Evaluation of the Bioprocessing Research Industry Club

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This document presents the views and conclusions of a Review Panel of experts.

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

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ABBREVIATIONS

BBSRC:	Biotechnology and Biological Sciences Research Council
BIG-T:	Bioscience Innovation and Growth Team
BIS:	Department for Business, Innovation and Skills
BRIC:	Bioprocessing Research Industry Club
CASE:	Collaborative Awards in Science and Engineering
DRINC:	Diet and Health Research Industry Club
DSP:	Downstream processing
EBS:	Engineering and Biological Systems Committee
EPSRC:	Engineering and Physical Sciences Research Council
HEFCE:	Higher Education Funding Council for England
IM:	Introducing Member
IP:	Intellectual property
KE:	Knowledge exchange
QR:	Quality-related
RA:	Research Assistant
RAE:	Research Assessment Exercise
REF:	Research Excellence Framework
SG:	Steering Group
SMEs:	Small and Medium-sized Enterprises
TPS:	Targeted Priority Studentships
USP:	Upstream processing

EXECUTIVE SUMMARY

This document reports the findings of the independent Review Panel set up to provide an expert evaluation of BBSRC's Bioprocessing Research Industry Club (BRIC). The objectives of the evaluation were to assess the quality and strategic relevance of BRIC research; to examine the extent to which BRIC is building capacity in UK bioprocessing; to assess the effectiveness of BRIC in promoting interactions between academia and industry; and to identify ways to build on successes and to address identified gaps and issues. As BRIC research projects are still ongoing, the Panel was asked to review the current achievements of BRIC and to consider the potential for future impact as the research develops.

KEY CONCLUSIONS

1. **BRIC is an effective and timely scheme that is achieving its objectives and is on track to deliver future impact**

   In the three years since its inception, BRIC has made very good progress towards achieving its objectives. BRIC is supporting high-quality, industrially-relevant research in a strategically important area, and this research has the potential to deliver significant impact. BRIC has already produced a number of promising achievements: strengthening the UK bioprocessing research community; encouraging new academics to conduct bioprocessing research; providing relevant training to postdoctoral researchers; and developing networks and partnership links between academia and industry. BRIC management and administration are effective and the scheme has developed over time to ensure it is addressing the needs of the bioprocessing community. Overall, BRIC is a very successful scheme which has reenergised the UK bioprocessing community.

2. **BRIC is supporting high-quality research which is of broad relevance to the UK bioprocessing industry**

   The overall standard of research funded through BRIC is very high. BRIC is supporting international-quality science and is contributing to the emergence of centres of excellence in UK bioprocessing research. BRIC research is addressing key bioprocessing challenges and is of broad strategic relevance to the UK bioprocessing industry. Research projects are almost all on track to meet their stated objectives and are likely to deliver long-term economic and social impacts, for example, through the improved manufacture of biopharmaceuticals and regenerative medicine therapies.

3. **BRIC grantholders are developing intellectual property and it is important that this is protected**

   BRIC research projects are producing knowledge and other outputs that are potentially commercially exploitable. It is important that this intellectual property (IP) is protected and there must be more explicit consideration of IP protection within BRIC. The Steering Group should continue to emphasise the importance of IP protection to researchers, and grantholders should provide more details of their plans for IP protection within annual reports. BRIC should also provide Research Assistants (RAs) with IP awareness training. Although there is pressure for researchers to produce outputs such as publications, this must not compromise the protection of their IP.

4. **Training of postdoctoral researchers within BRIC is good, although there is scope to improve training in transferable skills**

   There is a marked need to provide bioprocessing skills training, as demonstrated by the observation that the majority of BRIC RAs had no previous bioprocessing experience. BRIC is starting to meet this need, delivering good quality training to postdoctoral researchers, particularly in practical and technical skills. However, there is scope to improve transferable skills training and RAs would benefit from some standard industry training including, for example, project management training. Existing training modules for BBSRC Enterprise Fellows and at Doctoral Training Centres could be modified to provide this.

5. **BRIC should encourage Research Assistants to spend time in industry as part of their training**

   BRIC has made good progress in promoting direct interactions between RAs and industry. However, it is disappointing that so far only a small proportion of RAs have spent time in an industry environment. Industry placements should form part of BRIC's training strategy and, ideally, these should be long-term placements (e.g. minimum six months) occurring at an early stage of each project. There is also significant value in RAs participating in shorter placements and site visits, and these should be encouraged. It was a concern that fewer than a third of BRIC RAs were considering industry as their next employment destination and greater exposure to industry should help to improve this.

6. **The lack of postgraduate training opportunities within BRIC is a weakness and could have a negative impact on building capacity in UK bioprocessing**

   In order to build capacity and critical mass in UK bioprocessing, there is a need to support training at several levels, including PhD studentships. Although bioprocessing is a priority area for BBSRC's PhD funding, postgraduate training is formally outside BRIC's remit and this is potentially a serious weakness with the scheme. As a key BRIC objective is to develop core bioprocessing skills and expertise, Research Councils should consider funding studentships that are aligned to individual BRIC grants. The Diet and Health Research Industry Club, which aims to develop research skills for the UK's food sector, funds Targeted Priority Studentships that are directly associated with grants, and a similar model would be suitable for BRIC.

7. **BRIC has strengthened the UK bioprocessing community and is successfully promoting partnership links between academia and industry**

   BRIC research funding and other BRIC activities have strengthened the UK bioprocessing community. A prior lack of Research Council support for bioprocessing research led to a 'missing generation' of UK researchers with bioprocessing experience and BRIC has made noteworthy progress towards rectifying this, with new academics and postdoctoral researchers entering the community as a result of BRIC. BRIC has also successfully promoted networks and partnership links between grantholders and industry members, aided in part by the Knowledge Transfer Network 'bioProcessUK'. The development of partnership links was most difficult for research groups with few or no previous links to industry, and BRIC should provide more support to these groups at the earliest possible stage. Knowledge exchange between BRIC members is good given the relatively early stage of the research projects. As projects develop BRIC should seek to deliver a greater level of knowledge exchange.

8. **The research projects provide good coverage of most of the BRIC remit, although there are gaps in a few specific areas**

   Over the three rounds of funding, the balance and coverage of the BRIC research portfolio was good. The funded research projects cover the majority of the BRIC remit, although there is a lack of coverage in some areas, particularly whole process modelling. Any future BRIC scheme should pursue areas that have not received funding and, if necessary, conduct specific activities to encourage or commission high-quality cross-disciplinary proposals.

9. **BRIC dissemination events are a highlight of the scheme and are highly regarded by grantholders and industry members**

   BRIC organises regular meetings where project results are shared with grantholders and BRIC industry members. These dissemination events are highly regarded by all participants, and provide excellent opportunities for networking and knowledge exchange. The events are very successful and are evolving as the scheme develops and matures. There is a slight concern that dissemination events may be perceived as exclusive by other members of the research community, and there is scope for BRIC to organise additional open events to showcase its achievements to a broader audience.

10. **The Research and Technology Club model is an effective way to support industrially-relevant research**

    BRIC was the first of the Research and Technology Clubs to be launched by BBSRC, and its success demonstrates the effectiveness of this funding model. It is unlikely that similar progress to that achieved by BRIC could have been realised through responsive mode. BRIC is supporting a coordinated programme of research which is addressing key bioprocessing challenges, aided by industry input in setting the research agenda. Additional BRIC activities including dissemination events, workshops, networking, and contact with the BRIC Programme Manager and bioProcessUK are adding value to research grants and, as a result, BRIC is substantially more than a portfolio of 25 individual research projects.

11. **Research Councils should continue to support bioprocessing research of this kind through a BRIC successor scheme to ensure that progress is not lost and the potential for impact is maximised**

    The community supported by BRIC is currently vibrant but there is a high risk that without further ring-fenced funding for bioprocessing research the community will dissipate and opportunities for impact may be lost. Research Councils should build on the success of BRIC by funding a successor scheme, both to ensure continuity through follow-on funding and to broaden the bioprocessing community. Many academics working in related fields could contribute to BRIC and they should be encouraged to participate; BRIC should approach other professional bodies to help identify and attract these scientists. Greater involvement from small and medium-sized enterprises (SMEs) would also be beneficial, especially in the field of regenerative medicine. Research Councils should also ensure that funding opportunities are available for early-career researchers conducting bioprocessing research to establish their own research groups and obtain permanent academic positions.

12. Research Councils should publicise the success of BRIC to a wide audience

BRIC enables companies to gain exposure to a large amount of science for a relatively small investment, and is an excellent example of how academia and industry can work more closely together for mutual benefit. The accomplishments of BRIC should be publicised to government, relevant industry and other academics. In particular, the Department for Business, Innovation and Skills should be made aware of the success of the Research and Technology Clubs in delivering the Research Councils' 'Excellence with Impact' agenda.

CHAPTER 1: BACKGROUND

Introduction

1. The Biotechnology and Biological Sciences Research Council is one of seven Research Councils sponsored through the Department for Business, Innovation and Skills (BIS) 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.

Evaluation context

2. 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:
   - enabling BBSRC to account to government, the public, the scientific community and other stakeholders for the funds it allocates
   - demonstrating achievements
   - justifying BBSRC's funding allocation and providing evidence to BIS, the Treasury, and government of achievements and successes from public investment in bioscience research
   - informing internal funding decisions, providing evidence of progress and achievement, and facilitating the development of a strategic overview for future funding decisions
   - 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.

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

Project:	• Evaluation of final reports from grants
Scheme:	• Evaluation of Research Committee responsive mode portfolios • Evaluation of Research Initiatives (time-limited research funding in strategically significant areas), 2-3 years after the grants have ended • Evaluation of funding schemes (e.g. New Investigator, international Partnering Awards, fellowship schemes, Research and Technology Clubs)
Institution:	• Institute Assessment Exercise, conducted every five years at the BBSRC-sponsored Research Institutes

4. BBSRC's Evaluation Strategy[1] outlines the Council's approach to evaluation and the methodology used. Along with reviews of the responsive mode portfolio and research initiatives, funding schemes such as the Bioprocessing Research Industry Club (BRIC) form an important part of BBSRC's evaluation programme.

5. The objectives of the BRIC evaluation were to:
   - assess the quality and international standing of the research funded through BRIC
   - comment on the extent to which BRIC is supporting research relevant to the UK bioprocessing industry

[1] http://www.bbsrc.ac.uk/organisation/policies/reviews/funded_science/bbsrc_evaluation_strategy.pdf

- comment on the extent to which BRIC is building capacity in UK bioprocessing
- assess the effectiveness of BRIC in promoting interactions between academia and industry
- assess the balance and coverage of the BRIC portfolio
- comment on the BRIC application, assessment and administration procedures
- comment on the potential long-term economic and social impacts of BRIC research
- identify ways to build on successes and address any gaps and issues

6. The evaluation was conducted by an independent Review Panel comprising scientists and other experts who between them have expertise relevant to the BRIC remit (see Appendix 1 for Panel membership). The Review Panel was asked to provide an independent scientific evaluation of the evidence drawn from:

    - questionnaires returned by 14 out of 19 Principal Investigators (PIs) on BRIC grants funded in the first or second BRIC calls (74% response rate)
    - questionnaires returned by nine out of nine PIs awarded funding in the third BRIC call (100% response rate)
    - questionnaires returned by 14 out of 21 postdoctoral Research Assistants (RAs) employed on BRIC grants (67% response rate)
    - questionnaire responses or telephone interviews of 17 out of 61 unfunded applicants (28% response rate)
    - questionnaires returned by 8 out of 16 workshop delegates who attended a BRIC launch workshop, but who did not subsequently make an application as a PI (50% response rate)
    - questionnaires returned by 8 out of 15 BRIC Steering Group members (53% response rate)
    - questionnaires returned by 19 out of 19 BRIC industry members (100% response rate)
    - collated data from 16 grantholder annual reports[2]
    - additional information obtained from BBSRC databases

7. The remainder of this report presents the findings of the Review Panel, in five broad areas:
    a) standard of research
    b) building capacity in UK bioprocessing research
    c) developing partnership links between academia and industry
    d) balance and coverage of the portfolio
    e) application and administration processes

[2] All BRIC grantholders submit annual reports at the same time each year (during the summer). However, as the start date of each BRIC project varies, the length of time covered by individual reports is not identical.

CHAPTER 2: STANDARD OF RESEARCH

Summary

- The quality of research within the BRIC portfolio is very high
- The strategic relevance of BRIC research projects is very clear
- BRIC is facilitating the emergence of centres of excellence in UK bioprocessing
- BRIC research projects are developing new intellectual property which must be more explicitly protected
- BRIC research is likely to deliver future impacts which will benefit the UK bioprocessing industry

Overview

8. The Bioprocessing Research Industry Club (BRIC) was established in 2005 as part of the Research Councils' response to recommendations contained in the Bioscience Innovation and Growth Team (BIG-T) report: *Bioscience 2015*[3]. It is the first of several Research and Technology Clubs[4] established by BBSRC to invest funds in industrially-relevant bioscience research. Since 2006, BRIC has funded 25 research projects through three annual funding calls, and the overall quality and strategic relevance of the supported research is very good. BRIC research projects are on track to produce a variety of outputs that will benefit the UK bioprocessing industry and are likely to deliver important long-term economic and social impacts.

Research quality

9. The overall quality of the research funded by BRIC is very good. BRIC is supporting international quality research projects which are making significant advances in the field of bioprocessing. Some projects in the BRIC portfolio are already very successful and are delivering research at the top end of the international scale.

> *The crystallisation of biopharmaceuticals is poorly understood and is a rarely used commercial process for the primary separation and purification of proteins. Researchers at Imperial College London are investigating novel solid templates for protein crystallisation and have developed a circulatory system that maximises the yield of crystals obtained. This exciting research shows signs of being an advance over static crystallisation systems; it offers promise not only for the optimisation of crystal growth in bioprocessing, but also for structural studies.*
>
> *Scientists at the University of Birmingham are conducting excellent research into novel manufacturing and bioseparation technologies for biopharmaceuticals, and are generating world-leading 'multifunctional' chromatography technology. The next-generation materials that are being developed by the BRIC project have the potential to improve downstream processing and greatly advance the separation of contaminants that are very similar to the desired product.*
>
> *Viruses dominate the types of vectors currently being tested in clinical gene therapy trials and of these, retro- and lentiviruses are the most numerous. Scientists at the University of Cambridge and King's College London are collaborating to develop a novel lentiviral packing cell line, in which manufacturability is built into the genome of the cell line and co-expressed*

[3] www.bioindustry.org/bigtreport/
[4] www.bbsrc.ac.uk/business/collaborative_research/industry_clubs/

on the surface of the viruses produced thereafter. The researchers are making excellent progress, and there is significant potential for patents and high-quality publications.

10. Almost all BRIC projects are making good progress and are on track to meet their stated objectives; 82% of project milestones[5] are either complete or on track. There was some slippage in progress towards meeting long-term objectives, partly because grantholders had difficulty in estimating the timing of their third year deliverables at the project's outset. To an extent this is to be expected, as scientific investigation is inherently unpredictable.

11. So far, the most successful BRIC projects are those that have a focused set of objectives or strong links to industry partners. In general, research groups with pre-existing links to industry partners are making very good progress. Moreover, researchers who are new to the bioprocessing field are establishing links with industry through their participation in BRIC (see Chapter 3, p. 16). It is likely that over time these links will have a positive impact on their projects.

Scientists at the University of Birmingham have partnered with industrial collaborators to deliver important research relating to optimising the production of 'difficult' proteins. The primary objective of the project is to develop improved generic production methods and define physiological, biochemical and genetic factors that limit or enhance recombinant protein production. The project's milestones have been reached significantly ahead of schedule, and this is attributable to the close interactions between the academic and industrial groups.

12. There is evidence of centres of excellence being established in UK bioprocessing research, particularly in London universities. BRIC support has made an important contribution to the emergence of these centres of excellence, and this reflects the high standard of research in the BRIC portfolio.

Strategic relevance and potential for future impact

13. The strategic relevance of BRIC research projects is very clear. BRIC grantholders are conducting research which is addressing key challenges in bioprocessing and which is directly relevant to the UK bioprocessing industry. An important aspect of the Research and Technology Club model is that industry helps define the research agenda, and this has ensured the industrial relevance of the funded projects. The feedback provided to researchers during the application process has also helped to improve the strategic relevance of BRIC research.

14. A principal objective of BRIC is to support research that will deliver benefits to the UK bioprocessing industry. The expected outcomes of BRIC research are:
    - a greater systems-based understanding of biology for improved bioprocessing
    - increased predictability of biological processes for bioprocessing, including improved scale-up and reproducibility
    - improved cost efficiency – both in manufacturing and development
    - increased flexibility to improve product characteristics and reduce product heterogeneity
    - increased speed to clinic and market
    - tools and methodologies for bioprocessing which may have potential for application in related fields

15. The evidence from annual reports and stakeholder surveys indicates that BRIC is highly likely to deliver these outcomes. In the long-term, BRIC research has the

[5] Gantt charts in annual reports are used to monitor the progress of BRIC projects

potential to produce substantial economic and social benefits to the UK, for example, by contributing to the improved manufacture of biopharmaceuticals and regenerative medicine therapies.

Researchers at the University of Strathclyde are developing methods of protein purification which aim to provide faster throughput and lower costs. They have shown that co-crystallisation can be used to remove proteins from complex fermentation mixtures, allowing separation from undesirable contaminants. The protein crystals can then be removed for further processing. The findings offer potential for significant improvements in industrial protein recovery technology.

16. In general, BRIC research which is addressing downstream processing (DSP) is more likely to deliver an immediate impact than research focusing on upstream processing (USP). The DSP projects are more directly aligned to challenges facing industry and therefore have greater potential for short-term impact. The USP projects tend to focus on more basic biological processes and are developing the bioscience understanding which underpins bioprocessing. There are more opportunities for the USP projects to go 'off course' and they could be considered as higher risk. The impact of USP projects may not be fully realised for many years but, over the long-term, the research has the potential to deliver great benefits and possibly even step-changes in bioprocessing. It is positive that BRIC has funded a broad portfolio of work that is likely to deliver both short and long-term impacts.

17. Some USP projects are using proteins that are not representative of those used in industry and this could limit the long-term impact of the work. BRIC researchers need greater access to industrially-relevant proteins, but this requires more openness from industry.

Research outputs

18. As BRIC projects develop, they are expected to deliver a variety of outputs including: publications; new products, processes, resources, tools and technologies; intellectual property; further funding to develop the research; and training for postdoctoral Research Assistants. The data for the evaluation were collected in December 2008, when the majority of grants from the first BRIC call had been running for less than two years; the annual reports reviewed by the Panel were submitted in July 2008. The following comments are therefore based on researchers' progress towards delivering the anticipated outputs.

<u>Publications</u>

19. To date, about half of BRIC projects funded in the first call had resulted in an original research article being published. Researchers who had previous experience conducting bioprocessing research were more likely to have published their work at this stage; this is as expected because they were building on pre-existing research and they had a greater critical mass of bioprocessing experience in their research groups.

20. BRIC grantholders are publishing in journals that are appropriate for bioprocessing research. It is unlikely that BRIC research will be published in high-impact multi-disciplinary journals such as 'Nature' or 'Science'; this is a consequence of the field of research and is not a reflection of the quality of BRIC science, which is of an international standard. It is also important to recognise that the outputs of basic and strategic / applied research are different, and publications are not necessarily the main output of BRIC grants.

21. It is a concern that universities often evaluate research performance primarily on the basis of published outputs and associated journal impact factors. This has been driven to a large extent by the Research Assessment Exercise (RAE) and its subsequent allocation of HEFCE 'QR' funding. The RAE places a strong emphasis on the publication of research in high-impact journals as a measure of scientific excellence, and does not readily reward researchers for other equally valid outputs and impacts of their work. Under the new Research Excellence Framework (REF) greater emphasis will be accorded to other outputs. This is welcome and should benefit academics who are conducting strategic research or working closely with industry.

New products, processes, resources, tools and technologies

22. 93% of grantholders reported that their grant had led or could lead to the development of new products, processes, resources, tools, and technologies; this is a good and anticipated outcome of BRIC. The outputs varied depending on the nature of the grant, but included cell lines, equipment, methods, new materials and software. The users identified were primarily the bioprocessing industry, but also included other academic researchers. The outputs will be made accessible to others through various means, including patents and intellectual property rights, licensing to industry, a commercial service, publication in peer-reviewed journals and material transfer agreements.

23. So far, the majority of new products, processes, resources, tools and technologies reported by grantholders are conceptual in nature. This is to be expected at this stage: progress is encouraging and the development of these types of outputs is notably higher than reported for responsive mode research in the former Engineering and Biological Systems (EBS) Committee and other former BBSRC Committees[6]. However, there was a slight concern that the nature of BRIC's remit may create additional pressure to report these types of output and some anticipated outputs may be unrealistic.

Intellectual property

24. BRIC research projects are generating knowledge which is contributing to the development of new intellectual property (IP), and the majority of grantholders stated that the new products, processes, resources, tools and technologies arising from their grant had the potential to be commercially exploitable. 93% of grantholders indicated that they are likely to apply, or had applied, to secure IP rights. This is very encouraging, and is substantially higher than reported by researchers with responsive mode grants from the former EBS Committee or other former BBSRC Committees[7].

> *Researchers at University College London are developing new microfluidic tools to rapidly analyse protein stability and integrity in bioprocesses. This is important research as current methods are slow and require too much of an exceedingly valuable biopharmaceutical to be useful in guiding bioprocess development or control. The BRIC project has highly focused objectives and this has contributed to the excellent progress that has been made. Two patent applications for analytical devices have already arisen from the research.*

25. It is essential that the intellectual property developed by BRIC grantholders is protected. There must be more explicit consideration of IP protection within BRIC to ensure that the UK benefits from its investment and that companies based outside the

[6] 71% of grantholders in the EBS Committee responsive mode portfolio evaluation reported that their grant had or could result in new products, processes, resources, tools or technologies; across all former Research Committees, the figure was 47%.

[7] 42% of grantholders in the EBS Committee responsive mode portfolio evaluation reported that they had applied or were likely to apply to secure IP rights as a result of their grant; across all former Research Committees, the figure was 17%.

UK do not exploit the published data from BRIC projects. The Steering Group (SG) should continue to monitor progress towards IP protection and ensure grantholders' positive intentions are followed through; although the conversion of research into published outputs is usually good, the conversion into IP is often patchy. In particular, in their annual reports, researchers should provide a greater narrative on their plans for, and progress towards, IP protection.

26. BRIC has not established a rigid mechanism to deal with the IP arising from grants. However, IP is being actively managed and BRIC is likely to develop its own procedures as the need arises. There are opportunities within BRIC for industry members to learn about potential IP, including dissemination events, the BRIC web-portal, and previews of publications. The SG's encouragement of grantholders to protect IP is very welcome although, as with most Research Council grants, the responsibility for IP protection ultimately resides with individual institutions. The emphasis placed on IP protection can vary substantially between institutions and their associated Technology Transfer Offices, and BRIC and the Research Councils should work with institutions to facilitate IP protection where appropriate.

27. A potential weakness within BRIC is a lack of IP awareness amongst Research Assistants (RAs). BRIC should provide RAs with IP awareness training to ensure that they adopt best practice, for example, ensuring lab books are counter-signed and presentations at conferences do not disclose information prematurely.

28. There is understandable pressure for researchers to produce outputs such as publications. However, this must not compromise IP protection. The terms and conditions of BRIC grants require grantholders to provide industry members with a 28 day period to review publications before they are submitted. This is very welcome, as it provides an opportunity for industry to identify potentially valuable IP.

29. Two BRIC grantholders reported that the research from their grant is likely to contribute to the formation of a start-up company. This demonstrates another mechanism by which BRIC research can be commercialised and deliver impact and is very positive. However, the number of start-up companies should not be used alone as a measure of BRIC's success; the primary route for delivering impact is likely to be through knowledge transfer to existing UK industry.

<u>Further funding</u>

30. It is currently too early for BRIC grantholders to have applied for and secured further funding to develop the research from their grant. However, 25% of grantholders from the first BRIC call have received some associated funding. This was primarily for CASE studentships[8] running alongside the BRIC grant.

> *Researchers at the University of Sheffield are developing a systems-level understanding of how mammalian cells both influence and adapt to their environment, which will underpin further developments in bioprocessing. The researchers have a good record of other successful project applications that are associated with the BRIC-funded work, and they have received major financial contributions from industry, including a number of CASE studentships. These related grants and industrial collaborations are directly benefiting from the technical expertise and research outcomes derived from the BRIC project.*

[8] Collaborative Awards in Science and Engineering (CASE) allow students to receive high quality research training in collaboration with an industrial partner. Students spend a period of between 6 and 18 months working with the company, and the company makes a financial contribution to the costs of the project and the training of the student.

Researchers at the University of Manchester are using a metabolomics approach to investigate cell-environment interactions in recombinant mammalian cell lines producing antibodies. They have close links with several BRIC industry members and have been awarded CASE studentships from two individual companies since their grant began.

Training

31. An anticipated output of BRIC is an increase in the number of personnel trained in bioprocessing research. This is discussed in detail in Chapter 3 (p. 16).

Issues affecting grant progress

32. BRIC projects have experienced several issues which could affect performance and result in slower progress towards meeting objectives. These include issues with staff retention, technical challenges, and over-ambitious project objectives. In the majority of cases, grantholders dealt with these problems effectively, ensuring that the overall impact on the project was limited.

33. About one third of grantholders stated that an RA left the project during the course of the grant, so they had to re-recruit. Such issues with staff retention often resulted in spend on the project being frozen for a substantial period of time and slowed progress. Research Councils should monitor why RAs are leaving the grants and determine whether this was primarily due to dissatisfaction with their employment, personal circumstance, or recruitment into better jobs, including those in industry.

34. A small number of grantholders were forced to make changes to their project because of technical challenges. This is inherent in the nature of scientific investigation and should be viewed sympathetically. However, based on the interim assessment of the information available, the Panel considered that in one or two cases these changes may have lessened the potential impact of the research; for example, where an industrially-relevant protein was replaced with a model protein that has less strategic relevance.

35. For a few grants, progress was affected because the original objectives were too broad or over-ambitious. It would have been more productive if these grants had focused on a more limited set of objectives, and it should be possible for the SG to provide feedback to researchers at the outline application stage to address this. It was noted that the application process has evolved over time, and in later calls more effort was made to ensure that feedback from the SG was acted on by applicants.

Less successful grants

36. The general standard of research funded through BRIC is very high and almost all projects are making good progress. However, based on the interim assessment of the annual reports, the Panel was concerned that the performance of two or three grants appeared less successful than expected. It should be noted that all projects were still active at the time of the evaluation and a final assessment of performance should be reserved until after they are complete. It is encouraging that there are opportunities within BRIC to identify and address issues affecting project performance while the research is still ongoing, for example, through annual reports, dissemination meetings, and interactions with the Programme Manager.

CHAPTER 3: BUILDING CAPACITY IN UK BIOPROCESSING RESEARCH

Summary

- BRIC is building capacity in UK bioprocessing research and has brought new academics and postdoctoral researchers into the bioprocessing community
- The training of postdoctoral researchers within BRIC is good, although there is scope to improve transferable skills training
- Postdoctoral researchers should be encouraged to spend time in an industrial environment as part of their training
- There is a gap in provision of postgraduate training within BRIC
- The training provided through BRIC will have a positive impact on the recruitment of skilled engineers and scientists within the bioprocessing sector

Overview

37. Prior to BRIC, Research Councils' support for bioprocessing research was relatively limited, and this resulted in a weakened bioprocessing community. BRIC is helping to rectify this, and has made noteworthy progress in reenergising the bioprocessing community. New academics have entered the bioprocessing field as a result of BRIC, and BRIC is providing essential bioprocessing training to postdoctoral researchers. In general, postdoctoral training is good, although there are several areas where there is some scope for improvement, most notably through the provision of industry placements. In addition, postgraduate training is formally outside BRIC's remit, and this is potentially a serious weakness of the scheme.

New academics conducting bioprocessing research

38. A skilled bioprocessing research base is vitally important for both UK industry and academia. However, a prior falling away of Research Council support for bioprocessing weakened this research base and resulted in a 'missing generation' of UK researchers with bioprocessing experience. Academics in the bioprocessing field found it very challenging to win funding for their research, and many moved abroad. It is currently very difficult to recruit senior bioprocessing research scientists.

39. BRIC is making noteworthy progress towards rebuilding capacity in the UK bioprocessing research community. BRIC has attracted and funded applications from researchers without previous bioprocessing experience; 43% of funded BRIC applications were from academics who had not previously received funding to conduct bioprocessing research. In addition, 71% of RAs employed on BRIC grants had not previously been involved with bioprocessing. The engagement of researchers without long-term exposure to bioprocessing was very good, particularly for postdoctoral researchers, and demonstrates the success of BRIC in broadening the appeal of bioprocessing research.

40. There was a perception among some of the wider research community that BRIC had not really helped to broaden the bioprocessing research community and that only established bioprocessing researchers had received BRIC funding. The Panel did not

share this view. The first BRIC round had supported a number of established researchers, possibly because they were more experienced at writing high-quality bioprocessing research proposals. However, in subsequent rounds a substantial number of researchers new to the field were supported.

Training and skills development

41. An essential BRIC objective is to build capacity in the UK bioprocessing research base through the provision of relevant training to postdoctoral RAs. There is a marked need to provide this training, given that the majority of BRIC RAs had no previous bioprocessing experience and the difficulties with recruitment experienced by BRIC grantholders and industry members.

42. BRIC is delivering good quality bioprocessing training to postdoctoral RAs, particularly for practical and technical skills. However, there is scope to improve transferable skills training and RAs would benefit from some of the standard training that is available in industry, including training in project management, communication skills, design of experiments, six sigma, lean sigma, statistics, and quality by design. Existing training modules could be modified to provide this training, for example, those for BBSRC Enterprise Fellows or at Doctoral Training Centres.

43. BRIC should seek to deliver the highest quality training in bioprocessing to RAs and this cannot be achieved if their training is based only in universities. There is a need to involve industry in RAs' training, although this will require a willingness from industry to participate. It was especially disappointing that so far only a very small proportion of RAs have spent any time in an industrial environment.

44. Industry placements should form part of BRIC's training strategy. Ideally, these should be long-term placements of at least six months, to enable RAs to conduct research which is related to the BRIC project. The placements should occur at an early stage of the BRIC project, so that the skills learned can be transferred back to academia and benefit the future development of the research. It was noted that PhD students who have participated in industry placements tended to be more project and goal oriented when they returned to the academic environment. Industry placements could also enable RAs to gain practical experience that cannot be achieved in university laboratories, such as process scale experience. In addition, there is significant value in RAs participating in shorter placements and site visits, and these should be encouraged.

45. Although the lack of industry placements is a current weakness with the scheme, it is encouraging that RAs have received a wider exposure to industry through BRIC. All RAs reported direct interactions with industry. These were varied, and included technical advice, exchange of experimental materials, participation in workshops, visits to industry facilities, and informal conversations and discussions. However, fewer than a third of RAs reported that they were considering a career in industry as their next employment destination. This is a concern, as one expected impact of BRIC was the provision of trained individuals to the bioprocessing industry, but greater exposure to industry should help to improve this.

46. The bioprocessing training provided to BRIC RAs is very valuable. However, BRIC has only supported 25 research projects, which represents a relatively small amount of training. This is unlikely to meet the overall demand for trained individuals in academia and industry, and there is a clear need for Research Councils to provide additional, long-term support for training in this area.

Postgraduate training opportunities within BRIC

47. In order to build capacity and critical mass in UK bioprocessing, there is a need to support training at several levels, including PhD studentships. Although bioprocessing is a priority area for BBSRC's PhD funding, postgraduate training is formally outside BRIC's remit and this is potentially a serious weakness with the scheme. This was recognised by researchers, industry members, and the SG alike. There is a risk that BRIC is expanding the bioprocessing research sector without also increasing the number of postgraduate training opportunities.

48. BBSRC funds Targeted Priority Studentships (TPS) in bioprocessing and is currently supporting 23 PhD students. This is very welcome. However, because TPS in bioprocessing are allocated as groups of studentships via Doctoral Training Grants, they are focused in a small number of institutions and are not building capacity more widely.

49. Moreover, current BBSRC provision for postgraduate training in bioprocessing is not sufficient to meet the needs of academia and industry. The limited number of funding opportunities for PhD studentships in bioprocessing in the past has contributed to a lack of postdoctoral researchers with bioprocessing experience, and has probably resulted in a steep learning curve for many BRIC RAs. Increased support for studentships will increase the supply of experienced RAs, and should help to address the issues of staff recruitment and retention for bioprocessing research grants.

50. A key objective of studentship training in bioprocessing is to develop core skills and expertise applicable to industry. This could be best achieved by enabling students to work alongside exciting, varied and well-funded research projects. As such, Research Councils should consider funding studentships directly aligned to research grants within BRIC. The Diet and Health Research Industry Club, which aims to develop research skills for the UK's food industry, funds TPS that are associated with grants, and a similar model would be suitable for BRIC. The Panel shares the view of Research Councils that the primary focus of PhD studentships must be the training opportunities provided to the student, but aligning studentships to grants need not be incompatible with this goal.

51. Although BRIC cannot fund PhD studentships directly, many CASE studentships are aligned with BRIC grants. Grantholders were very positive about the benefits the associated studentships provide, both to the student and the research grant. For example, related PhD projects led to the exchange of ideas and techniques, helped foster closer links with industry partners, and contributed to the critical mass around a project.

52. There is also a need for Masters training in bioprocessing. The Panel noted the 2009 competition for BBSRC Masters Training Grants and was encouraged that 'strategically important training for industry' was a priority area in this competition.

Career development opportunities for early-career researchers

53. A vibrant UK bioprocessing industry cannot be sustained without a healthy academic research community and it is very important that the next generation of research leaders is supported. Research Councils should ensure that there are follow-on funding opportunities available to enable the highest calibre early-career scientists to establish their own bioprocessing research groups. They must also ensure there is a long-term

commitment to support bioprocessing research as otherwise researchers will be discouraged from pursuing academic careers in this field.

54. BBSRC provides funding opportunities for early-career scientists to establish independent research careers through the David Phillips Fellowship scheme[9]. The competition for these awards is fierce, and the assessment criteria are perceived to have a strong academic focus that favours basic research. Successful candidates tend to have published in high-impact journals such as 'Nature' or 'Science'; this may disadvantage scientists who conduct strategic or applied research, as they are unlikely to publish in these journals despite the high quality of their science. Research Councils should ensure that Fellowship schemes for early-career scientists are supporting all types of excellent research – basic, strategic and applied. In particular, BBSRC must continue to ensure that industry is represented on the Training and Awards Committee.

55. Industry is another anticipated key employment destination for BRIC RAs. Industry currently experiences problems with recruitment because the number of skilled individuals within the UK is not sufficient to meet demand. BRIC industry members were positive about the about the future impact of BRIC on recruitment, and it was clear that industry is looking towards BRIC as a potential recruitment forum, both for their own company and the sector as a whole.

[9] www.bbsrc.ac.uk/funding /fellowships/david_phillips.html

CHAPTER 4: DEVELOPING PARTNERSHIP LINKS BETWEEN ACADEMIA AND INDUSTRY

Summary

- BRIC is an effective vehicle for promoting academia-industry and academia-academia partnership links
- BRIC is supporting knowledge exchange between its members and, as projects mature, more should be expected in this area
- Dissemination events, where researchers share their work with other BRIC members, are a highlight of the scheme
- Similar progress in networking and promoting partnerships would not have been achieved through responsive mode

Overview

56. In addition to supporting high-quality, industrially-relevant research, BRIC conducts a number of wider activities which are having a very positive influence on the development of the UK bioprocessing community. Participation in BRIC has enabled researchers to develop improved academia-industry and academia-academia partnership links, and these links have benefited their research programmes. BRIC has fostered the development of networks, aided by the Knowledge Transfer Network 'bioProcessUK'. In addition, academia and industry have been involved in knowledge exchange within BRIC, particularly through BRIC dissemination events. These are important achievements, and it is unlikely that similar progress could have been realised through responsive mode funding.

Academia-industry partnership links

57. BRIC is an effective vehicle for enabling academic researchers to engage with industry. All researchers funded through the first call have established new or improved academia-industry partnership links as a result of their grant, and 75% reported links to an industry member who was previously unknown to them. So far, fewer researchers funded in the second call have established academia-industry partnerships, but this is to be expected as it takes time for partnerships to develop. The establishment of new links is attributable to participation within BRIC; 90% of researchers who developed new or improved partnership links with industry stated that they would not have met one or more of their contacts without BRIC.

58. Grantholders reported a variety of new and improved academia-industry partnership links that have developed as a result of BRIC. These included CASE studentships, consultancy, exchange of materials, informal discussions, formal research collaborations and research contracts. In general, more researchers have established partnership links with large companies than with SMEs, and most grantholders have contacts with multiple industry partners. The lack of exclusivity in partnership links is positive and demonstrates that individual BRIC research projects are of broad interest to many bioprocessing companies.

59. Some grantholders already had well-established links with specific industry partners at the outset of the BRIC project from their previous research, whereas others, who were

often new to the field, had no prior contacts within the bioprocessing industry. Research groups with pre-existing links to industry were making the best progress in developing academia-industry partnership links. It was more difficult for researchers new to the bioprocessing field to establish such links, and it was taking them longer to do so.

60. Although groups without previous experience in the bioprocessing field have found it more difficult to finalise partnership links, they are open to developing such links and are keen to do so. Groups who are new to the field are likely to benefit to the greatest extent from developing partnership links, but they may need additional support or follow-up. BRIC should therefore focus its support on these researchers, and this support should be provided at the earliest possible stage. It was good that every grantholder who had not previously received funding for bioprocessing research has established new partnership links with industry, although so far many of these links are still at the discussion stage. It should be noted that without BRIC, it would have been very difficult for some of these researchers to form links with industry.

61. The Panel was encouraged by the feedback from the Programme Manager that the development of academia-industry partnership links is improving over time, and that partnerships can now form quicker than at BRIC's launch. For example, researchers funded in the first round are acting as 'role models' whose interactions with industry are observed by other researchers at dissemination events.

62. Although industry involvement in BRIC is an essential aspect of the scheme, this is not in itself sufficient. It is vital that industry involves enthusiastic representatives, who can devote sufficient time to develop links with BRIC researchers. It was pleasing that industry reported providing 400 person hours per annum to support visits to BRIC academics, and a further 200 person hours per annum to host visits by BRIC researchers.

Academia-academia partnership links

63. Innovative research in bioprocessing is likely to require substantial multi-disciplinary working. Consequently, one aim of BRIC is to encourage new academia-academia linkages, bringing together skills from different scientists and institutions.

64. BRIC is successfully promoting partnership links between academic members. 71% of researchers funded in the first or second BRIC calls have established new or improved academia-academia partnership links with other BRIC researchers. Some genuinely new partnerships have been formed as a result of BRIC, and 36% of researchers reported links to an academic who was previously unknown to them. The establishment of new links could be attributed to participation in BRIC; 70% of grantholders who developed new or improved academic links would not have met one or more of their contacts without BRIC.

65. 48% of BRIC research grants are multi-institutional (i.e. they either involve a co-investigator at a different institution to the PI or are classified as a joint grant[10]). This is very positive, and is similar to the proportion of multi-institutional responsive mode grants funded through the former EBS Committee.

66. There was evidence that a number of smaller networks and sub-groups are developing within BRIC. For example, researchers working on animal cell expression had

[10] A joint grant is where two or more grants are awarded to different institutions for the same research project

established a forum to discuss their research. These smaller networks involved other members of the BRIC research groups, including PhD students.

Industry-industry partnership links

67. The opportunities for industry-industry networking within BRIC have enabled industry members to develop an increased awareness of one another, which is another positive outcome of the scheme. However, no applications involving two or more companies were submitted to BRIC, and no formal industry-industry collaborations have been formed. This is not surprising as encouraging industry-industry interactions is difficult; the commercial environment is competitive and an individual company's participation in BRIC will focus on their own interests.

Developing partnerships with non-BRIC members

68. Non-BRIC academics have also developed partnership links through BRIC, for example, at launch workshops or during the application process. This is an area where it is more difficult for BRIC to have an impact. However, 29% and 33%, respectively, of unfunded applicants and workshop delegates reported that they have established new or improved industry links as a result of their involvement in BRIC; 29% and 56%, respectively, of unfunded applicants and workshop delegates developed new or improved academic partnership links.

Knowledge exchange

69. An important objective of BRIC is to promote knowledge and skills transfer between the science and engineering base and industry. In the short term, BRIC aims to encourage the exchange of materials, expertise and ideas between its members. In the longer term, knowledge exchange (KE) is important to ensure that the full impacts of BRIC research are realised and research outputs are used by industry.

70. The current level of KE between BRIC members is good. 64% of BRIC grantholders have received material contributions from other BRIC members (academia or industry). These include systems knowledge, experimental samples or vehicles, experimental or analytical techniques, literature material and contacts with third parties. 47% of industry members have either made or received material contributions. However, a competitive commercial environment means that companies can be guarded about providing materials to academics and it has taken time for BRIC industry members to become forthcoming. The provision of relevant materials from industry is very important, as academics need access to the relevant genes, proteins and cell lines to ensure their research delivers the maximum possible impact.

71. In general, the majority of grantholders' annual reports describe plans for KE rather than specific examples of where it has taken place, which is reasonable given the relatively early stage of most research projects. Grantholders reported a variety of plans for the dissemination of the results and outputs of their projects, depending on whether there would be IP that required protection and taking into account the required dissemination within BRIC which is a grant condition. For example, grantholders' plans for dissemination included: BBSRC 'Follow-on Fund'[11], bioProcessUK meetings, BRIC

[11] BBSRC commits £2.1 million a year to the Follow-on Fund programme, a funding stream that supports 'proof-of concept' work at the very early stage of turning research outputs into a commercial proposition. Typically grants are for £80K - £150K over twelve months.

dissemination events, commercialisation, formal publication, formal research collaborations, learned societies, national and international conferences, protecting IP rights, visits or talks to industry. As BRIC matures, there will be a need to improve the level of KE, and the SG should monitor progress in this area.

72. There are no formal relationships between BRIC academics and specific companies to exploit the research. This is appropriate, as the conditions of BRIC research grants state that the research must be available to all BRIC members. Some BRIC projects are an extension of previous research, for example, a CASE studentship sponsored by a specific company. Although this can result in a strong and focused project, such cases must be managed carefully to ensure that close links to an individual company do not cause concern to other BRIC members.

BRIC dissemination events

73. BRIC organises bi-annual meetings where project results are shared with other grantholders and BRIC industry members. These dissemination events are very successful and have evolved over time to meet the needs of the community. They are highly regarded by all participants and should be recognised as a major highlight of the scheme.

74. Dissemination events are a good vehicle for encouraging KE between academia and industry. They provide excellent opportunities for BRIC researchers to interact directly with industry and to develop one-to-one collaborations. The events provide companies with access to a wide variety of research and act as a ‘shop window’ for BRIC science. In addition, dissemination events allow industry to speak to academics about the specific research challenges in their company. This information is very valuable: it helps researchers learn about the research problems the bioprocessing industry needs to solve, and enables them to align their own research programmes accordingly. Further openness from industry within BRIC would be welcome, but it should be recognised that industry is usually very guarded about these issues and even limited KE of this nature is a notable achievement.

75. Only BRIC grantholders, research assistants and industry members are invited to attend dissemination events. This is appropriate, as BRIC industry members are paying for privileged access to the research and early sight of emerging IP through membership fees. However, closed events may reinforce a perception that BRIC is exclusive and not open to other members of the community, and there is scope for BRIC to organise additional open events to showcase its achievements to a wider audience. It is good that PhD students working alongside BRIC research projects have attended the most recent meetings.

CHAPTER 5: BALANCE AND COVERAGE OF THE PORTFOLIO

Summary

- The BRIC remit is appropriate and covers the major areas of UK bioprocessing activity
- The BRIC portfolio is balanced and provides good coverage of most of the BRIC remit
- The main gap in coverage is in whole process modelling
- BRIC is supporting an appropriate balance of conservative and higher-risk projects

Overview

76. BRIC is supporting a well coordinated programme of industrially-relevant research projects. The BRIC research agenda is focused on addressing generic bioprocessing issues, which ensures that individual projects are of interest to the whole bioprocessing industry, and the remit covers the major areas of UK bioprocessing activity. Over the course of the scheme, the SG has adjusted the calls for funding, with the result that the overall balance and coverage of the BRIC portfolio is good and all critical areas have been supported.

BRIC scientific remit

77. BRIC supports research in two priority research areas, within which there are a number of specific research challenges:
    - Bioscience underpinning bioprocessing
        - Understanding, controlling and manipulating metabolism in microbial fermentation
        - Understanding, controlling and manipulating metabolism in mammalian cell culture
        - Growth of stem and tissue cells in vitro
        - Improved understanding of the properties of proteins
    - Improved tools for bioprocessing
        - High throughput process technologies
        - Effective modelling of whole bioprocesses
        - Analytical methods for bioprocessing
        - Improved downstream processing
        - Advances in downstream processing including formulation

78. This scientific remit is appropriate and covers the major areas of UK activity in biomedical bioprocessing. Some areas of translational medicine may overlap with the remit of the Medical Research Council, but the bioprocessing aspects are all within BBSRC's or EPSRC's remits. It is encouraging that emerging areas such as regenerative medicine are included as the central bioprocessing issue is the same as for more traditional technologies: how to make a large amount of pure product cost-effectively?

79. The BRIC research agenda is focused on addressing generic bioprocessing issues, rather than the development of individual products. This is welcome, as the results from

BRIC research will benefit the whole bioprocessing industry. It is also consistent with the Research and Technology Club model, where the results from BRIC research must be made available to all participating companies.

Balance and coverage

80. The balance and coverage of the BRIC portfolio is good, and all the critical areas of the remit have been supported. While the funded projects from the first call largely focused on the manipulation of mammalian cell expression, the SG adjusted the subsequent calls to focus on specific themes not covered in previous rounds.

81. There are some gaps in coverage within the BRIC remit. The most notable was whole process modelling, although there are other areas where more support would be welcome, such as understanding the properties of proteins. A lack of applications contributed to this, exacerbated by very few UK academics working in particular areas of the remit. Any future BRIC scheme should pursue areas that have not received funding and, if necessary, conduct specific activities to encourage or commission high-quality cross-disciplinary proposals. There are UK researchers whose work could contribute to addressing these challenges, and they should be made aware of the opportunities available to them through BRIC.

82. Research Councils and BRIC must use their limited resources in the most effective way to deliver the maximum impact. There are a few examples in the BRIC portfolio where there is overlap between funded projects, which is not ideal and could result in the duplication of effort. BRIC has also invested a substantial amount of resource into projects in the theme of understanding, controlling and manipulating microbial fermentation. This is a relatively advanced area of research, where many tools and resources are already available. Although BRIC should be funding research in this area, some of the resource invested might have been used more effectively supporting other areas of the remit.

83. Some members of the research community were concerned that the BRIC portfolio was too conservative, and did not reflect the adventurous nature of the remit. The Panel felt that the balance of conservative and higher-risk projects within the BRIC portfolio was appropriate and was consistent with responsive mode, where the majority of applications tend to build on pre-existing research. The first round of BRIC projects was relatively conservative, but in subsequent rounds the funding was more adventurous. The Programme Manager also noted that BRIC received very few unconventional, high-risk applications.

84. Research in some areas of the BRIC remit, such as regenerative medicine, is relatively expensive, and there was a risk that this might have discouraged the SG from supporting proposals in these areas. It was pleasing that this was not the case: scientific excellence and strategic relevance were the primary application assessment criteria, and the relative costs of specific research areas were not considered as part of the assessment process.

85. A very positive impact of BRIC is that it has broadened the scope of bioprocessing research in the UK. In particular, BRIC has supported researchers from other disciplines whose work can impact on bioprocessing challenges. BRIC must continue to do so in future, and must avoid the risk of developing an inward-looking, narrow definition of bioprocessing. For example, there are many academics who are conducting research which is not formally considered to be bioprocessing, but who are nevertheless seeking to develop products that will eventually need to undergo large-

scale manufacture (e.g. gene therapy). BRIC could be a useful forum to help these researchers identify what would constitute a bioprocess for their product, and how bioprocess issues could influence the development of their own research programmes.

CHAPTER 6: APPLICATION AND ADMINISTRATION PROCEDURES

Summary

- BRIC has attracted a good number of high-quality applications
- The application processes were fair and appropriate, but some aspects should be made more explicit to the research community
- The outline application process was popular with researchers, and provided opportunities to improve the application and increase the strategic relevance of proposals
- BRIC management is effective, and researchers' interactions with the BRIC Programme Manager and bioProcessUK have been beneficial
- Similar progress to that achieved by BRIC could not have been realised through responsive mode funding

Overview

86. BRIC was the first of several Research and Technology Clubs to be supported by BBSRC, and it introduced several modifications to the peer-review mechanism used in responsive mode. The application and assessment procedures were appropriate, and industry involvement and feedback from the SG during the application process helped to improve the strategic relevance of proposals and the funded research. The wider activities supported by BRIC have added value to research projects, and it is unlikely that a similar programme of coordinated research projects could have been supported through responsive mode funding. The success of BRIC illustrates the effectiveness of the Research and Technology Club model for supporting industrially-relevant research.

BRIC applications

87. BRIC has received a good number of applications for each of its three funding calls. In total, 125 outline applications were received and, of these, 56 were invited to make full applications and 25 awards were made. The success rate for outline applications was 20%; for full applications it was 45%. The number of applications rose between the first and second call, and then remained constant for the third call.

88. The quality of applications was generally high. For example, 59% of full applications were rated as being fundable and 44% were rated as 'being at the forefront of UK activity and internationally competitive in a significant proportion of the research proposed'. There were several high-quality applications that could not be funded because of limited resources, particularly in the third call.

Application and assessment processes

89. BRIC uses a two-stage application process. Researchers submit a brief outline proposal which is assessed by the SG. Authors of the most promising outline proposals are then invited to submit full applications which are externally peer-reviewed prior to final assessment by the SG. As with other Research Council grant proposals, applicants have the opportunity to respond to the reviewers' comments. Applications

are primarily assessed against two criteria: scientific excellence and strategic relevance.

90. The research community had mixed views about BRIC's application and assessment procedures. The use of outline applications was predominantly regarded as beneficial. However, there were concerns about the transparency of the assessment processes, the involvement of industry in the assessment of proposals, and the provision of feedback. The Panel felt the application and assessment processes were fair and appropriate, and industry involvement was important to ensure the strategic relevance of BRIC research. The majority of negative comments appeared to be related to researchers' unfamiliarity with the BRIC application process; similar feedback has been received regarding other schemes that modify the usual responsive mode peer-review mechanism.

91. Outline applications were popular with the majority of researchers: they take less time to prepare, they prevent researchers from writing uncompetitive full proposals, and they reduce the burden on peer-reviewers and the SG. They also provide a useful opportunity for the SG to provide feedback to researchers, and this helps to improve the quality and strategic relevance of full proposals. However, when some researchers incorporated the SG's suggested changes into their application, particularly the references to industrial relevance, these were subsequently criticised by peer-reviewers. This is unfortunate and efforts should be made to ensure peer-reviewers are fully briefed on the importance of industrial relevance to the BRIC research agenda. In addition, funded researchers were often disappointed that the outline process did not help to identify new academic or industrial collaborators.

92. Some members of the research community expressed concerns about the transparency of BRIC's application and assessment processes. This was surprising as details of these processes are readily available on the BBSRC website. There were, however, several areas where researchers' comments suggested that BRIC's application and assessment procedures were not well understood, and it may be helpful to make these more explicit, particularly:
    - Weighting of assessment criteria: the criteria of scientific excellence and strategic relevance are given equal weight in the assessment of proposals, and applications must pass on both criteria to be considered fundable
    - SG Introducing Members (IMs): for the final assessment by the SG, each full proposal has two IMs. One IM is from academia and the other is from industry
    - SG conflicts of interest: the procedure for dealing with conflicts of interest (e.g. where an industry member has pre-existing links to an applicant) is the same as for BBSRC Research Committees. Conflicted individuals leave the room while the proposal is being discussed

93. Many unfunded applicants were not satisfied with the feedback they received on their application, noting that feedback was too slow or too generic. This is not unique to BRIC, and similar comments have been received for other Research Council funding programmes. The comments are understandable and Research Councils should endeavour to provide prompt and specific feedback to applicants. The BRIC Programme Manager helps to provide more explicit feedback to applicants than would be received in responsive mode.

BRIC management

94. Since its inception, BRIC has adapted to take account of emerging issues and to ensure that the scheme is addressing the needs of its community. The Research and Technology Club model was a new funding mechanism, and it has taken time for BRIC to realise its full potential. This 'directed evolution' of BRIC by the SG is positive and indicates that the management by the SG and Research Councils is effective.

95. Help with BRIC management is provided by the BRIC Programme Manager. This is recognised as a crucial role by BRIC stakeholders and the work of the Programme Manager is highly regarded. Contact with the BRIC Programme Manager has provided academics with a number of benefits including: advice during the application process; advice on potential industry partners; and regular feedback about their progress. RAs have also benefited from contact with the Programme Manager and, in particular, they noted the support and encouragement the Programme Manager had provided.

96. bioProcessUK[12] also provides BRIC with management support. bioProcessUK is a publicly funded Knowledge Transfer Network[13] supported by the Technology Strategy Board. It was established in 2005 to drive innovation performance across the UK biomedicine bioprocessing industry. It provides networking opportunities to connect companies, universities, funding bodies, national, regional and devolved administrations. bioProcessUK is highly regarded by academic and industrial BRIC members, and the close relationship between BRIC and bioProcessUK has provided valuable benefits. For example, bioProcessUK has raised awareness of BRIC among the bioprocessing community and facilitated contacts with industry. In addition, bioProcessUK's Technical Director provides representation for industry members who are not members of the SG.

97. The Research Council staff who support BRIC were regarded as very helpful by the research community. In addition, the SG was very impressed by the support they received from BBSRC staff in the Innovation and Skills Group.

98. Some academics commented that BRIC is over managed, and the provision and revision of Gantt charts, annual reports and meetings with the Programme Manager disrupts the normal process of research and could stifle creativity. The Panel was not persuaded that this was the case and noted that it is beneficial for academics to learn about industry approaches to project management.

99. BRIC was the first of several Research and Technology Clubs funded by BBSRC. Subsequently, BBSRC has launched the Diet and Health Research Industry Club (DRINC) and the Integrated Biorefining Technologies Initiative Research and Technology Club (IBTI Club), and is currently considering plans for two more Clubs in the areas of healthy ageing and crop improvement. BRIC has had a positive influence on the development of these other Clubs, which have modelled themselves on BRIC.

Comparison with responsive mode

100. BRIC is supporting a coordinated programme of industrially-relevant strategic research, which is addressing key bioprocessing challenges, aided by industry in setting the research agenda. BRIC is building capacity in the UK bioprocessing community, and additional BRIC activities including dissemination events, workshops, networking, and

[12] www.bioprocessuk-website.org
[13] www.ktnetworks.co.uk

contact with the Programme Manager and bioProcessUK are adding value to research grants. BRIC is providing important training to early-career researchers, promoting partnership links between academia and industry, providing opportunities for knowledge exchange, and raising awareness of end-user needs among academics and Research Councils. As a result, BRIC is substantially more than a portfolio of 25 individual research projects. The success of BRIC demonstrates the effectiveness of the Research and Technology Club model, and it is highly unlikely that similar progress could have been realised through responsive mode funding.

101. The provision of ring-fenced funding for bioprocessing has been necessary and effective; it is unlikely that a similar coordinated programme of bioprocessing research could have been supported through responsive mode. Although the quality of BRIC research is high, the number and variety of projects would probably be diluted if bioprocessing research were supported through responsive mode funding alone.

102. In the past, it has been very difficult for researchers to secure funding for bioprocessing research in responsive mode. There is a perception that BBSRC Research Committees favour basic research, and that proposals for industrially-relevant strategic or applied research are unlikely to be funded. The Panel welcomed the recent changes introduced by BBSRC to help to address this. In autumn 2008, BBSRC announced that it was restructuring its Research Committees[14]. An important driver for these changes was the need to deliver more inter-disciplinary and strategically focused science with greater impact in responsive mode. Under the new structure, a greater number of proposals for strategic and applied research are expected. In addition, from 2009 all applications will include statements about the impact of the research which will be assessed as part of the refereeing process.

103. While Research Councils' support for bioprocessing research through BRIC is very positive, it is very important to ensure research in this area is also funded through responsive mode. There are benefits from supporting researchers who are peripheral to BRIC, and further research in this area will generate knowledge that can subsequently be applied to industry.

[14] www.bbsrc.ac.uk/organisation/structures/committees

CHAPTER 7: FUTURE DIRECTIONS AND CONCLUSIONS

Summary

- Research Councils should build on the success of BRIC by funding a successor scheme
- A BRIC successor scheme should develop another level of network to encourage greater participation from industry and academics from other disciplines
- Research Councils should publicise the success of BRIC to a wide audience

Future Research Council support for bioprocessing research

104. BRIC has been very successful in reenergising the UK bioprocessing community. It has expanded a relatively small field, bringing new academics and postdoctoral researchers into the community, and it has broadened the appeal of bioprocessing research, attracting researchers from other disciplines. BRIC is also an excellent vehicle for promoting academia-industry interactions. However, so far, the community developed by BRIC is relatively small, involving 25 research projects and 18 industry members. The community is vibrant and highly valued by its members, but it is also fragile; there is a high risk that, without further ring-fenced funding for bioprocessing research, the community may dissipate and opportunities for impact may be lost.

105. Research Councils should build on the success of BRIC by funding a successor scheme. This should encourage continuity through follow-on funding opportunities, but also seek to broaden the community even further by involving more academics from other disciplines and an increased number of UK companies. Any future scheme will need to develop another level of networking to achieve this goal.

106. There are many academics whose work could contribute to the BRIC research agenda, but who would not currently consider themselves to be part of the bioprocessing field. BRIC should promote its activities more widely to ensure researchers are made aware of the opportunities available. BRIC should approach other professional organisations to attract these scientists including, for example, the International Society for Pharmaceutical Engineering, the Joint Pharmaceutical Analysis Group or the Protein Society. BRIC should also organise its own presentations to a wider academic audience to raise awareness and demonstrate its achievements. The perceived changes in the funding climate among academics are likely to encourage attendance at such events. In addition, BRIC grantholders should speak with colleagues in their own institutions about how their colleagues' work could contribute to the bioprocessing research agenda.

107. BRIC should also seek to promote further links with the industrial bioprocessing community. There are many more companies with an interest in bioprocessing than are currently involved in BRIC. In the future, BRIC should seek to widen industry participation, and particular consideration should be given to attracting more small and medium-sized enterprises (SMEs). Increased participation by SMEs would be beneficial for both BRIC and the companies themselves. BRIC should also ensure SMEs are adequately represented on the SG; SMEs suffer from a general lack of representation, despite making up a substantial proportion of the UK biotechnology industry.

108. BRIC should make particular efforts to attract SMEs in the field of regenerative medicine. This may be challenging as SMEs which are commercialising stem cell or tissue engineering science are often at an early stage of development and may be more interested in research which contributes to the development of individual products; BRIC's remit is to fund research that addresses generic issues which will benefit the whole bioprocessing sector. However, SMEs in the regenerative medicine field would benefit from interacting with academics and with one another within BRIC. It was noted that these SMEs would not participate in BRIC until related projects had been funded. This should no longer be an issue, as BRIC is now funding four projects investigating the growth of stem and tissue cells *in vitro*.

109. BRIC membership fees could be a barrier to entry to companies, particularly small start-up companies with very limited discretionary funds. The sliding scale of membership fees is welcome and helps to ensure companies of all sizes are able to participate. However, the current economic climate may create difficulties for BRIC in the future, as it may be harder for industry members to justify their investment in BRIC especially as it is not tied to a specific research project.

110. BRIC enables companies to gain exposure to a large amount of science for a relatively small investment, and is an excellent example of how academia and industry can work more closely together for mutual benefit. BRIC's achievements should be publicised to a wide audience, including government, relevant industry, and other academics. In particular, the Department for Business, Innovation and Skills should be made aware of the success of the Research and Technology Clubs in delivering the Research Councils' 'Excellence with Impact' agenda.

Summary of findings and recommendations

111. BRIC is a very successful scheme and is making very good progress towards meeting its objectives. BRIC is supporting high-quality, industrially-relevant research in a strategically important area, and this research has the potential to deliver significant impact. The Panel was unanimous in its view that BRIC has had an extremely positive effect in reinvigorating bioprocessing research in the UK and that mechanisms must be found to maintain this momentum.

112. There were some areas within BRIC where the Panel identified potential gaps and weaknesses, and addressing these will help BRIC to be even more effective in the future. The following text summarises the issues and recommendations raised throughout the report.

Standard of research

- A very small number of grants were less successful than expected
- The primary issues affecting grant performance were staffing difficulties or over-ambitious objectives
- Long-term objectives were most likely to show delayed progress

Strategic relevance and potential for future impact

- DSP projects are more likely to deliver short-term impact than USP projects
- Some USP projects are using model proteins that are not representative of those used in industry

Publications

- Institutions place too much emphasis on publications in high impact-factor journals as a measure of research excellence

Intellectual property

- It is essential that intellectual property developed by BRIC grantholders is protected
- There must be more explicit consideration of IP protection within BRIC
- BRIC should provide RAs with IP awareness training

Research Assistants' training and skills development

- There is scope to improve transferable skills training for postdoctoral RAs (e.g. project management, communication skills, design of experiments, six sigma, lean sigma, quality by design)
- Long-term industry placements should form part of BRIC's training strategy
- The training provided through BRIC is unlikely to meet the overall demand for skilled individuals with bioprocessing experience in industry and academia

Postgraduate training opportunities within BRIC

- Postgraduate training is formally outside BRIC's remit and this is potentially a serious weakness with the scheme
- BBSRC's Targeted Priority Studentships in bioprocessing are focused in a small number of institutions and are not building capacity more widely
- Research Councils should consider funding studentships that are directly aligned to BRIC grants
- There is a need for Masters training in bioprocessing

Career development opportunities for early-career researchers

- There must be funding opportunities available to enable the highest calibre early-career scientists to establish independent bioprocessing research groups
- Research Councils should ensure their fellowship schemes recognise all types of excellent research – basic, strategic and applied

Developing partnership links between academia and industry

- It is more difficult for researchers who are new to the bioprocessing field to establish academia-industry links; BRIC should focus its support on these groups when promoting partnerships

Knowledge exchange

- The majority of annual reports describe plans for knowledge exchange rather than specific examples of where it has taken place
- As BRIC matures, there will be a need to improve the level of knowledge exchange and the SG should monitor progress in this area
- Industry can be guarded about providing industrially-relevant materials to BRIC researchers

BRIC dissemination events

- The closed nature of dissemination events may reinforce a perception that BRIC is exclusive
- There is scope for BRIC to organise additional open events to showcase its achievements to a wider audience

Balance and coverage of the portfolio

- There are some gaps in the coverage of the BRIC scientific remit (e.g. whole process modelling)
- There are a few examples in the BRIC portfolio where there is overlap between funded projects

Application and administration procedures

- The research community expressed some concerns about the application processes (e.g. transparency, the involvement of industry, the provision of feedback)
- Some aspects of the application process should be made more explicit to the community (e.g. weighting of assessment criteria, the role of IMs, procedures for dealing with conflicts of interests)

Future Research Council support for bioprocessing research

- BRIC has had an extremely positive effect in reinvigorating bioprocessing research in the UK and mechanisms must be found to maintain this momentum
- Research Councils should build on the success of BRIC by funding a successor scheme
- A future scheme should encourage continuity through follow-on funding opportunities but should also seek to broaden the bioprocessing community even further
- A future scheme should attract more academics from other disciplines whose work can contribute to addressing bioprocessing research challenges
- A future scheme should widen industry participation and should encourage more involvement from SMEs, especially those in the regenerative medicine sector
- A future scheme should pursue areas that have not received funding in BRIC and, if necessary, conduct specific activities to attract or commission high-quality cross-disciplinary proposals

APPENDICES

APPENDIX 1

PANEL MEMBERSHIP

Dr Fiona Marston (Chair)
RFM Associates

Dr Paula Marques Alves
Animal Cell Technology, Instituto de Biologia Experimental e Tecnológica, Portugal

Dr Walter Cook
Pfizer Global R&D

Professor Nigel Jenkins
National Institute for Bioprocessing Research and Training, Ireland

Dr Martin Welch
Department of Biochemistry, University of Cambridge

APPENDIX 2

TERMS OF REFERENCE

1. The task of the Review Panel is to carry out an independent evaluation of the Bioprocessing Research Industry Club (BRIC) covering the three years since its inception. The Panel is asked to review the achievements of BRIC to date and to consider BRIC's potential for future impact as research projects develop.

2. Specifically, the Panel is asked to review the information presented and to:

    a. take an overview of the evidence from annual reports and surveys to assess the quality and international standing of the science supported by BRIC

    b. comment on the extent to which BRIC is supporting research relevant to the UK bioprocessing industry, including the bioscience that underpins bioprocessing and improved tools for bioprocessing

    c. assess the effectiveness of BRIC in promoting interactions between academia and industry

    d. assess the effectiveness of BRIC in promoting knowledge and skills transfer between the science and engineering base and industry

    e. comment on the extent to which BRIC is building capacity in UK bioprocessing research through the provision of relevant training for post-doctoral researchers and by encouraging academics to conduct industrially-relevant bioprocessing research

    f. in the context of priorities for UK bioprocessing, assess the balance and coverage of the BRIC portfolio, identifying strengths and weaknesses

    g. comment on the BRIC application, assessment and administration procedures

    h. comment on the potential long-term economic and social impacts of BRIC-funded research and identify ways to ensure that, as BRIC matures, these impacts are maximised

    i. make recommendations to the Research Councils on ways to build on successes and ways to address identified gaps and issues.

APPENDIX 3 **LOGIC CHART FOR BIOPROCESSING RESEARCH INDUSTRY CLUB EVALUATION**