# BBSRC SUPPORT FOR BIOENERGY AND INDUSTRIAL BIOTECHNOLOGY: THE USE OF SCIENCE AND TECHNOLOGY TO SUPPORT ENERGY, CHEMICALS AND HEALTHCARE INDUSTRIES

## EXECUTIVE SUMMARY

BBSRC is the principal public sector sponsor for research and training in industrial biotechnology (IB) covering the biological models and the associated biotechnologies for their exploitation. This sponsorship is of great importance to the future of the UK because this research will lead to new forms of energy, chemicals and therapeutics contributing to increased sustainability and with an estimated value to the economy of between £4B and £12B by 2025 (quoted in *IB 2025*). The financial support provided by BBSRC to IB research overall (with the exception of Bioenergy) is either stable or declining. If BBSRC is to help the UK realise both the sustainability aspects and economic value of IB, it will need to reverse this decline through increased funding to IB research, training and knowledge exchange in the coming years.

## GENERAL RECOMMENDATIONS

***Recommendation 1:*** BBSRC should increase the size of its IB portfolio as a proportion of its total budget

***Recommendation 2:*** To ensure that IB is recognised a priority for BBSRC funding, and is eligible for all forms of funding, BBSRC should establish IB as a new council-wide research priority.

***Recommendation 3:*** BBSRC should review its systems for ranking responsive mode grant and training proposals to ensure that strategic and applied research can be supported through these routes and that the appropriate expertise is available to assess applications in the area of IB.

***Recommendation 4:*** BBSRC should promote IB nationally and internationally through all forms of BBSRC literature and its website to raise the awareness of IB as a strategic priority both within the office and externally. Promotion of IB should involve working with a range of interested groups including other research councils, knowledge transfer networks, learned societies and trade associations.

***Recommendation 5:*** BBSRC should provide leadership in IB research, training and knowledge exchange and establish an advisory panel, including representatives from the key areas covering the interests of academia, industry and the international community, to advise on how to prioritise and implement the evolving strategy in IB and to monitor its progress over the lifetime of the current strategic plan (2010-15). The panel would be responsible for identifying priorities within the main areas of BBSRC's IB portfolio for targeted investment, particularly focusing on the production of industrial chemicals.

***Recommendation 6*****:** BBSRC should seek to identify, develop and promote new and existing mechanisms for working with the private sector which can assist in the translation of the research that it supports. BBSRC needs mechanisms for working with companies where the evidence for translation can be clearly demonstrated.

***Recommendation 7 :*** BBSRC should be more strategic with the allocation of training resources and seek to increase the size of its training portfolio in IB, proportional to BBSRCs overall level of investment in IB. In particular, BBSRC should seek to ensure that a significant proportion of training in IB is industrially relevant.

## RESEARCH PRIORITIES

***Recommendation 8:*** BBSRC should promote collaborative approaches in the area of industrial chemical production from living organisms and should facilitate the bringing together of cross-disciplinary research teams with industry to develop programmes of industrially-relevant research. An ideas factory-style approach may help to bring together the relevant teams, and the use of industrial facilitators would ensure that resulting research proposals tackled industrially relevant questions.

***Recommendation 9:*** BBSRC should seek to diversify its portfolio of fundamental, underpinning research in bioenergy to focus more on next generation sources, in particular the generation of straight and branched chain alkanes from living organisms, as direct replacements for petrol, diesel and aviation fuel. The use of systems and synthetic approaches will be of particular importance in delivering this aim. Redrafting BBSRC's current council-wide priority in bioenergy may be one way in which such diversification could be encouraged.

***Recommendation 10 :*** BBSRC should consider the most effective mechanisms of support for bioprocessing research, including the possibility of further directed mode funding, to ensure that the capacity and industrial linkages built through recent directed mode activities are not lost.

***Recommendation 11:*** BBSRC should seek to co-ordinate and build upon the current expertise in the UK plant science research community and expand research in the area of non-food crops by encouraging plant scientists and breeders to translate their research towards more industrially relevant non-food areas.  This should involve encouraging plant scientists to work alongside engineers to ensure traits are selected for improved processing as well as for desirable end products.

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## INTRODUCTION

1. In January 2010, BBSRC published a Strategic Plan for 2010-2015, titled: '*The Age of Bioscience'*[1]. The plan identified Industrial Biotechnology including Bioenergy (IB) as one of three high level strategic priority areas where BBSRC investment and leadership will have significant impact. The purpose of this document is to develop a more detailed description of priorities for future investment and how this might be achieved.

2. The document has been produced with the assistance of a panel of experts who have analysed the current and past BBSRC activities in IB and produced a set of recommendations on BBSRC's future support for this area. The Panel met three times between May and September 2010. The second meeting featured presentations from representatives of the TSB, NERC, EPSRC and BIS regarding their activities in IB and a discussion of the landscape of funding activity. This led to an analysis of the unique contributions that BBSRC funded research has to offer and the scope for co-operation with other sponsors.

## BACKGROUND

3. Industrial Biotechnology is a set of cross-disciplinary underpinning technologies that make use of biological resources to process and produce chemicals, materials and energy. Governments around the world are becoming increasingly concerned about maintaining citizens' lifestyles in an era of declining 'fossil' hydrocarbon sources for both energy and feedstock chemicals; coupled to this is the need to reduce carbon emissions in response to environmental change. Industrial biotechnology offers solutions to these problems by providing the means for generating sustainable sources of energy and feedstock chemicals from the precursors of immediately available sunlight, water and carbon dioxide. Industrial biotechnology also has considerable value to the UK economy, estimated to be between £4B and £12B by 2025.

4. The potential of IB to help the UK meet its sustainability targets was part of the motivation for the Department of Business, Innovation and Skills (BIS) to create the Industrial Biotechnology Innovation and Growth Team which produced its first report in May 2009: '*IB 2025: Maximising UK Opportunities from Industrial Biotechnology in a Low Carbon Economy'*. The report described the significance of IB to the UK economy and contained proposals to support the growth of IB in the UK. As non-departmental bodies associated with BIS, the Research Councils, and especially BBSRC and EPSRC, have been involved in the IB-IGT process. A final report and a series of recommendations about next steps are due shortly.

5. Most recently the European Commission has produced a report *The Knowledge Based Bio-Economy In Europe (KBBE): Achievements and Challenges* which sets out the key demands for sustainable supplies of raw materials, fuels and food and that in the future these must be met through biological means. Europe is in a strong position to lead this international aim which should be delivered through an integrated approach in preference to a sector-based approach. The UK is potentially in a leading position to help develop this area further provided there is future investment in appropriate research and training.

[1] www.bbsrc.ac.uk/strategy

6. Research Councils UK (RCUK) has research priority themes that are designed to enhance cross-disciplinary approaches to research challenges. The 'Living with Environmental Change' [2] (LWEC) and the Council's Energy Programme' are two themes with relevance to IB. The cross-council Energy Programme, which has supported programmes like SUPERGEN is of particular relevance to IB. BBSRC has recently assumed responsibility for Bioenergy under the RCUK Energy Programme with the aim of better co-ordinating the currently rather fragmented bioenergy research portfolio in the UK. The BBSRC Bioenergy Champion will chair the cross-council panel and lead the development of the UK position.

7. BBSRC has undertaken a number of high-profile activities in IB, including the BBSRC Bioenergy Review of 2006[3], which considered the contribution of bioscience to the development of renewable energy. Whilst replacements for some fossil fuels can be met by other alternatives, the only viable alternative to liquid fossil fuels are biofuels of which the best current examples are ethanol and butanol. BBSRC established the Sustainable Bioenergy Centre (BSBEC) in 2009 with an initial investment of £20M (along with an integrated programme of industrial research valued at an additional £6M) with the aim of tackling many of the challenges associated with the production of liquid biofuels from sustainable sources[4].

8. Specific BBSRC- funded activities relevant to IB include the Integrated Biorefining Research and Technology Club (IBTI). The IBTI Club brings together academics and industrialists in a partnership between BBSRC, EPSRC and a consortium of leading companies whose aim it is to support the development of examples of integrated biological processes which will ultimately reduce our current dependence on fossil fuels as a source of chemicals[5].

9. BBSRC also supports a number of grants and training awards concerned with bioprocessing for the healthcare industries eg through the Bioprocessing Research Industry Club (BRIC). Whilst these grants do not fit the strict "definition" of IB (**Annex 1**), they have been included in the analysis since the knowledge gained from a better understanding of bioprocessing of these complex materials will be beneficial in the production of all biological materials (see also paragraph 12 below).

10. The central role of BBSRC in supporting the science underpinning future needs in energy and biotechnology has been recognised in '*The Age of Bioscience'.* The strategic plan indicates BBSRC's commitment to support UK bioscience to ensure that it remains world-class and ultimately delivers significant social and economic benefits. This document seeks to develop a more detailed understanding of how this might be achieved in IB.

## BBSRC'S FUTURE SUPPORT FOR INDUSTRIAL BIOTECHNOLOGY

### The Scope of Industrial Biotechnology for BBSRC

11. To ensure consistency across Government, BBSRC has adopted the "definition" of IB developed by BIS as part of the IB-IGT process, which states: "industrial biotechnology is the use of biological resources for producing and processing materials, chemicals and energy. These resources include plants, algae, marine life, fungi and micro-organisms."

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[2] http://www.lwec.org.uk/about-living-environmental-change/aims
[3] http://www.bbsrc.ac.uk/web/FILES/Reviews/0603_bioenergy.pdf
[4] http://www.bbsrc.ac.uk/media/releases/2009/090127-public-investment-bioenergy.aspx
[5] http://www.bbsrc.ac.uk/business/collaborative-research/industry-clubs/ibti/ibti-background.aspx

12. This “definition” expresses IB in terms of products, namely: ‘materials, chemicals and energy’. As BBSRC funds mostly basic and strategic research, it is necessary to consider which of its research areas fall within the scope of this definition, and this is explored at **Annex 1**, where it is established that, for BBSRC, the application of the technologies and biological sciences associated with the pharmaceuticals sector to the production of chemicals, materials and energy, is relevant to IB, and so the science underpinning these areas in the pharmaceuticals sector is a part of BBSRC’s research portfolio in IB**.**

**BBSRC’s IB Portfolio**

13. Using the IB “definition” and scope for BBSRC (as described above) a list of keywords was developed and used to create a search strategy to identify research grants and training awards of relevance to IB within BBSRC’s overall research and training portfolio. The portfolio produced as a result of this search was further refined with industrial relevance being a key consideration for selection. A detailed summary of the areas within the portfolio is at **Annex 2.**

**BBSRC IB Expert Panel**

14. An expert panel was established to provide technical and strategic advice. The Panel Membership (**Annex 3**) included representatives from academia and industry, with expertise in research areas underpinning BBSRC’s “definition” of IB.

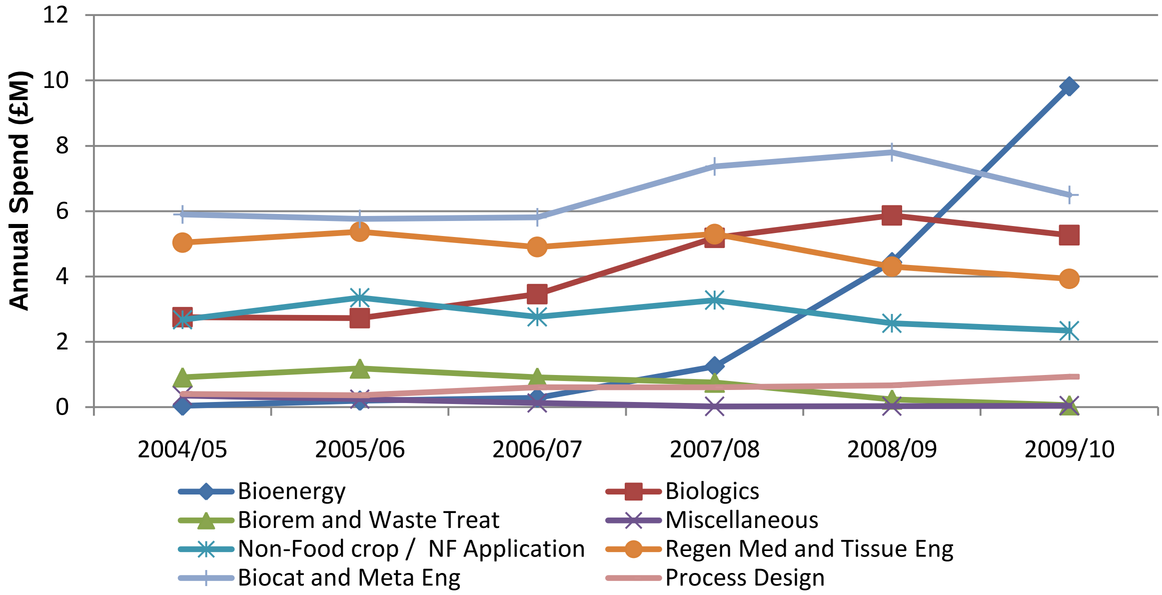
**BBSRC IB PORTFOLIO ANALYSIS**

15. The BBSRC IB portfolio has been sub-divided into a number of cross-disciplinary scientific areas for research, training and knowledge exchange. Many of these areas are scientifically distinct and have different histories within BBSRC and are supported through different mechanisms, thus they must be treated as separate entities. These categories, with the associated annual research spend for 2008/09 in brackets, are:

- Biocatalysis and Metabolic Engineering (£7.8M)
- Bioenergy (£4.4M)
- Non-Food Crop / Non-Food Application (£2.6M)
- Bioremediation and Waste Treatment (£0.24M)
- Process Design (£0.67M)
- Biologics (£5.9M)
- Tissue Engineering (£4.3M)

16. The following graph shows how the annual research spend in each of these areas has changed over the last six years.

**Annual research spend in the sub-areas that comprise IB from 2004/5 to 2009/10**




17. A more detailed analysis of each of these areas is presented as **Annex 2.**

18. The total annual spend in IB overall has remained fairly constant at 7-8% of the total BBSRC budget or around £26M at 2008/9 values. In most areas, the annual spend is concentrated within HEIs rather than at BBSRC sponsored institutes (with the exception of Non-food Crops), with the institutes accounting for 16% of annual expenditure. Responsive mode is becoming a less significant funding route for IB (40% of total funding in 2009/10), with initiatives making up an increasing proportion of the total spend from 2006/07 onwards (46% of total funding in 2009/10). Initiative spend is mainly accounted for through BSBEC, the BRIC and IBTI clubs.

19. The BBSRC IB portfolio has a relatively low level of investment when compared to the BBSRC strategic priority in Food Security (£96.5M pa) but has approximately the same as that supporting Bioscience Underpinning Health priority (£28.1M pa).

20. The financial support provided by BBSRC to IB research overall (with the exception of Bioenergy) is either stable or declining, when the funding for the introduction of full economic costing is taken into consideration (from 2005/6 onwards). It is not clear why there is declining investment and a number of explanations are possible. However, if BBSRC is to arrest or reverse this decline, additional targeted funding will need to be committed to IB projects through all types of funding mechanisms in the coming years.

**The unique contribution of BBSRC**

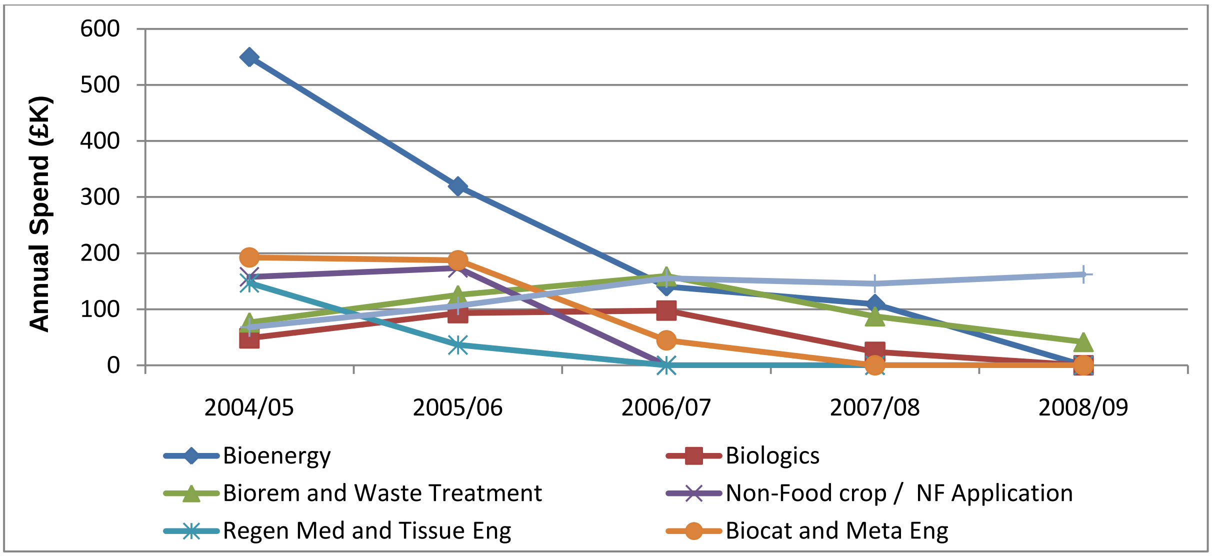
21. BBSRC is one of a number of government sponsors of IB (see **Annex 1**); it makes a unique contribution through the support of basic, strategic and applied research and training in all aspects of the *bioscience* that underpins IB, providing the biological models and technologies to enable future exploitation. The exploitation routes in the future will involve greater use of systems-level approaches and increasingly synthetic biology methodologies, both of which are key areas for current and future BBSRC investment.

22. BBSRC shares parts of its IB portfolio with EPSRC (chemical biology, process engineering technology) and NERC (environmental and marine biotechnology) with DEFRA and DECC (under LINK) and TSB (Biosciences and Sustainability Strategies). Further sharing of responsibilities occurs at the interface with MRC in the bioscience underpinning tissue engineering (see **Annex 1**). BBSRC has worked successfully with these organisations in the past (through collaborative programmes such as the research council industry clubs) and should continue to work with other sponsors to explore the possibility of aligning funds for IB research in order to gain maximum benefit.

**Collaborative funding with industry**

23. Formal interactions (involving collaborative funding of research) with industry in IB are featured in the Industrial Partnership Award (IPA) scheme of the responsive mode, LINK, the industry clubs and CASE studentships. A number of informal interactions which include some level of collaborative funding also exist but this has not been possible to quantify.

**BBSRC Annual Spend on IPAs by Research Area**




24. The evidence available (see graph) suggests there is a declining level of interest in the IB community for the BBSRC IPA scheme. The amount spent on IPAs in IB in 2008/9 was £475K. The reduction in interest in IPAs in the areas including biologics and tissue engineering is probably connected to the industry spend under BRIC: the annual spend on research projects funded under BRIC in 2008/9 was £3.0M (see **Annex 2**).

25. The current LINK schemes (which are being slowly phased out) support a limited number of projects either as a stand-alone scheme (where BBSRC is the only public sector partner) or as collaborations with DECC and DEFRA . The amount spent on LINK projects relevant to IB was £440K in 2008/9. In their current forms, neither the LINK mechanism or the IPA mechanism is likely to meet BBSRC's future needs in collaborative working with industry in IB.

26. The BBSRC managed "club" mechanism appears to be popular in the community because it focuses industry and research council support in a given area for a fixed period and builds a community around a scientific subject. However, this approach is not applicable to all areas: sustaining the community beyond the period of the club may require continued access to directed mode funding and the mechanism is highly

resource intensive, so its use must be restricted to meeting very specific industry requirements. The only other formal collaborative schemes BBSRC currently supports with industry that is capable of providing a recognisable volume of support each year is CASE studentships. If BBSRC is to increase the volume of its formal collaborative funding with industry in IB, it is likely that a revision to the current industry engagement mechanisms will be required.

27. One major feature observed by the Panel is the lack of a clear "pull" from the UK chemical industry for both the biological models and the associated biotechnologies of IB. This is probably because biologically-derived industrial chemicals are currently more expensive to produce than their fossil fuel- derived equivalents. The examples of recently commercialised biologically-derived industrial chemicals reviewed by the Panel (covering 1,3 propanediol and isoprene) were developments from the interaction between large companies (DuPont and Goodyear respectively) and SMEs which appear to have produced competitively-priced alternatives. This suggests that if BBSRC wishes to be influential about the translation of new products or technologies supported through its research funding (eg using systems and synthetic approaches) in this sector, direct interaction with SMEs is likely to be the most advantageous approach. Reticence about using IB and the associated new technological approaches in the chemicals industry has also been observed in the work of the BIS supported IB-IGT activities. Improved communication (and consequently knowledge of industry "pull") with representatives from UK based SMEs and chemical companies could lead to the more rapid uptake and translation of IB in the UK (see Recommendation 5).

**Training**

28. BBSRC has a relatively large investment in places on Masters' courses that develop skills in IB (13 out of the 57 places awarded for courses starting in 2010 fell into the BBSRC description of IB) and the Panel welcomed this investment. However, there is a relatively low level of investment in support for PhD places in IB. The portfolio analysis was able to identify 50 current studentships in the sub-areas that comprise IB of which approximately one third are CASE studentships. If the investment in studentship numbers were scaled to the current (but inadequate) investment in the grant portfolio, BBSRC should expect to have at least 150 current studentships in the areas that comprise IB, indicating that there is considerable disparity between the distribution of BBSRC training resources and research resources in IB. If BBSRC is to fulfil its unique position and contribute to increasing the *capacity* of the UK research base in IB in the coming years, the present distribution of BBSRC training resources will need to alter to ensure an appropriate volume of training to sustain UK capability in IB.

29. BBSRC currently supports six fellowships in IB (from a current total of c.68 fellowships) including three in Bioenergy, two in Biocatalysis and one in Tissue Engineering. These training awards are included in the analysis of research spend described in **Annex 2.** This level of investment is consistent with BBSRC's overall investment in IB (c.8% of investment overall) but the proportion involved with IB research should be increased in line with research grant funding if BBSRC is committed to providing the research leaders of the future in the IB area.

**Gaps in the portfolio**

30. A number of possible gaps in the portfolio have emerged from the analysis. These areas emerged because either the area has seen a rapid decline in funding, or that there were very few or no grants in a given area of activity that was identified as being important. The following areas were identified as gaps in the portfolio:

- Marine biotechnology
- Bioremediation
- Anaerobic microbiology
- The microbiology of organisms in industrial chemicals manufacture
- Next generation biofuels

31. In the case of marine biotechnology, bioremediation and anaerobic microbiology, these gaps were not regarded as being of sufficient priority to recommend specific remedial actions. (The gap identified in biofuels and industrial chemicals manufacture is identified below).

## CONCLUSIONS AND RECOMMENDATIONS

32. BBSRC is the principal public sector sponsor for research and training in IB covering the biological models and the associated biotechnologies for their exploitation. This sponsorship is of great importance to the future of the UK because this research will lead to new forms of energy, chemicals and therapeutics contributing to increased sustainability and with an estimated value to the economy of between £4B and £12B by 2025 (quoted in *IB 2025*). The financial support provided by BBSRC to IB research overall (with the exception of Bioenergy) is either stable or declining. If BBSRC is to help the UK realise both the sustainability aspects and economic value of IB, it will need to reverse this decline through increased funding to IB research, training and knowledge exchange in the coming years.

## GENERAL RECOMMENDATIONS

***Recommendation 1:*** BBSRC should increase the size of its IB portfolio as a proportion of its total budget

33. The Panel expressed concern that although IB was featured in the BBSRC Strategic Plan as a strategic research priority, it was not recognised as a strategic priority in the current set of council-wide research and policy priorities for research grants and training awards. In particular there was concern that applications in the area of IB were not currently eligible for the strategic longer larger grant scheme.

***Recommendation 2:*** To ensure that IB is recognised a priority for BBSRC funding, and is eligible for all forms of funding, BBSRC should establish IB as a new council-wide research priority.

34. The Panel expressed concern about the perception that it was more difficult to obtain responsive mode funding in IB than in other areas, due to the more strategic, applied and in some cases non-hypothesis driven nature of the research.

***Recommendation 3:*** BBSRC should review its systems for ranking responsive mode grant and training proposals to ensure that strategic and applied research can be supported through these routes and that the appropriate expertise is available to assess applications in the area of IB.

35. In relation to the above, it was suggested that one of the reasons for the decline in the size of the IB grants portfolio could be that there was a lack of awareness of the importance of IB and its contribution to sustainability and the low carbon economy.

***Recommendation 4:*** BBSRC should promote IB nationally and internationally through all forms of BBSRC literature and its website, to raise the awareness of IB as a strategic priority both within the office and externally. Promotion of IB should involve working with a range of interested groups including other research councils, knowledge transfer networks, learned societies and trade associations.

36. At present there is no formal route through which current investments and future priorities in the areas that comprise IB can be brought together and analysed on a continuing basis, as befitting a strategic priory area, thus:

    ***Recommendation 5:*** BBSRC should provide leadership in IB research, training and knowledge exchange and establish an advisory panel, including representatives from the key areas covering the interests of academia, industry and the international community, to advise on how to prioritise and implement the evolving strategy in IB and to monitor its progress over the lifetime of the current strategic plan (2010-15). The panel would be responsible for identifying priorities within the main areas of BBSRC's IB portfolio for targeted investment, particularly focusing on the production of industrial chemicals.

37. BBSRC's formal mechanisms for promoting interaction with industry in the area of IB are currently unable to demonstrate satisfactory levels of interaction and translation of ideas with the private sector. Thus:

    ***Recommendation 6*:** BBSRC should seek to identify, develop and promote new and existing mechanisms for working with the private sector which can assist in the translation of the research that it supports. BBSRC needs mechanisms for working with companies where the evidence for translation can be clearly demonstrated.

## TRAINING AND DEVELOPING FUTURE RESEARCH LEADERS

38. The IB training portfolio is even smaller (relatively) than the research grants portfolio. To ensure future capacity to undertake in IB research, BBSRC will need to increase the size of its IB training portfolio. The importance of industrially relevant training in the area of IB was noted.

    ***Recommendation 7 :*** BBSRC should be more strategic with the allocation of training resources and seek to increase the size of its training portfolio in IB, proportional to BBSRCs overall level of investment in IB. In particular, BBSRC should seek to ensure that a significant proportion of training in IB is industrially relevant.

## RESEARCH PRIORITIES

39. Industrial Biotechnology is broad area, receiving significant investment internationally and through the private sector. It was agreed that BBSRC should focus its funding on the research areas where it can make the most difference and which are likely to have the greatest impact for the UK, economically and socially. The priorities for future development are described below.

### Biocatalysis

40. The UK community is relatively strong in biocatalysis but the BBSRC portfolio is mostly focused on the needs of the pharmaceutical industry. A major challenge in this area is to build on the current strengths and encourage projects involving the production of industrial chemicals from living organisms. This is an area where cross-disciplinary research involving biologists and chemists, as well as integration with the chemicals industry is of particular importance.

***Recommendation 8:*** BBSRC should promote collaborative approaches in the area of industrial chemicals production from living organisms and should facilitate the bringing together of cross-disciplinary research teams with industry to develop programmes of industrially-relevant research. An ideas factory-style approach may help to bring together the relevant teams, and the use of industrial facilitators would ensure that resulting research proposals tackled industrially relevant questions.

**Bioenergy**

41. Bioenergy is an area in which there is considerable international and private sector investment. However, BBSRC still has the potential to remain a key player in this field, as it is able fund underpinning research which can contribute to longer term challenges that industry is less able or prepared to investigate.

42. BBSRC's current bioenergy portfolio is currently heavily focused on the BSBEC activities, primarily involving ethanol and butanol production; research on $3^{rd}$ and $4^{th}$ generation bioenergy production was a gap in the portfolio that it was considered important to address.

    ***Recommendation 9:*** BBSRC should seek to diversify its portfolio of fundamental, underpinning research to focus more on next generation sources, in particular the generation of straight and branched chain alkanes from living organisms, as direct replacements for petrol, diesel and aviation fuel. The use of systems and synthetic approaches will be of particular importance in delivering this aim. Redrafting BBSRC's current council-wide priority in bioenergy may be one way in which such diversification could be encouraged.

**Biologics**

43. Supporting bioprocessing research, training and knowledge exchange will remain an important part of BBSRC support for the biotechnology industries in the coming years. However, there were concerns that this cannot be effectively supported through responsive mode due to the more strategic nature of the research and that further support through directed mode may be required to ensure that the value of previous investments is not lost.

    ***Recommendation 10 :*** BBSRC should consider the most effective mechanisms of support for bioprocessing research, including the possibility of further directed mode funding, to ensure that the capacity and industrial linkages built through recent directed mode activities are not lost.

**Non-food crops**

44. There is a requirement for the UK to develop processes to increase the production of high value chemicals from plants. As the primary funder of plant science research in the UK, BBSRC could help to co-ordinate the UK plant science research community by encouraging the translation of fundamental plant science research (including knowledge from model plants such as *Arabidopsis*) into economically useful plants (food and non-food).

    ***Recommendation 11:*** BBSRC should seek to co-ordinate and build upon the current expertise in the UK plant science research community and expand research in the area of non-food crops by encouraging plant scientists and breeders to translate their research towards more industrially relevant non-food areas. This should involve encouraging plant scientists to work alongside engineers to ensure traits are selected for improved processing as well as for desirable end products.

**Annex 1**

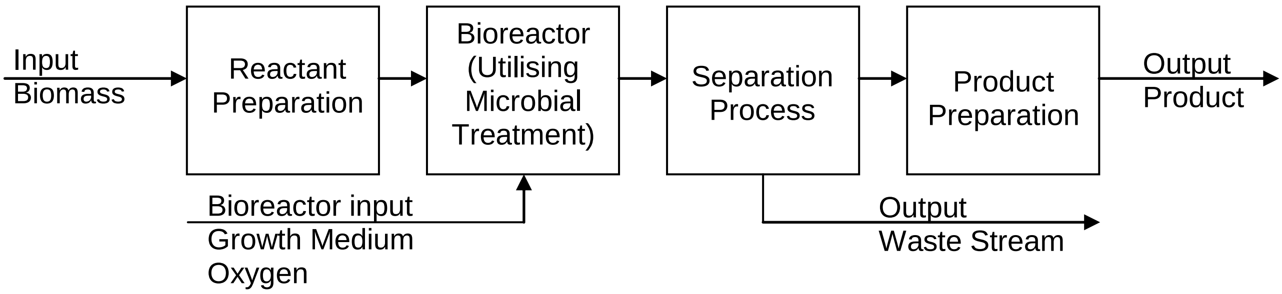
## SCOPE FOR INDUSTRIAL BIOTECHNOLOGY WITHIN BBSRC

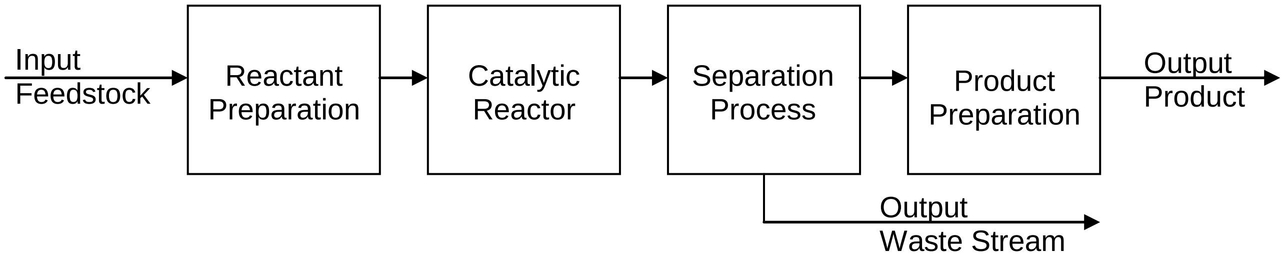
### INTRODUCTION

1. There exist a number of definitions of IB which potentially include a wide range of different technologies and industrial sectors. BBSRC accepts that IB is a broad sector and adopts the IB-IGT definition from May 2009 for completeness and because it acknowledges this breadth. Due to the relatively limited amount of funding that is available, it may not be possible for BBSRC to make meaningful investments in this diverse range of areas. In addition, BBSRC's remit is limited to a specific set of technologies within IB, so that to fully address research needs underpinning IB, it will be necessary for BBSRC to co-operate with other relevant research councils. For this reason, the scope of IB research and technologies within BBSRC's remit will now be considered.

### Processes and Technologies associated with Industrial Biotechnology

2. Broadly speaking, IB that makes use of biological resources for processing feedstocks will follow one of the two following process flow diagrams, depending upon whether microorganisms or enzymes are used:




3. The input and reaction stages are those that are most likely to use BBSRC funded science. The separation, reactant preparation and product preparation stages may make use of biotechnology as well.

4. The Input stage may rely upon biomass feedstock, which may be derived from non-food crops, algae and the biological components of waste or chemical feedstocks. The reaction stage may involve the use of microorganisms, which must be identified and potentially altered to improve yield and to suit the reactor environment. Enzymes may also be used and these must be identified and generated beforehand. In addition to this, BBSRC funded science may be used to identify potential products.

5. The reactant preparation stages may make use of separation technologies or even bioconversions to get the reactants to a suitable state of purity and concentration.

6. Downstream of the reaction step, there will be separation and preparation stages that are required to deliver the product at the correct purity and state. Physical or chemical processes may be used to achieve this as well as biotechnological processes. Often the non-biological processes make use of technologies that are within the scope of EPSRC and so it is not unusual for cross-disciplinary collaboration to take place at this interface.

7. For BBSRC funding to have the most impact it is better to support science that generates technology that underpins a variety of different processes. As can be seen here, feedstock generation, microbiology, fields relating to the use of micro-organisms in bioreactors, and enzymology are areas with wide potential impact across the biotechnology industry.

8. EuropaBio defines areas of biotechnology by the product that is generated and the science and technology used, as well as by the origin of their biomass or organisms. There does not seem to be any reason to definitely exclude biomass or organisms from any specific source from being used in IB, especially as doing so could needlessly limit the biological resources available to industry. For this reason, it is suggested that an origin-based definition would not be desirable. The potential products of IB are so wide that a product-based definition could become outdated as new uses for this technology are found. As a result, developing a scope for IB that is focused upon the technologies and science required to underpin IB is preferable. Furthermore, as BBSRC would be involved in funding scientific research and the development of technologies, this approach could be the most practical when deciding whether a grant is within the scope of IB.

**Table 1: IB technologies and their associated biological resources**

| Technology Types | Biological Resources |
|---|---|
| Biocatalysis | Enzymes |
| Biodesulphurisation | Bacteria |
| Biofiltration | Algae, Bacteria |
| Bioleaching | Bacteria, Enzymes |
| Bioprocessing | Bacterial, Enzymes |
| Biopulping | Bacteria, Fungi |
| Bioreactors | Algae, Bacteria, Yeasts |
| Biosynthesis | Algae, Bacteria, Yeasts |

9. In Table 1, it may be seen that technologies associated with IB are typically resourced through the use of microbes and enzymes. This ties into the IB-IGT definition from December 2008, which explicitly states that: “IB involves the use of enzymes and microorganisms to make products”. It is clear that further development in IB will be dependent upon progress in microbial sciences and enzymology.

**Industrial Biotechnology and the Pharmaceuticals Sector**

10. The May 2009 definition of IB from the IB-IGT matches the BIS definition and considers IB to be the use of biological resources for producing and processing materials, chemicals and energy. The definition goes on to mention how IB uses biotechnological knowledge to develop processes for making products such as industrial enzymes or chemical building blocks (platform chemicals). The December 2008 IB-IGT definition explicitly identifies the Pharmaceutical Industry as a sector which involves IB. As

discussed earlier, BBSRC funds research into bioprocessing and the basic science involved in the identification of bioactives. The kinds of technologies included, such as fermentation, cell culture, tissue engineering, separation processes and so on, are similar to the kinds of technologies required for IB and are often at more advanced stages of development in the pharmaceutical sector. As a result, aspects of the manufacturing process for pharmaceuticals are within the scope of BBSRC's activities in IB, although they may sit outside of commonly accepted definitions of IB which are based upon products rather than processes.

**Biomass and Industrial Biotechnology**

11. The generation of feedstocks is not typically included in a discussion of IB, however BBSRC already funds research into the growth of non-food crops (green biotechnology) as a source of feedstocks for bioenergy through BSBEC which was an outcome of the bioenergy strategy.

12. In March 2006 BBSRC conducted a strategic review of its involvement in the bioenergy sector[6]. The six fundamental research challenges that were identified in the review fell into two categories, photosynthetic carbon fixation and biomass processing and utilisation. The challenges were summarised in two tables and are presented at the end of this paper in **Appendix 1**.

13. Each of these challenges is directed towards the development of biofuels. If biofuels were successfully delivered then there would be a number of developments that would benefit the IB sector more broadly. Examples would be the creation of a sustainable supply-chain of biomass and the creation of a series of biorefineries which would generate waste co-products that would act as feedstocks for other processes.

14. The biomass processing and utilisation challenge is being addressed in BBSRC primarily by the activities of BSBEC along with industry clubs such as the IBTI Club and BRIC. The industrial members influence the direction of research within these clubs, and so the IBTI Club is focused more upon the conversion of biomass to biochemicals and biomaterials, whereas BRIC is concerned more with the development of protein and cell therapies through bioprocessing. Strategic research programmes at BSBEC are meeting other aspects of this challenge.

15. Reliable and sustainable sources of feedstock will be vital for the success of bulk biofuels, biochemicals, and other products, such as the use of hemp in producing hempcrete; a renewable building material. BBSRC's commitment to food security means that it is desirable for us to support the investigation of alternative crops that could alleviate land-use pressures. As BBSRC's current bioenergy strategy involves the development of non-food crops, it is clear that this must remain within the scope of our IB activities, especially as BBSRC is one of the few organisations able to fund this research.

16. It is also worth noting that other sources of biomass, such as the biological components of waste and aquatic or marine organisms, such as algae are, potentially, a significant source of biomass. Currently, the main use of marine biotechnology is as a source of bioactives for pharmaceuticals and nutraceuticals, bioremediation, and also as a potential source of biomass for bioenergy. These areas are within the scope of IB for BBSRC.

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[6] http://www.bbsrc.ac.uk/organisation/policies/reviews/scientific_areas/0603_bioenergy.pdf

17. Biomass feedstocks may also be utilised through chemical or physical processes that do not make use of bioscience. These processes could be suggested to be outside of the scope of IB for BBSRC, however, their continued development may deliver benefits to industry, and so the research in these areas should be supported. Cooperation with EPSRC allows BBSRC to fund multidisciplinary research programmes and provide more comprehensive support to IB research. A current and successful example of this is the IBTI club. BBSRC was able to broaden the areas of research that could be supported by the club; this enabled EPSRC to participate which led to the club's funding being significantly increased. There are other aspects of IB that fall outside of BBSRC's scope but which may be supported by other research councils. For example, the sustainability issues surrounding the growth of non-food crops and the effects of land-use change upon the natural environment would be an area of interest to NERC. Similarly, issues surrounding the adoption of biofuels, such as economics and social acceptability would be within ESRC's domain.

18. Delivering a holistic strategy for IB research will require coordination with other research councils, and could become a focus for the development of multi-disciplinary, cross-council activities.

**CONCLUSIONS**

19. As the IB-IGT report is a key driver for BBSRC's interest in IB it is desirable that BBSRC's scope for and definition of IB relate to those set out by the IB-IGT. BBSRC also has a role to play in encouraging the use and development of IB as a way to improve the sustainability of manufacturing processes either through replacing non-renewable feedstocks or otherwise by, for example, reducing the energy demand or waste streams of a manufacturing process.

20. The IB-IGT provides a definition of IB that is "the use of biological resources for producing and processing materials, chemicals, and energy". The resources include plants, marine life, fungi and micro-organisms. The definition goes on to cover working at the molecular level and the ability to work within cells, tissues and whole organisms. The previous section discussed the scope of IB for BBSRC within the core areas relating to the definition provided by BIS.

21. The key public sector sponsors with whom BBSRC shares responsibility for this area includes EPSRC, NERC and TSB as well as DEFRA and the Department of Energy and Climate Change (DECC). This area would form the core of any BBSRC activities in industrial biotechnology.

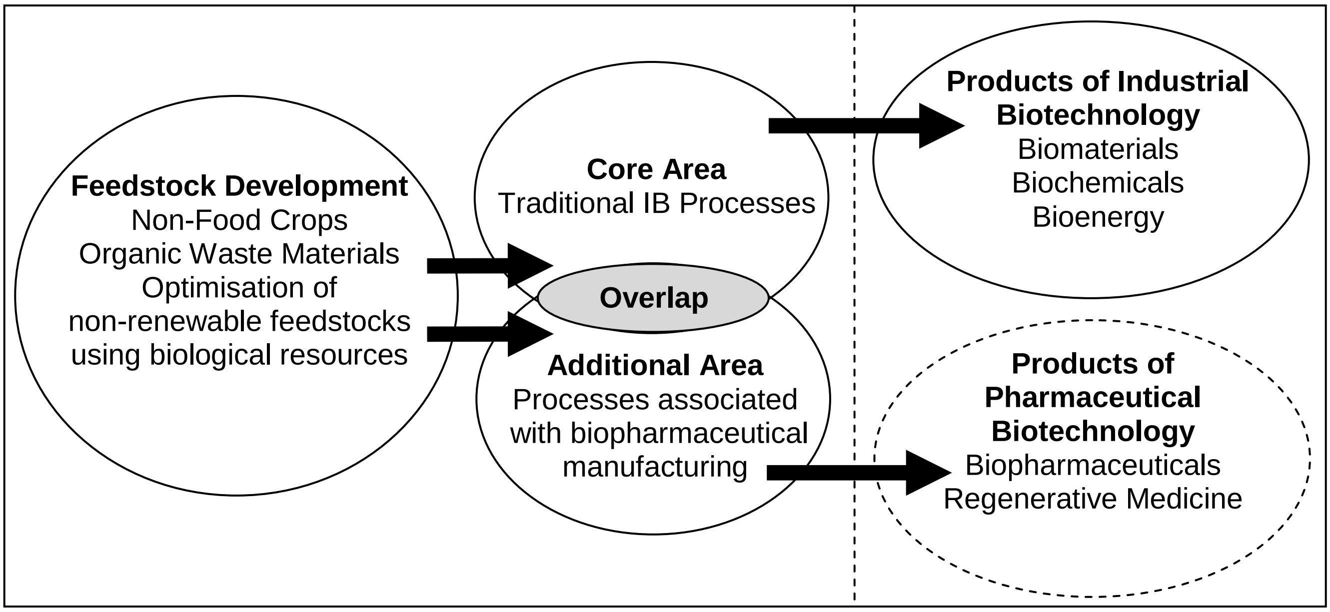



**Figure 1: Representation of BBSRC's support for IB**

22. It is often the case that definitions of IB do not include the synthesis and manufacture of advanced biological products for the pharmaceutical industry, such as biologics (e.g. proteins or other high molecular weight chemicals) or cells and tissue engineered products (sophisticated materials), and furthermore, individuals within this sector often would not regard themselves as working within the industrial biotechnology sector, as it is often associated with ‘red’ or ‘medical’ biotechnology.

23. These biological products are of importance to the future of high-technology manufacturing and this is reflected in BBSRC’s support for BRIC, and the TSB Regenerative Medicine programme, which is described in the Strategic Plan. Furthermore, these areas of manufacturing have been assigned to BBSRC in the new cross-cutting priority “Health and Well-being”, and have a wide applicability outside of the pharmaceutical sector. Due to these considerations, it is desirable to include these technologies within the broader scope of IB for BBSRC, as additional areas which lie outside of the core, but are still critical to BBSRC’s support for IB, due to the large amount of connectivity between the technologies underpinning these sectors and those which are typically associated with IB. The key public sector sponsors with whom BBSRC shares responsibility for these additional areas include EPSRC, MRC and TSB.

24. Both the core and additional areas of IB are connected to each other through a set of process technologies. A key feature of BBSRC’s support for this sector should be the focus upon these processes, and the fundamental science that supports them, rather than any particular group of feedstocks or potential products.

25. As a result of these considerations, BBSRC adopts the definition of IB provided by the Department for Business Innovation and Skills (BIS), which states that: “industrial biotechnology is the use of biological resources for producing and processing materials, chemicals and energy. These resources include plants, algae, marine life, fungi and micro-organisms.” Within this definition of IB, BBSRC has identified the scope to include the application, for these purposes, of the technologies and biological sciences associated with the pharmaceuticals sector.

## APPENDIX 1 – RESEARCH CHALLENGE TABLES

These tables have been taken from the BBSRC Bioenergy Review of March 2006.

**Table 3: Fundamental research challenges and associated strategic outputs within the area of photosynthetic carbon fixation (and interacting pathways)** [7]

| Research challenges | Associated strategic output |
|---|---|
| **A.** Understanding efficiency of carbon sequestration and carbon fluxes in plants. | Production of high biomass crops. |
| **B.** Control of assimilate and biomass partitioning in plants. Including, notably, control of plant cell wall metabolism/composition (links to microbial processing- see Table 5). | Production of crops with high proportions of carbohydrate, sugar, protein or oil.<br><br>Production of solid plant biomass with manipulated chemical compositions, e.g. lignin, cellulose, hemicellulose; optimised for processing and the composition of derived fuels (e.g. biodiesel). |
| **C.** Understanding the control of growth rate. | Production of fast-growing biomass crops |
| **D.** Understanding the mechanisms of disease susceptibility and resistance. | Production of crops with greater and more durable disease resistance. |
| **E.** Agricultural systems context for carbon assimilation and partitioning. | Indirect factors that influence the system for carbon assimilation, e.g. water and nutrient availability and use, and strategic outputs, e.g. production of low-input crops. |

**Table 4: Fundamental research challenges and associated strategic outputs within the area of biomass processing and utilisation** [7]

| Research challenges | Associated strategic outputs |
|---|---|
| **F.** Integrated bioprocessing. Understanding and manipulation of processing conditions to maximise outputs. Including microbial metabolism: structure, function and interactions of proteins. | Discovery and/or engineering of enzymes, microbial strains and environmental conditions optimised for efficient biofuel extraction through the processing of raw or waste biomass.<br><br>Efficient, scaled-up production of biohydrogen from microbial fermentation.<br><br>Understanding the biological, environmental conditions for efficient, scaled-up bacterial photobiohydrogen and dark fermentative hydrogen production. |

[7] http://www.bbsrc.ac.uk/organisation/policies/reviews/scientific_areas/0603_bioenergy.pdf

## RESEARCH AREAS WITHIN THE PORTFOLIO

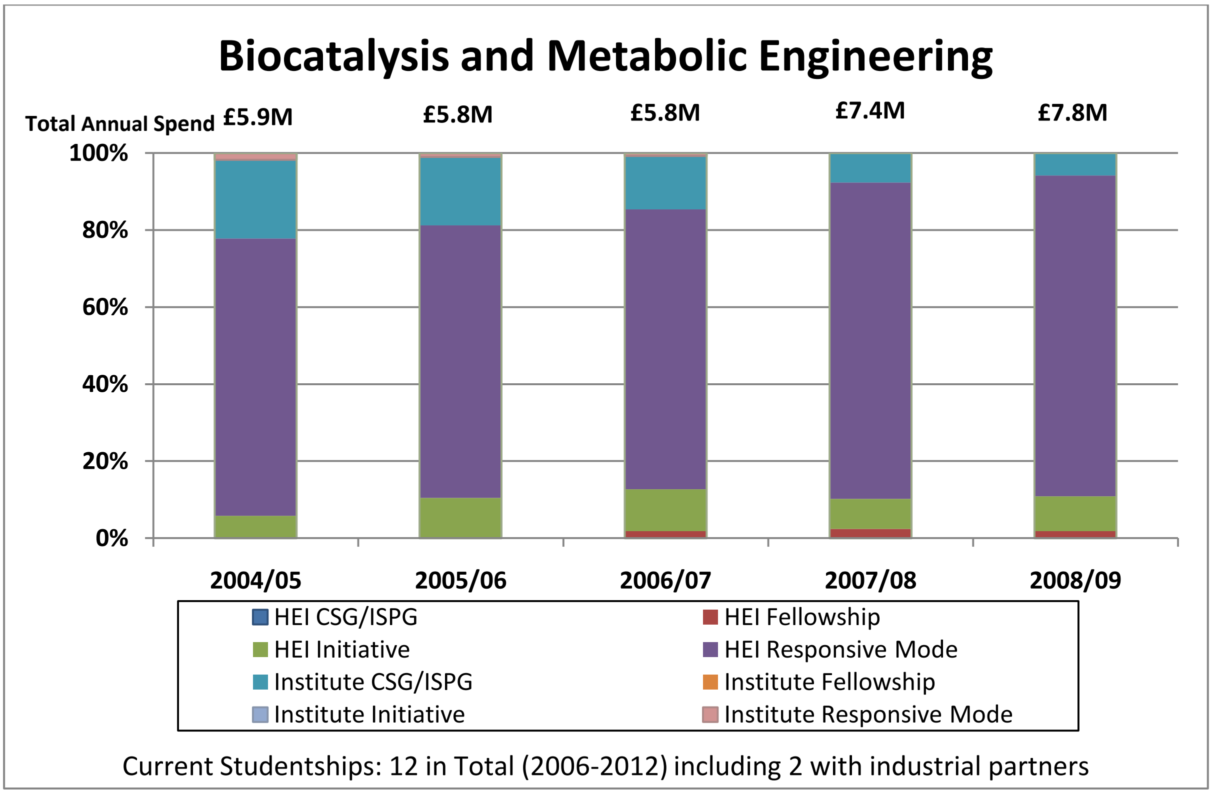
1. Under the sub-areas the Panel was asked to identify strengths and weakness within BBSRC's IB portfolio and the results are presented in this section.

### BIOCATALYSIS AND METABOLIC ENGINEERING

#### Definition

2. Biocatalysis refers to the use of either isolated enzymes or whole cells to carry out chemical reactions of industrial relevance. Biocatalysis has become a recognised way of carrying out specific reactions to produce for example high-value compounds with the correct stereochemistry or using whole cell approaches to produce platform chemicals to be used in manufacturing processes.

#### Annual Spend Chart




3. Biocatalysis and Metabolic Engineering is currently the largest area within the portfolio and all projects assigned to this area have a specific industrial application. The balance of responsive mode to initiative spending is fairly stable with initiatives accounting for between 10% and 15% of the total. The amount of research undertaken in institutes has decreased. In this area, Manchester, JIC, Oxford, Warwick, York and Rothamsted contribute significantly. There are currently 12 studentships working in this area.

#### Current Activity

4. The current portfolio covers the discovery of new and novel catalytic entities, the exploration of mechanisms and molecular structures to explain catalytic mechanisms. There are also projects on the production of useful enzymes from non-traditional

sources, such as plants, unusual microorganisms and pathways for secondary metabolite biosynthesis.

5. TSB, EPSRC, the Biosciences KTN and the Chemical Innovation KTN are potential partners in this area, due to its relevance to manufacturing and chemistry.

**Strengths**

6. BBSRC has a strong background in funding projects on individual enzymes. This support has led to the UK being internationally recognised as a world leader in protein structure determination, enzymology and structure-based design. As a result, the UK community can access funding from a variety of sources, and interest from industry has led to increasing private-sector research investments.

7. A particular strength in the UK is the discovery, biosynthetic elucidation and manipulation of structurally complex bioactive natural products. The UK has a long and distinguished history of researching these products which have particular uses as antimicrobials (eg those derived from *Streptomyces*), fungicides and anti-cancer drugs. BBSRC has been a significant supporter of research, training and knowledge exchange underpinning product discovery in this area over the last 20 years. Identification of new natural products and new catalytic activities from microbial biodiversity is an area for potential development with NERC.

**Weaknesses**

8. In the IB portfolio, there is an emphasis on products for the pharmaceutical industry while there is far less investment in whole cell based biocatalysis: projects on biofuels, industrial chemicals, materials or biorefinery feedstocks are in the minority. Examples of how other nations have invested in the production of bulk chemicals involved in the manufacture of eg plastics and car tyres from sustainable sources can be found in Otero and Nielsen, 2010; and Bozell and Petersen, 2010). The lack of projects on whole cell biocatalysis represents a significant weakness for the UK and will present difficulties if the UK is to meet likely future requirements for platform chemicals from renewable resources.

9. Despite the obvious appeal of using biocatalysis in industrial processes, the Panel's industrial members felt that there was a cultural barrier in the UK chemicals industry that has limited the uptake of biocatalytic approaches to date. This barrier is currently being addressed by the special interest group of the IB-IGT.

**Opportunities**

10. The challenge to BBSRC is to maintain the strength and depth of the current portfolio such as the identification of new enzymes that perform more effectively or catalyse reactions that lead to novel products and also projects that build a greater understanding about the properties of enzymes, such as stability. Research projects should ideally seek to improve the interaction with engineers at an early stage of development.

11. Encouraging and supporting more projects that focus on both experimental and theoretical approaches to metabolism (such as construction of metabolic networks/genome scale metabolic models in both plants and micro-organisms, described in detail in Otero and Nielsen, 2010) will take away the hit-or-miss approach of the past and further promote the development of predictive and quantitative approaches in the community. This should provide the basis for improved whole cell

biocatalysis studies in the current timeframe and pave the way for future synthetic biology approaches in this increasingly important area.

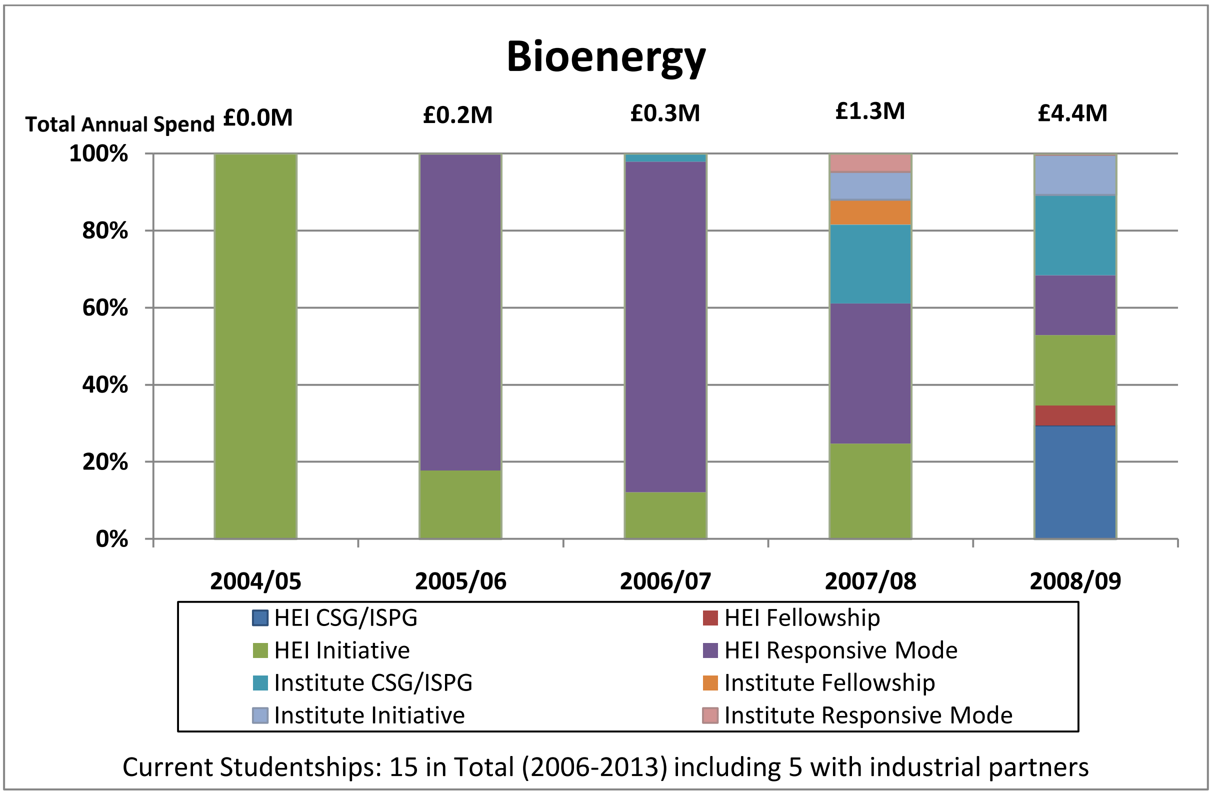
12. The UK has made an investment in pilot scale facilities to scale up processes at the Centre for Process Innovation (CPI) based at Wilton in the North East of England. This facility, part funded by government, is able to provide test facilities to help scale-up chemical and biochemical industrial process. A few BBSRC funded grants so far have led to the use of the CPI and in future BBSRC should hope to have more of its funded grants using the facility.

**BIOENERGY**

**Definition**

13. Bioenergy is the use of biological resources to produce energy through the generation of biomass or to process material to produce energy vectors. Research in this area can contribute to a variety of technologies such as co-firing, where woody biomass is used to supplement coal, or the production of liquid fuels such as ethanol or butanol.

**Annual Spend Chart**




14. Bioenergy has experienced considerable growth from 2004/05 to 2008/09, and the schemes which contribute to this growth have greatly changed. Initially initiatives accounted for all activity in this area however this has developed into a more varied mixture of funding with increased institute activity. Responsive mode funding has increased during this period, but much more slowly than other modes. Rothamsted, Nottingham, Aberystwyth, York, Dundee, Cambridge, Manchester, Warwick and UCL are all major research centres. The HEI CSG/IPSG funding in 2008/09 takes place at IBERS which is now located at Aberystwyth University.

**Current Activity**

15. BBSRC has a tightly focused portfolio in bioenergy, which includes investments in the BBSRC Sustainable Bioenergy Centre (BSBEC). The BSBEC research programme covers the selecting and growing of different biomass crops with desirable traits and the processing of this biomass into alcohols through fermentation. The programme also investigates the potential of using yeast or bacterial strains to ferment sugars leading to the production of ethanol or butanol, which have importance as potential fuels and also as platform chemicals (see Bozell and Petersen, 2010). Coupled to this is the integration with industry and scale up of processing which is currently being achieved through partnerships with the companies involved in BSBEC.

16. This area has a high profile in government and there are a number of potential partners; TSB, EPSRC, NERC and DECC are of particular relevance There is also potential for BBSRC to work with the Devolved Administrations in Wales, Scotland and Northern Ireland, as well as EU initiatives, such as the ERA-NET for Bioenergy.

**Strengths**

17. BBSRC undertook a Bioenergy review in March 2006[8] which led to a greater understanding of BBSRC's ability to contribute to this area. This was reflected in the establishment of BSBEC in January 2010.

18. Analysis of the existing portfolio suggests that there are strengths in this area relating to *Clostridium* systems biology and the analysis of the relationship between lignin content/composition and the ultimate ability to further utilize the carbohydrate fraction.

**Weaknesses**

19. There is significant investment in this area to a range of international groups from a variety of international sponsors so any investments that BBSRC makes will be in an area that is already well-supported. It is important that BBSRC identifies how any contribution it makes will be unique, and whether there are opportunities to leverage funding by identifying partner organisations. The current portfolio is focused on fermentation to alcohols and greater diversity in the portfolio will need to be achieved in the coming years

**Opportunities**

20. There has been significant growth in this area due to initiative funding. However, it will be necessary to consider how the portfolio in grants, fellowships and studentships is to be developed, particularly in preparation for when the initiative funding ends. Preserving the current investment in bioenergy (and potentially including the Non-food Crops and Non-food Applications) through the institute programmes may be best achieved through a cross-institute programme and such a mechanism should be explored in the future.

21. BBSRC has recently assumed responsibility for Bioenergy under the RCUK Energy Programme with the aim of co-ordinating and directing future bioenergy research in the UK. The BBSRC Bioenergy Champion will chair the cross- council panel and lead the development of the UK position in the coming months.

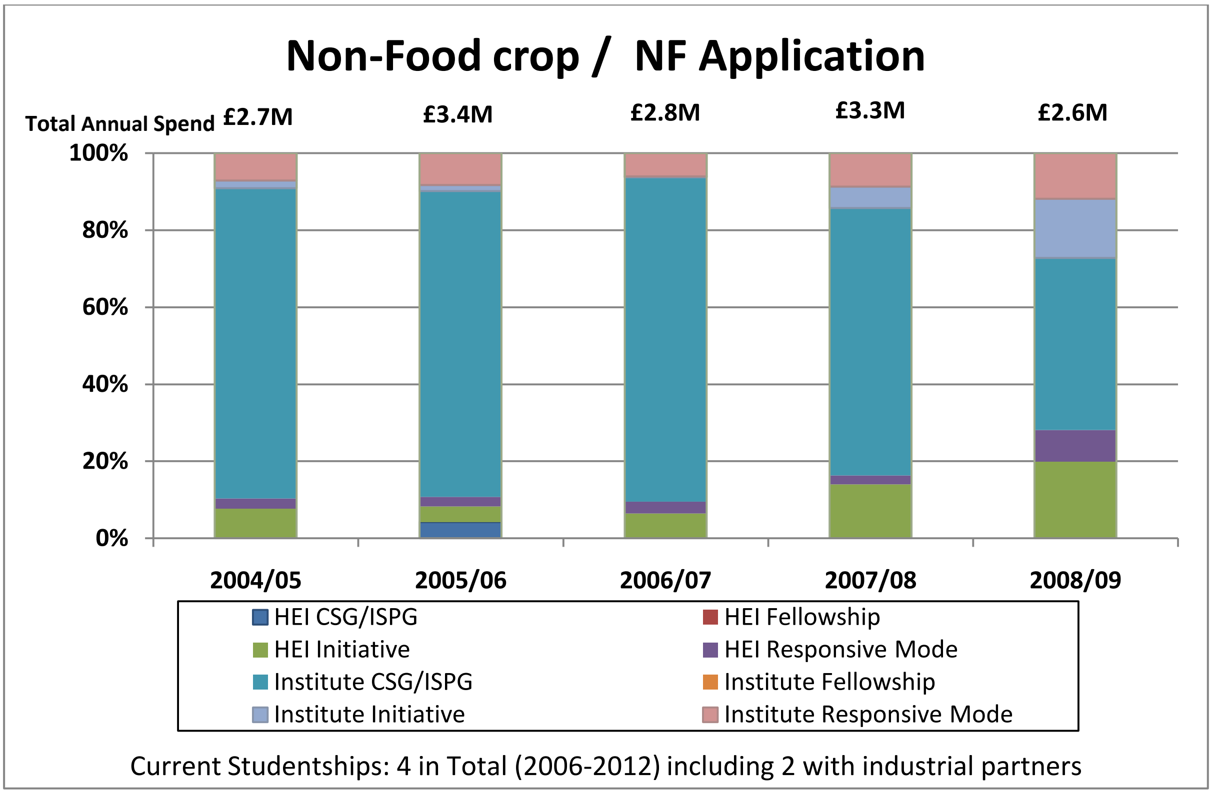
[8] http://www.bbsrc.ac.uk/web/FILES/Reviews/0603_bioenergy.pdf

## NON-FOOD CROPS AND NON-FOOD APPLICATIONS

### Definition

22. Research in this category focuses on the use of crops for purposes other than food production; there are many varieties of crops that are grown for non-food purposes, such as textile production (cotton, flax) and thermal bioenergy (willow, poplar and *Miscanthus*). Seed oils also have industrial uses as solvents or lubricants and the residues of food-crops, especially straw, which are suitable for non-food applications.

### Annual Spend Chart




23. This area of the portfolio has not increased significantly in value from 2004/05 to 2008/09. As a percentage of Annual Spend, Institutes account for the majority of this area. The majority of research takes place in JIC, Rothamsted and IFR.

### Current Activity

24. The projects in this area focus on a range of approaches for the production and exploitation of primary metabolites (starch, protein, oil) in plants and their partitioning into seeds. Most projects deal with cereal crops, brassicas and bioenergy crops. The approaches involve breeding for selected traits and in particular for specific properties of interest to industry (e.g. biodegradable film formation for starches, emulsifying properties of seed proteins and lubricant properties of seed oils). These projects use metabolic studies but appear not to routinely use modelling, simulation and prediction to explore how the pathways are controlled and thus offer limited future opportunities for synthetic biology approaches.

25. Potential partners in this area include NERC, DEFRA and DECC due to the effects of non-food crops on the environment including land-use change. The NNFCC is also prominent in this area.

**Strengths**

26. The UK has considerable strengths in the area of food-crop development that are highly relevant to this area. This is apparent in the presence of integrated collaborations between BBSRC institutes and affiliated universities in large-scale breeding programmes.

**Weaknesses**

27. The current research projects do not appear to link improvements in food and non-food uses for example improving both straw and grain quality in the same crop. There appears to be relatively little connection between plant breeding and processing; the knowledge of microbiologists, biochemical engineers and chemists is crucial in determining the desirable properties of non-food crops.

28. When compared to projects that focus on bioenergy production there appears to be a lack of research into crops as a feedstock for other applications, such as high value chemicals and bioenergy crops for the production of platform chemicals other than ethanol and butanol.

**Opportunities**

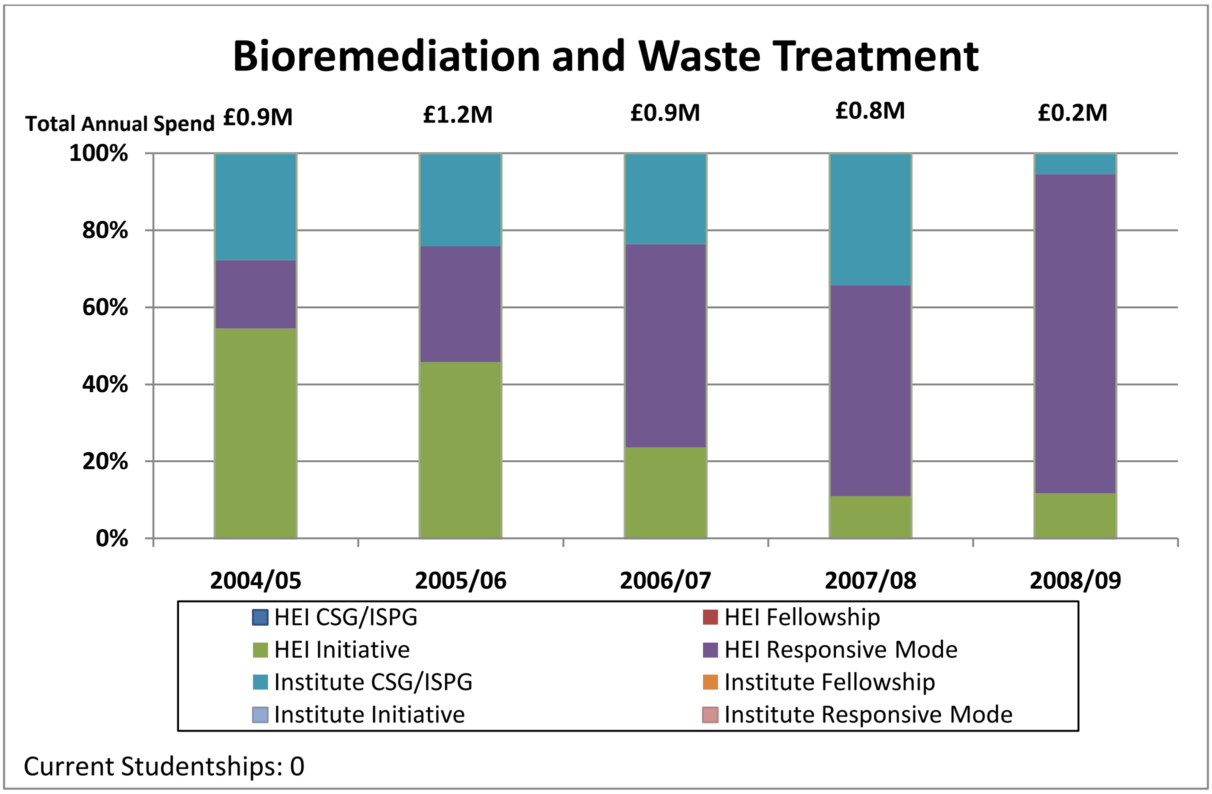
29. This area would benefit from the application of the knowledge and expertise currently applied in breeding for selected traits in **food crops** and the linking of research to the biorefineries concept. Non-food crops research would also benefit from increased multidisciplinarity, such as collaborative working with engineers to ensure the traits being selected improve suitability for processing. Working with natural product chemists should ensure the extraction of maximum value from phytochemicals. Collaborative work is also needed to monitor the impact of non-food crops upon the environment, due to land use change.

## BIOREMEDIATION AND WASTE TREATMENT

### Definition

30. Bioremediation is the use of biological resources to remove or reduce the prevalence of selected substances from the environment. Research in this area is often directed at using biological processes to overcome environmental problems, such as contamination or waste treatment.

### Annual Spend Chart




31. Spending in this area was largely sustained by the Bioremediation LINK programme, and as such, the activity in this area has decreased to a very low level in recent years. Rothamsted, Manchester and Sheffield have research efforts in this area.

### Current Activity

32. Bioremediation features in the IB portfolio as a relatively small collection of projects covering a range of different remediation strategies, such as using plants and micro-organisms, to treat organic solvents, chlorinated solvents, remediation of mine waters and metal ion contaminated sites, the removal of nitrogen and phosphorous from agricultural waters and the removal of selenium by microbial processes.

33. NERC, EPSRC and TSB are all potential partners in this area because of its potential relevance to environmental remediation and industry.

**Strengths**

34. Although few in number, the portfolio contains a variety of projects and has very clear applications; as a result of this any investments that BBSRC makes can have clear impacts on relevant user industries.

35. Bioremediation is of interest to other research councils; NERC features bioremediation under its remit through environmental microbiology and environmental biotechnology, as the use of biological tools for the monitoring, transformation and amelioration of the environment[9]. EPSRC also has interests in this area and participated alongside BBSRC in the LINK Bioremediation programme[10].

**Weaknesses**

36. The portfolio analysis clearly shows that the number of projects in this area has decreased dramatically from the 2005/06 financial year to the 2008/09 financial year BBSRC's limited activities in bioremediation are unlikely to lead to significant advances in this area.

**Opportunities**

37. The number of projects related to Bioremediation in BBSRC's portfolio is decreasing. As this area is of interest to NERC it may be that this research council is the key funder, rather than BBSRC. There appears to be a need to coordinate BBSRC's activities with NERC in this area and to remind the research community that BBSRC will support applications through stand-alone LINK.

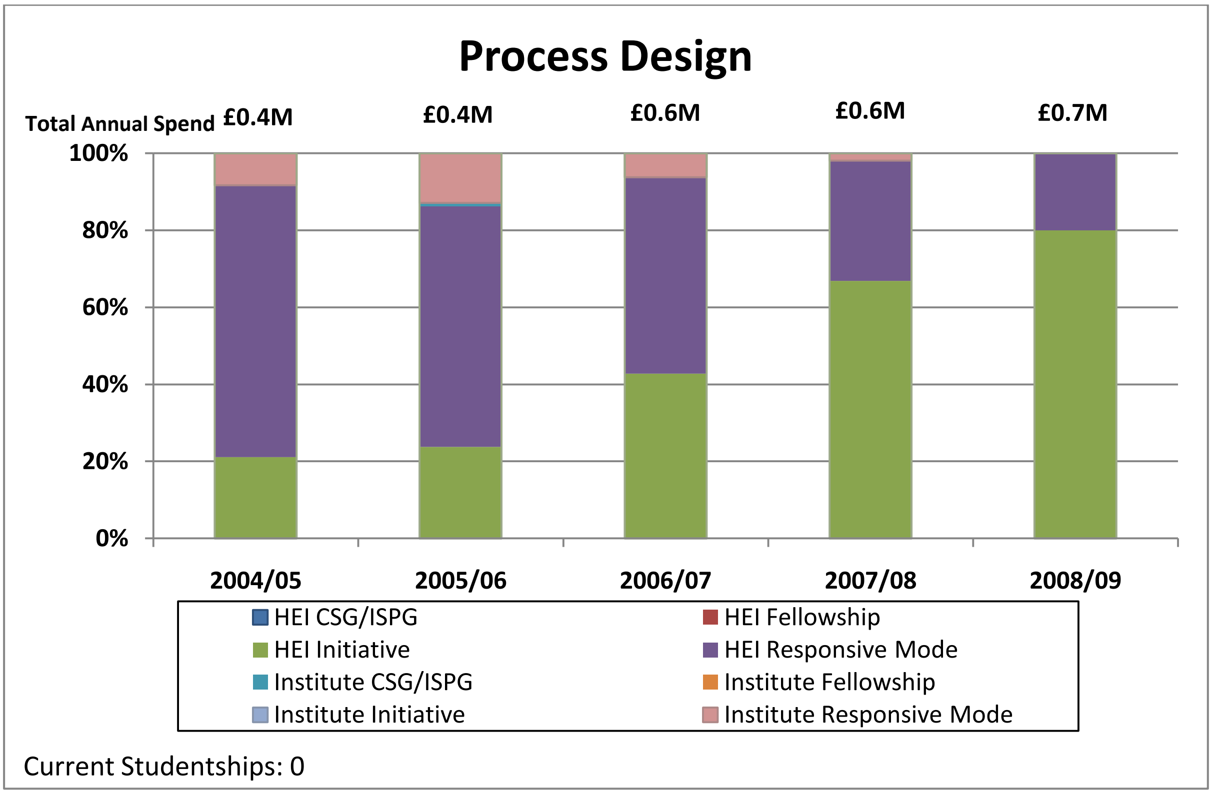
[9] http://www.nerc.ac.uk/funding/application/topics.asp
[10] http://www.clarrc.ed.ac.uk/link/

**PROCESS DESIGN**

**Definition**

38. Projects in this area aim to develop new processing equipment which can be used by industry. This includes bioreactors as well as the processes which are upstream or downstream of that unit, such as product treatment or separation units. Projects in this category usually have a clear industrial relevance.

**Annual Spend Chart**




39. Spend in this area has remained fairly constant over the period with UCL, Cambridge, Kent and Oxford Universities being the major research groups.

**Current Activity**

40. Research projects tend to deal with the development of bioreactors/fermentors and separation processes (especially chromatography columns). Most of the projects are multidisciplinary in nature and rely upon aspects of engineering or chemistry.

**Strengths**

41. This is an area where BBSRC should work with EPSRC. Projects in this area have clear industrial relevance; the majority of the projects deal with developing equipment that is directly relevant to industrial processes.

**Weaknesses**

42. Growth in this area is completely reliant on initiative funding, particularly from BRIC; responsive mode funding has decreased over the five year period.

43. The development of equipment which is able to process biomass or produce and separate biological products at an industrial scale is crucial to the transfer of research results to industry, however there is a question over whether this research is best funded by industry directly, or other organisations such as EPSRC or the TSB, or BBSRC in partnership with other groups.

**Opportunities**

44. There is an opportunity to coordinate our activities with EPSRC in this area to ensure that there are no gaps in funding and that there is clarity about the remits of the two research councils within the academic community.

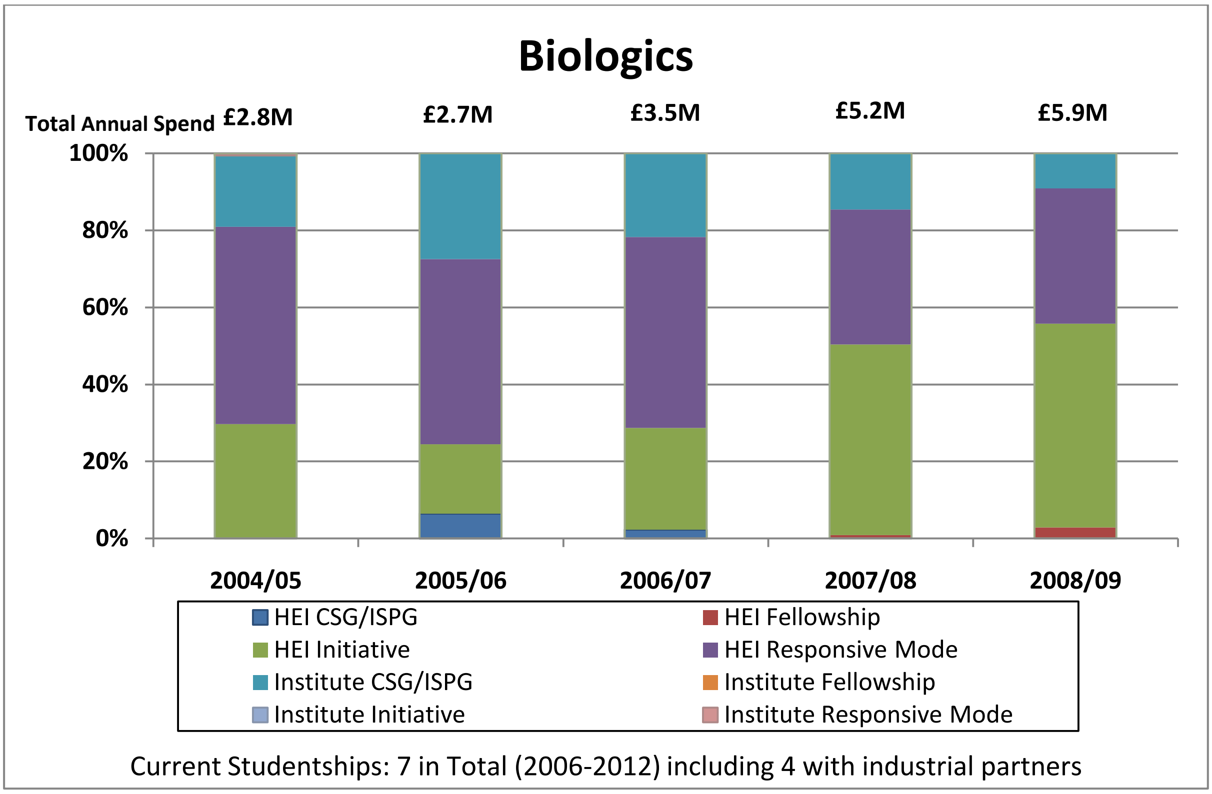
**BIOLOGICS PRODUCTION**

**Definition**

45. Biologics are a class of products comprising proteins, sugars and nucleic acids that have a medicinal application and are produced or extracted from a biological system. Biologics come in a variety of types, but often replicate the effects of substances already present in the body, such as key signalling proteins, (monoclonal) antibodies and receptor constructs.

46. As these products are of a medicinal nature they do not fit into BBSRC's stated definition of IB, however, projects relating to the production of these substances using biological resources have been included due to the potential for technology transfer to other sectors.

**Annual Spend Chart**




47. Annual Spend in this area has increased but seems to have reached a plateau in recent years. Between 2004/05 and 2008/09 responsive mode spend decreased while initiative spending increased as a proportion of the total. Cambridge, Oxford, Manchester, Rothamsted, Warwick and JIC are all leading centres in this area.

**Current Activity**

48. BBSRC currently has a small portfolio of projects, covering the characterisation and development of a range of expression systems for recombinant therapeutic proteins production including insect cells (baculovirus-based), chinese hamster ovary cells *Saccharomyces*, *Pichia*, *Aspergillus, Agaricus E.coli, B.subtilis and Pseudomonas.* The projects cover expression, glycosylation, secretion, down-stream processing to remove host cell proteins, protein extraction and purification techniques, the crystallisation and lyophilisation of purified protein and methods of assessing protein stability during processing. Increasingly, metabolic modelling approaches are being used in a

predictive way to understand how the biological processes are controlled to ensure the optimal rates of authentic protein production.

49. The TSB is a potential partner in this area due to its relevance to healthcare. There is potential for further co-operation with EPSRC in supporting research in the bioprocessing of biological products.

**Strengths**

50. Current research is focused on eukaryotic protein product systems and there is evidence of strong use of systems biology approaches. The existing themes, networks and interactions between groups lead to high quality science that reflects industry needs.

**Weaknesses**

51. There is comparatively little research on prokaryotic recombinant protein production systems and such an approach would be a worthwhile area to pursue.

**Opportunities**

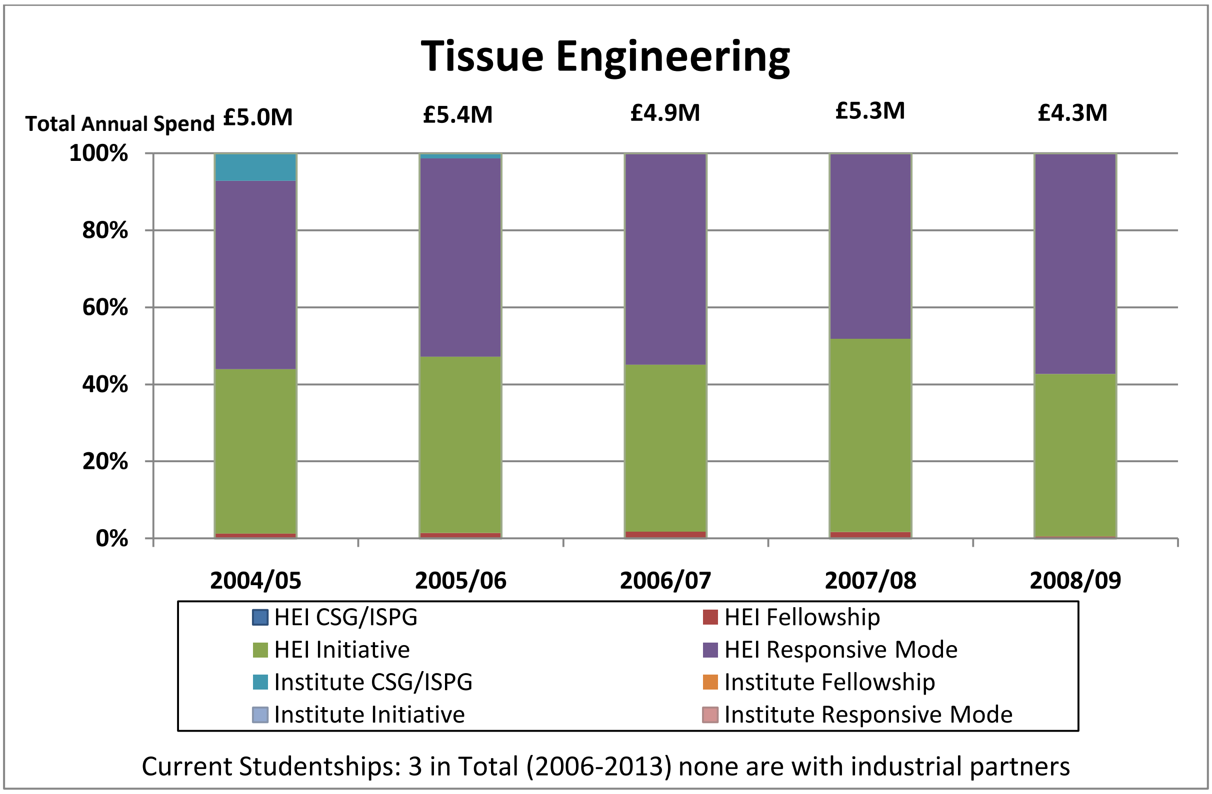
52. The focus of this area is the transfer of knowledge from the pharmaceutical industry to IB sectors, and many of the grants in this category have been sponsored through BRIC as a managed mode activity. Research and training on biologics is a key area for the pharmaceutical industry as many of the top drugs in the coming years are likely to be biologics. The challenge for BBSRC the future will be to provide continued support of this area through the directed mode (and responsive mode) where this is possible.

## TISSUE ENGINEERING

### Definition

53. Tissue engineering is a subject which focuses on the repair of living tissues. There are techniques and technologies associated with regenerative medicine, especially around cell culturing, scaffold technologies and bioreactors that are of relevance to industrial biotechnology.

### Annual Spend Chart




54. This data set does not contain fundamental research on stem cell biology. From 2004/05 to 2008/09 there has been a slight decrease in funding in this area, which is otherwise broadly stable. This stability continues in the balance of initiative to responsive mode spending, with initiatives between 50% and 40% of the total in this period. Manchester, Nottingham, Sheffield, ICL and Southampton are leading centres in this area.

### Current Activity

55. BBSRC has a strong history in providing grant funding to support research for stem cells an area that is currently strategically led by MRC and TSB. Currently BBSRC has a wide-ranging portfolio covering the basic underpinning of subjects such as wound healing, development of bone and cartilage replacements, growing tissues as mechanical units, engineering scaffolds and matrices for tissue replacements, bioreactor-based expansion of different stem cell types, non-invasive techniques for visualisation of stem cells *in vivo*, techniques for sorting cells and selecting cell types in culture, as well as grants to establish synthetic approaches to regenerative medicine.

**Strengths**

56. Analysis of the BBSRC's research portfolio has shown that the research funded by BBSRC in this area is already multidisciplinary in nature. BBSRC is the host of the UK National Stem Cell Network (UK NSCN) sponsored by BBSRC, MRC, EPSRC and ESRC which has done much to promote the integration between basic, strategic and applied research and business interest in the area of tissue engineering.

**Weaknesses**

57. The tissue engineering research funded by BBSRC is not fully focused on "industrial" problems.

**Opportunities**

58. The challenge for BBSRC is to maintain the diversity of the current portfolio whilst further integrating the basic science with engineering at an early stage and promoting development of collaboration with the private sector in research projects. This will be delivered by the activities within BRIC and collaborative programmes involving BBSRC, EPSRC, MRC and the TSB, promoted through UK NSCN.

**Annex 3**

## MEMBERSHIP OF THE BBSRC INDUSTRIAL BIOTECHNOLOGY EXPERT PANEL

The table below provides the membership of the Panel that was assembled in order to advise BBSRC on the development of its strategy for IB.

| Expertise | Nominee | M/F | Company/HEI |
|---|---|---|---|
| Chair | Fiona Marston | F | |
| Animal Cell Biotechnology | John Birch | M | Independent |
| Animal Cell Biotechnology | Mark Carver | M | Avecia |
| Microbial Biotechnology | Greg Challis | M | University of Warwick |
| Microbial Biotechnology | Gill Stephens | F | University of Nottingham |
| Plant Biotechnology | Rob Edwards | M | University of Durham |
| Bioenergy | John Pierce | M | BP Biofuels |
| Regenerative Medicine | Alicia el Haj | F | University of Keele |
| Biochemical Engineering | Surinder Chahal | M | Croda |
| Systems/Synthetic biology | David Fell | M | Oxford Bookes University |
| Systems/Synthetic biology | Andrzej Kierzek | M | University of Surrey |
| SME Biotech | Mike Dawson | M | Novacta Biosystems |
| Green Chemistry | James Clark | M | University of York |
| Chemical Engineering | Peter Fryer | M | University of Birmingham |
| Chemistry | Keith Wiggins | M | DOW Chemical Company |
| BIS Observer | Patrick Walsh | M | BIS |
| EPSRC Observer | Anne Farrow | F | EPSRC |
| TSB Observer | Merlin Goldman | M | TSB |
| NERC Observer | Simon Jackman | M | NERC |

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