall, there were a good number of papers in refereed journals, an excellent number of trained staff, and an impressive number of new tools and technologies in the sample of grants assessed. There were some inconsistencies in the level of detail provided by PIs in both final reports and survey responses, which made it difficult for the Panel to assess the overall level of outputs. For example, there appeared to be over-reporting of publications, with some PIs listing papers that were likely to have resulted from other grants, but under-reporting of follow-up funding. In addition, more evidence of measures of esteem would have been useful, for example, invited presentations at international conferences.

### Publications

18. A total of 617 papers in refereed journals are known to have been published and reported so far from the completed grants. This gives a median of 3 publications per grant, similar to the level of published outputs from the evaluations of BBSRC's other committees.
19. A proportion of the refereed papers had international (7%) or industrial (12%) co-authors. These figures seem lower than might be expected considering the number of new international and industrial contacts reported by PIs (see below); however, it is possible that many of the new contacts were informal, and therefore less likely to result in identifiable outputs, or were at an early stage when the survey was carried out.

20. The journals in which the papers appeared varied. Although a smaller number of papers than in other areas of bioscience were published in widely circulated, multidisciplinary journals such as *Nature* or *Science*, this is likely to be due to the high number of engineering papers, which are not always welcomed by those journals. Moreover, PIs tend to target the most appropriate journal for their research discipline which, for EBS researchers, will often be in more specialist journals. The journals with the highest number of papers were: *Chemical Communications*, *Journal of Biological Chemistry*, *Langmuir*, *Applied and Environmental Microbiology*, and *Biotechnology and Bioengineering*.
21. The potential for conflict between the need to publish papers quickly in fast moving fields and the push to publish in more widely circulated journals is clear. Moreover, PIs whose work involves collaborations with industry and has intellectual property (IP) implications face a further conflict: it is not always possible to publish, because of concerns over commercial confidentiality and the potential risk to IP rights. Also, PIs in universities are pressurised by the requirements of the Research Assessment Exercise, which is a key driver of publishing patterns and may have affected the timing and placement of some papers.

#### New contacts and collaborations

22. Over half the PIs who responded to the survey had established new contacts, mostly with academics in the UK and in a wide range of disciplines, and over a third of PIs reported that these new contacts had resulted in formal collaborations, leading to pilot studies, joint funding applications, joint studentships and/or joint publications.
23. Almost half the PIs had established new contacts with overseas academics, some of which had led to full research collaborations. Most collaborations were with researchers in Europe and the US, with a small number in Australia, China, Japan, Malaysia, Brazil, Pakistan, Russia, Canada and Argentina. The lack of collaborations with India and Singapore was slightly surprising as this is where a significant amount of EBS-related research is being carried out currently. However, collaboration with researchers in these regions was a relatively recent development.
24. The Panel acknowledged that it can be difficult for research staff to establish new international collaborations but felt that BBSRC should do more to encourage this. BBSRC could consider adding small amounts of funding to grants for overseas visits and should also provide more information to PIs about the funding opportunities open to them, such as the Partnering Awards (with China, India, Japan and the US) and the International Scientific Interchange Scheme (ISIS).
25. New contacts and collaborations had also been established with industrial researchers, both in the UK and overseas; further details of these contacts are given in Chapter 4 on page 21.

#### Further funding

26. It was pleasing that over half the PIs had received further funding to continue the research funded by the EBS grant. Funding had been received from many sources, including: research councils, government departments and agencies, EU, ESF, industry, Wellcome Trust and other charities, NIH, Royal Society and Regional Development Agencies. This was a much wider range of organisations

than reported in other BBSRC committee evaluations and probably reflects the diversity and multidisciplinary nature of the research funded by EBS. However, there was a large amount of information on further funding missing from PIs' questionnaire responses, further supporting the need for a system to capture outputs for a period of time after grants have finished.

27. 42% of PIs had applied to EBS for further funding, 39% of whom had been successful; a very good success rate which compares well with the current BBSRC average of 26% for responsive mode.

#### Trained people, new skills

28. 85% of PIs reported an increase in the skills base of their research groups as a result of the EBS grant. The majority of grants employed one research assistant (RA), with a small number of grants employing two or three RAs. 99% of RAs worked full-time on the project and were employed on average for 31 months. In addition, technicians were employed on 42% of the grants. One large grant, awarded for strengthening the infrastructure and academic research base of the North West Centre for Bioarray Innovation, employed a total of 17 RAs and 4 technicians.
29. Despite the seemingly impressive number of trained staff resulting from the EBS portfolio, there is still a shortage in the UK pool of trained staff in multidisciplinary research relevant to the committee's science. This was emphasised by several Panel and EBS committee members, particularly those from industry, who commented that there were insufficient trained research staff to meet their needs and they had recently had to recruit from outside the UK. The implication is that the UK is in danger of losing its leading position in the field if this situation is not addressed, a view supported by recent reports by Bioprocess UK and EPSRC.
30. Some PIs had experienced difficulties when recruiting research staff onto the grant, because it was difficult to find someone with the necessary skills, a problem which might be alleviated by increased funding for studentships within grants. There had been a high level of staff turnover in some grants, with over a quarter of PIs reporting a change in staff during the grant, a similar level to that reported in other committee evaluations.
31. One of the main reasons for these difficulties is the distinct and on-going lack of numeracy skills among UK biology graduates, which affects their ability to carry out multidisciplinary research effectively. The Panel felt that these students should be required to undergo more training in mathematics, and was pleased to note that BBSRC is helping to address this problem through several routes, including funding Masters courses in mathematics and computational science, by contributing funding to the Discipline hopping awards run by MRC and EPSRC, and by running mathematics summer schools. To complement these schemes BBSRC should also consider ways of attracting more mathematics, physics and engineering graduates into research in the life sciences.
32. Although a reasonable number of research staff employed on EBS grants moved to new institutions on completion of the grant, the Panel was surprised that as many as a third of staff remained in the same laboratory. Among those who had moved on, nearly a quarter went to another fixed-term academic post and 12% moved to the private sector, industry or commerce, a higher proportion than reported in other BBSRC committee evaluations.

33. It was apparent from this evaluation that EBS grants had not particularly helped the career development of the RAs employed: none of those in the sampled grants appeared to have progressed immediately to being PIs in their own right. It should, however, be recognised that by its very nature, interdisciplinary researchers need to gain a broad range of skills and may take longer to reach sufficient scientific maturity to develop independent careers than more narrowly focused researchers. Although BBSRC has schemes in place to assist young researchers early in their careers, such as the New Investigators scheme and David Phillips Fellowships, opportunities within the EBS remit appear to be limited. EBS funds 9% of all BBSRC New Investigator grants, slightly lower than the proportion of responsive mode grants funded by EBS (11%), and at the lower end of the scale when compared with other BBSRC committees. The level of training for RAs appeared to vary considerably between institutions and it might be helpful for BBSRC to track this more rigorously by requiring that information on funding options and career guidance is offered to students.
34. Over half of the EBS grants had PhD projects running alongside them but there is, nevertheless, a shortage of studentships in the EBS field. The introduction by BBSRC of Doctoral Training Grants (DTGs) in place of Committee studentships appeared to adversely affect availability for EBS researchers: DTGs tend to be awarded to departments who traditionally win funding and not necessarily to those in the EBS field. There appear to be insufficient studentships available at the interface between the research councils, but the EPSRC Doctoral Training Centres were considered to be a good model, as they provide a multidisciplinary approach to postgraduate training.
35. The failure to train sufficient numbers of staff to meet the needs of both academia and industry is exacerbated by problems of retaining trained people in research. For example, it is becoming more difficult to retain mathematicians in academia when they can earn considerably more working in other sectors, for example, finance. This is likely to be the case until academic salaries and/or career structures become more competitive with those in the business world.

#### New products, processes, tools and technologies

36. New tools and technologies were developed by 71% of PIs, considerably higher than the figures for other recent committee evaluations (GDB: 48% and AF: 41%). Developments included methods, equipment, reagents, models, software, and new materials, and had a wide range of potential users including academic researchers, industry, clinicians, teachers and students, conservationists and vets. Most of these technologies remain accessible and relevant, and it is clear that continuing to develop novel approaches is vital for the health of the discipline. This remains the case even if within the lifetime of a grant it does not prove possible to solve a 'real' biological problem.
37. The new tools and technologies were made available to the community via publications, on the internet, or as commercial products. Although few PIs were able to give evidence of the level of uptake or impact of the technologies, as it was often too early to do so, several were confident that their technologies had or were having significant impact on the research community. For example, two groups that had developed new software have collected notable usage statistics. In addition, 75% of the new technologies were thought by PIs to have the potential to be exploited commercially.

38. Given the impressive number of new tools, technologies and methodologies that had been developed, there is now a clear need to encourage more translational work to take these technologies forward. This is particularly so in the clinical area and might best be addressed in collaboration with MRC. Moreover, BBSRC should provide information for PIs on possible mechanisms and sources of funding for translational research.

#### Intellectual property and spin-out companies

39. Intellectual property activity had arisen from 25% of the EBS grants, with more PIs planning this in the future. 10% of applications have resulted in a patent being licensed to a company; one of these had received income at the time of the survey.
40. EBS-funded research had contributed to the establishment of 14 spin-out companies, 8 of which are still trading. This figure is much higher than the total of 6 reported from other BBSRC evaluations and most likely reflects the more applied approach of EBS grants compared with other committees, and the relevance of this area of research to sectors in the UK economy which are strong.

#### Contribution to the reduction, refinement and replacement of animals in research (3Rs)

41. A small number of PIs (7%) reported that their research had contributed to the 3Rs. Examples given by PIs included: reduced reliance on *in-vivo* experiments due to the development of novel cell cultures and modelling tools, improved cell culture reagents which avoid animal products, and novel assays for the assessment of compatibility of alternative materials. Additionally, over half the EBS committee members consulted felt that EBS research had made a contribution to the 3Rs, with the use of tissue engineering to create artificial organs cited as an important example.
42. The comparatively low level of outputs relevant to the reduction, refinement and replacement of animals in research was appropriate as relevant research is not central to the EBS remit. BBSRC funds this research through other committees (particularly Animal Sciences) and through core funding for the National Centre for the 3Rs of over £450k per year.

## Highlights

### *A novel strategy for bioanalytical and biocatalytic devices: biomolecule immobilisation on nanoporous TiO<sub>2</sub> electrodes*

The aim of this project was to develop the knowledge to underpin future biotechnological applications of biomolecular immobilisation on nanoporous metal oxide films. The project achieved all of the original objectives and the PI has patented the use of nano-titania for this application and signed a licence deal with an Irish company. The PI reported a large number of new collaborations, both in the UK and overseas, and six papers were published in refereed journals.

### *Applications of Bacillus megaterium cytochrome P450 in synthetic chemistry*

This grant explored the scope for exploitation of cytochrome P450 BM3 to carry out biotransformations of interest in synthetic chemistry by: examining its catalytic repertoire and substrate specificity using a range of substrates of potential synthetic interest; and using mutagenesis to alter and extend its specificity. The project resulted in the development of electrochemically driven P450 enzyme, in which several pharmaceutical companies have shown an interest. Five refereed papers resulted from this grant.

### *Biological phosphorus removal from wastewaters: a novel approach*

The project developed a simple but effective methodology for enhanced phosphorus, phosphate and polyphosphate removal from sludge, and resulted in the development of a pilot plant that removed up to 80% of the phosphorus when operated as a single-stage reactor. The work is being taken forward by collaborators in the wastewater treatment sector. Six refereed papers were published and the PI carried out a range of public engagement activities.

### *Biosynthesis of nanophase hydroxyapatite by a species of citrobacter*

This project set out to use a bacteria normally employed in environmental cleaning (citrobacter or serratia) to form a hydroxyapatite of higher strength than bone repair materials currently available. The researchers showed that through the growth of the bacteria on polyurethane foam, and subsequent furnace treatment, a complex and porous shape of HA could be formed to design by the bacteria. The grant resulted in one patent application, and the PI established a large number of new collaborations. Five refereed papers were published.

### *Cell separations in expanded beds*

This grant supported the development of simple and scaleable methods based on expanded bed adsorption for the separation and recovery of particular cell types from mixtures of cells, while maintaining their function. A major part of the work focused on human cell separations (e.g. for cell based therapies such as transplants) which was carried out in collaboration with clinical colleagues in the UK. Two refereed papers were published.

### *Characterisation of a specific articular cartilage progenitor cell*

This project studied a chondroprogenitor cell that the researchers had isolated from the surface of articular cartilage by differential adhesion to fibronectin. Study of the cells in culture revealed their ability to be involved in cartilage repair through collagen II generation and other assays. A signalling molecule from the Notch family was found to be important in the cell cycle, and further funding has been acquired to investigate its possible use in treating arthritic disease. This grant resulted in a patent application and four refereed papers.

### *Chemo-enzymatic synthesis of the thylakoid lipids*

The objectives of this collaborative grant were to develop chemo-enzymatic routes to the major glycolipids of thylakoid membranes, and to synthesise specific glycolipids to be used in structural studies on photosystem II. The methods developed should now allow others working in the photosynthesis field to have ready access to these and other natural glycolipids and analogues. A new collaboration was established with a French group.

### *Continuation support for the development of 'smart' membranes for solute delivery*

This was a continuation from a previous grant, the output of which was the development of a range of stimuli-responsive hydrogel materials, primarily for drug delivery applications. During the course of the research, the materials were also evaluated more broadly for use in analytical systems and in separation processes. The research resulted in four refereed papers, a conference proceeding and a

book chapter, and was protected by a GB patent filing.

*Creation of a nanoparticle biosensor for multiplex single nucleotide polymorphism analysis*

The grant was awarded for the creation of a biosensor based on formation of 3D silver nanoparticle clusters, and resulted in the first ever SERRS from DNA functionalised nanoparticles in a molecularly specific manner, the data from which are now being used as the background for further investigations. Outputs included a patent application and one refereed publication.

*Development and optimisation of an immunological and cellular tool-kit for pollutant biosensing*

The aim of this grant was to probe for pollutants in environmental samples using a combination of two types of biosensor. The first was based on an immunoassay and provided information on the amounts of specific pollutants in samples; the second provided information on the biological toxicity of the sample using a decrease in light output from bioluminescent organisms as an indication of biological contamination. The research resulted in the establishment of a spin-out company, Remedios, and six refereed papers.

*Engineering haem binding sites in monomeric rop*

The objective of this grant was to engineer haem-binding sites in the repressor of primer, rop, to generate a new class of biomaterials for derivatisation of electrode surfaces. A number of haem binding sites were engineered and the electrochemical properties of two mutations adsorbed on electrode surfaces were studied. Three refereed publications and one book chapter were published, two patents granted, and a spin-out company, Nanobiodesign, was established.

*Enhancing the degradative activity of bacteria by genetic augmentation with P450cam to provide novel catabolic pathways*

This project looked at developing a generic approach to increase the effectiveness of bioreactors by a combination of engineered and indigenous bacteria for the degradation of environmental contaminants. The work demonstrated the feasibility of using genetically augmented micro-organisms to degrade otherwise inert compounds. Four patents were applied for and the results from the project were taken forward by the university's technology transfer company. Twelve refereed papers were published.

*Enzyme action under very low water conditions: hydration hysteresis and sulphatase reversal*

This research studied the action of a variety of enzymes, including subtilisin and chymotrypsin, with a focus on the effects of hydration hysteresis and the use of acid-base buffering. The group developed a new method to produce PCMCs and established research collaborations with groups in Lisbon, Moscow and Wageningen, which led to joint publications. The work resulted in seven refereed publications, a UK patent application and the establishment of a spin-out company, XstalBio.

*Enzyme-catalysed acylation as a new strategy for tethered oligosaccharide synthesis with minimal protection*

The project demonstrated novel methods for the construction of glycoconjugates. This was done by exploiting peptidases as efficient environmentally benign and specific catalysts to construct carbohydrate-peptide and carbohydrate-carbohydrate linkages in a more efficient manner. A patent application has been filed and the results of this work have been used as the basis for establishing a spin-out company, Glycoform Ltd. The PI published two refereed papers and gave a large number of presentations at scientific conferences.

*Evolution in spatial systems; long term changes in disease behaviour*

This grant considered the effects of network topology on the dynamics of effective diseases for example, evolution of disease on unclustered transmission networks such as sexual contact led to diseases with longer infectious periods than those such as airborne transmission. The findings have implications for public health, both in planning counter measures to outbreaks of smallpox and understanding which kinds of disease are likely to mutate. The work led to five refereed papers, radio interviews and other media interactions.

*Experimental (micro-fluids) and theoretical (modelling) engineering of electro-mechanically active cardiac cell cultures, and*

*Origin and spread of cardiac excitation: an anatomico-physiological computer model of rabbit SAN*

These related grants represent the UK's part of a leading international effort to produce a comprehensive model of the heart, a key motivation for which is to replace *in vivo* experiments and

thus reduce animal suffering. Outputs included the development of a new cell culture that is qualitatively similar to *in vivo* heart tissue, and contributions to an integrated computer model of the whole heart, based on data from rabbits. There is a strong link with the world leading group in Auckland where the integrated computer model is being assembled. Outcomes have been the finding that conduction through fibroblasts has a role to play in heart attack, and the ability to test *in silico* several different kinds of mechanical intervention in terminating arrhythmias. A total of 19 refereed papers have resulted from these grants, and over a dozen public lectures, several press briefings and popular articles.

*Hyperthermophilic microorganisms: applications to hot waste gas biofiltration*

This project aimed to investigate a biofilter suitable for high temperature waste-gas scrubbing. The researchers demonstrated that extremophiles can be applied in bioreactors for pollution control, and that they are solvent tolerant as well as being able to treat pollutants at elevated temperatures. Several sequences have been lodged in GenBank, and new collaborations have been established with academics, both in the UK and overseas. Eleven refereed papers have been published.

*Immunosensor based on the direct enzymatic degradation of thin films*

The purpose of this grant was to develop a new generic immunosensor using biodegradable polymers such as polyester amides, which can be degraded specifically as a direct result of an enzymatic reaction. The resulting novel disposable sensor is a highly efficient enzyme detector with potential applications in healthcare, detection of bacterial infection, environmental monitoring and the detergent industry. The project resulted in three refereed publications and one patent.

*Isolation, identification, modification and exploitation of sugar mimics which occur in plants*

This project, on the identification and chemical synthesis of new sugar mimics, and of analogues to compare a wide range of their biological activities, was a continuation of a previous collaboration between a number of academic institutions, including a collaborator in Japan. A patent was filed on the work derived from the project and industrial collaborations initiated with three pharmaceutical companies. Outputs from the grant have included ten refereed publications and a large number of international lectures.

*Light-harvesting complexes as nanoscale reporters of inter membrane protein association forces and as optical circuit components*

The aims of this project were to use a multidisciplinary approach to harness the properties of immobilised light harvesting biomolecules on nanoscale gold strips to act as efficient light guides, to test the boundaries of the biology/technology interface. It was found that the bound LHC protein became resistant to damage when bound to gold. The project resulted in new interdepartmental links and new international contacts. Six refereed papers were published.

*Lipid bilayer biosensors: development of cell surface display to produce porins with novel affinities*

This project aimed to alter the variable loops of porins to enable them to bind a variety of ligands. Two new methods were developed: the efficient folding of porins with insertions in the inner loops; and the measurement of protein-protein interactions with the porins while they are still in whole cells. Nine refereed papers resulted from this project, one patent was filed, and the findings were taken forward by a spin-out company, Orla Protein Technologies.

*Macromolecular assemblies and interactions at the air-water interface of bio-molecular foams*

This work undertook a detailed characterisation of ranaspumins (proteins from frog-foam) using novel techniques to understand their properties and explore the potential biomedical and environmental applications. Ten protein sequences were submitted to GenBank and two refereed papers were published. New academic and industrial contacts were made both within the UK and overseas. Efforts were also made to promote the work to the public through public and school lectures.

*Metabolic control analysis and engineering of the yeast sterol pathway*

This project achieved the first systematic study of metabolic control of the yeast sterol biosynthetic pathway and identified the enzymes that contribute the largest flux-control coefficients. As a result of the grant, new overseas collaborations were established within Framework Programme 6 and six refereed papers were published. The group carried out a range of public engagement activities.

*Methods for monitoring, control and optimisation of animal cell cultures*

The original aims of this project were to develop and demonstrate the effectiveness of control

procedures to increase the consistency and optimise the productivity of a range of animal cell lines. It resulted in the development of a methodology for building virtual sensors for monitoring cell culture, and the validation of its application to a number of industrial processes. Collaborations were established with both academia and industry and the PI gave presentations at several conferences.

*Molecular evolution approach for the affinity maturation of anti-microcystin antibodies from phage display libraries*

The original objective of this grant was to develop an immunoassay for the detection of microcystins, but the research changed direction following 9/11, when microcystins were considered as a possible bio-terrorism agent. The anti-microcystin antibodies developed are being used in a number of lab-on-a-chip and bio-chip formats and are being expressed as antibodies in plants as a possible route to bioremediation of polluted water courses. The group came second in the BBSRC/MRC Business Plan competition, and established a spin-out company, Haptogen Ltd. The group's collaborators have become the world's major commercial supplier of microcystin for research and diagnostic purposes.

*Monitoring of mutagenic and toxic chemicals by fluorescence induction and detection. Phase 2.*

This, the second phase of a project, enabled a portable device to be constructed to assess genotoxicity accurately and a micro-titre plate assay to be developed, based around quantitative analysis of GFP fluorescence. The research generated a large amount of media interest, as well as 13 refereed publications, plus steps towards commercialisation. The group entered the BBSRC Bioscience Business Plan competition and was the runner-up in the form of a spin-out company Gentronix.

*Nanofabrication of protein fibres and matrices using self-assembly peptides of de novo design*

The objective of this grant was to develop a designed self-assembling protein fibre (SAF) system with a view to making derivatised fibres and fibre networks for applications in nano/biotechnology. The group stabilised the SAFs, aligned them on surfaces and in partly dried fibres, made branched fibres, and functionalised the fibres by recruitment of small molecules, peptides and proteins. Seven refereed papers were published and two patents applied for (one licensed to Novozymes).

*Northwest Centre for Bioarray Innovation*

The key objective behind this grant was to strengthen the science infrastructure and academic base in the North West. It comprised 10 separate research projects across four institutions and across disciplines including biology, surface chemistry, nanotechnology, detection technologies and bioinformatics. It resulted in a highly networked research environment between the major research institutions with links into regional and UK biotechnology companies. The work resulted in a range of new technologies, six patents and over 70 refereed publications.

*On-line monitoring of bubble size distribution and gas liquid dispersion in biological processes using an acoustic technique*

The aim of this project was to develop an on-line novel acoustic method to measure bubble size distribution and to describe gas liquid characteristics. An on-line system was developed in which the acoustic emission signal from any gas-liquid dispersion is acquired directly onto a computer for immediate analysis, as well as non-intrusive measurements made from outside laboratory scale vessels. Several new collaborations were established and one refereed paper was published.

*Quantitative visualisation of biodegradation during natural attenuation of organic pollutants in groundwater*

This project aimed to test existing conceptual and mathematical models used for assessing the performance of Natural Attenuation (NA) as a groundwater bioremediation technology. The research allowed the group to move into a new research area, and established techniques to study fundamental processes occurring during biodegradation and reactive transport of pollutants in groundwater, using a combination of microbiological, chemical and physical data. One refereed paper was published.

*Rapid screening of heparan sulphate-protein interactions*

This grant was set up to establish a microarray system for rapid screening of the interactions of heparan sulphate (HS) with proteins, peptides and cells, and resulted in the generation of useful data on the mechanism of immobilising HS/heparin saccharides onto surfaces, which will facilitate the development of technologies for rapid screening of saccharide libraries. Four refereed publications resulted from this grant, as well as a patent and several new academic collaborations.

*Regulation of stem cell differentiation for the tissue engineering of cartilage*

This project set out to select stem cells and drive them towards forming chondrocytes for cartilage repair whilst creating an environment that would encourage cartilage growth. It resulted in a detailed understanding of nuclear receptor expression on bone marrow stem cells and how they change during chondrogenic differentiation and the development of a new cartilage tissue engineering process. Five refereed publications were published, a patent applied for, and new collaborations established with overseas industrialists.

*Smarter assays: a "brighter" luciferase*

This project started with an application-oriented idea to make a brighter luciferase to improve biological assays, and revealed new insights into the catalytic mechanism of luciferase and a new application for determining the outcome of PCR reactions. The latter discovery resulted in four patents and in the foundation of a spin-out company. Four refereed publications were published and a number of new collaborations were established both in the UK and overseas.

*Solid phase dendrimer synthesis; multiple valency and assay amplification*

This research developed methods for solid-phase preparation and derivatisation of dendrimers, together with their use as amplifiers in a number of cell-based screening assays, and led to the development of micro-array transfection chip technology and new transfection reagents, new tools for biological assays using fluorescent enhancement and rapid approaches to multi-valent display and amplified ligands. Several new overseas collaborations have been established, patents filed, and four refereed papers have been published.

*Synthesis and characterisation of novel betaine-based copolymers for high performance biocompatible coatings*

The overall aim of this collaborative project was to develop a range of biomimetic polymers with controlled architectures for biomedical applications. It investigated the bioadhesion properties of phosphobetaine polymers compared with sulfobetaines and developed a self-assembling phosphobetaine copolymer that is suitable for nanoparticulate drug encapsulation or formation of biocompatible gels. The work led to four joint patent applications with Biocompatibles Ltd, and resulted in 15 refereed papers.

*The carrier erythrocyte as an antigen delivery vehicle for the enhancement of the immune response*

This grant was awarded to investigate the potential of the erythrocyte as a vehicle for delivering antigens directly to the antigen presenting cells, with the aim of facilitating a potential primary and memory humoral response to the entrapped antigen. The aims were met and the findings provided a basis for more research on carrier erythrocytes as cellular carriers for vaccines and gene constructs. The grant resulted in one refereed paper and the establishment of an international consortium.

*The development of a biotransformation system for the synthesis of carbon-fluorine bonds*

The aim of this grant was to determine the substrate for the fluorination enzyme, to establish cell free activity for biological fluorination and then to develop an assay to purify the enzyme. The group found the first fluorination enzyme in a biological environment, isolated it and cloned the gene, which was then utilised in an aldol type reaction. Twelve refereed papers were published and several important new collaborations were established with academia and industry.

*The development of genetic systems to facilitate the exploitation of Clostridium genome information*

This aim of this project was to develop a molecular toolbox for the study and genetic manipulation of *Clostridium*, including the human pathogen *C. difficile* and other industrially important strains. The group was able to develop reproducible methods for the high frequency transfer of autonomously replicating plasmids into several different strains of *Clostridium difficile*, a finding which will make *Clostridium* more accessible for future research and exploitation and should assist in the development of more effective countermeasures. Five refereed publications were published.

*Wavefront correction in confocal microscopy*

This grant focused on the development of confocal microscopy to enable higher resolution images to be obtained from thick biological samples. High quality images were achieved following the design of a novel, adaptive microscope that contains a novel wavefront sensing method together with a wavefront element for adaptive aberration correction. This device was patented, and has been used by other laboratories around the world. Eight refereed papers resulted from the work.

## CHAPTER 3. BALANCE AND COVERAGE OF THE PORTFOLIO

### Overview

43. The remit of EBS is broad, with the Committee funding a mix of multidisciplinary and interdisciplinary research carried out by biologists, physical scientists, mathematicians and engineers, often working in partnership. The work may be basic, strategic or applied as exemplified by the themes describing the remit: Bioengineering for Industry and the Environment, Engineering Towards Medical Applications, Systems Biology, Theoretical Biology, and Tools and Technologies. As a result the committee has significant interfaces with other BBSRC research committees, with other research councils (EPSRC, MRC, NERC) and with the Technology Strategy Board (TSB).
44. Since its inception, the role of EBS has been to support multidisciplinary and interdisciplinary work to:
- further the understanding of biological systems
  - exploit that understanding to address user need, and
  - develop tools and technologies for use in the life sciences.

The committee has been successful in fulfilling this role and in 2007 the highest proportion of BBSRC's interdisciplinary responsive mode grants were in the EBS area (38%). For this analysis, interdisciplinary grants were defined as those on which a PI is from a life sciences department and collaborates with a researcher in a non-life sciences department, or where the PI is based in a non-life sciences department. It is recognised, however, that the figure will be an underestimate as it does not include scientists from other disciplines who work in life science departments.

45. Interest in EBS from the research community is growing and this is reflected in the increasing spend within responsive mode on EBS since its establishment. However, it still has the lowest responsive mode investment in BBSRC which may explain the lack of cover in several areas.
46. Being positioned at the interface with several other funders brings challenges, particularly in ensuring that applicants understand how different programmes operate and which funder is most appropriate for their research proposals. The published remit, alongside position statements from other research councils, plays an important role in guiding the community and BBSRC staff must continue to work closely with the other research councils to ensure there are no gaps in funding.

### Remit and coverage of the portfolio

47. Evidence from the sample grants gives rise to concerns that the responsive mode investment across the areas covered by EBS lacks depth. The remit is very broad and the committee has a comparatively low level of funding, so the funds are spread thinly. EBS has the lowest responsive mode investment of the seven research committees in BBSRC, accounting for 11% of funds. However, the committee's budget is dependent on the number of applications that are considered worthy of funding so, if the community was larger and/or more applications were encouraged, it is possible that the budget would increase over time. There are signs that this is already happening, as the EBS proportion of

BBSRC's total investment in responsive mode has increased each year since the Committee was established.

48. The apparent lack of depth in the responsive mode investment is clearly exacerbated by the large number of research initiatives that are relevant to the EBS remit. For example, Systems Biology is identified as an EBS theme but is not yet a major component of the responsive mode portfolio. Funds have been concentrated in centres and research initiatives and it is likely that applicants have directed research proposals to the initiative calls rather than to responsive mode through EBS. While Systems Biology potentially crosses all committee remits, EBS would be a natural home for much of this research and it is hoped that, when the initiatives come to an end, funding for systems biology responsive mode grants via EBS will be increased appropriately.
49. Areas which appear to be under-funded in responsive mode include: theoretical biology, bionanotechnology, biophysics, tissue engineering (but excluding cartilage), biocatalysis, biochemical engineering, biomechanics, bioinformatics, novel spectroscopic methods, glycomics, biologically-active natural products, stem cell biology, bioremediation, marine biotechnology, and microbial biosciences.<sup>4</sup> It was also considered that the emerging area of synthetic biology should be explicitly recognised.
50. A high proportion of PIs (84%) reported that their perception of the EBS remit had affected the scope and format of their application. A large percentage was also reported in the Agri-Food evaluation (63%) but not in other responsive mode evaluations. This may reflect the more applied nature of the research funded through EBS and/or the number of different potential sources of funding.
51. Some concern was expressed about the range of the EBS committee membership, and whether the committee's expertise was always adequate to cover the diverse nature of the grants that were submitted. It is important to ensure that all potential areas of the remit can be judged appropriately by the panel, and relevant referees chosen. In particular, proposals for multidisciplinary grants need to be assessed equitably.

### **Interdisciplinary research**

52. The EBS committee has successfully tackled the issue of interdisciplinary research, which is a most significant achievement. As would be expected, EBS funds a high level of interdisciplinary research and ranks first out of all BBSRC committees, with 84 interdisciplinary grants totalling £28.9M current on 1 April 2007. This was 38% of all interdisciplinary responsive mode grants funded by BBSRC at that time, and is slightly higher than the figure for Biomolecular Sciences. Together, EBS and BMS account for just under three-quarters of all interdisciplinary grants.
53. Although the number of EBS interdisciplinary grants was higher than all the other committees, the figure was lower than the Panel had expected. In particular, there were fewer collaborations between bioscience and mathematics departments than might be expected, with 13% of the interdisciplinary grants in this category. It is

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<sup>4</sup> While EBS covers many of these areas, it was noted that some fall within the remit of other BBSRC research committees (e.g. stem cell biology) and others cut across several BBSRC research committees (e.g. biophysics, theoretical biology, marine biotechnology, biologically-active natural products).

possible that the investment in systems biology centres and initiatives affected the number of collaborations between biologists and mathematicians in EBS responsive mode.

### **Other funders**

54. Several other UK organisations fund research that potentially overlaps with the research funded by the EBS committee, and DIUS, EPSRC, MRC and NERC were invited to comment on potential gaps and/or overlaps in funding between the organisations. The Panel noted that a funding concordat is in place between research councils to ensure equitable peer review and funding of applications that cross traditional boundaries.
55. Given the expansion of interdisciplinary and multidisciplinary approaches in biological research, the interface with EPSRC is key. While the linkages between EBS and EPSRC's Life Sciences Interface programme are a strength, there is uncertainty within the research community over who to approach for funding. BBSRC should organise a series of roadshows, which would help to articulate the interface more clearly and might minimise the number of proposals submitted to the wrong research council. If submissions are made to the wrong research council, however, it is important that they are re-directed as appropriate, as quickly and transparently as possible. The differences in process (timing and refereeing) between the research councils make this particularly important, as these differences exacerbate the challenges for researchers at this interface.
56. As there is currently little interaction between EBS and MRC, increased dialogue between EBS- and MRC-funded researchers must be encouraged. As well as enhancing the existing portfolio, this would strengthen translational work by making it more clinically informed. As identified by committee members, there are potential gaps in the coverage of tissue engineering and drug delivery, where proposals in pre-clinical stages of development may currently be too medical for EBS, but are not sufficiently developed for MRC.
57. The Natural Environment Research Council (NERC) did not identify any obvious gaps in cover, but highlighted some areas of common interest such as: ecosystem modelling and bioengineering for the environment. However, the Panel identified marine biotechnology as an area of common interest where there is a definite gap in funding at the BBSRC/NERC interface, which should be addressed.
58. In taking forward research findings and undertaking more translational work, some research groups are likely to move from one funder to another as their research moves closer to an identifiable application (e.g. BBSRC to MRC, BBSRC to TSB). To facilitate this, it might be helpful to make clear to PIs the routes they can follow to ensure that the potential impact of their research is realised, particularly given the problem-solving nature of much of the EBS portfolio.

## CHAPTER 4: INTERACTION WITH INDUSTRY

59. A quarter of PIs reported co-funding from the outset of the award, half of which was through an existing partnership scheme, with a small number of PIs reporting support in-kind, such as the supply of sample materials and instrumentation. While there was a lower level of industrial investment in the grants than might be expected, given the user-oriented nature of much of the research funded through EBS, the level was significantly higher than for other BBSRC Committee areas. There were, moreover, some good examples of collaboration, in particular in engineering.
60. PIs reported improved contacts with industry both in the UK (39%) and overseas (24%) as a result of the EBS grant. These figures were similar to those of the Agri-Food committee and significantly higher than other committee evaluations. New contacts were made with a range of industries, including major companies such as Pfizer, Procter and Gamble, and Unilever, other pharmaceutical and food companies, and utility companies such as British Gas. Overseas collaborations were established with companies in Belgium, France, India, Japan and the US. Just under half of the new contacts led to formal collaborations which resulted in joint publications or joint funding applications.
61. Publications with co-authors from industry are a clear indicator of collaborative work: 8% of publications reported by PIs had one or more industrial co-author. This is a similar figure to that seen in other portfolio evaluations (AF: 8%; AS: 7%).
62. Many PIs had either started to exploit the results of their research, or recognised the potential to do so: a quarter of PIs had applied for patents to secure IP and 71% reported that this grant had or could result in new tools and technologies, including methods, equipment, reagents, models, software and new materials. In addition, 14 spin-out companies had been developed, 8 of which were still trading at the time of the survey.
63. This level of interaction with industry was appropriate, particularly given the constraints within which PIs have to work. There is evidence, for example, that some industrial companies may be discouraged from contributing to the funding of grants because of the growing commitment under the full economic costs model: other companies may prefer to fund research in-house, or to fund research at overseas academic institutions, as this can be less expensive than the equivalent in the UK. This is an issue that needs to be monitored as fEC comes fully online.
64. In addition, as reported by industrial committee members, some PIs are over-stretched and are not always able to commit fully to collaborative work with industry. It is also arguable that PIs who devote considerable time to commercialisation of their research do so at the expense of more usual publication routes and other research outputs. This could adversely affect their prospects of attracting future funding, and their ability to perform well within the Funding Councils' Research Assessment Exercise.
65. Although there can be a considerable difference in culture between scientists in academia and industry, there is much to be gained by both parties from increased interactions. A greater awareness within industry of BBSRC's approach to the exploitation of research results, and a clearer understanding by academic researchers of the benefits and risks of IP protection may improve the level and quality of interactions. Furthermore, PIs should have greater awareness of the

needs of industrial partners, particularly in relation to the protection of IP and the potential for extending such protection to other outputs from their research, such as databases and datasets.

66. To help this BBSRC should consider how it might help bring about a change in culture in universities by providing more guidance for EBS-funded PIs to pursue further collaborations with industry and other users, and to identify the wider economic impact of their research. BBSRC should also consider making more funding available through joint schemes such as CASE studentships, Industrial Partnership Awards and Knowledge Transfer Networks.

## CHAPTER 5: PUBLIC ENGAGEMENT

67. BBSRC carries out a range of activities to encourage and equip its scientists to engage with the public and expects PIs or a member of their group to spend 1-2 days each year carrying out these activities. In addition to providing information to the public on the science, the aim of this is to encourage discussion on issues of potential concern, for example, the use of animals in research or the use of stem cell biology.
68. The panel felt that public engagement is important and considered that the BBSRC's centrally-run programme is well executed and very effective. However, participation by individual PIs was much less productive, even though it is a condition of grant funding. Only 74% of completed PIs reported any public engagement activities (lower than the average of other committees evaluated so far, 76%), and only 29% of current PIs.
69. Of those who had participated, very few PIs had developed an original activity or resource, with the majority of activities being schools events, open days and public meetings. In addition, some PIs reported interactions with the media, including contributions to newspaper articles and books, publications in general interest magazines, and radio and television interviews.
70. BBSRC provides small grants for public engagement activities which are available to PIs, but the evidence suggested that grantholders are not sufficiently aware of this. There are no real incentives for PIs to carry out these activities, no recognition within the HEI system, no financial rewards and no dedicated time set aside for them to do it. Moreover, there is little monitoring by BBSRC of whether or not PIs are carrying out these activities, and no consequences for not undertaking them.
71. It is evident that some PIs are not fully aware of BBSRC's policy on public engagement and do not give these activities a high priority. Also, some PIs are clearly much more expert at this than others. BBSRC should concentrate its efforts on encouraging these individuals to do more, rather than compelling all PIs to do this regardless of their aptitude for it. This could be done by setting up a network to provide practical support and a suitable level of financial assistance.
72. It would be appropriate for BBSRC to reconsider the current requirement for its funded PIs (or a member of their team) to spend 1-2 days each year on public engagement activities, as this does not appear to be working effectively. Other initiatives should be considered, such as assisting research teams to set up websites where information for the general public could be published.

## CHAPTER 6: ECONOMIC AND SOCIAL IMPACTS

### Introduction

73. Economic and social impacts relate to the overall objectives of BBSRC as an organisation, and are generally expected to arise in the longer-term. The following ultimate impacts (relating to the objectives in the BBSRC 10-year vision) should arise from BBSRC support for engineering and biological systems through responsive mode funding:
- research findings are used for the 'public good', e.g. medical research, biotechnology, government policy
  - income to the research community and broader economic benefit to the UK, e.g. from new technologies, intellectual property, spin-out companies, etc
  - the UK maintains high international standing in engineering and biological systems research
  - BBSRC maintains its role as a key funder of engineering and biological systems research in the UK
  - public confidence in UK engineering and biological systems research is upheld.
74. These impacts relate to how effectively BBSRC is functioning and delivering the impact expected of publicly funded research, and it is therefore very important that they are identified and, where possible, attributed to BBSRC funding. It is recognised that measurement and attribution of these impacts is difficult and often imprecise.

### Contributions to the public good and broader economic benefit

75. The support provided by BBSRC contributes to the public good in a number of ways, as it:
- trains scientists in basic scientific research; many go on to work in industry and other sectors
  - supports a bedrock of fundamental scientific knowledge that underpins future research, commercial and other applications, and helps shape government policy
  - contributes to public engagement with science, and supports science of public interest.
76. The immediate beneficiary of the research supported by EBS is the scientific community itself, particularly with regard to the advances in bioinformatics which have allowed scientists from all disciplines to complete complex computing functions increasingly easily. Other direct contributions from EBS research included strengthening developing industries in the UK by fostering interdisciplinary research, and the economic and social impact of tissue engineering and nanotechnology.
77. Training of skilled staff has also made a substantial contribution to the public good. However, there are still insufficient numbers of suitably skilled scientists in the EBS area and, in particular, very few scientists who are equally comfortable in both the physical and biological sciences. This reinforces the comments in Chapter 2, where the lack of numeracy skills in biologists was identified as a major obstacle to cross-disciplinary research.
78. PIs identified the following contributions to the public good from their research:

- 53% felt their work already has contributed, or has the potential to contribute, to human health. Examples included new routes to tissue engineering devices, screening of chemotherapeutics, and drug screening and metabolism.
  - 23% of PIs thought that their research has, or could, benefit the environment, for example, by developing improved models for bioremediation, better software for managing populations, and food safety assays.
  - 14% of PIs commented that their research had, or could have, the potential to be of benefit to animal health and welfare, including: measuring biomarkers for the onset of heart disease, mastitis control in dairy cows, and reducing the number of animals used in research.
  - 7% of PIs reported actual or possible contributions to government policy, for example in wildlife and biodiversity monitoring, detecting pollutants in drinking water, and the application of stem cell-derived therapies.
79. Some research had led relatively quickly to applications:
- Development of rupture event scanning (REV™) has resulted in a rapid, quantitative and potentially economical method for virus detection
  - The nanoparticle biosensor is now being used to develop new methods of measuring biomarkers for the onset of heart disease in animals and humans
  - The spin-out company Lumora has developed medically relevant assays based on the technology (bioluminescent assay in real-time) resulting from the grant. In addition, Lumora is now in the process of developing food safety analysis
  - Haptogen Ltd has commercialised a diagnostic test for microcystins (liver toxins) which are environmental pollutants and have the potential for use in bioterrorism.
80. All the major outputs from EBS research, including publications, new methodologies, tools, instruments and materials/processes, contribute to the public good in some way. Moreover, although to date there is a relatively low level of income to 'UK plc' from these outputs, this is because, even though nearly three quarters of PIs had developed (or had the potential to develop) new tools and technologies, most of these have been taken up by the academic research community and would not be expected to generate income. A quarter of PIs have applied for patents to secure the IP arising from their research, but only one of the applications has generated income so far. It is however likely that this level will grow over time.

### **UK ranking in engineering and biological systems research**

81. Evidence on the quality of research funded through EBS suggests that much of the portfolio is of international standing, although it is difficult to quantify this as there are no robust international data for comparison, partly because of the multidisciplinary nature of much of the research. Nevertheless, metrics comparing the performance of the UK in biosciences with other major research countries using bibliometric data from ISI National Science Indicators 2005 show the UK to be ranked very highly for the quality of its bioscience research. It ranked second (behind the USA) for its relative share of citations in the biosciences for 2000-2005 and ranked first in 'citation impact' (ratio of citations to publications) for biosciences for 2005. In addition, the UK had the lowest proportion of uncited papers for biosciences for 2000-2005 amongst the G8 countries.
82. Collaborations with international scientists give a further indication of the international standing of EBS research. Nearly half the sampled PIs reported new or improved contacts with overseas academics, with 10% resulting in joint funding

or publications, and 7% of refereed publications having international co-authors. Just over a quarter of sampled PIs reported edited international conference proceedings as part of their publications. In addition, there is some evidence of participation in international research programmes funded by the EU.

83. While EBS-funded researchers have developed a wide range of new tools and technologies, not all of these have been taken forward to viable outcomes. The international standing of EBS research would be strengthened by developing further collaborations and by carrying out more translational research.