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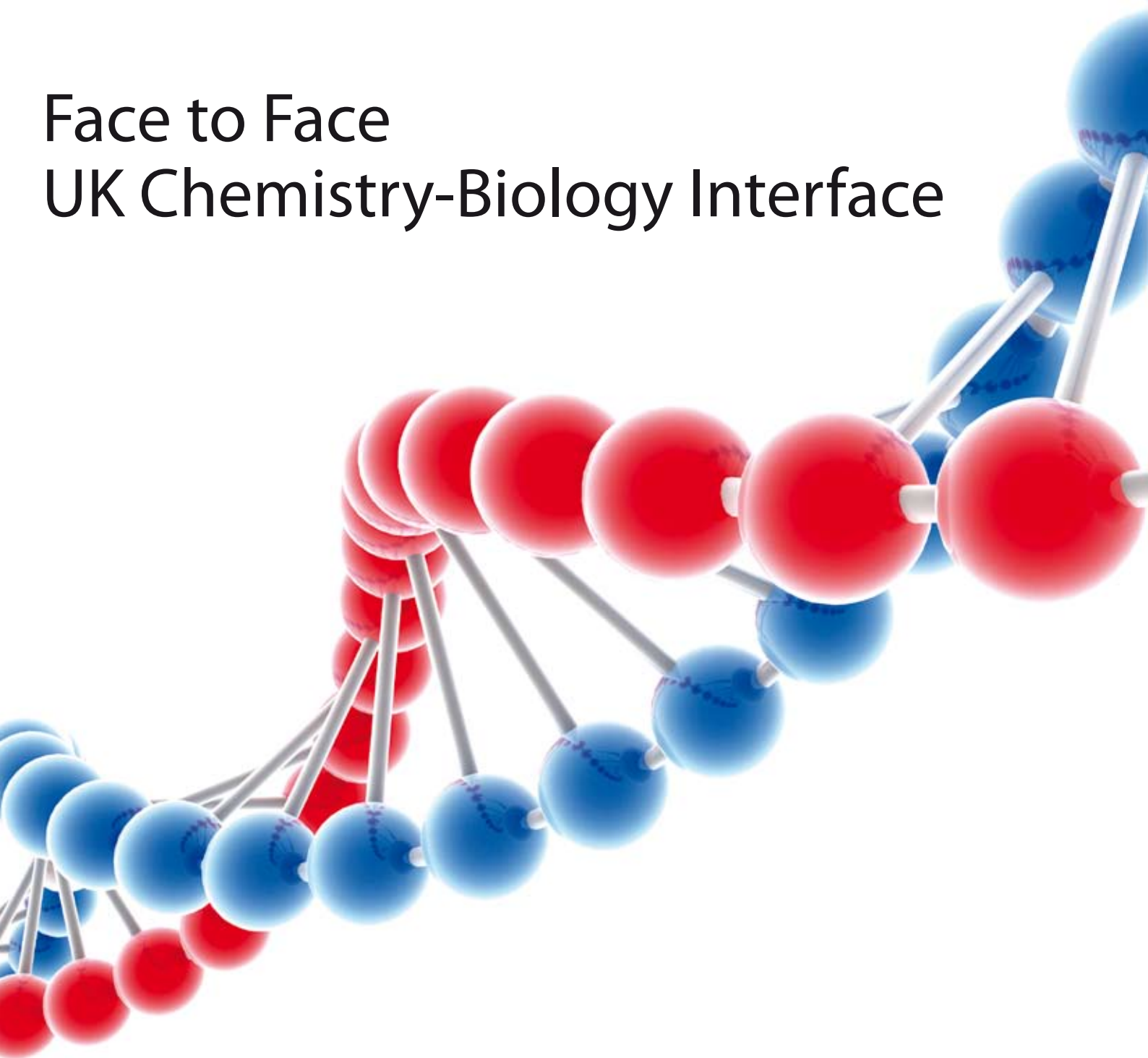
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# Face to Face UK Chemistry-Biology Interface



# Contents

<b>Acknowledgements</b>	<b>3</b>
<b>Summary</b>	<b>4</b>
<b>1 Introduction</b>	<b>8</b>
1.1 Background	8
1.2 Objectives	8
1.3 Method	8
1.4 Review of previous studies	8
1.5 Definitions	12
1.6 The report	13
<b>2 The respondents</b>	<b>16</b>
2.1 Introduction	16
2.2 Professional characteristics	16
2.3 Research areas	16
2.4 Reasons for working at the interface	17
2.5 Summary and conclusions	17
<b>3 Working practices</b>	<b>20</b>
3.1 Introduction	20
3.2 Working together	20
3.3 The role of chemists	21
3.4 Collaboration	21
3.5 Summary and conclusions	22
<b>4 Institutional support</b>	<b>25</b>
4.1 Introduction	25
4.2 Institutional support	25
4.3 Enabling research at the interface	25
4.4 Institutional barriers to interface research	27
4.5 Learning from industry	29
4.6 Summary and conclusions	30
<b>5 Research funding</b>	<b>33</b>
5.1 Introduction	33
5.2 Funding levels	33
5.3 Sources of funding	33
5.4 Funding programmes	34
5.5 Funders and funding mechanisms	35
5.6 Research Council remit	36
5.7 Writing applications	36
5.8 Reviewing grant applications	37
5.9 What could funders do?	38
5.10 Future researchers	39
5.11 Summary and conclusions	39
<b>6 Research at the chemistry-biology interface</b>	<b>43</b>
6.1 Introduction	43
6.2 Research areas	43
6.3 The nature of research at the chemistry-biology interface	45
6.4 The relationship between chemistry and progress in medical science	45
6.5 The state of chemistry-biology interface research	46
6.6 Hot topics	47

6.7	Research outputs	47
6.8	The future	48
6.9	Summary and conclusions	48
<b>7</b>	<b>The role of the RSC</b>	<b>49</b>
7.1	Introduction	49
7.2	Actions	49
7.3	Summary and conclusions	50
<b>8</b>	<b>Conclusions and recommendations</b>	<b>51</b>
8.1	Introduction	51
8.2	Working practices	51
8.3	Infrastructure and environment	51
8.4	Funding	52
8.5	The current health of chemistry biology interface research	53
8.6	Training of researchers at this interface	53
<b>Appendix 1 References</b>		<b>54</b>
<b>Appendix 2 Research method</b>		<b>55</b>
<b>Appendix 3 Research areas of support</b>		<b>72</b>
<b>Appendix 4 Institutional support</b>		<b>73</b>
<b>Appendix 5 Research funding</b>		<b>84</b>

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# Face to Face: UK Chemistry-Biology Interface

## Summary

### Background

In order to adequately represent the interests of the chemical sciences the Royal Society of Chemistry (RSC) wanted to have a better understanding of the role of chemistry in biological research today. People Science and Policy Ltd (PSP) was commissioned by the RSC.

### Objectives

The overall aim of this project was to deliver evidence to underpin recommendations to academic and other research institutions and to funding bodies in the UK regarding how best to foster high quality research across the chemistry-biology interface.

### Definitions

RSC and PSP used the following definitions in this project:

*Interdisciplinary research requires individual researchers to know about both chemistry and the biological science disciplines*

*Multi-disciplinary research requires people from both chemistry and the biological science disciplines to collaborate*

### Previous studies

Previous studies in the UK and the USA have made recommendations for funders, professional bodies and institutions that want to support interface research. Importantly, there is recognition in reports from the National Academy of Sciences (2004) and the RSC (2003) that funding such research presents significant challenges for funders.

### The respondents

Seven out of ten (69%) of the sample were either PIs, co or joint PIs and 77% had been in research for more than ten years. Half (52%) had chemistry first degrees, 14% had a biological science degree and 21% a biochemistry degree. Current research interests spanned a wide range of research questions.

### Working practices

The driving force behind working practices was the nature of the work being done and the contribution required from each discipline. Key to successful collaboration seems to be a shared vision of the objectives of the work and an acknowledgement that experts in both disciplines have more than subject knowledge and techniques to offer.

Physical proximity is important in facilitating collaboration and, for some fields, teams that include both biologists and chemists are important. Chemists do not just provide a service to the biological research community; their input is more fundamental. Two-thirds (65%) of respondents indicated that they could find suitable collaborators by disagreeing with the statement 'I cannot find suitable collaborators'.

### Institutional support

Over six in ten (63%) respondents felt that their institution enabled research at the chemistry-biology interface. The main actions that had been taken were to bring people together in seminars and similar activities and to establish interdisciplinary centres. Mechanisms that enable people to meet relatively informally appear to be key.

Timescales, profit motive and depth of exploration were all thought to distinguish industry from academia. However, industry was seen as being more problem focused but many respondents see industry as having different objectives from academia and the model as not necessarily transferable.

## Research funding

The perceptions of respondents, most of whom have benefited indirectly or directly from research funding at the chemistry-biology interface, suggest there is a significant communications gap between funders and researchers. Only 2% of respondents indicated that there was nothing more that the Research Councils could do to better support research at the chemistry-biology interface.

The chemistry-biology interface research community identified that this research area is under funded and not understood by funders. Over half (57%) of respondents agreed with the statement that 'It is difficult to get funding in the UK because grant reviewers do not have the right expertise'. Those based in chemistry departments were more likely to agree strongly than those in biological science departments.

## Research at the chemistry-biology interface

### Research fields

This research found that the field is broad and disparate and there is evidence of a lack of cohesion and awareness within the community to the breadth of research being conducted.

### Publication

Not everyone had published in the chemistry-biology interface field, 80% of respondents had had a paper accepted for publication in the last 12 months. However, this does not preclude them from publishing other types of work. Most commonly respondents were publishing their chemistry-biology interface research findings in US journals.

The differences in impact factors and name order conventions between biology and chemistry were of concern with respect to success in the 2008 RAE and promotion prospects for respondents.

### Knowledge transfer

In addition to publications, 35% of the respondents had been awarded a patent, 12% had been involved in the setting-up of a new company, 7% had developed new therapy(ies) and 7% new medicine(s).

### The role of the RSC

The RSC's interest in, and support for, research at the chemistry-biology interface was welcomed.

## Conclusions and recommendations

### i. Working practices

Researchers need to be proactive in finding collaborators and developing relationships. This work has found that researchers find collaborators in a variety of ways, including:

- the reputation of individual researchers or groups;
- meeting at conferences;
- searching the web for researchers with relevant expertise;
- being referred to relevant individuals by colleagues in their department;
- from published articles; and, of course,
- some are themselves found by other researchers.

### ii. Infrastructure and environment

The RSC recommends that institutions look across their structures to identify administrative barriers that impede collaboration, such as different cost structures, and seek harmonisation. In addition, institutions should proactively bring heads of department together to identify mutual benefits for their departments that could arise from collaboration. The RSC has a role in spreading good practice through its academic members.

### iii. Funding

There has been a concerted effort by funding bodies to develop new funding routes for interdisciplinary science, including at the chemistry-biology interface. However it remains a perception that the funding bodies, especially the Research Councils, are not supportive of interdisciplinary research in the way in which research proposals are assessed and that more specialised schemes are needed. Key initiatives to help clarify the funding process could include:

- 'road shows' by all funders;
- the Research Councils developing a more systematic way of deciding which Research Council a project should be directed towards;
- a harmonisation of the Research Councils' application processes;
- the production of a written, step by step guide of the funding process for the chemistry-biology research community, either in hard copy or as a web portal; and
- better guidance for reviewers to ensure that appropriateness of method carries more weight than novelty of method.

At the application stage more and better communication is required between grant funders and potential grant holders in order to make optimum use of existing funding mechanisms and administrative procedures.

The RSC recommends that applicants seek advice directly from BBSRC, EPSRC and MRC at any time in the grant application process but specifically prior to submission of a formal application. It is vital that applicants seek clarity on remit and procedures from Research Councils prior to submission to ensure that applications are sent to the right Research Council to minimise delays.

### iv. The current health of chemistry biology interface research

Further conference and seminar activities are necessary to raise awareness, stimulate interest from chemists and generally bring people together. These events must be jointly co-ordinated with the biological associations and the titles for joint events must be welcoming for those from both disciplines. In particular there is no regular conference in the UK that draws international level speakers and acts as a focus for the community.

### v. Training of researchers at this interface

Institutions must ensure that interface training is available to PhD level across departments. The RSC recommends a further study to assess existing mechanisms for providing adequately trained interdisciplinary researchers.

### vi. The RSC

The RSC should:

- revise its membership and accreditation to those working at the chemistry-biology interface to become members of the RSC;
- bring people together through seminars and workshops;
- work more closely with biological professional societies to support joint events;
- ensure that titles for joint events are welcoming for those from both disciplines;
- work with the funders to reduce the barriers to interdisciplinary and multidisciplinary working;
- promote ways of working that have supported the development of collaborations in some HEIs to other HEIs;
- identify industrial champions who can raise the profile of chemistry-biology research in industry more widely;
- support a regular large scale international conference every three years;
- enable those working at the chemistry-biology interface to become members of the RSC;

- award prizes for work in the field; and
- publish occasional special editions of existing journals but the RSC should not launch a new journal.

## Method

The project comprised:

- interviews with the BBSRC, EPSRC, MRC and the Wellcome Trust;
- a review of the existing literature on inter- and multi-disciplinary research and research at the chemistry-biology interface;
- an Internet survey of 446 scientists working at the chemistry-biology interface; and
- six follow-up case studies with survey respondents, which involved 27 researchers.

## Selenium gets the cold treatment

How and do selenium supplements really work? Analytical scientists are helping to find the answer.

Selenium compounds such as methylseleninic acid have known anticancer activity, but the way they work is not well-understood. Now, UK scientists have used analytical methods to study how selenium compounds are metabolised in human cancer cell lines. 'These novel methods will be used in the context of clinical trials investigating selenium supplementation to identify the mechanisms by which selenium exerts its biological effects,' said Heidi Goenaga Infante, at the LGC in Teddington, who fronted the research.

Goenaga Infante and her colleagues used a combination of analytical techniques, including mass spectrometry and gas chromatography, to detect the selenium metabolites. To analyse the volatile metabolites, the team employed a technique called cryogenic oven-cooling gas chromatography, which involves cooling the apparatus rapidly down to temperatures as low as -60 °C. 'This method showed advantages in terms of cost and simplicity,' said Goenaga Infante.

The researchers found that Se-methylselenocysteine is the major selenium metabolite in lymphoma cell lines treated with methylseleninic acid. They have also reported the first mass spectrometry data for water soluble precursors of methylselenol – a metabolite with anticancer activity – and volatile methylated selenium species formed in the selenium-treated cells.

Peter Uden, a US expert in analytical science at the University of Massachusetts, Amherst, said, 'this is among the most innovative and valuable contribution to organoselenium speciation in recent years. Any elemental speciation, not solely for selenium, is accessible to this approach. The ability to sample small cellular samples is a substantial advance and the links between selenocysteine and cell metabolism are key findings.'

In the future, Goenaga Infante says, she hopes to develop methodologies for measuring and identifying analogous sulfur-containing biomolecules in biosamples.

By Kathleen Too

### Reference

H Goenaga Infante *et al*, *Journal of Analytical Atomic Spectrometry*, 2007, **22**, 888-896

# 1 Introduction

## 1.1 Background

In order to have a better understanding of the role of chemistry in biological research today, the Royal Society of Chemistry (RSC) commissioned this report *Face to Face: UK Chemistry-Biology Interface*. The work was carried out by People Science & Policy Ltd (PSP). The Biotechnology and Biological Sciences Research Council (BBSRC), the Engineering and Physical Sciences Research Council (EPSRC), the Medical Research Council (MRC) and the Wellcome Trust all contributed funding to this project. The Natural and Environment Research Council (NERC) was not involved in the project but it should be acknowledged that research at the chemistry-biology interface is funded by NERC for projects that fall within its remit.

## 1.2 Objectives

The overall aim of this project was to deliver evidence to underpin recommendations to academic and other research institutions and to funding bodies in the UK regarding how best to foster high quality research across the chemistry-biology interface. The objectives of this project were to:

- improve awareness in Government, funding agencies and university management of the importance of chemistry in underpinning modern biological research;
- stimulate the revision of mechanisms for funding interdisciplinary research to facilitate high quality research of this type, if necessary; and
- influence university infrastructure so that it will better facilitate research that crosses the traditional disciplines of chemistry and biology, if necessary.

Where possible the report has drawn out where issues related to work at this interface are relevant to work across other interfaces.

## 1.3 Method

The project comprised:

- interviews with relevant managers at the BBSRC, EPSRC, MRC and the Wellcome Trust;
- a review of the existing literature on interdisciplinary and multidisciplinary research and research at the chemistry-biology interface;
- an Internet survey of 446 scientists working at the chemistry-biology interface, a response rate of 57%; and
- six follow-up case studies with survey respondents, which involved 27 researchers.

Full details of the methodology are set out in appendix 2.

## 1.4 Review of previous studies

### 1.4.1 Introduction

A review of the literature has identified reports that look generally at the issues related to conducting interdisciplinary and multidisciplinary research, but there is little on research specifically at the chemistry-biology interface. Key studies are discussed below, followed by a discussion of the definitions of interdisciplinary and multidisciplinary research.

### 1.4.2 Background

The Biosciences Federation report (2005a), *Building on success*, states that since 1998 the government has invested in science and innovation with the aim of enabling Britain to remain at the forefront of the growing global knowledge economy. Their report assesses the outcome of that investment. They emphasise that while there have been many successes there are also a number of threats to developments in the biosciences. These threats include:

- too few students choosing to study core bioscience disciplines;
- graduates with too little practical training;
- the deterioration of working environments in academia; and
- funding mechanisms.

The authors of *Building on success* believe that the “future of the UK bioscience sector depends above all on industry choosing the best technologies on which to focus, and pursuing viable business strategies to achieve profitable growth. The government role is primarily to create a steady supportive environment”.

A report by the ABPI (2005) emphasised the decline in the number of students taking chemistry courses, both chemistry degrees and chemistry components in other degrees. It suggested that possible reasons for this decline would include:

- a reduction in funding of laboratory-based courses compared with non-laboratory courses; and
- a perception of high student debt allied with poor salary and career expectations.

The report also highlighted a need for scientists to show an appreciation of science beyond their specialist discipline. They supported continued dialogue between universities and industry.

A later Biosciences Federation report, *Enthusiasing the next generation (2005b)*, examined biosciences education. It highlighted that many bioscience students are “weak in chemistry, mathematics and physics and are thus ill-equipped to cope with the cross-disciplinarity of modern science”. The report made a number of recommendations for improving biosciences education in order that future scientists have the appropriate skills.

- Students must be made aware of the advantages of studying another science or mathematics in addition to biology.
- Universities should not overspecialise in the early stages of undergraduate biosciences courses.
- Graduates should have sufficient practical experience for the workplace.

### 1.4.3 Research at the chemistry-biology interface

In 2002, the RSC organised a workshop where chemists and biologists could discuss issues relating to those scientists working together. The report of the workshop highlighted that “chemists often complain that they are used as a service and have no real input into the projects with biologists levelling the charge that chemists are simply not making the right biologically relevant compounds”. The main issues that came out of the workshop discussions can be summarised as follows:

- establishing better ways to communicate is key;
- the chemistry community needs to be more open to multi-disciplinary work;
- both communities should learn from each other and projects should present challenging science for both biologists and chemists; and
- collaboration and communication must start early in the work of chemists who need assistance from biological scientists when attempting to choose the biological targets.

The workshop report also highlighted a need for further workshops that are led by biologists who are experienced in handling issues at the chemistry-biology interface. The need for input from industrial partners was also noted as essential to broaden the interface. A key conclusion drawn from the workshop discussions by the RSC was that “development of this area will be key to providing the kind of ‘flexible workforce’ essential to the further development of the UK biotech sector, SMEs, etc”.

Following on from this, *Chemistry at the centre: an international assessment of university research in chemistry in the UK (2003)*, known as the Whitesides report, co-ordinated by the RSC on behalf of EPSRC, noted that chemical biology and materials science were thought to represent the most important new opportunities for chemistry. The report argued that the expansion of UK chemistry into biology (and materials science) should be progressed. Chemistry, by virtue of its ability to provide concepts, processes and materials to all disciplines, is uniquely suited

to link them. That is, chemists can talk with physicists, biologists and engineers, and can help these fields to communicate with each other. However, the report says that in these two areas (chemical biology and materials), the UK was internationally weak.

Amongst other things the report found that *"the infrastructure supporting chemistry assumes that it is small science... Mechanisms to support the multi-group, interdisciplinary projects important in materials science and some areas of chemical biology and biomedicine are not well developed."* As a result, one of the three major recommendations was to *"restructure PhD education and support for chemical research to encourage revolutionary and multidisciplinary science and engineering"*.

The Whitesides report collected and assessed the opinions of a variety of individuals; this included a survey of chemistry departments, a survey of panel members' peers outside the UK and visits by members of the panel to a small number of chemistry departments. The findings show that it was believed that good multi-disciplinary research would only flourish if the core sub-disciplines of chemistry were also strong. The need for adequate infrastructure, equipment, technical support, and staff funding in order to achieve or maintain international competitiveness was often emphasised. It was further noted in the Whitesides report that funding mechanisms need to be developed *"that support multidisciplinary research, especially in chemical biology and in chemical aspects of materials science. Appropriate mechanisms should also be developed to strengthen chemical engineering, and strengthen its connections (and connections of other relevant areas of engineering) to chemistry"*.

In response, EPSRC, as the main UK funder of chemistry research, highlighted its funding mechanisms (such as Platform grants and Portfolio Partnerships) which assess and support multidisciplinary research, although it acknowledged that problems still occurred at the Research Council boundaries. It also undertook to play an expanded role in supporting work at the interfaces, particularly in chemistry and biology. For example, the Chemistry and Life Science Interface (LSI) Programmes ran an exercise to support jointly a number of Platform grants involving interdisciplinary research between chemists and life scientists. The LSI programme continues to act as a bridge for EPSRC into the life sciences-relevant Research Councils and charities.

EPSRC also had managed activities in this area (such as High Throughput Methods and Green Chemistry, which are funded from EPSRC's Chemistry and other Programmes). In addition, EPSRC's Chemistry and Engineering Programmes were allocated funding to work specifically at bridging the chemistry-biology interface.

EPSRC also committed to working closely with appropriate professional organisations, such as the RSC, IChemE and the Chemistry Leadership Council with the aim of increasing mutual understanding of the current relationship between chemists and chemical engineers and looking at where training may be targeted at this. In addition, Universities were to be encouraged to explore creative use of their DTA funding, for example, supporting a studentship across departments and the provision of modular integrated courses.

BBSRC's response was to establish the 'Selective Chemical Intervention in Biological Systems' (SCIBS) Initiative with a budget of £6 million. This was the result of a workshop run as a result of advice from the working group set-up to advise BBSRC on the best way of stimulating work in 'chemical biology'. The primary objective of the SCIBS Initiative was *"to advance BBSRC strategic priorities by use of selective chemical interventions to investigate biological processes"*.

Those surveyed for the Whiteside report thought that the UK was leading in protein chemistry and associated areas of chemical biology. They suggested that the UK build on this to expand the development of other complementary areas of chemical biology. However, the report also highlighted that the integration of chemistry and biology was proceeding much more rapidly outside the UK, and that the UK was weak in the (then) specific growth areas in biological chemistry of molecular evolution and chemical genetics. Such a conclusion is reinforced by the more recent report *The future of U.S. chemistry research: Benchmarks and challenges* (National Academy of Sciences 2007), which argues that the United States is the leader in biological chemistry (defined as 'the use of chemistry to develop a better understanding of biological processes').

#### **1.4.4 Interdisciplinary and multidisciplinary research**

*Facilitating Interdisciplinary Research* (National Academy of Sciences 2004) examined interdisciplinary research efforts in the USA and recommended ways to stimulate and support such research. The report identifies steps

that researchers, teachers, students, institutions, funding organisations, and disciplinary-based learned societies can take to more effectively conduct, facilitate, and evaluate interdisciplinary research programmes and projects.

In their view interdisciplinary thinking is rapidly becoming an integral feature of research as a result of four powerful drivers:

- the inherent complexity of nature and society;
- the desire to explore problems and questions that are not confined to a single discipline;
- the need to solve societal problems; and
- the power of new technologies.

The report concluded that the characteristics of this type of research pose special challenges for funding organisations that wish to support it. This is because it is typically collaborative and involves people from disparate backgrounds. Thus, it may take extra time to build consensus and to learn new methods, languages and cultures. The report's authors believe that researchers interested in pursuing interdisciplinary research often face obstacles and disincentives, such as:

- personal communication or cultural barriers; and
- barriers related to the tradition in academic institutions of organising research and teaching activities around discipline-based departments – a tradition that is commonly mirrored in funding organisations, professional societies, and journals.

The NAS report suggests that the increasing cross-fertilisations in science and engineering require new modes of organisation and modified reward structures to facilitate such research. Professional societies, it suggests, have the opportunity to facilitate this research by:

- producing state-of-the-art reports on recent developments and on curriculum, assessment, and accreditation methods;
- enhancing personal interactions;
- building partnerships among societies;
- publishing interdisciplinary journals and special editions of disciplinary journals; and
- promoting mutual understanding of disciplinary methods, languages, and cultures.

The NAS (2004) made the following suggestions for improvements:

- networking events and internships in industrial and non-academic settings for postdoctoral researchers as well as identifying institutions and mentors favourable to interdisciplinary research;
- researchers should immerse themselves in the languages, cultures, and knowledge of their collaborators in interdisciplinary research;
- institutions should develop policy to help reduce barriers and also develop programmes with industry and government and non-government organisations;
- team leaders should bring together potential research collaborators early in the process and work toward agreement on key issues, and also strike a good balance between contribution and benefits to each member of the team.

Interdisciplinary research has long been accepted and familiar in many industrial and US government laboratories and other non-academic settings, say the authors; such settings traditionally emphasise teams and problem-driven research, and they permit researchers to move easily between laboratories, to share their skills, and to acquire new ones. In universities, however, such collaboration is often impeded by administrative, funding and cultural barriers between academic departments, around which most research and teaching activities are organised.

In August 2007, an article in ACS Chemical Biology by Joseph Ready and Kristen Lynch reported on how the University of Texas Southwestern Medical Centre has handled training in interdisciplinary research. Importantly for this project, they say:

*"... because graduate programs function separately from the administrative departments, students and faculty interact frequently with research groups from multiple departments. This horizontal structure facilitates cross-pollination among disciplines."*

A recent report (2007) from the Academy of Medical Sciences and the Royal Academy of Engineering, *Systems Biology: a vision for engineering and medicine*, discussed the issues relating to 'working across cultures'. Like work at the chemistry-biology interface, systems biology requires interdisciplinary work that challenges the current structure of UK academic research and therefore the current practices for funding. The report also recognises the increasing importance of interdisciplinary work to the progress of scientific development and highlights that it is important that such work should not fall into gaps between university departments or between research funders. The report also suggests that undergraduates be exposed to interdisciplinary work as good preparation for working as scientists in the future. Limited training could lead to a lack of awareness of other disciplines and how they can help/support one's own work.

Researchers from different disciplines can be brought together through workshops, seminars, training sessions and conferences. The authors emphasise, however, that such events need to become more routine and consistent across the UK to ensure that all scientists have access. They, like others, suggest that academia learns from industry which tends to have research groups that are problem focussed rather than discipline centred; these teams are interdisciplinary and their work is aimed at finding the solution to a problem. To do this in academia however, they believe would require a complete reorganisation of traditional universities and a re-think with regard to how researchers are assessed. Assessment procedures determine promotion and tend to be subject-specific. Researchers could therefore be disadvantaged by doing interdisciplinary research. Furthermore, research papers can be subject to different peer review systems in different disciplines. The merits of bringing researchers together physically or as a distributed network were discussed. The pros and cons were seen to depend on the nature of the research taking place, for example, whether access to large and expensive equipment is required.

#### **1.4.5 Conclusion**

Drawing on the above reports a number of themes emerge. A great deal of science is now multidisciplinary and interdisciplinary and therefore insights from chemistry and physics are increasingly important for research in the biosciences (Biosciences Federation 2005c). The recent decline in popularity of the chemical and physical sciences among young students has been seen as a threat to future progress in the biosciences. Furthermore, science and engineering are seen to be fundamental to a globally competitive economy and increased levels of research in the public and private sectors increases the competitiveness of the economy. In addition, ensuring transfer of knowledge between the science base and the commercial sector is crucial if the UK is to achieve the maximum benefits that science and engineering can provide.

It is clear that success and improvements in multidisciplinary and interdisciplinary work requires the coordination of all those involved – academia, industry, research funders and government. Evidence in the reports described above implies that proximity and a focus on common goals may require significant changes to traditional single discipline academic ways of working, university structures, research funding and the research (and researcher) assessment mechanisms.

#### **1.5 Definitions**

The terms interdisciplinary and multidisciplinary are used throughout the literature where there is some debate as to whether research at the chemistry-biology interface is interdisciplinary or multidisciplinary.

Facilitating Interdisciplinary Research (National Academy of Sciences 2004), for example, provides this definition of interdisciplinary research:

*"Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts and/or theories from two or more disciplines or bodies of specialised knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice."*

Multidisciplinary research is described by the National Academy of Sciences (2004) as:

*"...research that involves more than a single discipline in which each discipline makes a separate contribution. Investigators may share facilities and research approaches while working separately on distinct aspects of a problem."*

RSC and PSP used the following definitions in this project:

*Interdisciplinary research requires individual researchers have a broad knowledge of both chemistry and the biological science disciplines*

*Multi-disciplinary research requires people from both chemistry and the biological science disciplines to collaborate*

## **1.6 The report**

This report sets out the findings from an Internet survey of a representative sample of those working at the chemistry-biology interface. The findings are supplemented by six institutional case studies, which provide examples of ways of working at the interface and help to explain and enhance the findings from the survey. PSP also interviewed the Biotechnology and Biological Sciences Research Council (BBSRC), the Engineering and Physical Sciences Research Council (EPSRC), the Medical Research Council (MRC) and the Wellcome Trust.

Section 2 describes the characteristics of the achieved sample and the nature of the research respondents were undertaking. Section 3 looks at the working practices of respondents and how they bring chemistry and biological knowledge together in their projects. Section 4 considers institutional support and the ways in which institutions are supporting research at this and other interfaces. Section 5 considers the issues around funding and funders. Section 6 tries to assess the condition of research at the chemistry-biology interface in the UK today. Section 7 considers the role of the RSC in the chemistry-biology interface. Finally, section 8 draws the themes together to come to some key conclusions and make recommendations to the RSC on what it can do to influence funders and HEIs.

Throughout this report quotations are used in support of quantitative evidence. Some quotes are taken from the questionnaire; others come from interviews held during the case study visits. In total 27 researchers were interviewed during the case study visits.

Appendix 1 provides the full references to the literature review discussed in section 1 above, while appendix 2 provides the detailed methodology and a copy of the Internet questionnaire. Appendix 3 lists the self-reported research areas of respondents. Appendix 4 provides a full list of the responses to the open-ended question on what respondents' institutions are doing to support research at the chemistry-biology interface.

The project was overseen by a Steering Group convened by the RSC and chaired by Dr Nick Westwood. The group were keen to include some scientific case studies that would illustrate why research at the chemistry-biology interface is important. These were sourced from RSC publications and can be found throughout the report.

### Introduction

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The size of Professor Colin Kleanthous' group varies between 8 and 12 researchers, with between a third and a half of the group having chemistry first degrees and the remainder first degrees in a biological science. Sometimes it includes a physicist but mainly the focus is on biology and chemistry. The main interest of the group is in how proteins interact with each other in a number of biological settings. The group's main area of expertise is protein chemistry. They purify proteins and study protein structure and the behaviour of proteins in-vitro, although there is some in-vivo work as well.

### University infrastructure

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The university has been trying to develop capacity at the chemistry-biology interface, largely driven by a 'bottom-up' process where the two departments identify areas of mutual benefit. For example, in conjunction with Biology the Department of Chemistry led a £3M SRIF bid to the university to create a new Centre for Magnetic Resonance that caters for core chemistry needs while at the same time providing a significant new investment in biological NMR. The two departments consolidated this development with their first joint appointment, in biological NMR spectroscopy.

### Personnel

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Both the Department of Biology and the Department of Chemistry are very strong in their own fields. Both are rated 5 in the 2001 RAE and they have come together to undertake research at the chemistry-biology interface because a number of staff are keen to work in this area. Some chemists have been working on biological problems since the 1970s, especially in the areas of chemical biology, protein crystallography, computational methods and, more recently, biological NMR. This means that the chemistry department, or at least parts of it, has a strong ethos of understanding the molecular sciences in biology. Similarly, some biologists take a distinctly chemical approach in their research. This interdisciplinarity in the two departments has provided the momentum for the bottom-up development of research at the chemistry-biology interface.

### The built environment

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The development of the biology-chemistry interface in York has been expedited by the move in 2002 of some of the chemistry department (specifically the York Structural Biology Laboratory) into the same building as the biology department. The new building includes a large reception area and café area where staff can come together informally.

### Management structure

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A biology-chemistry planning group oversee developments across the interface. The group is comprised of academics from across the two departments and includes staff who may have little or no immediate relationship with the other but are interested in seeing the interface develop. The planning group has a number of roles. It helps plan postgraduate teaching, spearheads new initiatives (for example, a recent, successful joint bid to the Wellcome Trust for £0.50M equipment that required financial support from both departments), monitors use of space and infrastructure, and assesses the need for staff working at the interface both in terms of teaching and research. An example of the group's work is the creation of a high throughput gene expression/protein purification facility (HiTEL). This was the result of a joint SRIF bid to the university, which awarded the project £0.75M. The success of the project required input of research and technical staff from both departments. This required negotiations and agreements over issues such as access and cost-recovery.

Despite the high level of joint working and mutual interest it is recognised that what is good for one department may not always be good for the other; not helped by the RAE process which has tended to make departments somewhat inward looking in order to submit as strong a return as possible to a single, specific Unit of Assessment. Stumbling blocks in joint working can also arise due to the different financial models that operate in the two departments and differences in operational practices. Ironing out problems even before they arise is helped by monthly, informal lunch meetings between the two Heads of Department. This keeps each abreast of the other's plans. Not only are the heads of department able to ask staff to deal with emerging problems but staff are able to ask their head of

department to raise issues for resolution.

## **Teaching**

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The Biology and Chemistry departments at York have taught a jointly-administered Biochemistry degree for more than 30 years (there is no biochemistry department in York). This has helped foster research at the interface since staff appointed within each department to teach on the biochemistry degree programme are invariably biochemical in outlook but approach the subject from a distinct discipline. As a result of teaching on joint biochemistry-specific modules, numerous research collaborations between biology and chemistry have developed.

There are between 45 and 50 undergraduate students per annum on the biochemistry course and about 10 staff from each department contribute to the teaching. In addition, the two departments collaborate in teaching MRes courses in computational biology and functional genomics (about 15-20 students each), both courses are in receipt of research council studentships.

## 2 The respondents

### 2.1 Introduction

The four research funders (BBSRC, EPSRC, MRC and the Wellcome Trust) provided contact details for researchers holding grants which they believed to be broadly within the field of chemistry-biology. In addition, the RSC provided details of members of the Chemistry-Biology Interface Forum (CBiF). CBiF is a society-wide grouping for RSC members working at the boundary between chemistry and biology. The forum aims to improve interdisciplinary research at the chemistry-biology interface and promote the importance of this area to the Government. This resulted in 1,718 individuals being identified, from which a simple stratified one in N sample of 1,000 was drawn. Allowing for emails that no longer reached the named person, the response rate was 57%, resulting in 543 respondents. (Full details of the methodology are given in appendix 2.)

Of these 543 respondents, 8% said that they were not currently involved in any 'research on a biological or medical science topic'<sup>1</sup>, which reduced our sample to 498. A further 10% said that they did not consider any of their research work to be at the interface between chemistry and biology, reducing the sample size to 446. This report is based on this group of 446 researchers. Most of the questions were compulsory but there is some routing dependent on respondents' answers, which means that not all questions were answered by all respondents. The percentages presented throughout the report are based on the number of respondents who answered the specific question.

In reading this report it is important to remember that most of those surveyed have been funded by either BBSRC, EPSRC, MRC and/or the Wellcome Trust for research which both they and their funder consider to be at the chemistry-biology interface.

### 2.2 Professional characteristics

The way in which the sample was constructed (see appendix 2) means that the sample is likely to be skewed towards Principle Investigators (PIs) and indeed, 69% of the sample were either PIs, joint or co-PIs, with the majority (53%) being PIs<sup>2</sup>. This is reflected in the number of years respondents had been in research and their seniority, with 77% stating that they had been in research for more than ten years and 41% that they were in a professorial grade. Equally, half of the respondents were aged 30-44, with a further 45% aged 45-65. One in five of the respondents were women.

Respondents were presented with a list of disciplines and asked to indicate the subject of their first degree. The list included subjects that most respondents would have studied at undergraduate level but also allowed them to add other subjects. Half (52%) of the respondents indicated that they had a first degree in 'chemistry', one in seven (14%) a first degree in a 'biological science' and one in five (21%) were initially qualified in 'biochemistry', with a few (2%) saying that their first degree was a 'joint bio-physical science' award. A few others had first degrees in 'physics' (5%), 'medicine' (2%), 'pharmacy' (2%) and 'engineering' (1%).

Just over a quarter (28%) of respondents were based in chemistry departments and nearly as many were based in biological science departments (24%), most of the remainder were based in an interdisciplinary centre (21%) with one in ten based in another single subject department, and a similar proportion (8%) in biochemistry departments. Just 5% were based in stand alone research institutes, mainly MRC and BBSRC Units.

Throughout the report, responses from those based in chemistry departments were compared with those based in biological sciences departments, because these two groups frequently differ significantly in their responses.

### 2.3 Research areas

As discussed in more detail in section 6.2, the researchers who responded to this survey and classified their work as chemistry-biology interface research, were working in a diverse range of areas.

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<sup>1</sup> This is the wording used in the questionnaire.

<sup>2</sup> Unless otherwise specified, throughout this report when reference is made to PIs, this includes respondents who stated that they were a PI, a co or joint PI.

## 2.4 Reasons for working at the interface

The reasons given for working at the interface between biology and chemistry reveal the problem-solving focus of researchers who also enjoy a challenge. On one case study visit a view was put forward by two PhD students that not only was interface research more interesting and a more powerful way of looking at problems but it provided broader training in a wider range of techniques than a single discipline PhD.

Nearly all respondents (88%) said that they had chosen to work at the interface of chemistry and biology because their research topic needed both disciplines to address their research questions. Over half (55%) said that they felt it was a more useful way of addressing problems and 41% that it was likely to generate real benefits to society.

Some enjoyed the challenge, with around a third saying each of the following: it is more challenging (33%); it is more dynamic (37%); and 'to remain at the cutting edge of the field' (35%).

One in seven (13%) respondents had been approached by another researcher to collaborate. Of these 56 individuals, 21 were based in chemistry departments and 11 in biological science departments.

Six in ten respondents (61%), said that the interaction between chemistry and biology is 'very critical' to their research and a further 34% that it is 'fairly critical'.

## 2.5 Summary and conclusions

Researchers working at the chemistry-biology interface form a very diverse group, working on a wide variety of research topics. They enjoy the challenge of working at the chemistry-biology interface and feel both disciplines are needed to address their research questions. Many are motivated by possible benefits to society of their research.

Respondents to the survey were divided fairly evenly among chemistry departments, biological sciences departments and interdisciplinary centres.

### Spinal injection to cut out surgery

Microgels could be used to repair damaged spinal discs.

Microgels are cross-linked polymer particles that are swollen with solvent. Brian Saunders and colleagues at the University of Manchester have developed a microgel that responds to pH. At low pH, the material is a fluid, but at higher pH, the microgel particles act like sponges and absorb water, creating a stiff gel.

Saunders injected the material into a damaged bovine intervertebral disc, and increased the pH to biological levels by injecting alkaline solution. The disc returned to its normal height, and regained its mechanical strength.

'Chronic lower back pain due to spinal disc degeneration is a major health problem,' said Saunders. 'The most common treatment is spinal fusion, a major surgical procedure which can result in a significant loss of mobility at the fused and adjacent discs. Our approach has the advantage of being minimally invasive, and being able to restore spinal mobility.'

To develop the technology into a viable alternative to spinal fusion, Saunders and his team plan to investigate biodegradable microgels that release additives to stimulate the regeneration of spinal disc tissues.

By Susan Batten

Reference:

J M Saunders, T Tong, C L Le Maitre, T J Freemont and B R Saunders, *Soft Matter*, 2007, 3, 486-494

### Introduction

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Professor Tim Bugg is professor of biological chemistry at the University of Warwick. His group's research concerns the study of enzyme-catalysed reactions. The 'Bugg Group' uses a combination of chemical and biochemical techniques to study the catalytic mechanism of multi-step enzymatic reactions, and they use chemical synthesis to prepare mechanism-based inhibitors for enzymes of medicinal importance.

Since school, Professor Bugg has had an interest in biological chemistry and he describes himself as a chemist who works on biological problems. He has ensured that he is sufficiently knowledgeable of biological approaches and terminology to enable him to either do any necessary biological work himself or be able to talk to others who can. His group currently collaborates with a microbiologist and a protein crystallographer at the university; one of the attractions for Professor Bugg of moving to Warwick was the microbiology group.

### Working practices

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In enzymology Professor Bugg thinks that the most effective way of working is if scientists in the group can work in one lab and use both chemical and biological techniques. The group's approach is to look for an interesting problem to solve and then uses the appropriate techniques to undertake the work. If the appropriate skills are not within the group then collaborators will be sought. This is how the major enzymology research groups around the world work. The scientists in Professor Bugg's group are mainly from chemistry backgrounds. From his experience, chemists are easily able to learn the appropriate biological skills in order for them to work successfully in enzymology.

Collaborations, while essential, take time to set up and need maintenance; individuals need to meet regularly and discuss objectives. A spirit of mutual cooperation is needed and results in the most effective collaborations. Professor Bugg has organised events/activities at the university to promote links between chemistry and biology. For example, symposia in areas where there is some common interest between chemistry and biology; focussed events such as these are found to be most productive.

### Teaching

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Warwick University runs a joint degree course in chemistry and biology. It is about two thirds chemistry and one third biology, although there is flexibility in the fourth year of the four year course. There are about 20-30 students in total each year and the Bugg Group has had project students from this course.

### Facilities and the built environment

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Scientists based in a chemistry department who do biological work need access to a whole set of equipment and facilities, for example, a cold room, autoclaves and a centrifuge. If these facilities are not already available in a chemistry department it can be difficult to secure funding for buying and maintaining the equipment.

The chemistry and biology departments are separate in Warwick; about a 15 minute walk apart. Physical proximity of biology and chemistry departments, however, is advantageous, especially with regard to sharing equipment, but distance does not make collaborations impossible. If departments are nearby, students, their skills and knowledge can also be more easily shared.

### University support

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The chemistry department at Warwick is supportive of interdisciplinary work. There are loose rather than rigid research clusters within the department. As a consequence of this those in the department know each other well and there are a great deal of intradepartmental links. Interdepartmental collaborations are also encouraged

but are generally led by individuals. Three interdisciplinary doctoral training centres (DTC) have been set up by the university, one of which is the Molecular Organisation and Assembly in Cells (MOAC) DTC. MOAC is a four year degree programme (MSc plus PhD) at the interface between mathematics, chemistry, biology, physics and computing. The centre has enabled new collaborations to be established at the university and there have been project students and some PhD students who have been recruited from MOAC into projects that involve biological chemistry. However, there is some concern that the benefits of MOAC to biology are more limited compared with the benefits to chemistry, physics and mathematics departments. For example, it was felt that the students don't necessarily get to pursue the biology aspects of projects to full fruition.

There are no administrative difficulties with regard to more than one department having work funded by one grant as the university has a common accounting system. The university also has small funding schemes to help promote pilot scale projects and they have various funding schemes for travel, particularly for USA; such funding can be useful for collaborative work. The university's PhD training process is moving to a four year model where students in their first year do two or three long projects of two to three months. This allows students to get an appreciable amount of work done in those projects that can perhaps lead to a full grant application.

### **Publishing**

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The group are able to put forward articles for publication to a wide range of journals. The specific journal depends on the nature of the work and whether it has biochemistry or chemistry focus. It was thought that articles should be reviewed by those who do biological chemistry as single discipline referees may not be able to review all elements of the work; this is sometimes also a problem with grant proposals.

### 3 Working practices

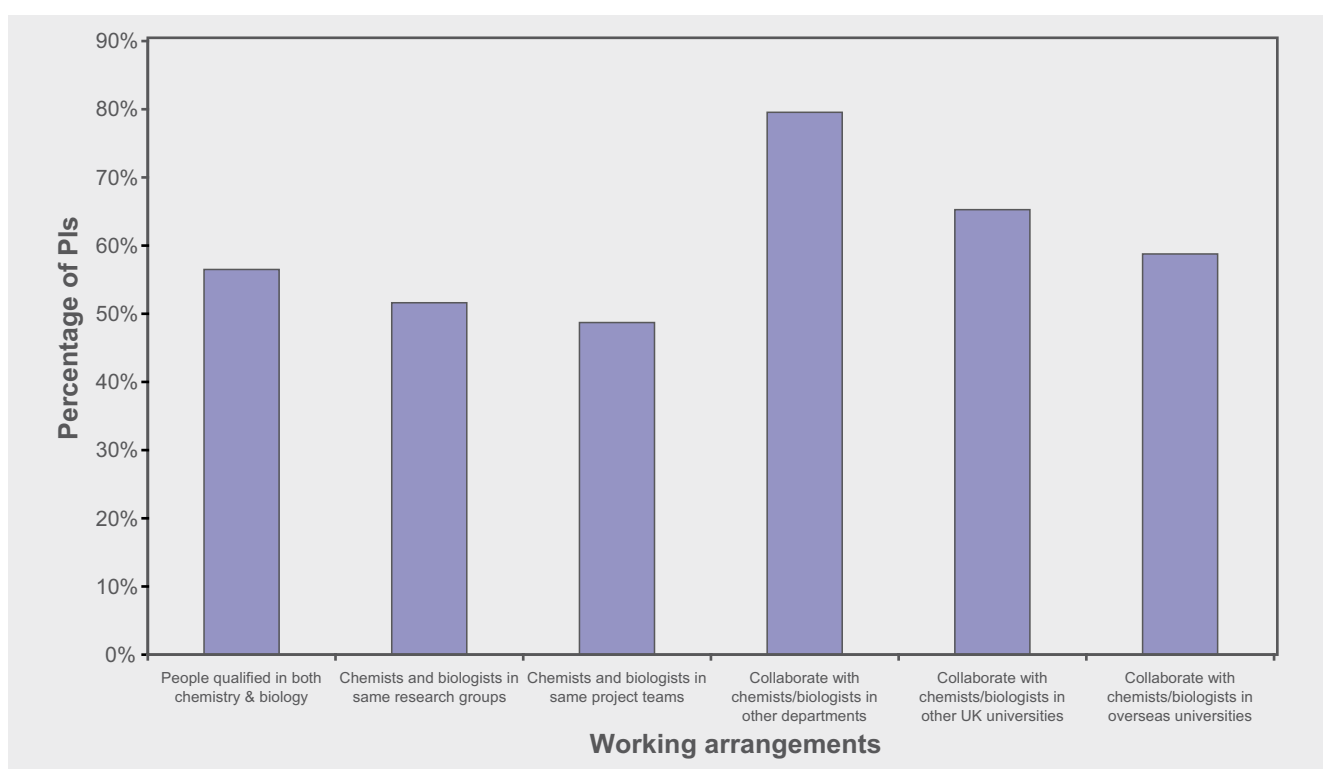
#### 3.1 Introduction

This section looks at how research teams bring together the relevant chemistry and biology expertise to address their research aims.

#### 3.2 Working together

Figure 3.1 below shows that the most common working relationship for PIs was to collaborate with other departments in the same institution. Four out of five used this approach. However, it is clear that many PIs were using a variety of working practices.

Figure 3.1 Working practices



Base: 308 – All PIs, co and joint PIs

The driving force behind these working practices was the nature of the work being done and the contribution required from each discipline. Nearly all (91%) PIs gave this as their reason for the working practices they adopted.

While 89% of respondents collaborated across groups, whether at the same or a different institution, the case study interviews presented us with strong evidence that physical proximity is also important. This of course, can be achieved within an institution.

*“We very soon realised that to really make an impact in the area you had to be able to do this in house. ...Collaborating at a distance, even when you’re collaborating with the best is OK, but you can’t do the ‘suck it and see’ experiments unless you can just talk to each other, get in the lab and get it done.”*

*Case study participant*

It also aids efficiency.

*“We realised very early on that it was not going to work to have geneticists and biochemists a mile away [from the chemistry department].”*

*Case study participant*

This report explored whether there was any rationale behind the ways of working and found that the nature of

the research and not the institutional structures or funding mechanisms were indeed the driving force behind the working practices adopted.

In addition the report explored whether there were different working practices in different sub-fields (for those sub-fields where there was a sufficiently large number of respondents). The findings showed that for those working in protein chemistry, organic chemistry and pharmacy, having individuals qualified in both chemistry and biology or teams with researchers from both disciplines was important to a greater extent than in other fields.

### 3.3 The role of chemists

The questionnaire asked about the role that chemists played in the life science research in which the respondent was involved. For around two-thirds of respondents chemists provided subject knowledge that other team members did not have and a similar proportion saw them as 'integral to our research' but as table 3.1 below shows, they also played other roles. Chemists were seen as important in helping teams to keep abreast of developments in chemistry and for a minority they provided access to additional funding streams and to high impact journals. Contrary to the concerns expressed by participants at the RSC's 2002 workshop, chemists are not 'used as a service' by the biological research community; their input is more fundamental than this.

**Table 3.1 Role of chemists**

Role of chemist	Percentage of all respondents* Base: 446
Provide subject knowledge others do not have	68%
They are integral to our research	65%
No specific role, equal members of team	32%
The project is led by chemists	28%
Keep up to date with chemistry developments	24%
The objectives are set by chemists	18%
They provide access to funding	16%
They undertake routine elements of the research	15%
Help research to get in high impact journals	10%
Some other role	2%

\* Respondents were able to select more than one answer, hence the total sums to more than 100%.

When respondents in biological science departments were compared with those in chemistry departments over half (55%) of those in biological science departments said that chemists were integral to the research and 77% said that chemists provide subject knowledge others do not have. Chemists were more likely to be undertaking routine elements of the research in biological science departments than in chemistry departments but this is only occurring in a minority of cases. Only 18% of those in biological science departments and 7% of those in chemistry departments said this.

Respondents were more likely to say that chemists played a leading role on projects in the fields of organic chemistry, pharmacy/pharmaceuticals and synthetic chemistry than in other fields.

### 3.4 Collaboration

Three-quarters (75%) of PIs said that finding collaborators was either very (25%) or fairly easy (50%), although for a minority (10%) it depended on the particular project.

The case study discussions revealed that researchers find collaborators in a variety of ways, including:

- the reputation of individual researchers or groups;
- meeting at conferences;

- searching the web for researchers with relevant expertise;
- being referred to relevant individuals by colleagues in their department;
- from published articles; and, of course,
- some are themselves found by other researchers.

The core of collaboration was seen to be *“a coming together of individuals sharing common goals and a common vision”*. Collaborations were said to *“take effort to maintain”* and if they are in different institutions, funding is needed to cover travel and subsistence costs for meetings and periods of working at the same location. Undertaking the work within a single group was thought to be a much easier way of working, although a common vision and good personal relations can clearly overcome most barriers.

### 3.5 Summary and conclusions

The most common working relationship at the chemistry-biology interface involves cross-departmental collaboration within an institution. Physical proximity facilitates collaboration and should be supported by institutions. Personal interaction is important to the success of collaborations at the chemistry-biology interface. Common goals and a common vision about a problem to be solved or a challenge to be addressed are at the core of a successful collaboration. However, distance between researchers need not be a barrier to collaboration if goals are shared and personal relationships developed.

Chemists play a key, integral role in research at the chemistry-biology interface.

## Pollen to deliver drugs

Pollen capsules that can be filled with nanomaterials could be used for drug delivery.

Some plant pollens can cross the gut wall where they are destroyed within the blood stream, releasing their contents. This has led researchers to investigate pollen as possible drug delivery vehicles.

Vesselin Paunov at University of Hull, UK, and colleagues have developed a way of filling pollen capsules with nanomaterials. Paunov says the method will allow sporopollenin, the material that makes up the outer layer of pollen, to be used in pharmaceutical and cosmetic formulations.

The researchers used the sporopollenin capsules as chemical micro-reactors, adding starting materials and then allowing a chemical reaction to generate the product inside the pollen. Paunov's team used this method to fill pollen capsules with organic, inorganic and magnetic nanoparticles.

'Future developments may include preparation of "stealth" sporopollenin capsules which have longer circulation time and provide controlled release. Advances also may include functionalisation of the outer surface of the capsules that specifically bind to particular types of biological tissues,' said Paunov.

Orlin Velev, a biomaterials researcher at North Carolina State University, US, said the work represents a beautiful example of the convergence of natural and man-made materials on the microscale. 'The creative use of capsules of biological origin as reactors for nanoparticle synthesis illustrates the richness of approaches that can be used in the fabrication of new biomimetic materials with potential applications in drug delivery and biomedical technologies'.

By Rebecca Gillan

Reference:

V N Paunov, G Mackenzie and S D Stoyanov, *J. Mater. Chem.*, 2007, 17, 609-612

### Introduction

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The genesis of this inter-departmental team was the arrival of Professor Tom Simpson in the School of Chemistry. He brought with him a project grant and an associated PhD student to work on the molecular biology of polyketide synthesis. This work needed supervision from a biological perspective as well as from the School of Chemistry and Dr Colin Lazarus agreed to take on that role.

The outcomes from that first project were considered useful and interesting in both Schools and the collaboration continued, largely through jointly supervised studentships, yielding a flow of good quality work.

### The group

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Over time a clear group has grown up around the original partnership. Within the Organic and Biological Chemistry Section of the School of Chemistry there are five core members of the Bristol Polyketides Group: Professor Simpson; Professor Chris Willis; and Drs Russell Cox, Matt Crump and John Crosby, John Crosby having previously worked with Tom Simpson at both Edinburgh and Leicester. All five academics have their own research interests in addition to the work of the group, which does not have a formal management structure.

Colin Lazarus remains a core member of the group and has been joined by Dr Andy Bailey in the School of Biological Sciences. A further member of the group from the School of Medical and Veterinary Sciences is Dr Andrea Hadfield in the Department of Biochemistry.

The group is held together not by management structures, but by shared interests, especially in the basic science associated with natural biologically active products. Polyketide synthases, which almost all occur in bacteria and fungi, manufacture an enormous range of biologically active compounds in nature. Understanding how polyketides work and how they can be manipulated requires skills and techniques from across the fields of chemistry, biology and biochemistry. Group members believe that the naturally emerging shared interests provide a powerful cohesive force.

The group is working in an internationally competitive field so it is vital to be able to draw on a spectrum of expertise. The group members tend to believe that they are simply doing science the way it has to be done in a field that straddles disciplines.

### Working practices

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The group is driven by research problems, and leadership of individual projects will rest with the most appropriate person. A strong biological slant could see Colin Lazarus or Andy Bailey leading the drafting of proposals to BBSRC and papers for biological journals. Conversely Russell Cox or Tom Simpson may at the same time be preparing a bid to EPSRC.

Across the group researchers are familiar with the basic techniques from other disciplines that allows a certain amount of multi-disciplinarity. However, there is a firm view that while this is useful for exploratory work and helps mutual understanding across the group, the very best science is that which draws upon the highest level skills from the different disciplines.

A steady flow of PhD students between the two schools is a feature of the group's work and a relaxed attitude towards departmental territory help to instil a way of working that is inherently collaborative. The culture of co-operation is supported by relatively light touch management at the institutional level and mutual respect for the skills that different group members bring.

### The physical infrastructure

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Within the School of Chemistry there has been a conscious decision to invest in infrastructure and it now hosts analytical facilities that function as university-wide resources not simply departmental or group facilities. Two members of the polyketides group Matt Crump and John Crosby respectively manage NMR and mass spectrometry facilities, which provide access to powerful analytical tools.

The School of Biology is located a few minutes walk away, but this is not seen as a hindrance to effective working.

In comparison to other collaborations on a national and international scale, in which group members participate the location of the group members is not seen as a logistical issue. As part of an aggressive building and refurbishment strategy at Bristol, the School of Biology will be moving into new facilities within the next couple of years.

Both Schools are large with broad ranging research interests, this can mean that individuals' research portfolios may have more in common with colleagues from another department than from their own department. This is recognised and accepted as a natural part of the university's working.

### **Applying for grants**

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Writing proposals is a collaborative process, but will generally be led by one of the group members. The group recognises that working across interfaces can make targeting grant proposals harder and they rely on one another's expertise to identify the best opportunities within different funders' portfolios. Generally proposals will be led by the group member or members with most experience of the selected funding route.

Full economic costs have helped with the apportioning of overheads in proposals that involve more than one department, which has helped to overcome difficulties that used to be experienced within the University's financial management. However, allocation of directly allocated costs from the centre to the departments is an issue that needs to be resolved.

### **Publication**

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Working in an interface area is seen as a significant advantage when it comes to publishing. There are many options available with inter-disciplinary journals augmenting those in the individual disciplines. As with grant proposals, individual group members will take the lead in drafting papers according to their role in the project and experience of the target journal. As with grants, the question of PI, or senior author status, in this interdisciplinary team work area becomes a serious issue in terms of RAE submissions.

### **Teaching**

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There is no separate chemical biology degree. The chemistry undergraduate syllabus includes some short courses that reflect the interface research interests within the school as do some of the final year research projects in the School of Biology. Within both schools the teaching focus is on delivering a solid core of the individual disciplines.

### **Conclusion**

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This is a collaboration that has grown out of individual relationships and has been sustained by a body of high quality work. There is no formal management structure associated with the group so it is reliant upon the mutual respect that the individual members have for each other's skills and knowledge.

The group members are united by an interest in addressing practical problems through basic science and although many have developed multi-disciplinary skills, they all believe that high quality inter-disciplinary work requires expertise within the different disciplines.

## 4 Institutional support

### 4.1 Introduction

This section looks at what institutions have done to support research at the interface and identifies institutional barriers. It also looks at what lessons, if any, can be learnt from the way in which industry is organised.

### 4.2 Institutional support

Some 61% of respondents indicated that their university/institution supports research at the chemistry biology interface by disagreeing with the statement: 'My university/institution does not support work at the chemistry biology interface'. The main point of interest is that those in chemistry departments were more likely to disagree with the statement (70% of this group did so) than those in biological science departments (57%).

### 4.3 Enabling research at the interface

Some 63% of respondents felt that their institution enabled research at the chemistry-biology interface and only 9% said that they thought it actually hindered such research. Respondents were asked to write-in what their institution was doing to enable research at the interface and table 4.1 shows that they identified a variety of different activities.

**Table 4.1 Enabling research at the interface**

How institutions support research at the interface	Percentage of all respondents* Base:
Interdisciplinary centres	34%
Bringing people together (e.g. seminars)	29%
University management and communication structures	12%
Provide funding	12%
Physical location	10%
Cross-disciplinary appointments	7%
Supporting proposals for cross discipline funding	7%
Joint appointments	5%
Virtual Centres	2%
Other positive	6%
Don't get in the way	3%
Institution does nothing	3%

\*Respondents were able to choose or write in more than one response, hence the total sums to more than 100%.

Supporting interdisciplinary centres (34%), initiatives to bring people together such as seminars (29%), institutional management and communication structures (12%) and providing funding (12%) were the main ways that respondents said their institutions were supporting research at the chemistry-biology interface. Other enabling behaviour included physically locating chemistry and biology researchers in the same building and with shared spaces or facilities (10%), cross-disciplinary appointments that straddle traditional departmental boundaries (7%) and making joint appointments through which a researcher can hold a post in more than one department (5%). Establishing virtual centres for chemistry and biology was also mentioned as another way in which some universities enabled collaboration (2%). The full list of activities can be found in appendix 4.

The case studies highlighted the need for physical proximity. In one case study institution the workspace was

specifically designed to ensure that biologists and chemists have to interact to access resources. Generally, the cost of specialised equipment also forces sharing as institutions have central services. In several departments the PSP team visited there were regular dissemination seminars across departments, management meetings of team leaders to discuss work and informal areas for postdoctoral and postgraduate students from chemistry and biology to mix.

When looking at the actual descriptions written in by respondents, it becomes more obvious that anything that brings people together and promotes interaction at a personal level is thought to foster collaboration and inter-departmental working. Amalgamating departments into larger units was thought to overcome some of the institutional barriers, such as cost centres and physical proximity, although respondents did not provide sufficient detail to allow us to identify models of how this was accomplished.

*"Biologists and chemists have a joint meeting from time to time in which everyone presents a summary of their research and ideas/collaborations develop naturally from this. We also have a Research Centre that has dedicated laboratory space and is occupied by staff from both departments (although it is geographically located in the Chemistry Dept.). This centre serves as a focus for communication, problem solving and new research ideas."*

**Questionnaire write-in**

*"[My university] has set-up "Knowledge-Bridging"<sup>3</sup> schemes to encourage collaboration."*

**Questionnaire write-in**

*"By promoting interdisciplinary research via consortiums, who have funding for studentships, joint meetings and other initiatives. Also by the merger of traditional departments into larger units."*

**Questionnaire write-in**

*"The University is designed to allow overlap - all departments are connected by a long corridor that means we can walk to Biology without changing buildings!"*

**Questionnaire write-in**

The collegiate model was said to support contact and communication between those in different disciplines. This is because while disciplines provide a structure within which relationships can be formed, the collegiate system provides a structure which cuts across disciplines and thus provides an alternative structure within which to meet potential collaborators. This is similar to the approach reported by Texas Southwestern Medical Centre, mentioned in section 1.4.4.

Joint undergraduate course provision was also a mechanism which brought researchers together. Similarly, at post graduate level one university provided 'half PhDs' to departments who then had to find another 'half' with which to collaborate.

An institutional strategy was thought to be important. In one of the case studies, one participant said that an institution needed someone to be *"thinking about how we bring people across disciplines together... I [as a scientist] don't know the best way of doing that."*

Understanding each other's language was a potential barrier to collaboration and this could be a barrier to cross-departmental seminars, if the title of the seminar was not understood by researchers from other disciplines. Some researchers are understandably wary of giving up time to something they assume they will not understand. Again, this reflects the findings from earlier reports discussed in section 1.

A few respondents (3%) said that their institution was doing nothing. The case study interviews and some of the responses, indicate that this is sometimes seen to be a good thing.

*"By keeping out of the way and letting them get on with it."*

**Questionnaire write-in**

Respondents were also asked how their institution could better enable research at the chemistry-biology interface. Table 4.2 below shows the most commonly mentioned responses. Interdepartmental seminars and building new research facilities were the most popular additional activities.

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<sup>3</sup> Knowledge bridging is the practice of applying knowledge from one technical domain to innovate in another.

**Table 4.2** How research at the interface could better be supported

How institution could better enable research at the interface	Percentage of all respondents* Base:
Fund regular inter-departmental seminars	38%
Build new research facilities	36%
Restructure around research topics rather than disciplines	24%
Incorporate chemistry-biology as a specific discipline	23%
Bring people together in a single department/school	21%
Create a virtual centre for chemistry-biology research	21%

\*Respondents were able to choose more than one response, hence the total sums to more than 100%.

Those researchers who were younger and earlier in their careers were more keen on regular inter-departmental seminars, restructuring the institution around topics and building new research facilities than average.

Interestingly, only 7% of respondents thought that there was nothing that their institution could do, although some survey respondents said that they had not ticked this option because they thought that their university was already doing a lot and that to give this response would reflect negatively on an institution that was trying to take action.

#### 4.4 Institutional barriers to interface research

Participants were asked: 'What do you think is preventing your university/institute from changing its structure to better support research at the chemistry-biology interface?' They were asked to select from a list of options and given the opportunity to write-in other answers. Respondents were not asked to actively disagree with items on the list. The findings show that institutional barriers often have their origins in issues related to securing funds for the institution or for individual departments.

**Table 4.3** Institutional barriers to interface research

Institutional barriers to interface research	Percentage of all respondents* Base: 396
University structures are designed to maximise RAE scores	42%
Lack of coordination between departments	38%
There are other interfaces it has to consider	30%
Competition between departments	30%
There are other priorities for investment	29%
Insufficient funding for interface research	23%
Because of the way it markets itself to undergraduates	21%
This university focuses on other subject areas	12%
There is not a problem	8%
Other	7%
Inertia/reluctance to change	2%
Costs	2%
Closing or closed chemistry department	1%

\*Respondents were able to choose more than one response, hence the total sums to more than 100%.

As table 4.3 shows, the most often cited barrier to institutions changing their structures to better support research at the chemistry-biology interface was thought to be the 2008 RAE (42% of respondents cited this as a barrier).

One case study participant felt that it was more difficult to establish esteem factors for someone working at an interface than for someone working at the core of a discipline. This was much less of a barrier for researchers in stand alone institutes.

The other major barrier was seen to be the lack of coordination between departments; 38% cited this as a barrier, although this seems to be more of an issue in Russell group institutions, where 42% of respondents cite this as a barrier, compared with 28% of non-Russell group institutions.

Nearly a third (30%) thought that competition between departments was preventing their institution from better supporting research at the chemistry-biology interface but 29% acknowledged that there were other priorities for investment.

The case study discussions revealed that devolution of budgets to departments has led to competition between departments for funding and other resources. Of particular relevance to multidisciplinary research is departmental cross-charging for the use of facilities. This work has not given any indication of how common cross-charging might be.

Dividing research income between departments seemed to be a problem in some, but not all, institutions, even where cross-departmental working was encouraged.

*"They [the university] encourage it and also create research centres - real or virtual. There is constant dialogue. However, we still have to struggle with fairly rigid income streams."*

**Case study**

*"It [the university] makes it clear that cross-departmental collaboration is desirable and does not place barriers in the way of such collaboration e.g. facilitating the transfer of (external) funding among project partners."*

**Case study**

Problems of allocating budgets between departments seem to have become easier more recently. It was reported to us that Full Economic Costing (FEC) had helped with this as applications for funding now have to make clear each individual's contribution to the project. Hence once funding is won, it is clear how to allocate it between departments.

The lack of funding for inter-departmental preliminary work needed to develop grant applications was an issue for some. Within a department some flexibility could be found for this type of work but across departments it was more difficult. It was suggested that providing this type of funding was one way in which institutions could help their researchers.

To accommodate multidisciplinary research some case study participants said that more laboratory space is needed overall. This is because researchers need to be able to move between chemistry and biology laboratories to use different facilities. Hence there will be times when the number of researchers using a particular laboratory is greater than the number of researchers in that department.

On the whole, arrangements appear to work because departments, at senior levels, agree to co-operate. One case study interviewee regarded other departments not as competitors but as *"colleagues doing similar things"*.

Some (23%) indicated that they thought that there was not enough funding for research at the chemistry-biology interface to make it worthwhile for their institution to put in place specific structures. However, the case study interviewees pointed out that some areas of chemistry and biology have more in common across the disciplinary boundary than do some sub-fields within the single disciplines.

One of the funders had indicated that HEIs may be reluctant to move away from traditional disciplinary structures because of the need to attract undergraduates with subjects they recognise from their school curriculum. However, only one in five respondents (21%) believed that the way their institution markets itself to undergraduates dictated structures. Demand for interdisciplinary undergraduate courses was generally said to be good because many students are not sure what they want to do in the future. At one institution it was reported that among undergraduate chemistry students, biological options proved popular. Indeed, some reported that rather than undergraduate teaching imposing structures on research, research interests influenced what was taught on undergraduate courses.

Only 8% of respondents said that the structure of their institution was not a problem. This was consistent across all subgroups considered thus there are clearly a lot of positive initiatives going on in institutions (see table 4.1).

#### 4.5 Learning from industry

In the questionnaire respondents were asked to write-in what they thought academia might learn from industry. The main lesson respondents felt could be learnt from industry was the problem focus of industry and the ability to organise specific teams with the relevant expertise to address the problem. However, most tempered this with an understanding that industry and academia have fundamentally different perspectives, roles in the research process, timescales and objectives. While there are lessons that can be learned from industry, many valued the differences and what they perceived as the freedom of academia.

Illustrative of responses that saw industry's problem-focus to research as something from which academia could learn were:

*"... place more emphasis on rationally designed novel synthetic targets. Stop holding so many inward looking chemistry meetings and hold more interdisciplinary meetings where chemists can be introduced to real problems."*

**Questionnaire write-in**

*"The major difference is that industry sets up properly integrated cross-disciplinary project teams with focus on a common goal. This is starting to happen in academia but too many projects still have a "senior" partner directing the research and a "junior" partner expected to fall into line. In industry (in most cases) all the disciplines work together to achieve the end result. This only happens, of course, because "the company" or a senior manager has ownership and executive powers over the direction of the project. I am sure that most academics do what they do because they do not wish to relinquish their autonomy to a project manager. The elusive ingredient in promoting more effective cross-disciplinary projects in academia is to remove the ego factor: not an easy prospect."*

**Questionnaire write-in**

Others considered not repeating the mistakes of industry; for example a short-term outlook and a profit motive:

*"We can learn the "what not to do". We have the ability to be inventive and innovative ... we still have a lot of flexibility in how/when and why we want to tackle a given problem. This should not be given up."*

**Questionnaire write-in**

There were also those who believed that the two sectors are intent on fundamentally different tasks and therefore naturally have different ways of working. Timescales, the profit motive and depth of exploration were all thought to identify industry as different from academia. A minority of respondents (15%) felt that academia could not learn anything (8%) or very little (7%) from industry.

*"It would be hard to translate industrial interface research which is very much specific-goal led; in university research the subject matter is often more open-ended and moves with time in a different time frame. University research is also not budget/profit driven so that management pressures are different."*

**Questionnaire write-in**

*"Certain areas of chemical biology are already integrated in industry. The development in industry is very much target-based and therefore brings people together when needed to solve a specific problem. In spite of the above, industry generally lacks the ability to go in depth into problems and therefore certain challenging questions in the chemistry/biology interface are much better tackled in Universities and research centres."*

**Questionnaire write-in**

Although there is a good deal to be learned from industry, researchers in academia should be aware of what industry is not focusing on, which may present areas that academia could potentially develop.

## 4.6 Summary and conclusions

The findings in this chapter accord with those from the NAS (2004) report.

Many institutions appear to have developed ways to support interdisciplinary research and some have specifically identified research at the chemistry-biology interface as a specific area for support. Mechanisms that were reported to be in place in institutions to support multidisciplinary and interdisciplinary research include:

- facilitating physical proximity and promoting interaction at a personal and departmental level; although infrastructure is seen as important, it is not pre-eminent in facilitating effective collaboration.
- interdisciplinary centres (including physical buildings and virtual centres);
- regular inter-departmental seminars;
- joint undergraduate course provision;
- cross-departmental PhDs;
- joint faculty appointments; and
- physically adjacent chemistry and biological sciences laboratories.

Respondents also suggested that institutions could consider restructuring around research topics, rather than disciplines, to support interdisciplinary research. Whilst this would be a positive step to facilitate effective collaboration, it will require a significant cultural change in some institutions.

Respondents identified a number of barriers to research at the chemistry-biology interface, including:

- institutional structures that are designed to maximise RAE scores;
- a lack of coordination between departments;
- competition between departments for funding and other resources; and
- a lack of suitable laboratory space

Academia, it was thought, could learn from industry's goal-oriented culture and focus on solving problems.

However, respondents also said that academia should avoid adopting industry's short-term outlook and emphasis on profits.

### Introduction

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The Centre for Biomolecular Sciences (CBS), which opened in 2003, brings together biologists, mathematicians, engineers, pharmacists, clinicians and chemists. Researchers located within the interdisciplinary Centre remain formally attached to their Schools.

Associate Professor Neil Thomas (School of Chemistry) is part of two collaborations with colleagues from bio-science Schools at Nottingham, involving a total of five joint PhD studentships and two Post Doctoral Research Assistants. These include a collaboration with researchers from the School of Molecular Medical Sciences and the School of Pharmacy, aiming to develop an enzyme which kills MRSA, potentially leading to a prophylactic that could be used by healthcare workers. Another collaboration involves working with researchers from the School of BioMedical Sciences on a novel technique to label the targets of enzymes involved in inflammatory responses that lead to disease. Both of these collaborations draw upon Professor Thomas' expertise in enzyme structure and mechanism.

### Institutional support

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Interdisciplinary working is encouraged through institutional support at Nottingham. Financial arrangements have been simplified, for example, researchers in the CBS remain attached to their Schools, and grant money is allocated to the Schools rather than the CBS. Research income is assessed on a Schools basis for RAE purposes.

The university funds 'half PhD studentships', which are given to Schools on the understanding that they should find another School or Industrial partner with matching funding with which to collaborate.

The university also promotes interdisciplinary poster and discussion events with high profile plenary speakers, and hosts Research Council funded sandpit events that bring researchers together from across the university. Sandpits provide brain storming opportunities and distribute seed funding money to help teams develop proof of concept for promising research ideas.

The Centre for Biomolecular Sciences itself demonstrates the institutional commitment to interdisciplinary research. It is a facility shared between seven Schools, and includes common spaces that encourage researchers to meet and talk informally.

### Working practises

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One of Neil Thomas' chemistry-biology interface collaborators is located in a separate building on the campus. However, they are still physically close enough to enable contact to be kept up on a daily or weekly basis if necessary. Collaboration within the university allows for PhD students to be jointly supervised, and meetings with PhD students are scheduled on a monthly basis, with both supervisors present. This shared workforce and frequent contact enables the project to develop in an organic, as opposed to a linear way. Collaborators mentioned this as important in enabling discussion and response to unforeseen developments during the project.

The frequent contact made possible by this physical proximity is also beneficial in enabling the collaborators to develop a common language. They can take time to explain concepts and terms to one another, a common understanding of which improves the efficiency of the collaboration. It was remarked that Biology and Chemistry are more compatible in this respect than Chemistry and Physics, since Biologists are already familiar with complex molecules such as DNA, whereas physicists work mainly at an atomic level.

The process of collaboration itself is held to provide opportunities for further collaboration, since the new knowledge generated can open doors onto wider horizons of opportunity for interdisciplinary research and promotes increased networking between Schools. It also leads to the development of new degree courses i.e. MSci in Medicinal & Biological Chemistry (Chemistry/Pharmacy) and MSc Nanoscience (Chemistry; Pharmacy; Physics; SCHEME (chemical engineering)).

## **Instigating collaboration**

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Collaboration at the interface between Chemistry and Biology occurs because it offers potentially fruitful approaches, where single discipline attempts to resolve problems have failed. Researchers who become known for collaboration are more likely to be recommended to help with such projects, not least because they are more likely to be known of in other departments. Neil Thomas has become known for collaboration across departments, and in addition to the bioscience projects outlined above, he has two chemistry-physics collaborations involving a further three joint PhD students. Over time, acquiring knowledge and experience across disciplines can better enable a researcher to see opportunities for collaboration where they exist.

## **Conclusion**

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These collaborations demonstrate the opportunities for fruitful research that work at the interface presents. Wide personal interests and willingness to learn about other disciplines enable researchers to see opportunities for collaboration where they exist, and where someone becomes known for this work, they may be approached with research ideas by those from other departments. In addition, the University of Nottingham provides both practical and financial encouragement to interdisciplinary approaches. The combination of these factors facilitates activity at the chemistry-biology interface.

## 5 Research funding

### 5.1 Introduction

This section looks at views on funding but not just levels of funding and awareness of schemes. It also looks at funding sources and views on how the funding system for chemistry-biology is working in the UK. By exploring these views and how grant applications are written for projects at the interface it is possible to draw some conclusions for research funding regimes at any interface.

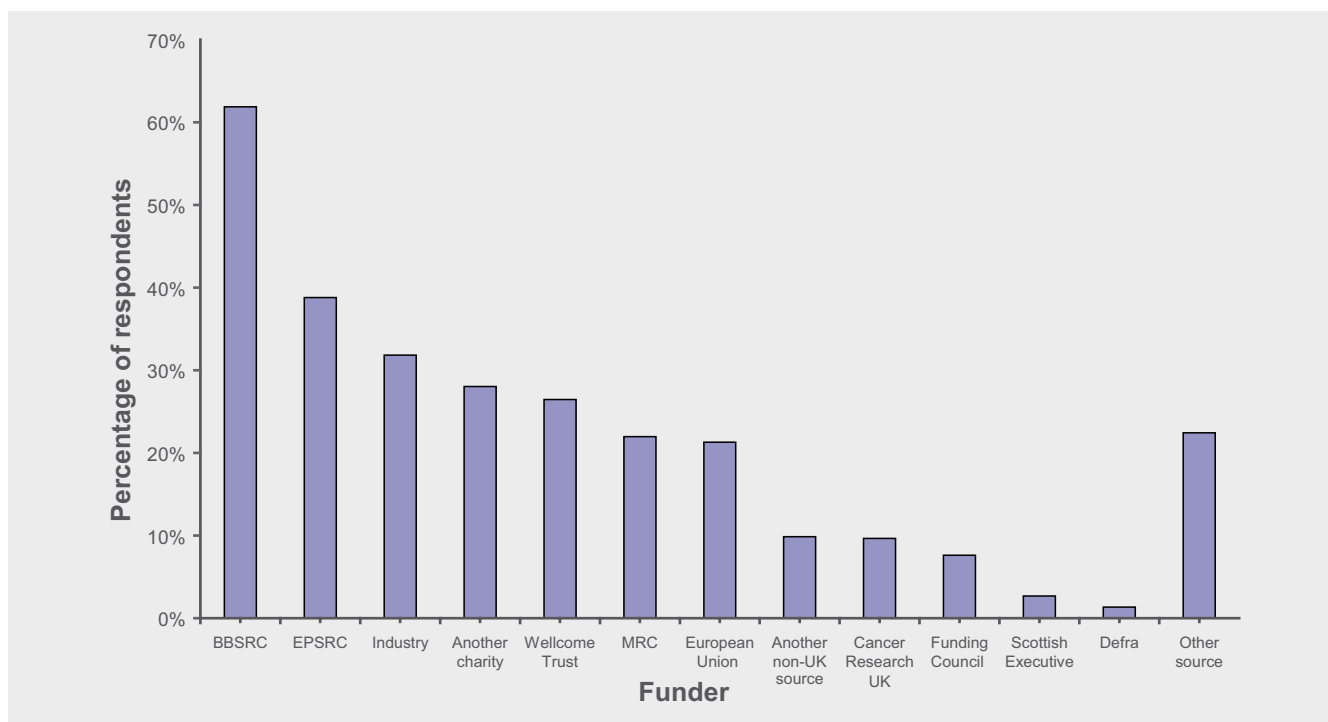
### 5.2 Funding levels

Unsurprisingly, the majority (63%) of respondents agreed that 'Chemistry-biology interface research in the UK needs more ring-fenced funding' but a quarter (24%) neither agreed nor disagreed. There was a tendency for those in chemistry departments to be more likely to agree than for those in biological science departments, with 66% of those in chemistry departments agreeing compared to 49% in biological science departments.<sup>4</sup>

### 5.3 Sources of funding

Respondents were asked to name all their funding sources for the last three years. Chart 5.1 below clearly shows that BBSRC was the most often cited funder but they provided the largest sample. (See appendix 2 for details of the sampling strategy.)

**Chart 5.1 All sources of funding, last three years**



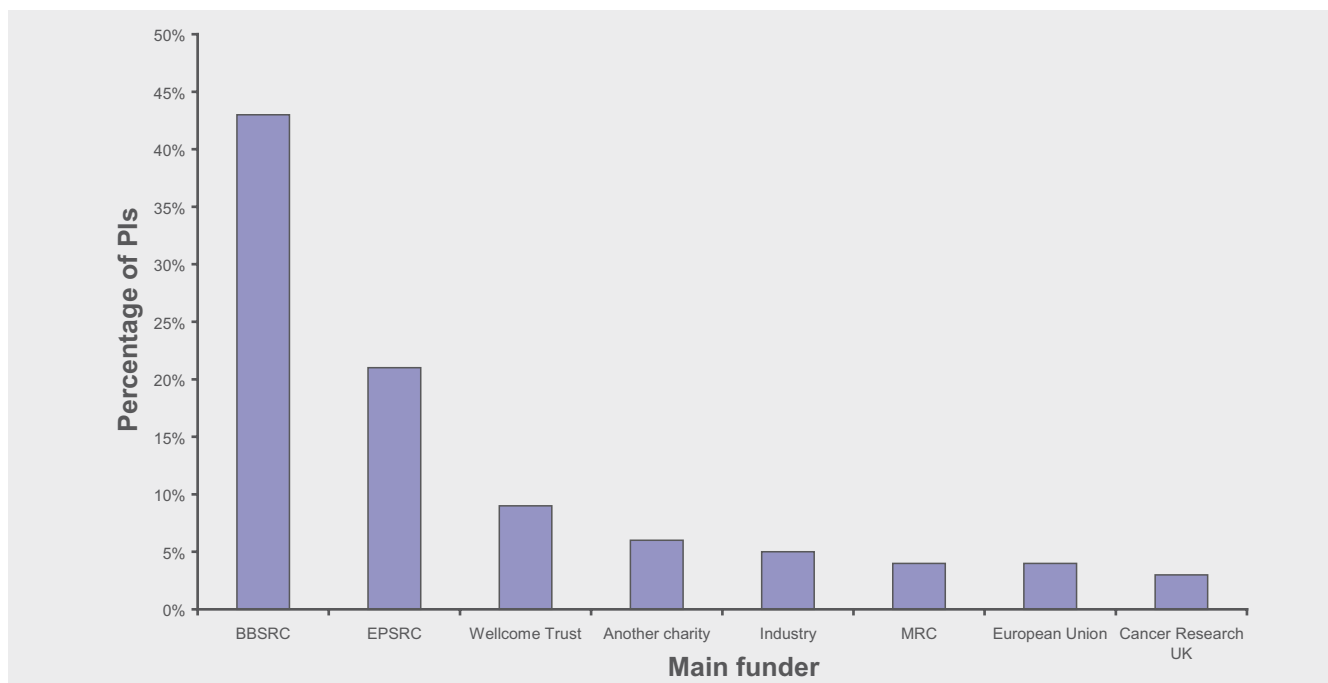
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Unsurprisingly, those in biology departments were much more likely than those in chemistry departments to receive funding from BBSRC (86% compared to 50%), while those in chemistry departments were more likely to be funded by EPSRC (61% compared to 21%).

When looking at current 'main funder' for PIs only (that is excluding joint and co-PIs to eliminate double counting) BBSRC still dominates, with EPSRC second and the Wellcome Trust third, as can be seen in Chart 5.2.

<sup>4</sup> The research Councils estimate their minimum investment to be £240m at the chemistry-biology interface, as at 1st April 2007

Chart 5.2 Main funder



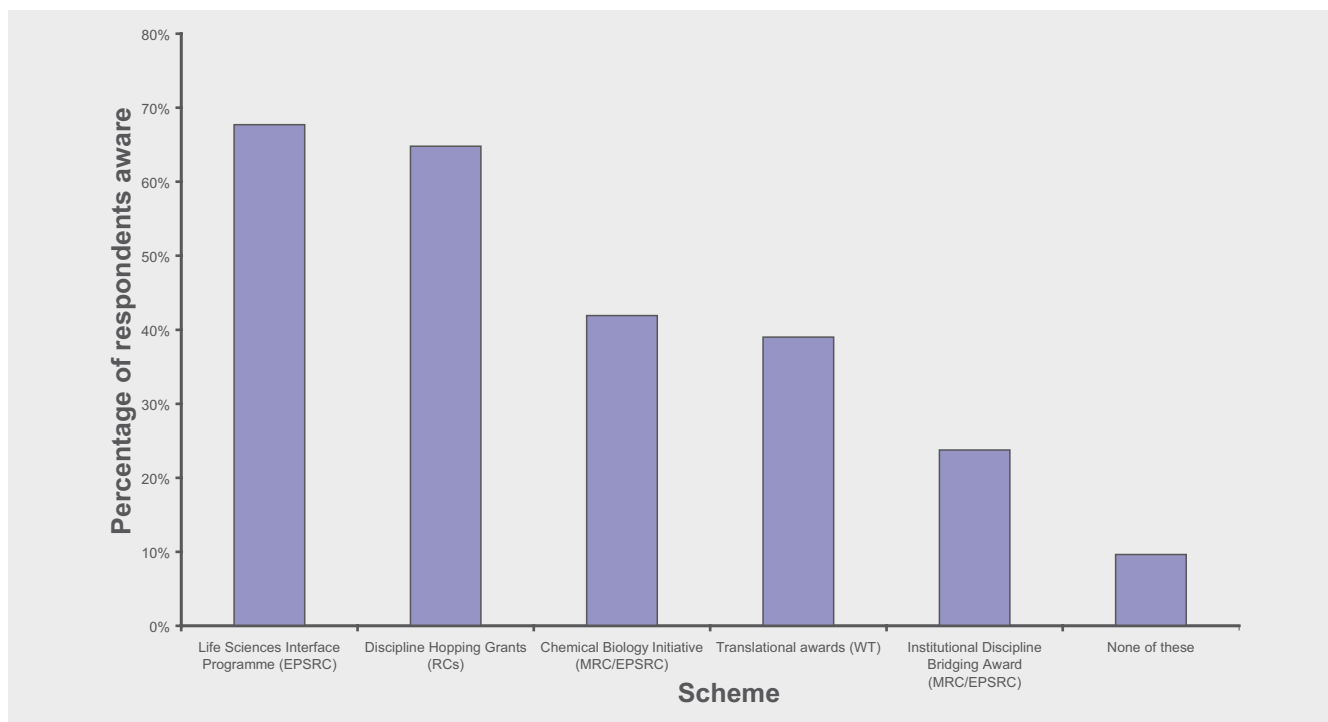
Base 235 All PIs, excluding joint and co PIs

Considering all respondents, only two of the total sample had funding solely from industry in the last three years, although 25 (6%) reported that industry was their main funder. Nearly a fifth (18%) had not received any funding from BBSRC, EPSRC or MRC and for 37% of the sample none of these Research Councils were their main source of funding. This 37% tended to be funded by the Wellcome Trust (24%), industry (15%), the EU (11%) and Cancer Research UK (10%).

#### 5.4 Funding programmes

In addition to main stream responsive mode funding, such as BBSRC's Biomolecular Sciences (BMS) and EPSRC's Life Science Interface Programmes (LSI), funders run a number of schemes to support research at the chemistry-biology, and other interfaces. Chart 5.3 shows awareness of some of these special schemes in comparison to the LSI Programme. None were universally known although interestingly Discipline Hopping Grants were almost as widely known as the LSI Programme. Only 10% of respondents had heard of none of the schemes.

**Chart 5.3 Awareness of interface research grants**

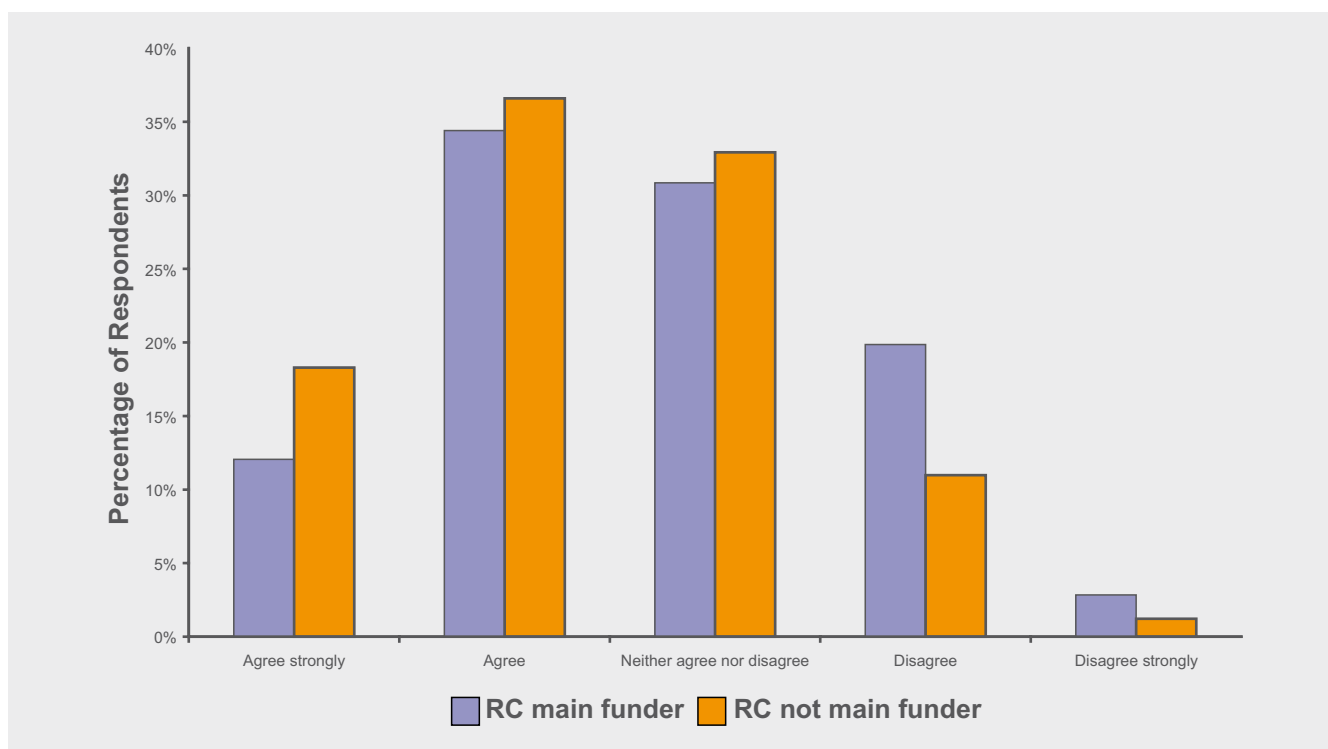


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### 5.5 Funders and funding mechanisms

Half of the respondents (50%) agreed or agreed strongly that 'The interface of chemistry-biology is not understood by funders' and 19% disagreed. This perception on the part of respondents, most of whom have benefited indirectly or directly from funding at the chemistry biology interface, suggests a significant communications gap. Chart 5.4 below shows that those whose main funder was BBSRC, EPSRC or MRC were more likely to disagree with this statement than those with other organisations as their main funder.

**Chart 5.4 The interface of chemistry-biology is not understood by funders**



Base: 446

Those based in chemistry departments were more likely to agree that 'The interface of chemistry-biology is not understood by funders' than those based in biological science departments (61% compared to 42%). Interestingly, PIs were more likely to disagree than non-PIs (23% compared to 10%), which may suggest that once researchers are more engaged in the funding process, whether as applicants or as reviewers and members of grant awarding committees, they are more aware of Research Council processes and funding opportunities.

The following discussion is based on questions regarding funding bodies; this includes the Research Councils and the Wellcome Trust. However, most of the feedback focuses on the Research Council funders. Further information on research funding including the Wellcome Trust funding structures can be found in Appendix 5.

Six per cent of respondents said that the Research Councils were able to deal with applications for chemistry-biology grants 'very adequately', although 38% felt that they deal 'fairly adequately' with applications. However, only 9% said that the Research Councils dealt with applications 'not at all adequately' while 10% acknowledged that it varies. Responses to this question may, of course, reflect respondents success at applying for funding from Research Councils.

The research suggests that some researchers feel that the US handles funding research at the chemistry-biology interface more effectively than the UK.

*"The US universities and colleges have led the way in funding at the chemistry/biology interface by having a clear funding agency (the NIH) that sits at this interface. The UK has BBSRC, which wants to do basic biology and does not really support chemistry, and the EPSRC which wants to support fundamental chemistry ... rather than the application of synthetic chemistry to biological problems."*

*Questionnaire write-in*

## 5.6 Research Council remit

Advice and support is available from BBSRC, EPSRC and MRC to help researchers during the drafting of applications to ensure that applications are submitted to the correct Research Council. Within EPSRC, the LSI programme enables the engineering and physical sciences research community to engage with the life sciences. As part of this, the programme operates an informal 'outline service'<sup>5</sup> which allows researchers to seek advice prior to submitting a formal application.

Despite this, for a range of different reasons, help is not always sought and applications are not always submitted to the correct Research Council. The case study interviews revealed that moving applications between Research Councils can cause delays and additional work for researchers. An example was given of an applicant for whom delay had meant that the researcher with the relevant expertise had moved on and the expertise has been lost to the applicant's group. Another example was cited where the work had been done elsewhere during the delay and was no longer relevant.

In addition, differences in application formats and information requirements between Research Councils mean that some researchers have had to spend time refocusing applications. Researchers write their applications with an eye to the audience and tailor applications for funding towards the aims and objectives of the funder or the specific scheme to which they are applying. Hence an application that is referred from one Research Council to another will be redrafted by the applicant to address what they see as specific requirements and interests of the Research Council or the specific research panel.

These examples emphasise the importance of applicants seeking clarity on remit and procedures from Research Councils prior to submission to ensure that applications are sent to the right Research Council to minimise delays and workload.

## 5.7 Writing applications

Forty-four per cent of respondents said that writing grant applications for research at the chemistry-biology interface was more difficult than applying for funding for single discipline projects and only 5% said that it was less difficult. Those based in chemistry departments seemed to find it more difficult than those based in biological science departments (53% compared to 44%).

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<sup>5</sup> This should not be confused with the submission of formal outlines required for some schemes operated by the Research Councils

The most commonly cited reason for interface applications being more difficult to write was the need to iterate applications with co-applicants. In the case study interviews it emerged that it takes longer to draft applications for research at any interface because of the need to involve more than one researcher. Using an expert from one discipline to ensure that each subject is comprehensible to someone from the other discipline, was a way by which researchers tried to ensure that their application would be understood by all reviewers.

*“There is a perception that when you are writing an inter-disciplinary proposal it is going to be read by an expert who is a chemistry expert, plus an expert who is a bio-chemistry expert, and then they may not appreciate the other part of the proposal quite as much, and then given the highly competitive nature of trying to get grant funding, anything that makes them judge something slightly lower is going to make it more difficult for that to be funded at the end of the day.”*

**Case study**

Sometimes researchers were applying for funding to funders with whom they were not familiar and this was said to be more difficult. Respondents also said that there tended to be more queries from funders for interdisciplinary and multidisciplinary applications. They also said that it is difficult to cost this type of research because of the need to collate costs for multidisciplinary research from more than one department and in some institutions different departments have different costing structures.

Researchers also raised the question of costs as a potential barrier for research at any interface, where one postdoctoral scientist from each discipline might be needed to progress a project.

*“You really need both of them [both postdocs] to be there at the same time. It is very hard for someone to be making molecules and not to have anyone to test them in the biological system, and then the biological system can't do very much if [you] don't have the chemical molecules.”*

**Case study**

## **5.8 Reviewing grant applications**

The major UK research funders mainly draw their peer reviewers from national and international academic experts in the relevant fields but industrial experts are also used.

In cases where an application is considered to cross Research Council boundaries, the lead Council will seek suggestions for referees from the co-funding Council, in order to ensure applications are assessed by referees with appropriate expertise.

There was a feeling among the case study participants that the UK pool of potential reviewers within any sub-field of the chemistry-biology interface is small. Over half (57%) agreed with the statement that ‘It is difficult to get funding in the UK because grant reviewers do not have the right expertise’. Those based in chemistry departments were more likely to agree strongly than those in biological science departments (34% compared to 17%). These perceptions may be a result of the way in which researchers receive feedback on grant proposals. Following panel meetings, the process of providing feedback varies between funders.

The appropriateness of reviewers was explored in the case study discussions. During this report, it was reported to us that in research at the chemistry-biology interface, often the chemistry is not ‘novel’ or cutting edge, even though the findings from the research would be new. This means that reviewers with a chemistry background may not see the proposed work as worthy of funding, although the biological questions may be important. This was seen as a major barrier to funding and it was suggested that this situation is not unique to chemistry-biology. Research at the interface between any two disciplines often involves the use of established techniques in one discipline enabling the exploration of key topics in another.

*“It can be difficult to get ranked doing interface work. You've got biology, you've got chemistry but you don't want to do chemistry that is cutting edge...You want chemistry that is doable, achievable and while it might look a bit dull, it is going to let you address the biological problem and is essential...The same goes for biology...It's the interplay that makes it interesting science...”*

**Case study**

From the discussions it appeared that chemists working on biological topics were driven by the desire to answer

questions, whereas organic and synthetic chemists were seen as being driven by a desire to make complex molecules or raise yields when synthesising molecules, irrespective of the molecule's use.

*"The RSC could help by putting together people with the right expertise. People who don't look down on making drug like molecules because it's easy to do. That's the whole goal – cheap and easy – not complex natural products. There are different drivers when it comes to translational research compared to fundamental chemical research."*

### Case study

The US was frequently held up as a good example of how to support and conduct research at the chemistry-biology interface. Implicit in these discussions was a sense that chemists and biologists there had greater respect for each others' expertise. It seemed that chemists in the US had a better understanding of addressing biological questions and biologists a better understanding of the importance of chemistry to moving biology forward than their equivalents in the UK.

## 5.9 What could funders do?

The questionnaire put forward some ideas on what the Research Councils could do to better support research at the chemistry-biology interface. The options were:

- Have a specific chemistry-biology panel/committee/board
- Have specific calls for chemistry-biology interface research
- Ensure that members of committees work at interface
- Ensure reviewers have expertise at the interface
- Provide broader training for researchers

The Research Councils advise that they already undertake a number of these initiatives, and the results from the questionnaire show support from the chemistry-biology interface research community for what the Research Councils are already doing. However, very few respondents, just 2%, indicated that there was nothing more that the Research Councils could do to better support research at the chemistry-biology interface. Overall, those based in chemistry departments were more likely than those based in biological science departments to want to see changes to the current funding system at its broadest level.

The survey findings are supported by the case study interviews. Analysis of the survey data by department, age and length of research career show consistent trends which indicate that in general chemists feel more disadvantaged than biologists and younger, less experienced researchers, tend to want special treatment for their subject. More experienced researchers who have probably developed a better understanding of research funding systems over time, appear to see not the overall system, but the way in which it is operated, as the main issue. It is important to remember that the vast majority of respondents have received Research Council funding and thus have experience of Research Council systems and processes.

Many of the researchers who took part in the case study research said that they preferred the application process whereby outline applications were submitted and only those who passed an initial pre-screening round were invited to submit a full proposal. This was because it saves researchers' time developing full applications that will not be successful.

Not everyone agrees however. A recent RCUK consultation on peer review has led the Research Councils to conclude that they should extend the use of outlines for managed programmes but not for responsive mode applications<sup>6</sup>. This is because the findings from the consultation showed that in general researchers felt that it is easier with managed schemes to assess whether applications meet the criteria. While current RSC policy supports the use of outline proposals in some cases, it does not see it as a way of reducing costs and is concerned that this may generate more proposals.

These findings accord with the NAS report discussed in section 1.4.5, which reported that interdisciplinary research poses special challenges for funding organisations that wish to support it. That report concluded that

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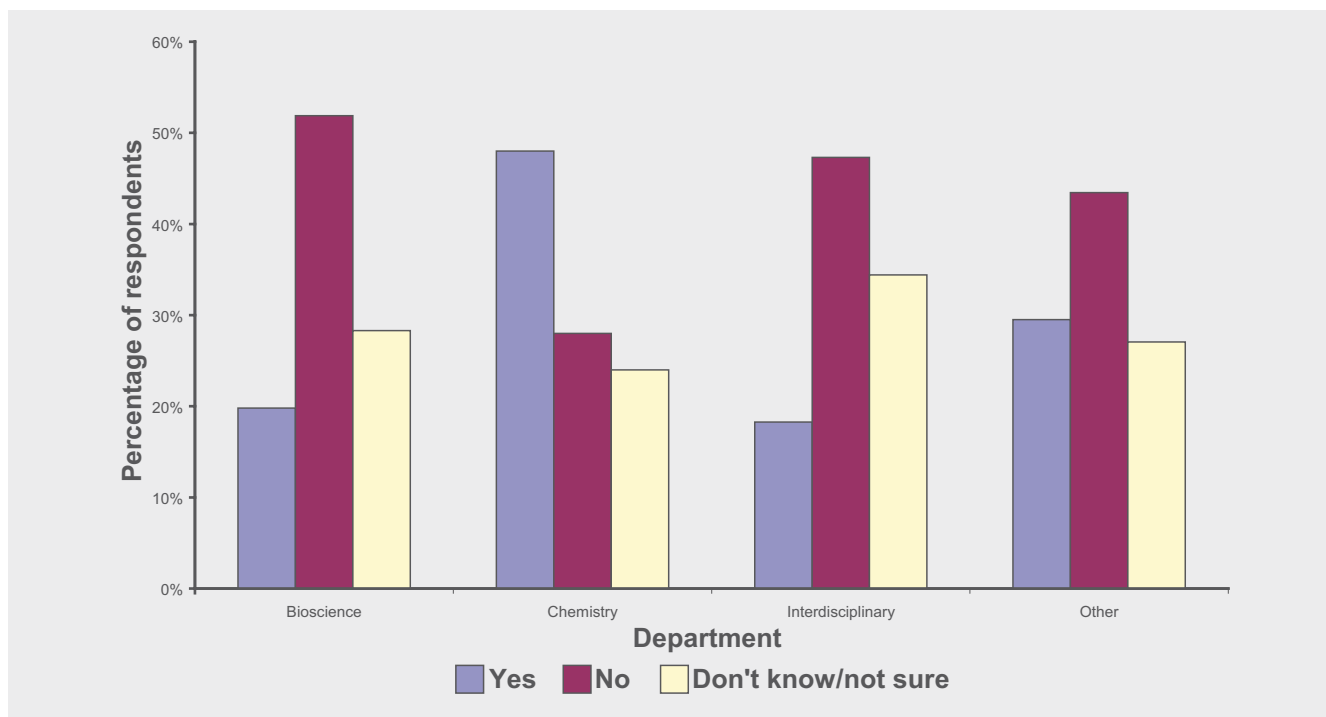
<sup>6</sup> RCUK Response to the Project Report & Consultation on the Efficiency and Effectiveness of Peer Review, RCUK, June 2007.

it was because of communication and cultural barriers and the tendency for institutions, journals, funding and professional bodies to be organised around traditional disciplines. Our findings support this conclusion.

### 5.10 Future researchers

Respondents were asked whether they felt that current undergraduates would be equipped to do research at the chemistry-biology interface. Some 42% said that they did not think that they would be. Those in chemistry departments were much more optimistic about this than those in other departments, including those in interdisciplinary centres, as chart 5.5 below shows. There was a feeling that students had to be open to new ways of looking at things, rather than academically gifted enough to master two disciplines.

**Chart 5.5 Whether current undergraduates equipped for interface research**



Base: 446

Respondents indicated that recruitment at post-doctoral level for research at the chemistry-biology interface is very difficult in the UK. Getting good PhD students for the field was also thought to be difficult but not as difficult as finding post-doctoral researchers.

*"I do find it a challenge here in chemistry to find people who are interested in ..."*

*Case study*

The different ways in which EPSRC and BBSRC fund PhD studentships was also said to cause difficulties.

*"You can apply directly on a research grant to EPSRC for a PhD student...You can't apply directly to BBSRC on a responsive mode grant for a PhD student."*

*Case study*

These different approaches cause further difficulties if applications are resubmitted to another Research Council.

### 5.11 Summary and conclusions

The perceptions of respondents, most of whom have benefited indirectly or directly from research funding at the chemistry biology interface, suggest there is a significant communications gap between researchers and Research Councils in particular.

The community identified that this research area is under funded and not understood by funders. Sixty-three per cent of respondents agreed that chemistry biology interface research in the UK needs more ring fenced funding. Fifty per cent of respondents agreed or agreed strongly that 'The interface of chemistry-biology is not understood

by funders' and 19% disagreed. Fifty-seven per cent of respondents agreed with the statement that 'It is difficult to get funding in the UK because grant reviewers do not have the right expertise'. Those based in chemistry departments were more likely to agree strongly than those in biological science departments (34% compared to 17%).

Only 2% of respondents indicated that they thought that there was nothing more that the Research Councils could do to better support research at the chemistry-biology interface. Overall, those based in chemistry departments were more likely than those based in biological science departments to want to see changes to the current funding system at its broadest level.

The case studies demonstrate that not all applicants are either aware that it is possible to, or see the need to, seek advice from the Research Councils on remit.

Forty-four per cent of respondents said that writing grant applications for research at the chemistry-biology interface was more difficult than applying for funding for single discipline projects and only 5% said that it was less difficult. Hence it is not surprising that many of the researchers who took part in the case study research said that they preferred the application process whereby outline applications were submitted and only those who passed an initial pre-screening round were invited to submit a full proposal. This was because it saves researchers' time developing full applications that will not be successful.

Forty two per cent of respondents said that they did not feel that current undergraduates would be equipped to do research at the chemistry-biology interface. There was a feeling that students had to be open to new ways of looking at things, rather than specifically academically gifted to master two disciplines.

## Let bacteria do the work

Micro-organisms could be employed to make drugs that are too complicated to synthesise chemically.

Greg Challis and colleagues at Warwick University say feeding bacteria with simple synthetic precursors of a required product could avoid the need for complex organic syntheses.

The bacteria *Streptomyces coelicolor* naturally produce antibiotics called prodiginines. Challis's team fed precursors of prodiginine molecules to mutant *S. coelicolor* bacteria that had been genetically engineered to be deficient in certain enzymes. Depending on whether or not the bacteria produced the expected prodiginines the researchers could identify which enzymes were involved in various stages of the synthetic pathway.

Challis said these precursor feeding experiments could also be used to make the bacteria produce analogues of the natural prodiginines. 'This combines the strength of organic synthesis, to produce large numbers of analogues of structurally simple precursors, with the synthetic power of biology, to assemble highly complex and synthetically difficult structures.'

Challis stressed the need for further understanding of the biosynthetic pathway to determine which precursor analogues will work, but he added, 'this approach will be particularly valuable for generating analogues of streptorubin B [a prodiginine] which are difficult to access using current synthetic approaches.'

'In the future, we envisage that other biosynthetic pathways to complex natural products will be elucidated using similar types of approaches,' said Challis.

By Michael Smith

### Reference

A E Stanley, L J Walton, M K Zerikly, C Corre and G L Challis, ChemComm, 2006, 3981-3983

### Introduction

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The division was established ten years ago and now has over 130 staff and PhD students in diverse range of disciplines including parasitology, structural biology bioinformatics, synthetic organic chemistry, medicinal chemistry, high throughput screening, pharmacokinetics and drug metabolism. The division contains academic researchers and a drug discovery unit, run along biotech business lines. The drug discovery work for neglected tropical diseases is funded by the Wellcome Trust with £8.2 million over five years. Professor Alan Fairlamb is head of the division and Professor Paul Wyatt (recruited from Astex) is head of the Drug Discovery Unit (DDU) and Professor Julie Frearson (recruited from BioFocus) is head of Hit Discovery and Biomolecular Pharmacology. The whole division is housed in a new, purpose built facility.

The primary goal of the DDU is to identify one preclinical candidate against one neglected tropical disease within five years, a demanding target in an area not well served by industry. There is also the aim of creating intellectual property (IP) for the university through commercialisation of basic research on other areas of biology. The ratio of these two activities is approximately two to one respectively. The philosophy of the DDU is to combine academic excellence with best biotech practice ("acatec") to take on some of the downstream risk not usually supported by university research funding.

### The management structure

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The division includes those with both bioscience and those with chemistry qualifications. There are five teams within the DDU. Two are bioscience teams, two are chemistry teams and the fifth is the hit discovery and molecular pharmacology team.

Each of the bioscience and chemistry teams include both academics working on projects funded by academic research grants and on projects for the DDU. These four teams are in essence single discipline teams. The interaction between the two disciplines comes from the structure of management meetings and the physical layout of the building.

### Working practices

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The schedule of management meetings ensures that the team leaders meet fortnightly together to discuss progress towards agreed timelines and milestones. The individual teams meet weekly. Information flows are passed between and within groups using this structure, which keeps everyone in touch. To aid this information flow individuals may be invited to other team meetings to present or discuss their work. In addition there are monthly meetings where individual researchers present their work to the whole DDU staff and people can follow-up later.

Biologists and chemists are working together. The drug discovery exercise as conceived at Dundee, needs researchers who understand the language of each others' disciplines while deferring to the knowledge of specialist individuals when trying to move forward. Some chemists have left the university but those who remain have come to share the vision of not only being involved in making fundamental biological discoveries, but also in translating those discoveries into useful products to help humanity.

The teams also mix academic researchers with researchers with industrial backgrounds, bringing together these different perspectives helps to move the work forward. For example, academic chemists acquire from industrial chemists a feel for drug-like molecules (which many do not fully understand). On the other hand, academic chemists can often suggest novel synthetic routes of which industrial chemists may not be aware.

### The physical infrastructure

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The structure of the built environment not only facilitates interaction between chemistry and biology teams, it forces it.

There are a number of small group work stations in an open plan layout for biologists, which is replicated for chemists. In the centre of the two areas are preparation and storage areas where researchers have to come

together for supplies. There are also other shared equipment areas elsewhere in the building. The building was purpose designed by Professors Fairlamb and Ferguson to facilitate multi-disciplinary working.

### **Applying for grants**

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When applying for funding the relevant individuals draft their sections of a grant application and one researcher draws these together into a single document that is accessible to all. It is important that neither chemists nor biologists use jargon that is incomprehensible to the other group.

The team felt that grants need to be larger than for single discipline projects because of the number of co-applicants and researchers involved. Time may also need to be allowed for meetings to a greater extent, especially where collaborators are in different institutions.

### **Publication**

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With respect to the publication of the unit's work, open access publishing is not an option because of the need to generate IP if they are to attract an industrial partner to take their drug discovery work further and eventually (hopefully) to market. This means that publication needs the approval of an IP committee, which is comprised of academics and representatives from the University and the Wellcome Trust. The aim is to publish as much as possible while retaining a competitive edge. Another implication of the need to generate IP is that all researchers and students are required to sign a confidentiality agreement.

It remains important to publish for the RAE and to further individual researcher's careers but where to publish remains a problem. Researchers in general want to publish in high impact journals to further their careers but in general journals that cover research at the chemistry-biology interface have lower impact factors.

### **Teaching**

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The University of Dundee no longer offers chemistry degrees, it now offers a pharmaceutical chemistry degree course. Students learn the basics of synthetic organic chemistry, medicinal chemistry and what characterises a validated drug target, enzyme mechanisms and structural biology. Recruitment has improved since the switch to this course and the closure of the more 'classical' chemistry course. It is hoped that this course is more relevant to the pharmaceutical industry but it cannot be accredited by the RSC.

### **Conclusion**

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The focus of the chemistry-biology collaborations in the DDU is on solving biological problems. This is what unites the individuals. Importantly, researchers must want to actively collaborate. While the physical proximity and layout of the building helps, this was not thought to be enough on its own.

## 6 Research at the chemistry-biology interface

### 6.1 Introduction

This section looks at the nature of research at the chemistry-biology interface and the importance of chemistry to medical research. It then looks at the health of the field in the UK and the current 'hot topics' as well as whether researchers feel that they will continue to work in the field, and if so, their reasons.

### 6.2 Research areas

Respondents were asked 'What is the main question your research is trying to address?' The Chair of the Steering Group categorised the responses into one of the following areas:

- analytical research
- biocatalysis
- biological goals
- biomaterials
- biosynthesis
- biotechnology
- carbohydrates
- chemical genetics
- chemical proteomics
- computational
- drug delivery
- general chemistry
- imaging
- interactions
- medical goals
- medicinal chemistry
- membranes
- metals in proteins
- natural product synthesis
- nucleic acid
- protein folding
- protein function
- protein structure function
- post-translational modifications (PTMs)
- signalling molecules
- structure
- systems biology

Each response was allocated to a single code based on an overall assessment of the response. The discussion below illustrates the breadth of the work being undertaken by the respondents and explains the categories identified. In some cases, while the overall response was allocated to a single category, mention was also made of other topics and this is brought out in the discussion below.

*Analytical research* includes research to develop new analytical techniques at the chemistry biology interface, for example: 'Development of mass spectrometry for biosciences' and 'how analytical techniques can be applied to a range of biological materials'. This category was dominated by mass spectrometry.

*Biocatalysis* involves the use of enzymes to carry out chemical transformation for a range of applications, and includes responses such as: 'how to use microbial enzymes as biocatalysis tools for organic chemistry' and 'understanding biocatalysis'. A related area is biotechnology, which includes, for example: 'how to automate science' and 'can we design carbon nanotubes as biomedical devices?'

Responses categorised as *biological* stated a research goal that is entirely a biological question, for example: 'How candida albicans grow as hyphae' and 'the cell biology of molecular chaperones'. Researchers giving this response provided a clear definition of their biological research goals with no reference to how chemistry interfaced with their studies.

The study of the roles and structures of carbohydrates includes, for example: 'how carbohydrates are involved in the onset and progress of diseases'.

*Computational*, *systems biology* and *interactions* are closely related areas and some entries could easily have been classified as both or either. These categories include applications of theoretical research in drug design, protein structure, protein-ligand interactions, database management and reaction mechanisms. Computational includes a range of techniques from rational drug design through bioinformatics and data storage to the study of reaction mechanisms in enzymes. Responses such as: 'how do various biological systems function at the molecular level?' are included within systems biology. Examples such as: 'how to inhibit protein-protein interactions' and 'how do

biological surfaces interact and how can this be controlled', are included in interactions.

*General chemistry* is a diverse category covering a range of chemical-biology interface studies. It includes responses that refer to the use of biorelevant polymers and the study of drug toxicity. The study of *biosynthesis*, *chemical genetics*, *chemical proteomics*, *drug delivery*, and *synthesis* are areas of chemical research which seemed worthy of separate classification.

Within *imaging* is included the synthesis of new imaging agents, for example: 'the design and development of novel radiopharmaceuticals as diagnostic tools for use in SPECT, PET and MRI imaging' and 'development of novel fluorescent ligands'.

Responses categorised as *medical* mentioned a disease state but did not explicitly refer to chemical synthesis or production of compounds. Included are responses such as: 'how microbial pathogens cause disease', 'the nature of allergenicity' and 'identification, validation of cancer targets and discovery of cancer drugs'. Researchers giving this response provided a clear definition of their medical research goals with no reference to how chemistry interfaced with their studies.

*Medicinal chemistry* is differentiated from 'medical' by the inclusion of terms referring to the chemical synthesis of compounds. These included responses such as: 'design and synthesis of new potential anti-tumour agents' and 'to produce a potent anti-MRSA drug'.

The study of processes occurring at *membranes* includes responses such as: 'structure and function of various membrane proteins' and 'membrane dynamics in bacteria and chloroplasts'.

The delivery and role of *metals in proteins* features in responses such as: 'to understand how metal ions are handled by cells, including metal ion up-take, storage and utilisation'.

Work classified as *nucleic acid* ranged from the study of gene slicing, splicing and DNA repair, through to structural work on DNA and the interaction of DNA with proteins.

Studies of the mechanisms involved in *protein folding* featured, although there was also considerable interest in the formation of aggregates. Many entries mentioning protein folding also had clear references to other topics and were placed in other categories, for example: 'how proteins fold and misfold, and how these processes are related to disease and cancer'.

There were three sets of researchers whose work, whilst closely linked, was separated according to either their expressed view that they predominantly assessed protein function using structural techniques or the study of very complex biological structures using techniques other than X-ray crystallography (structure category). These were protein function, protein structure function and structure.

Protein function includes responses where researchers reported that they wanted to understand how particular proteins work but did not define how they were doing this; for example: 'functions and mechanisms of regulation of an enzyme family' and 'to understand the proteins which drive cell migration and cancer cell invasion, molecular function of protein complexes'.

*Protein structure function* is predominantly researchers who are using X-ray crystallography as a means of gaining insight into protein function, although some other analytical techniques are also implied. Examples in this category include: 'understanding protein structure function' and 'structure and function of ion channels'.

*Structure* is closely related to protein structure function and includes structural work (X-ray) where no mention of trying to predict function was included and several examples of proteomics (mass spectrometry). Work to determine the structure of complex biological materials/systems was also placed in this category, for example: 'understanding the 3-D organization of the extracellular matrix' and 'protein identification and characterization by mass spectrometry'.

*Post-translational modification* includes responses such as: 'importance of protein glycation, oxidation and nitration in diseases processes'.

*Signalling* includes those interested in studying signalling pathways and those working on secondary messengers and small molecules of great importance in the cell including the study of metabolite formation. Examples of the former include: 'functional characterisation of novel kinase signalling pathways', while examples of the latter

include: 'to understand the targeting and trafficking of fast-acting neurotransmitters receptors to synapses,' new mechanisms by which cellular function is modified by the second messenger, cyclic AMP' and 'using metabolics to understand fat and carbohydrate metabolism in type II diabetes and obesity'.

This analysis shows that UK researchers are working on a wide variety of topics at the chemistry-biology interface. Details of the number of respondents in each area can be found in appendix 3; however, it should be noted that number of respondents working in a field is not necessarily an indicator of the strength of the field in the UK.

In considering whether different funders were supporting different categories of research no clear pattern emerged. BBSRC does not fund drug discovery.

### 6.3 The nature of research at the chemistry-biology interface

There is currently a debate about the extent to which the chemistry-biology interface is, or ought to be regarded as, a single discipline and the degree to which the field is interdisciplinary or multidisciplinary. An understanding of this is important for the funding of individual research projects, research infrastructure and researcher training. Whether teams with different skills (a multidisciplinary approach) or individuals with dual skill sets (an interdisciplinary approach) are required has implications for the size of grants, the number of researchers a grant needs to support and the training of PhD students.

The questionnaire attempted to explore the status of the chemistry-biology interface by asking respondents to agree or disagree with the statements set out in table 6.1 below.

**Table 6.1 Chemistry-biology - single, multi or interdisciplinary?**

	Agree/agree strongly	Neither agree nor disagree	Disagree/disagree strongly
The interface of chemistry-biology is developing into an independent discipline	39%	32%	29%
Chemistry-biology research is multidisciplinary, not interdisciplinary, that is, it requires people from both disciplines to collaborate	68%	21%	11%
Chemistry-biology research is interdisciplinary, not multidisciplinary, that is, it requires individual researchers to know about both chemistry and biology	52%	27%	21%

Base: 446

The responses to the questionnaire revealed no consensus on whether the field is developing into an independent discipline.

Table 6.1 also suggests there is confusion among researchers as to whether the field is interdisciplinary or multidisciplinary. Indeed, analysis of the answers to the questionnaire revealed that a third (34%) said that chemistry-biology interface research is both multidisciplinary and interdisciplinary.

Some researchers defined individuals as multidisciplinary when they had knowledge of both disciplines and saw interdisciplinary work as where researchers from more than one discipline worked together on a problem, suggesting some confusion over the terms 'multidisciplinary' and 'interdisciplinary'.

This was explored further in the case study interviews and it was found that interface researchers see the field as both multidisciplinary and interdisciplinary. Researchers working at the interface were said to need an understanding of both disciplines to be able to work at the interface. But they were also said to need the expertise of those with a grounding in each discipline to work together to solve fundamental problems.

### 6.4 The relationship between chemistry and progress in medical science

Some 82% of respondents agreed with the statement 'Medical research is dependent on chemistry to move forward in understanding basic biological systems'. Perhaps also unsurprisingly, those based in chemistry

departments were more likely to agree than those based in biological science departments (87% compared to 77%) and were more likely to agree strongly (49% compared to 28%).

We also asked respondents whether they agreed or disagreed that 'Medical research is dependent on chemistry to develop new medicines and therapeutic strategies'. Again, 86% agreed or agreed strongly, with those in chemistry departments, unsurprisingly, more likely to agree strongly.

## 6.5 The state of chemistry-biology interface research

In trying to gauge the health of the field in the UK, researchers were very unwilling or unable to comment. Some 43% of respondents to the survey neither agreed nor disagreed with the statement 'Research at the chemistry-biology interface in the UK is currently very healthy'. This is a very high level for this response. Over a third agreed (35% agreed but only 3% agreed strongly) and one in five disagreed (18%) or disagreed strongly (1%) with the statement.

In addition, those who took part in the case study element of the project were unwilling to comment on the broad field outside their own area of expertise. Based on discussions during the case study visits, this high level of neither agreeing nor disagreeing stems from the fragmented nature of research at the chemistry-biology interface, as shown by the wide variety of areas of research in which the respondents were working, discussed in section 6.2. Researchers tend to see themselves as enzymologists or protein chemists, working at the chemistry-biology interface rather than as chemical-biologists. They may therefore find it impossible to assess the strengths of research in fields unrelated to their own except by a coincidence of methodology.

In response to the statement 'Research at the chemistry-biology interface in the UK is currently very healthy', nearly half (48%) of those based in biology departments responded 'neither agree nor disagree'. In contrast, slightly over a third (38%) of those based in chemistry departments gave this response. This suggests that those in chemistry departments may have a stronger sense of chemistry-biology interface research as a 'field' than those based in biology. Nearly half of those in chemistry departments agreed (42%) or agreed strongly (5%) with the statement and only one in seven disagreed (11%) or disagreed strongly (4%).

Respondents were also asked to compare the state of UK research at the chemistry-biology interface with that done elsewhere in the world by asking them to agree or disagree with the following statement: 'Chemistry-biology interface research undertaken in the UK is among the best in the world'. Again, there was a reluctance to comment, with half (48%) of respondents neither agreeing nor disagreeing with the statement, which are very high levels giving these responses.

Those who felt that their institution enabled research at the interface compared with those who felt that their institution did not, were more likely to agree with the statement (39% compared with 25%). Again, those based in chemistry departments were more positive than those based in biological science departments (41% compared to 23%). PIs compared to non-PIs and younger compared to older respondents seemed to be more positive about the field in the UK.

### 6.5.1 Strong areas

Respondents were asked to state the sub-fields of research at the chemistry-biology interface in which they felt the UK was particularly strong or weak, and again a high proportion said 'don't know'. Over four in ten said either that they did not know which sub-fields the UK is strong in or did not give an answer (44%).

The most commonly cited area of strength, stated by 26% of all respondents was structural biology/enzyme function/structure function/protein folding. This accords with the conclusion of the Whitesides report, which identified protein chemistry as an area of strength. The second most commonly cited area was medicinal chemistry which was coded to include medicinal chemistry, drug discovery, drug delivery, drug design and informatics and chemical genetics. This was given by 18% of respondents. After this the numbers giving any specific area fall off quite rapidly.

The data was examined to see whether respondents were stating their own area of research. While this is true for some, in general this was not the case and it does not seem that the areas stated as UK strengths is merely a reflection of the research being conducted by the respondents.

## 6.5.2 Weak areas

Respondents were also asked for their views on which sub-fields of research at the chemistry-biology interface they felt were weak in the UK. Two-thirds (66%) indicated that they did not know which fields the UK is weak in or did not give an answer. These are very high levels of non-response.

Looking at those who gave a response, no particular areas of weakness are obvious, the responses are very disparate.

## 6.6 Hot topics

Respondents were asked what they thought were the current hot topics in chemistry-biology research. However, 40% said either that they did not know (27%) or did not answer the question (13%). Again, these high levels of non-response suggest that researchers do not believe that they have the background to feel confident in assessing a field which is broader than their area of expertise.

The two areas most often cited by respondents as hot topics were synthetic chemistry and protein chemistry.

## 6.7 Research outputs

Researchers were asked about the outputs from their research that they considered to be at the chemistry-biology interface and unsurprisingly, as a survey of academics, academic papers (92%), new knowledge (89%) and the training of new researchers (81%) were said to be the most likely outcomes.

### 6.7.1 Publication

Eight out of ten respondents had had a chemistry-biology interface research paper accepted for publication in the last 12 months and only one in seven (14%) of respondents had not submitted a publication in the area during the same period. Work was most commonly accepted for publication in the *Journal of Biological Chemistry* (published by the American Society for the Biochemists and Molecular Biology) and the *Journal of the American Chemical Society*. In the case study research, being published was an issue for some more than others but there is very little appetite for more journals and a strong feeling that there are already too many.

The questionnaire did not ask about ease of publication but some of the case study researchers said that a lot of journals are interested in their work and that getting published is not a problem. Several new journals have been launched in the last five or six years and this may have helped by increasing the number of outlets.

*"There are a lot of journals out there that are interested in the work we're doing. It's pretty well provided for."*

**Case study**

In contrast, others felt that publishing interface research was more difficult than getting single discipline research published.

*"I think if it goes to a chemist and a biologist, if it is a mixture of the two, one of them might really like it and the other may not really think it is that exciting, and it may be difficult to get it published."*

**Case study**

These differing views may be a result of the research fields or the background and experience of the researchers. However, even those who found it relatively easy to have their work published acknowledged that papers covering very new topics can be difficult to place, not least because it is not clear where to submit them.

Impact factors and name order conventions are different in biology and chemistry. Impact factors tend to be higher in biology than in chemistry and hence a biologist who publishes in chemistry journals could potentially lose out in the 2008 RAE and when being assessed for promotion. Name order also matters for esteem in biology but in chemistry, names are listed alphabetically, whereas in biology the last author is the most senior researcher and the first author will have carried out most of the research. When 2008 RAE panels are assessing work, they do so within the parameters of their own discipline and researchers felt interdisciplinary and multidisciplinary research is not given full weight. These findings accord with those from the Academy of Medical Sciences and Royal Academy of Engineering report of 2007.

### 6.7.2 Access to journals

When it comes to access to journals, one case study highlighted the need for those at the interface between any two disciplines to access a larger number of journals than those working in a single disciplinary field. Access to any single journal may not be required very often but subscriptions need to be maintained for the “maybe only once a year” when an article was required. The way in which publishers supply packages of journals can also leave researchers without access to key publications.

### 6.7.3 Knowledge transfer

Over a third (35%) of the respondents said that their work had led to a patent, 12% that it had led to the establishment of a new company, 7% that they had developed new therapy(ies) and 7% that they had developed new medicine(s). This indicates a fairly high level of knowledge transfer, which the Research Councils are increasingly interested in promoting.

## 6.8 The future

Almost all respondents said that they would continue to work at the chemistry-biology interface (93%) and the main reason for this was because their research topic needs this approach, which accords with the reasons set out in section 2 above, for being involved in research at the interface. Half (49%) of those intending to continue said that they would do so because they had a good collaborative arrangement in place. Some 16% said that they would do so because their university sees the field as a priority area.

A PhD student interviewed as part of the case study visits said:

*“Building on different disciplines gives more powerful ways of looking at problems...one and one is sometimes more than two.”*

*Case study*

## 6.9 Summary and conclusions

Chemistry-biology interface research is both multidisciplinary (requiring people from both disciplines to collaborate) and interdisciplinary (requiring individual researchers to know about both chemistry and biology). There is no consensus as to whether research at the chemistry-biology interface is evolving into an independent discipline.

Researchers were unwilling or reluctant to comment on the state of chemistry-biology research in the UK. They rarely named particular areas of either strength or weakness and many expressed uncertainty about what hot topics in the broader field might be. Such reluctance suggests a lack of cohesiveness in the field, which may be due to, and contribute to, a lack of awareness of research outside of individuals’ own speciality.

There are many opportunities for publishing in this field. The frequency of publication seems low but researchers may be publishing in other areas as well as chemistry biology interface research.

A good degree of knowledge transfer exists, but potentially could be much stronger.

There seems to be optimism about the future of research at the chemistry-biology interface, with most researchers planning to continue in this area due to the nature of their research topics.

## 7 The role of the RSC

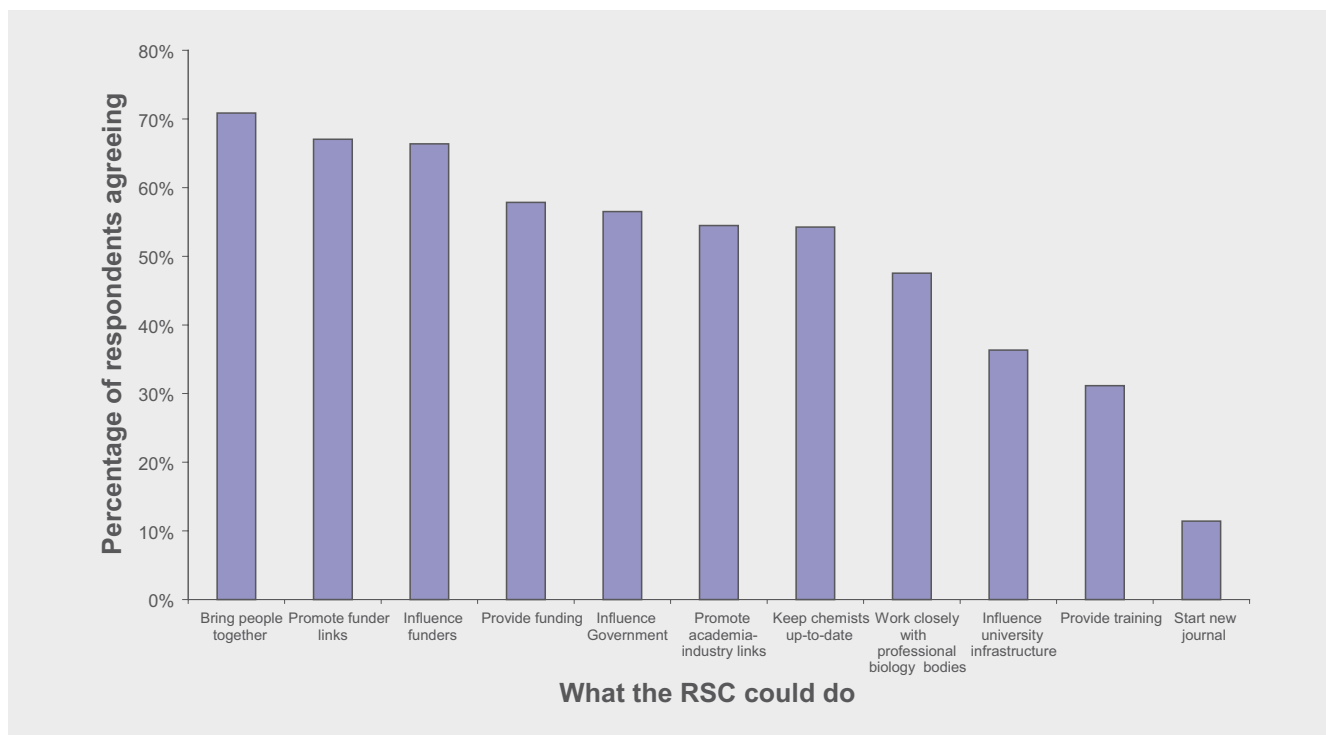
### 7.1 Introduction

Respondents were asked at the end of the questionnaire to select from a list of activities what they thought the RSC could do to support research at the chemistry-biology interface. This was followed-up in the case study visits. This chapter presents ideas that the RSC might consider taking forward.

### 7.2 Actions

Overall respondents saw a role for the RSC in supporting the development of research at the chemistry-biology interface.

**Chart 7.1 RSC support for chemistry-biology interface research**



Base: 446

Bringing people together is an important activity and one the RSC is well placed to undertake as long as it can reach out to all potential researchers across the disciplines. It is interesting to note that our achieved sample is fairly evenly balanced between chemists and biologists but at first it was heavily skewed towards chemists until the 'RSC' was removed from the email subject line. It will therefore need careful marketing to attract biologists to RSC meetings. Hence it is probably best to work with the specific biological bodies, for example the Biochemistry Society, the Society for Applied Microbiology and the Society for General Microbiology and to focus meetings on topics.

*"If the RSC are serious they need to target some biologists as well."*

*Case study*

Indeed, biologists were surprised at the proactive stance being taken by the RSC to this field.

Enabling those from a biological background to become members of the RSC might help to bridge the divide. While the RSC has made it easier for biochemists to become members, which has been welcomed, it was suggested that experience, rather than the nature of a first degree, should be considered as an eligibility criteria.

*"When do you become a chemist?"*

*Case study*

The RSC's Chemistry Biology Interface Forum (CBiF) is a membership forum for all those working at the chemistry

biology interface. One of the key aims of CBiF is to promote the critical contribution that the chemical sciences can make to challenges in the biological sciences. The activities of CBiF should be broadened to engage researchers from across the whole field.

Ensuring that funders have a clear understanding of the field and working to advise that funding structures are appropriate, is a role the RSC could play. In particular the case studies suggested that the RSC could play a role in bringing Research Councils and other funding bodies closer together.

This report has uncovered many examples of university practices that are supporting the development of research at the interface. There are probably more but it is clear that many universities could be more active in their support for interface research.

There is not really support for a new journal. This was borne out in the case study interviews and only 10% of survey respondents agreed that the RSC could help the interface by launching a new journal. Nevertheless, there may be a place for occasional special editions from existing journals focusing on chemistry-biology interface research or on specific areas within the field.

It was suggested in the case study interviews that the RSC could help by identifying industrial 'champions' to highlight the importance and uses of this work. Supporting awards to bring industry and academia together, particularly PhD studentships, would be welcomed by some. Awarding prizes and otherwise recognising work in the chemistry-biology interface would encourage those involved and help to enhance their profile in their institution.

One case study team reported that there is no large scale, regular meeting for those working at the chemistry-biology interface and that the 'big names' from outside the UK rarely speak here. They suggested that the RSC could run such an international conference, perhaps once every three years to bring the field together and to provide a focus for non-UK based researchers to speak in the UK.

These findings support the conclusions of the NAS report on how professional societies can help interdisciplinary and multidisciplinary research, but are in fact more focused on promoting partnerships and interactions.

### 7.3 Summary and conclusions

The RSC should:

- Bring people together through seminars and workshops
- Work more closely with biological professional societies to support joint events
- Ensure that titles for joint events are welcoming for those from both disciplines
- Work with the funders to reduce the barriers to interdisciplinary and multidisciplinary working
- Promote ways of working that have supported the development of collaborations in some HEIs to other HEIs
- Identify industrial champions who can raise the profile of chemistry-biology research in industry more widely
- Support a regular large scale international conference every three years
- Enable those working at the chemistry-biology interface to become members of the RSC
- Award prizes for work in the field

The RSC should *not*:

- Launch a new journal but might consider occasional special editions of existing journals

## 8 Conclusions and recommendations

### 8.1 Introduction

This section draws together the findings from this project and makes recommendations for all those involved in supporting research at the chemistry-biology interface. Many of the recommendations will be relevant to other areas of multidisciplinary research.

There are a limited number of strategic options and researchers themselves, institutions, funders and professional bodies have to be prepared to make changes in the way they operate. However, at a tactical level there are a number of options that can be considered.

### 8.2 Working practices

Physical proximity is a definite aid to collaboration between departments and some institutions have addressed this with new buildings bringing departments together. However, a common goal and vision, and good personal relationships can overcome distance.

Researchers need to be proactive in finding collaborators and developing relationships. This work has found that researchers find collaborators in a variety of ways, including:

- the reputation of individual researchers or groups;
- meeting at conferences;
- searching the web for researchers with relevant expertise;
- being referred to relevant individuals by colleagues in their department;
- from published articles; and, of course,
- some are themselves found by other researchers.

### 8.3 Infrastructure and environment

Given the working practices identified in this report, universities and other research institutions need to assess whether they are providing an appropriate infrastructure to enable chemistry-biology interface research to flourish. The results of this report suggest that while there are examples of good practice and many innovative ideas, there remain deficits. In some institutions there will need to be a significant cultural change to proactively encourage interdisciplinary collaboration and a project focussed approach.

Mechanisms that were reported to be in place in institutions to support multidisciplinary and interdisciplinary research include:

- facilitating physical proximity and promoting interaction at a personal and departmental level;
- interdisciplinary centres (including physical buildings and virtual centres);
- regular inter-departmental seminars;
- joint undergraduate course provision;
- cross-departmental PhDs;
- joint faculty appointments; and
- physically adjacent chemistry and biological sciences laboratories.

Respondents also suggested that institutions could consider restructuring around research topics, rather than disciplines, to support interdisciplinary research.

Respondents identified a number of institutional barriers to research at the chemistry-biology interface, including:

- institutional structures that are designed to maximise RAE scores;
- a lack of coordination between departments;

- competition between departments for funding and other resources;
- different cost structures; and
- a lack of suitable laboratory space.

Academia, it was thought, could learn from industry's goal-oriented culture and focus on solving problems. However, respondents also said that academia's research role is fundamentally different from industry and academia should avoid adopting industry's short-term outlook and emphasis on profits.

Institutions should look across at their structures to identify administrative barriers that impede collaboration, such as different cost structures, and seek harmonisation. The RSC recommend that institutions proactively bring heads of department together to identify mutual benefits for their departments that could arise from collaboration. The RSC has a role in spreading good practice through its academic members.

## 8.4 Funding

There has been a concerted effort by funding bodies to develop new funding routes for interdisciplinary science, including at the chemistry-biology interface. However there remains a perception that the funding bodies, especially the Research Councils, are not supportive of interdisciplinary research in the way in which research proposals are assessed and that more specialised schemes are needed.

Key initiatives to help clarify the funding process include:

- a series of funding 'road shows' highlighting funding remits and the application and reviewing process of the BBSRC, MRC, EPSRC and Wellcome Trust;
- for the BBSRC, EPSRC and MRC to develop a more systematic way of deciding which Research Council a project should be directed towards;
- for the BBSRC, EPSRC and MRC to undertake a harmonisation programme for processes such as grant application;
- the production of a written, step by step guide of the funding process for the chemistry-biology research community, either in hard copy or as a web portal; and
- better guidance for reviewers on how to assess research applications at the chemistry-biology interface, so that research questions and appropriateness of method carry more weight than novelty of method.

Feedback from respondents focused predominately on Research Council funding mechanisms. For organisations such as the Wellcome Trust that also support research at the chemistry-biology interface the RSC recommend that a communication programme is established with the research community, to disseminate information on funding schemes.

Not all grant applicants are either aware of, or see the need to, seek advice from the Research Councils on remit. At the application stage the RSC recommend that more and better communication is required between grant funders and potential grant holders in order to make optimum use of existing funding mechanisms. Research Councils need to ensure that they get potential applicants to the right Research Council as quickly as possible to avoid potentially damaging delays in applications. Existing systems may need streamlining to meet this need.

Applicants should seek advice directly from BBSRC, EPSRC and MRC at any time in the grant application process but specifically prior to submission of a formal application. It is vital that applicants seek clarity on remit and procedures from Research Councils prior to submission to ensure that applications are sent to the right Research Council to minimise delays.

Those based in chemistry departments were more likely to agree that 'It is difficult to get funding in the UK because grant reviewers do not have the right expertise' than those in biological science departments (34% compared to 17%). This calls for a fundamental cultural shift in perspective of research at the chemistry-biology interface. Researchers working at the chemistry-biology interface believe that the importance of the challenge is the key factor, not the complexity of the chemistry applied, and reviewers should take a similar perspective.

## **8.5 The current health of chemistry-biology interface research**

Given the importance of research in this area, an additional study of the UK's performance in terms of inputs (funding opportunities, postgraduate training, conference provision, etc.) and outputs, in an international context is required.

The field is broad and disparate and there appears to be a lack of awareness within the community of breadth of research being conducted in the UK at the chemistry-biology interface.

This report identified a need for further conference and seminar activities to raise awareness, stimulate interest from chemists and generally bring people together. These events must be jointly co-ordinated with those from the biological associations to ensure that researchers from across the field of chemistry-biology interface research become involved. Moreover, the titles for joint events must be welcoming for those from both disciplines and jargon eliminated as far as possible.

In particular there is no regular conference in the UK that draws international level speakers and acts as a focus for the community. The RSC is well placed to fill this gap. Such an event would provide a focus for awards in the field and an opportunity to raise the profile of industrial champions for this research.

In view of an emerging philosophy within the UK pharmaceutical industry to look 'outside' and increase investment in external collaborations within both academia and biotechnology companies, there is a large opportunity to develop a strong capability in chemistry-biology interface research within the UK.

## **8.6 Training of researchers at this interface**

The report emphasises the importance and growing volume of research at this interface, and therefore it is essential that appropriate training is provided at undergraduate and postgraduate levels in order that the UK maintains a sufficient community of skilled researchers active in this field.

Forty-two per cent of respondents said that they did not feel that current undergraduates would be equipped to do research at the chemistry-biology interface.

Institutions must ensure that training is available to PhD level across departments. A further study is necessary to assess existing mechanisms for providing adequately trained interdisciplinary researchers.

The RSC should consider revising its membership and accreditation to enable those working at the chemistry-biology interface to become members of the RSC

## Appendix 1 References

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## Appendix 2 Research method

### Introduction

The project comprised:

- interviews with BBSRC, EPSRC, MRC and the Wellcome Trust
- a review of the existing literature on inter- and multi-disciplinary research and research at the chemistry-biology interface;
- an internet survey of 446 scientists working at the chemistry-biology interface; and
- six follow-up cases studies with survey respondents.

### Funder interviews

Meetings were held with the relevant managers at the Biotechnology and Biological Sciences Research Council (BBSRC), the Engineering and Physical Sciences Research Council (EPSRC), the Medical Research Council (MRC) and the Wellcome Trust. These organisations all contributed a small amount of funding to enable the study to be as broad as possible.

### Literature review

At the start of the project the RSC provided PSP with a list of recent reports on topics related to this work; other reports were also sent to PSP from the steering group. PSP conducted a search of the Internet for any further material. Information of particular relevance to this work was highlighted in the literature review and used to inform the development of the questionnaire.

### Topic guide for interviews with research funders

Below are the topics covered in discussions with the funders.

- Introduction about the project
- Background on the respondent
- Discussion of research at the chemistry-biology interface
- Funding for research at the chemistry-biology interface
- Role of RSC
- Other research
- Survey of PIs and sampling issues

### Internet survey

#### Sample

The sample was built from a number of sources. BBSRC provided details of grants holders, joint and co-grant holders over the last five years. EPSRC provided details of fellowship holders and first grants award holders thought to be working at the chemistry-biology interface. They also provided details of college members who had indicated that chemistry-biology was an area of expertise. MRC provided details of relevant grant holder and institute staff working at the chemistry-biology interface. The Wellcome Trust provided a list of those they believed to be working at the chemistry-biology interface from their current grants. The RSC provided details of the members of the Chemistry Biology Interface Forum (CBIF).

The lists were amalgamated and those with non-UK email addresses and obvious duplicates removed. Where email addresses were not supplied these were sourced via the world-wide web for the remaining contacts. Further duplicates were identified from email address. Visual screening was used to try to ensure that where an individual had moved institution they did not appear on the list twice. The final list was checked by the Steering Group to ensure that no well-known researchers were missing. This process resulted in 1718 individuals being

identified. This list was sorted by institution and a simple one in N sample of 1,000 was drawn.

Allowing for emails that no longer reached the named person, the response rate was 57%, resulting in 543 respondents.

<b>Outcomes based on total initial sample</b>		
Total number of e-mails	1000	100%
Known ineligible	5	1%
Errors in e-mail address	44	4%
<b>Outcomes based on sample excluding ineligible and failed e-mail addresses</b>		
Total excluding known ineligible / failed e-mail address	951	100%
Refused by e-mail	17	2%
Away during fieldwork	4	* less than 0.5%
Non completes	387	41%
Completed questionnaires / overall response rate	543	57%

Of these 543, 8% said that they were not currently involved in any research on a biological or medical science topic, which reduced our sample to 498. A further 10% said that they did not consider any of their research work to be at the interface between chemistry and biology, reducing the sample size to 446. This report is based on this group.

Those who were involved in biological or medical research but who did not consider that their work was at the chemistry-biology interface tended to be working in the areas of biochemistry, cell and developmental biology, medicine and neuroscience.

### **Dispatching the survey**

Potential respondents were sent a personalised email with a unique link to the questionnaire. The covering email included a note from Professor John McCarthy (Chair of the CBiF executive committee) encouraging them to take part and explained the purpose of the survey.

Questionnaires were dispatched on 25 May 2007. Some potential respondents had recently been contacted by PSP and invited to take part in an unrelated survey on behalf of BBSRC. These individuals were not contacted for this survey until 1 June 2007, to allow a break between the two contacts. Those contacted on 25 May who had not replied were sent a reminder on 31 May 2007 and those who still did not respond were sent a second reminder on 14 June 2007. Those from the BBSRC survey were only sent one reminder on 14 June 2007.

No responses to the survey were accepted after 12 July 2007, although four further replies were received. In early August 2007 the questionnaire was removed from the Internet and anyone trying to access the questionnaire was directed to a page informing them that the survey had now closed.

A few people contacted PSP to inform us that they were ineligible to complete the survey because they did not consider that they worked in chemistry-biology. PSP completed their questionnaire on their behalf to this effect, routing them out at Q1.

### **Questionnaire**

The questionnaire was drafted and agreed with the RSC and the Steering Group. It was then piloted and revised based on comments received and by refocusing the questionnaire to shorten it. The final questionnaire required respondents to answer all the questions.

## Chemistry-Biology Interface

People Science & Policy Ltd (PSP) is undertaking a study to explore current issues in the funding and infrastructure support for those in research at the interface of the chemical sciences and biological sciences. We have worked with the Royal Society of Chemistry, BBSRC, EPSRC, MRC and the Wellcome Trust to construct a list of those working at the chemistry-biology interface, this is how you have been selected.

The project is funded by the Royal Society of Chemistry, with support from the research funders.

Your answers will be treated confidentially. Once you have clicked on 'Submit' at the end of the questionnaire you will not be able to access your answers. You can save or print out your responses before you submit your response. If you want to go backwards, use the 'back' button at the bottom of the page, not the 'back' arrow on your browser. You may skip questions as a result of routing.

I hope you will take the time to respond to this survey. The questionnaire should only take about 15 minutes to complete. If you have any queries please contact Suzanne King at PSP on 020 7554 8636, email:Suzanne.king@peoplescienceandpolicy.com.

Q1 Are you currently involved in any research, collaborative or otherwise, on any biological or medical science topic(s)?		
	Yes	92%
	No	8%

Q2 Which research topic(s) are you currently working on? Tick ALL that apply.				
	Biochemistry	65%	Nutrition	2%
	Biomedical engineering	8%	Organic Chemistry	24%
	Biophysics and biomolecular structure	51%	Pathology	5%
	Cell and developmental biology	24%	Pharmacology and toxicology	12%
	Chemical genetics and genomics	15%	Pharmacy/pharmaceuticals	16%
	Ecology, evolution and systematics	3%	Physiology	7%
	Entomology	1%	Plant biology	7%
	Immunology	8%	Protein chemistry	38%
	Medicine	16%	Psychology	0%
	Microbiology	21%	Public health	1%
	Molecular evolution	6%	Synthetic chemistry	21%
	Neuroscience	11%		
Other, please specify				

Q3 What is the main question that your research is trying to address? Please type in		
		100%

Q4 Do you consider any of your research work to be at the interface between chemistry and biology?		
	Yes	90%
	No	10%

Q5 Has YOUR research at the chemistry-biology interface led to the development of any of the following? Tick ALL that apply.		
	New knowledge	89%
	New technologies	48%
	Academic papers	92%
	New medicines	7%
	New therapies	7%

Patents	35%
New companies	12%
The training of new researchers	81%
None of these	2%

Q6 Which journals have you SUBMITTED chemistry-biology interface research papers to in the last 12 months? Tick ALL that apply.			
I have not submitted any chemistry-biology interface research papers to journals in the last 12 months	14%	Nature	8%
ACS Chemical Biology	3%	Nature Chemical Biology	4%
Angewandte Chemie	11%	Nature Medicine	2%
Bioinformatics	2%	Nature Protocols	3%
Biological Chemistry	3%	Organic & Biomolecular Chemistry	12%
Bio-organic and Medicinal Chemistry Letters	7%	Organic Letters	3%
BMC Bioinformatics	1%	PloS Biology (Public Library of Science)	2%
BMC Genomics	1%	Proceedings of the National Academy of Science (PNAS)	18%
Cell	2%	Science	4%
ChemBioChem	7%	Bioconjugate Chemistry	2%
Chemical and Engineering News	0%	Biomacromolecules	2%
Chemical Biology and Drug Design	0%	Biophysical Journal	3%
Chemistry and Biology	4%	Chemical Communications	4%
ChemMedChem	1%	Journal of Molecular Biology	7%
Current Opinion in Chemical Biology	1%	Proteins - structure, function and bioinformatics	2%
Journal of Biological Chemistry	26%	Biochemical Journal	2%
Journal of Chemical Information and Modelling	2%	Biochemistry	7%
Journal of Medicinal Chemistry	8%	Nucleic Acids Research	3%
Journal of the American Chemical society (JACS)	19%	Other Nature publications	2%
Journal of the Royal Society Interface	2%	Other publications	40%
Molecular Cell	2%		
Other, please specify			

Q7 And which journals have ACCEPTED chemistry-biology interface research papers from you in the last 12 months? Tick ALL that apply				
	I have not had any chemistry-biology interface research papers accepted by journals in the last 12 months	20%	Nature	2%
	ACS Chemical Biology	2%	Nature Chemical Biology	1%
	Angewandte Chemie	8%	Nature Medicine	1%
	Bioinformatics	1%	Nature Protocols	2%
	Biological Chemistry	1%	Organic & Biomolecular Chemistry	10%
	Bio-organic and Medicinal Chemistry Letters	6%	Organic Letters	2%
	BMC Bioinformatics	0%	PloS Biology (Public Library of Science)	0%
	BMC Genomics	1%	Proceedings of the National Academy of Science (PNAS)	8%
	Cell	1%	Science	1%
	ChemBioChem	5%	Bioconjugate Chemistry	1%
	Chemical and Engineering News	1%	Biomacromolecules	2%
	Chemical Biology and Drug Design	0%	Biophysical Journal	2%
	Chemistry and Biology	2%	Chemical Communications	4%
	ChemMedChem	1%	Journal of Molecular Biology	6%
	Current Opinion in Chemical Biology	1%	Proteins - structure, function and bioinformatics	1%
	Journal of Biological Chemistry	17%	Biochemical Journal	1%
	Journal of Chemical Information and Modelling	2%	Biochemistry	6%
	Journal of Medicinal Chemistry	6%	Nucleic Acids Research	3%
	Journal of the American Chemical society (JACS)	12%	Other Nature publications	2%
	Journal of the Royal Society Interface	2%	Other publications	37%
	Molecular Cell	1%		
Other, please specify				

Q8 Why have you chosen to work in an area that involves both chemistry and biology? Tick ALL that apply.		
	The topic I am interested in needs both disciplines to address the issues	88%
	It is more challenging/enjoyable/interesting than single disciplinary research	33%
	It is more dynamic than single disciplinary research	37%
	It is a more useful way of addressing problems than a single disciplinary approach	55%
	I was approached by another researcher	13%
	To remain at the cutting edge of the field	35%
	Because it is likely to generate real benefits to society	41%
	Funding available	1%
	Other	7%
Other, please specify		

Q9 How critical is the interaction between chemistry and biology to the success of your research?		
	Very critical	61%

	Fairly critical	34%
	Not very critical	4%
	Not at all critical	1%

Q10	Are you currently based in...	
	A biological science department	24%
	A chemistry department	28%
	A biochemistry department	8%
	Another single science or engineering department	10%
	An university interdisciplinary organisation, eg a Life Sciences Centre/school	21%
	A stand alone research institute, including MRC/BBSRC Units	5%
	Pharmacy	2%
	Medical school	2%
	Company	0%
	Other	0%
Some other organisational structure, please explain		

Q11	How are chemistry and biology brought together in your research? Please tick ALL that apply.	
	We have people who are qualified in both chemistry and biology	53%
	We have chemists and biologists working in the same research groups	45%
	We have chemists and biologists working in the same project teams	44%
	We collaborate with chemists/biologists working in other departments in our university/ institute	74%
	We collaborate with chemists/biologists working in other UK university departments	61%
	We collaborate with chemists/biologists working in other universities outside the UK	54%

Q12	Why have you chosen to use this way of working? Tick ALL that apply.	
	Because of the nature of the research we do	88%
	Because of the way this university is structured	17%
	Because of the way in which we are funded	21%
	Because of the type of input we need from chemistry/biosciences	51%
	Mutually beneficial	1%
	Other	4%
Another reason, please specify		

Q13	How easy is it for you to find collaborators for your chemistry-biology interface research?	
	Very easy	22%
	Fairly easy	48%
	Not very easy	15%
	Not at all easy	3%
	It depends on the specific project	11%
	Don't know	1%

Q14	What specific role or roles do those with a background in chemistry play in your life science research? Tick ALL that apply.	
	They provide access to funding	16%
	The project is led by chemists	28%
	The objectives are set by chemists	18%
	They are integral to our research	65%
	They do not have a specific role, they are equal members of the team	32%
	They provide subject knowledge other members of the team do not have	68%
	They ensure that we keep up-to-date with developments in chemistry	24%
	They help to ensure that the research gets published in high impact chemistry journals	10%
	They undertake routine elements of the research	15%
	Some other roles, please tick here and type into next screen	6%
	Other	2%

Q15 Please type in the other roles those with a background in chemistry play in your life science research.

Q16	And which is their most important role?	
	They provide access to funding	1%
	The project is led by chemists	13%
	The objectives are set by chemists	2%
	They are integral to our research	40%
	They do not have a specific role, they are just part of the team	9%
	They provide subject knowledge other members of the team do not have	30%
	They ensure that we keep up-to-date with developments in chemistry	1%
	They help to ensure that the research gets published in high impact chemistry journals	0%
	They undertake routine elements of the research	2%
	Some other role please tick here and type into the next screen	3%

Q17 Please type in the most important role that those with a background in chemistry play in your life science research.

Q18	Do you feel that your university/institute enables or hinders research at the chemistry-biology interface?	
	Enables	63%
	Hinders	9%
	Don't know/not sure	27%

Q19	In what ways does your university/institute enable academics from different departments to develop collaborations?	
	Physical location	9%
	Established virtual centre	2%
	Time to develop relationships	1%
	Initiatives to bring people together, eg seminars	24%
	Provided funding	11%
	Joint appointments	2%
	Cross disciplinary appointments	2%
	Interdisciplinary centres	24%

	Nothing	3%
	Other positive	45%
	Other	5%

Q20	How, if at all, could your university/institute better enable research at the chemistry-biology interface? Tick ALL that apply.	
	Bring people together in a single department/school	21%
	Fund regular inter-departmental seminars	38%
	Restructure around research topics rather than disciplines	24%
	Build new research facilities	36%
	Incorporate chemistry-biology as a specific discipline	23%
	Create a virtual centre for chemistry-biology research	21%
	Nothing it could do	7%
	Don't know	5%
	Physical location	0%
	Established virtual centre	0%
	Time to develop relationships	0%
	Initiatives to bring people together, eg seminars	1%
	Provided funding	4%
	Joint appointments	1%
	Provide better equipment	1%
	Better administrative structures/support	1%
	Other positive	9%
	Other	9%
Other, please say what		

Q21	What do you think is preventing your university/institute from changing its structure to better support research at the chemistry-biology interface? Tick ALL that apply.	
	There are other interfaces it has to consider	30%
	Because of the way it markets itself to undergraduates	21%
	Not enough funding for chemistry-biology research to make it worthwhile for the university doing anything	23%
	This university focuses on other subject areas	12%
	There are other priorities for investment	29%
	University structures are designed to maximise RAE scores	42%
	Competition between departments	30%
	Lack of coordination between departments	38%
	There is not a problem	8%
	Inertia/reluctance to change	2%
	Costs	2%
	Closing or closed chemistry department	1%
	Other	7%
Other, please say what		

Q22	What, if anything, do you think academia can learn from industry about doing research at the chemistry-biology interface?	
	Nothing	8%
	Not very much	7%
	Don't know	16%
	Project management skills	9%
	Problem focus	12%
	Working in teams	12%
	Better equipment and facilities	4%
	Better funding	9%
	Greater flexibility	3%
	Other	32%

Q23	Below are some statements that people have said about work at the chemistry-biology interface. For each statement please say whether you agree strongly, agree, neither agree nor disagree, disagree or disagree strongly					
		Agree strongly	Agree	Neither agree nor disagree	Disagree	Disagree strongly
	Research at the chemistry-biology interface in the UK is currently very healthy	3%	35%	43%	18%	1%
	The interface of chemistry-biology is developing into an independent discipline	3%	37%	32%	26%	3%
	Chemistry-biology interface research undertaken in the UK is among the best in the world	3%	31%	48%	16%	2%
	Chemistry-biology interface research in the UK needs more ring-fenced funding	26%	38%	24%	10%	4%
	It is difficult to get funding in the UK because those who review research grants do not have the right expertise	24%	33%	25%	16%	2%
	I cannot find suitable collaborators	3%	7%	25%	43%	22%
	My university does not support work at the chemistry-biology interface	4%	13%	22%	38%	22%
	Chemistry-biology research is multi-disciplinary, not interdisciplinary, that is, it requires people from both disciplines to collaborate	25%	43%	21%	8%	3%
	The interface of chemistry-biology is not understood by funders	14%	35%	32%	17%	2%
	Medical research is dependent on chemistry to move forward in understanding basic biological systems	38%	44%	14%	3%	0%

	Medical research is dependent on chemistry to develop new medicines and therapeutic strategies	44%	42%	11%	3%	0%
	Chemistry-biology research is interdisciplinary, not multi-disciplinary, that is, it requires individual researchers to know about both chemistry and biology	17%	35%	27%	18%	2%

Q24 Which sub-fields of chemistry-biology interface research do you feel the UK is particularly strong in?

Q25 And which sub-fields of chemistry-biology interface research do you feel the UK is particularly weak in?

Q26 What are the current hot topics in research at the interface of chemistry and biology?

Q27 In the last three years which of these organisations have you received funding from?

	BBSRC	62%	MRC	22%
	Cancer Research UK	10%	Scottish Executive	3%
	Department for Environment and Rural Affairs (Defra)	1%	UK Research Office (UKRO)	0%
	Environment Agency	0%	Wellcome Trust	26%
	EPSRC	39%	Another charity	28%
	European Union (EU)	21%	Another non-UK source	10%
	Funding Council (HEFCE/SFC/HEFCW/DFHETE)	8%	Some other source	22%
	Industry	32%		

Q28 And which organisation would you say is your main funder. Please tick ONE only.

	BBSRC	38%
	Cancer Research UK	4%
	Department for Environment and Rural Affairs (Defra)	0%
	Environment Agency	0%
	EPSRC	19%
	EU	4%
	Funding Council (HEFCE/SFC/HEFCW/DFHETE)	1%
	Industry	6%
	MRC	6%
	Scottish Executive	0%
	UK Research Office (UKRO)	0%
	Wellcome Trust	9%
	Another charity	5%
	Another non-UK source	2%
	Some other source	7%

Q29	Do you find it more or less difficult to write grant applications for research at the chemistry-biology interface than for single discipline research?	
	More difficult	44%
	No more or less difficult	51%
	Less difficult	5%

Q30	Why do you say it is more difficult?	
	Because I am applying to funders I have little experience of	36%
	Because I have to talk to funders a lot more in preparing my application	13%
	Because I have to go through a number of iterations with my co or joint applicants	41%
	Because there are more queries to deal with from funders	23%
	Because it is more difficult to cost this type of research	14%
	Because peer reviewers not appropriate	1%
	Making the application relevant to reviewers from both disciplines is difficult	15%
	Because the funders are less receptive	6%
	Different disciplines have different ways of working	2%
	Other	19%

Some other reason, please state

Q31	Which of the following funding initiatives have you heard of? Tick ALL that apply.	
	Translational Awards in Seeding Drug Discovery (Wellcome Trust)	39%
	Life Sciences Interface Programme (EPSRC)	68%
	Discipline Hopping Grants (MRC/EPSRC/BBSRC/PPARC)	65%
	Chemical Biology Initiative (MRC/EPSRC)	42%
	Institutional Discipline Bridging Award (MRC/EPSRC)	24%
	None of these	10%

Q32	To what extent do you feel that the Research Councils are able to deal adequately with your chemistry-biology grant applications?	
	Very adequately	6%
	Fairly adequately	37%
	Not very adequately	29%
	Not at all adequately	9%
	It varies	8%
	Don't apply to the Research Councils	2%
	Don't know/not sure	9%

Q33	How could the Research Councils better support research at the chemistry-biology interface? Tick ALL that apply.	
	Have a specific chemistry-biology panel/committee/board	58%
	Have specific calls for chemistry-biology interface research	63%
	Ensure that some members of the relevant panels/committees/boards work at the chemistry-biology interface	73%
	Ensure that reviewers have the relevant depth and breadth of expertise in research at the chemistry-biology interface	70%
	Provide opportunities for broadening the training of the researchers that they fund	29%

	There is nothing more they could do	2%
	Don't know	5%

Q34	Do you think that current undergraduate students will be equipped for doing research at the chemistry-biology interface?	
	Yes	30%
	No	42%
	Don't know/not sure	28%

Q35	Do you think you will continue to work at the interface between chemistry and biology, undertaking work that requires knowledge from both disciplines?	
	Yes	93%
	No	1%
	Not sure	5%

Q36	Why do you say that? Tick ALL that apply.	
	There is plenty of funding	4%
	My university sees this as a priority area	15%
	I have a good collaborative arrangement in place	49%
	My research topic needs this approach	82%
	The topic I am interested in needs both disciplines to address the issues	1%
	It is more challenging/enjoyable/interesting than single disciplinary research	8%
	It is more dynamic than single disciplinary research	0%
	It is a more useful way of addressing problems than a single disciplinary approach	0%
	I was approached by another researcher	0%
	To remain at the cutting edge of the field	1%
	Because it is likely to generate real benefits to society	1%
	Funding available	1%
	Other	3%
	Some other reason, please specify	

Q37	Why do you say that? Tick ALL that apply.	
	There is not enough funding	50%
	There are too many institutional barriers	50%
	I can't find suitable collaborators	25%
	The topic I am interested in no longer requires this approach	0%
	I will be moving on to a new topic	75%
	I am only working in this area because I am part of a bigger team at present	0%
	Some other reason, please specify	

Q38	What do you think the Royal Society of Chemistry can do to facilitate research at the chemistry-biology interface? Tick ALL that apply.	
	Promote links between funders	67%
	Influence university infrastructure	36%
	Promote links between academia and industry	54%
	Keep chemists up-to-date with chemistry-biology research	54%
	Bring people from the biological and chemical disciplines together	71%
	Provide ad hoc training to facilitate work at the chemistry-biology interface	31%
	Provide funding for research	58%
	Influence Government policy	57%
	Influence funders	66%
	Produce a new journal specifically for chemistry-biology interface research	11%
	Itself work more closely with the biological sciences' professional bodies	48%
	None of the above	1%

**The next few questions ask for some information about you. We need this so that we can look at the answers for different groups of people.**

Q39	Do you hold any grants in chemistry biology research as...	
	A PI	53%
	A joint PI	17%
	A co-PI	22%
	No, I do not hold any grants in chemistry biology as a PI	31%

Q40	How many years have you been working in research?	
	Less than 5	7%
	5-10	16%
	More than 10	77%

Q41	What was the main subject of your first degree?	
	Biological Science	14%
	Biochemistry	21%
	Chemistry	52%
	Engineering	1%
	Physics	5%
	Mathematics	0%
	Materials Science	0%
	Pharmacy	2%
	Biophysics	0%
	Medicine	2%
	Joint bio and physical sciences	2%
	Other	1%
	Other, please specify	

Q42	Which of these best describes your current position?	
	Professor or above	41%

	Reader/Senior lecturer/Senior researcher/Senior fellow	32%
	Lecturer/Researcher/Fellow	23%
	Research Associate	3%
	Research Assistant	1%
Something else, please state		

Q43	What was your age last birthday?	
	Under 30	2%
	30-44	49%
	45-65	45%
	Over 65	3%

Q44	Are you...	
	Male	81%
	Female	19%

Q45	The next stage of the project is to look at a small number of research groups in more depth to explore how research at the chemistry-biology interface is conducted and to enable a better understanding by policy-makers and funders of the issues. Would you be willing to take part in this next stage of the research? To do this a member of the PSP team will need to visit you and talk to some of the members of your team in more depth.	
	I would be willing to take part in the next stage of this project	40%
	I would not be willing to take part in any follow-up work for this project	60%

Q46	Please enter your name, phone number and preferred email address.	

Thank you for taking the time to complete this questionnaire. Responses to the questionnaire will be used as part of a study exploring current issues in the funding and infrastructure support for those using specific approaches in researching biological topics. Please click on submit to send your responses to PSP and end the interview.

## Case studies

Respondents were asked at the end of the questionnaire whether they would be prepared to take part in further research. They were informed:

*The next stage of the project is to look at a small number of research groups in more depth to explore how research at the chemistry-biology interface is conducted and to enable a better understanding by policy-makers and funders of the issues. Would you be willing to take part in this next stage of the research? To do this a member of the PSP team will need to visit you and talk to some of the members of your team in more depth.*

## Sampling

It was agreed that all case studies should be PIs so that we could visit a research group and that all would be in universities rather than in stand alone institutes. Working with the RSC we identified 21 potential case studies, at this stage protecting confidentiality.

PSP contacted the selected individuals and explained in more detail that we would like to talk to them and others in their group. Sixteen names went forward to the Steering Group but some combinations were not recommended because of the need to cover a variety of situations and because we did not want more than one case study at any institution. In the end, two volunteers who worked together became one case study and one had to drop out for reasons beyond their control. Nevertheless, we achieved the aim of completing six case studies.

## Case study discussion guide

Below is the interview schedule agreed with the RSC and the Steering Group.

### Assessment of the Chemistry-Biology Interface in the UK

All the discussions are with PIs and will focus on their group and the relationships they have built to facilitate research at the chemistry-biology interface. The primary discussion will be with the PI but we will also spend some time talking to other members of the group. The exact nature of these other individuals will vary between case studies. This document provides an overview of the topics that will be discussed across the six academic case studies. The researcher will have a copy of the interview responses to help structure and support the interviews.

### Background information for PI

There will be a one or two page case study summary which will take the form of an appendix to the report. This will be agreed with you in writing before being passed to the Steering Group or to staff at the RSC. Other information you provide included in the main body of the report will be non-attributable.

### Introduction

Background on PI and the group

Nature and objectives of the research

Outcomes of research to date

Whether the research involves work at other interfaces

Nature of the institutional arrangements in which they work

Why this work needs a chemistry-biology interface approach/how became involved in research at the chemistry-biology interface

### Staffing

Number in group

Qualifications and experience of all group members

Roles and responsibilities of group members

### **The institution**

How the institution supports/enables or otherwise, research at the chemistry-biology interface

Institutional barriers to cross-disciplinary working with specific reference to the chemistry-biology interface

How this impacts, if at all, on the nature, quality and success of the research

What could the institution do, or do better, or more of to support research at the chemistry-biology interface

If research is undertaken at other interfaces, how does the way the institution deals with the chemistry-biology interface compare with the way it deals with other interface relationships

### **Funding**

Which funders they have experience of, both current and recent past funders, scale of funding

Reasons for applying for funding to these organisations

Whether have made a conscious decision not to apply to certain funders and if so why

Following-up on response to the questions in the questionnaire on ease of completing applications for research at the chemistry-biology interface - How easy or difficult the application process is and how this varies between funders, if at all: what good practices would they highlight and what are examples of funding practices that make completing applications especially difficult. What else makes it more difficult or not.

### **Collaborations**

How chemistry and biology combined in the group, if at all

How collaborations with other groups come about

Why it is easy/difficult to find collaborators (picking-up on responses to Q13)

Nature and process of inter-departmental and/or inter-institutional relationships, within the UK and between the group and non-UK institutions. This will cover relationships between academic institutions and between the academic case study and industry, as appropriate.

The extent to which research at the chemistry-biology interface is becoming, or should become, a single discipline

The extent to which research objectives are achieved by researchers with different specialisms working together versus individual researchers having the relevant expertise in both chemistry and biology

Any relevant lessons from working with industry, if appropriate

### **Publishing**

Views on the difficulty or ease of publishing research findings from research at the chemistry-biology interface

Views on the need for additional journals

Feedback from reviewers

Is publishing on the internet assisting publication

### **RSC**

Role of the RSC in supporting/promoting research at the chemistry-biology interface

Action the RSC could/should undertake

Specific recommendations the PI wishes to make to funders, the RSC, wider policy-makers

## **Thank and close**

The report will be launched in the autumn and you will be invited to any launch event.

I will be drafting the case study in the next few weeks for you to agree.

## **The visits**

The PIs we contacted were extremely helpful in not only just giving-up time to meet with PSP staff but in organising their colleagues to be available to contribute as well. Some of these colleagues had taken part in the survey but others had not. These visits therefore enabled us to better understand the issues and to explain some of the responses to the questionnaire. Hence the data collected has largely been used to flesh out the report and the case studies themselves provide illustrations of different research groups and their work.

## Appendix 3 Research areas of respondents

Research Area	Proportion of respondents (Base=44)
medical	65
protein structure function	58
biological	37
medicinal chemistry	32
protein function	29
structure	25
nucleic acid	22
biotechnology	16
imaging	15
computational	14
general chemistry	14
analytical	13
interactions	13
biosynthesis	12
biomaterials	9
drug delivery	9
biocatalysis	8
metals in proteins	8
membranes	7
chemical genetics	6
signalling molecules	6
protein folding	5
systems biology	5
synthesis	4
carbohydrates	3
post-translational modifications	3
chemical proteomics	1

## Appendix 4 Institutional support

They allow meetings to take place; sharing of information regularly.
Interdisciplinary research groups, inter-department seminars
Academics from different departments are readily available via phone/e-mail
Institute funding opportunities; the nature of the institute is to support such collaboration
Our departments are cross-disciplinary
Multidisciplinarity at all levels is a key feature of the organisation that sets us apart from other research providers.
My university provides different type of equipment, seminars, lectures, meetings with members of other departments
By hiring top scientists that are relatively junior and open to collaboration
A seminar series where results and ideas can be disseminated. A biannual retreat. Through the institute for structural and molecular biology based at ....
Through research students, postdocs and formal duties within the department
Financial and logistic support
By keeping out of the way and letting them get on with it.
We have a new initiative in Chemical Biology
By encouraging interactions and the establishment of shared chairs between the biosciences and chemistry areas
They have established a Centre that includes both biology and chemistry members
Setting up an initiative and obtaining regional funding for development of interdisciplinary research
Provides some level of support...better than the funding councils anyway!
By allowing bioscientists to move from Biology to Chemistry physically
Biologists and Chemists have a joint meeting from time to time in which everyone presents a summary of their research and ideas/collaborations develop naturally from this. We also have a Research Centre that has dedicated laboratory space and is occupied by staff from both departments (although it is geographically located in the Chemistry Dept.). This centre serves as a focus for communication, problem solving and new research ideas.
By funding the construction of biology and engineering labs in the chemistry building
Teams are linked through an internal integration process through relational databases and meetings
Chemistry and biology are in the same department so we work closely together
It has developed a virtual interdisciplinary institute in clinical biosciences to encourage collaboration
Organises introductory meetings, encourages cross-disciplinary groupings etc

Openness in research constantly encouraged

Encourages collaboration through seminars etc

They have supported the Centre

By removing barriers to collaboration (e.g. financial) and encouraging collaboration through specific funding mechanisms (e.g. studentships)

We have a Centre, and the EPSRC and CRUK grant opportunities

Through interdisciplinary groupings

Research Excellence awards for interdisciplinary research groups

Multidisciplinary centres / institutes

Cross departmental studentships. Ease of establishing cross departmental research grant applications

Via a Centre (which includes a doctoral training centre and a couple of MRes courses) - this is an interdepartmental centre that brings together researchers from different disciplines to tackle biomedical projects.

The university supports a centre, which in turn fosters interaction.

Supportive of cross-departmental grant applications and initiatives (e.g. joint Chem + Biol PhD program)

Hosts seminars, establishes research clusters.

The science is driven by the Project Leaders and there are no barriers to intra- or inter-departmental collaborations - in fact, they are encouraged.

Networking meetings

Establishment of Multidisciplinary Research Divisions

Joint scientific meetings

We are organised into research groups which are different to teaching departments

Encourages cross School and faculty collaborations and interactions. New Institute brings various researchers of differing backgrounds together

The laboratories are located in vicinity under the same roof.

By encouraging joint applications for funding

Research Poster Days, Interdepartmental committee (Directors of Research), research website for each department, departmental seminars

We are in the same building

It is trying to organize one day meetings with other colleges to promote collaborations.

Different initiatives. It encourages crossing disciplines.

It has interdisciplinary initiatives
Has set up "Knowledge-Bridging" schemes to encourage collaboration
Interdisciplinary work is strongly encouraged - for example there is a cross-disciplinary seminar series
By promoting interdisciplinary research via consortiums, who have funding for studentships, joint meetings and other initiatives. Also by the merger of traditional departments into larger units
Encourages chemistry-biological science schools to keep in touch
By encouraging collaborative grant applications and facilitating opportunities for interface and interaction
By providing interdisciplinary research centres and university funding for PhD studentships, conference attendance etc
Centres of excellence
Joint Centres
Set up a multidisciplinary research institute in biomedical research which has chemists and biologists as members
Interdisciplinary research institutes
Chemists and biologists are in the same dept at my University
Created a new interdisciplinary centre. Access to people and kit
The creation and support of an interdisciplinary research institute that cuts across traditional Dept/School boundaries.
Special structures
Through real centres
Puts them in same buildings or nearby buildings, has a decent website, employs people with communication skills
It has established an interdisciplinary centre bringing together physical and bio-scientists to tackle biological problems using the tools and skills of physical scientists. It works extremely well.
Joint research equipment bids; joint grant proposals; shared lab facilities; shared postgrads;
They encourage it and also create research centres - real or virtual. There is constant dialogue. However, we still have to struggle with fairly rigid income streams
Providing interdisciplinary information and facilities
Promoting the formation of interdisciplinary centres/institutes
Single research institute allowing direct interaction
I work in the interdisciplinary centre which has a mix of academics with various backgrounds
Open seminar programmes.

Co-location in a single purpose-built facility

The University set up interdisciplinary centre

We have a school system such that cancer and imaging studies are together.

We have a central mass spectrometry facility that is developing technologies in collaboration with us as and when we need them. The core funding to the institute provides the funding for technology development. In addition CRUK has a new targets committee and we proposed new drug targets to this committee. The targets are validated by those specialising in work on human cells (we work on yeast) and then groups who specialise in high throughput screening put the target through their screen, then it is passed onto chemists for optimisation etc. We have one compound in this process at the moment. In addition CRUK will set up two or three new "drug discovery centres" where chemists will work alongside pharmacologists/biologist within our institute to develop the technologies and discoveries that are made in those institutes.

Organisation of meetings, talks, interdisciplinary thinking is stressed all the way

There is as medicinal chemistry department in my Institute that facilitates biology/chemistry collaborative efforts, particularly with regard to drug development.

Establishment of collaborative centres

Through cross disciplinary PhD programmes

Pump prime funding

New appointments in Chemical Biology

Speed dating activities, funding interdisciplinary studentships, encouraging collaborations

It is based on individuals making the effort.

Strategic use of DTAs for project students at interfaces.

Funding

Giving access to facilities - enable discussion between the departments/disciplines - Encouraging to write interdisciplinary research projects

Easy access to facilities. Networks in relevant areas

Provide environment to share knowledge and equipment

Promotes interdepartmental research collaborations

Strong support for spin off

We are physically located close together and inter-departmental applications are favoured. Once funding is achieved, allocation of funds to the different departments is amicably decided.

University innovation people do provide fora for interactions

Bringing people together via various interdisciplinary initiatives

Cross campus Collaborative Research network structure with central support (funding) to develop collaborations and talk across the disciplines

Funds for secondments to other departments. Cross campus research networks. Interdisciplinary lecture series.

Cross-departmental research themes and research priorities

By the formation of multidisciplinary collaborative research networks. These provide a framework for networking and joint symposia

Via interdisciplinary bridging awards

Actively encourages interdisciplinary collaborations. Establishment of institute as a medicinal chemistry/ cancer pharmacology activity was established by the university in a purpose built new building

No barriers. Actively encourages

Interdisciplinary research collaboration new building occasional interdepartmental workshops

It makes it clear that cross-departmental collaboration is desirable and does not place barriers in the way of such collaboration e.g. facilitating the transfer of (external) funding among project partners

Joint appointments; plenty of people working on biological problems in chemistry; and; vice versa, people working in biochemistry using chemical/physical methods; reasonable seminar and other links between departments.

My group is part of a Centre which encourages cross-discipline research. We have frequent research away days with staff from different departments. Research seminars are open to staff from different departments.

Research development team can coordinate meetings.

Through joint appointments between Departments

Joint get-togethers, joint seminars

Does not put up any barriers, encourages it with cross Department themes and research

The University doesn't hinder.... we just get on with it. The idea of interdepartmental collaborations is not really valid for us - we try to do everything we need to do in our group. Where we work with others outside the department it is through mutual interest and the relationship develops organically.

Joint faculty appointments in Chemistry and Biochemistry; some joint seminars; close physical proximity of the departments; Chemistry is taught to the Biochemistry students by the Chemistry department

By cross faculty interactions and appointments

The University provides a flexible environment and also develops thematic research projects.

Allowing joint grants, departments close together in space and administration, collegiate system, flexible bureaucracy.

No limits

It is up to the individual

The research group that I belong fosters collaborations

We have a School of Biology with an annual symposium. This allows one to meet members of other Departments beyond the usual channels (publications, word-of-mouth, web pages).

By encouraging inter-disciplinary interactions, for example by arranging seminars of interest to both groups.

Interdepartmental posting of seminars etc. Assistance in applying for joint grants. Taking a broad view of subjects, appointing staff beyond narrowly defined traditional subject areas.

Collaborations are encouraged; we had a 'contacts manager' - someone whose job was to find contact in other departments (chemistry, biology or other) that were useful to our research. This person is now doing the same job university wide.

There are numerous individuals who are employed by the University to facilitate interactions

Opportunities to meet - lectures/ symposia/ general science U/g course

Seminars, meetings, membership of Colleges, virtual research institutes with membership from different departments, joint teaching of courses

By making it possible for non-chemists to be appointed as researchers

Our College structure has no departments, only divisions (less competition for resources). Interdisciplinary collaborations are actively encouraged at all levels. Access to services and equipment is shared across divisions.

Life Sciences has appointed excellent chemistry teachers for undergraduate training, we have a biological chemistry division within the College, many biochemists here have a strong background in chemistry, synthetic chemistry professors have been appointed within the College of Life Sciences

The University has recently changed its structure and is now based on interdisciplinary Colleges. Chemistry is now an integral part of Life Sciences.

Inter-discipline symposia/meetings are encouraged to forge new links

Seminars where people from different research groups and different sections can present their work to each other. Poster days for post-graduate students, which allows people to find out what research is being conducted in which labs

Allow and encourage interdisciplinary research

Such collaborations are actively encouraged in a variety of ways

Common annual symposium

Funding of joint studentships sabbatical leave

All science schools administered under a single 'faculty'. Actually, the Head of Faculty is a chemist who works on biological problems. There is a long tradition here of collaboration between the Chemistry and Biology schools. Much more so than other Universities. We have long-standing joint seminars, for example.

The department is joint between chemistry and pharmacy and so includes cell biologists. The University is designed to allow overlap - all departments are connected by a long corridor that means we can walk to Biology without changing buildings!

There is a strong tradition of collaboration between the Schools of Biological Sciences and Chemical Sciences and Pharmacy. Against this background of significant interaction, new collaborations can be formed relatively easily.

It has a generally accepted philosophy to collaborate across disciplines PhD studentships are funded that require >2 supervisors, who should be in different departments

Offers funding, actively encourages interdisciplinary research to the point where every academic is involved in some sort of interdisciplinary project.

Joint seminar programs publishing lectures within other schools in chemistry joint lectureships between chemistry and biology

Through the establishment of various Centres

It supports the establishment of cross-disciplinary research centres. It has recently appointed a development manager with a specific remit in the Chemical Biology area.

Opportunities arise from mutual interests, meetings at seminars or links from teaching

Seminars

By giving general encouragement and support for major interdisciplinary initiatives

The University houses a centre for researchers in the physical and biological sciences. Collaborators are easily enticed by this facility!

Occasional meetings and encouragement

Provide research development awards and studentships for multi-disciplinary research. They recognise medical research needs biological and chemical inputs.

Organises many interdisciplinary research meetings for researchers to present their work and to highlight problems that need help. Chemistry and Biology departments are also very close together and thus interaction is very easy

Recently setting up new 4 year PhD studentships devoted to interdisciplinary research.

No influence at all. I collaborate with whoever I want both within and outside my Department/Institute.

Organise meetings of those interested in interdisciplinary work and provide highly prestigious, competitive scholarships for interdisciplinary research

It has built a new multidisciplinary Biomedical Research Centre

Shared Ph.D studentships. Otherwise, no specific ways, but no obstacles either.

Direct collaboration between chemistry/bioscience groups encouraged - joint seminars

Through the interdisciplinary Centre and thereby with a doctoral training grant and Wellcome Trust 4 year PhD scheme with part support from the University

Interdisciplinary centres and sharing post graduate students

A multidisciplinary centre for research at the chemistry biology interface. It has critical mass in this area and brings together physicists, chemists and biologists

The Centre is a cross-faculty centre including chemists, physicists and biologists. The Centre is an army of willing volunteers who can flexibly respond to funding opportunities and build competitive interdisciplinary teams quickly

Setting up of interdisciplinary centres

Interdisciplinary collaborations are encouraged and fostered by, for example, widely advertised relevant seminar programmes.

Through PVCs and general information

Primarily through the Centre - a good meeting place for PIs at this interface (involves researchers in molecular biology, chemistry, physics)

We have a joint research grouping which is cross faculty (Biology, Chemistry, Physics)

We are all part of the Centre that is deliberately set up with a remit to work at traditional disciplinary interfaces, one of which is Chemistry/Biology. The University recognises the strengths and competitive advantages of working this way and acknowledges the need to protect what might be minority interests within traditional organisational groupings.

Supports interdisciplinary science through SRIF and other infrastructures e.g. virtual centres and real ones

Through cross-disciplinary research centres

Supports joint degree program

There are buildings with chemists and biologists in them.

Co-authors on grant applications Interdisciplinary centres

In our case the tech transfer division helped us to develop links with more specialist scientists who have chemistry and biophysics backgrounds

We have set up a virtual institute that encourages interaction.

The University promotes cooperation and helps arrange mechanisms for sharing of ideas.

Through the formation of appropriate research structures and facilities including research Institutes.

Provision of funding for joint research projects

Provides the infrastructure (a new, purpose built multidisciplinary research centre) to support collaborations

Cross disciplinary centres. Funding for collaborative research

Interdisciplinary initiatives, appointments and centres. Also seminar series that are attractive to both disciplines.

Seminars, meetings, interdisciplinary programs

Inter-disciplinary doctoral training accounts.

Seminars, sandpits, forums

Strong interdisciplinary funding schemes and initiatives

There is a strong central management drive towards truly interdisciplinary research

Bridging and sandpit events. Establishment of a Centre. Funding of interdisciplinary PhD studentships between Schools

Sandpit meetings, joint day presentations, brain storm invites

We have interdisciplinary centres and we actively encourage interdisciplinary working

Establishment of interdisciplinary centres. Funding for cross-divisional researchers. In-house sandpits and workshops.

Provided a £25 million pound Centre with research staff from 7 Schools of the University

The university provides with a multidisciplinary researcher centre where chemists, biologist and medical scientists working together.

Cross disciplinary research institutes and research committee funding

Academics from several Schools located in a single building

Essentially by having a high concentration of different disciplines, all of the highest quality, within the university and mainly located on the same site.

Collaborative projects

Stimulating environment, interdisciplinary centres

We talk to each other. We apply for funding together.

The college environment builds links across different disciplines to allow an awareness of what might be possible

For many years we had a well funded joint interdisciplinary research programme whose legacy is still helpful

The College system allows full integration at a social level between academics in all disciplines. It is easy therefore to establish personal links with chemists (and physicists) who can advise on the most appropriate person to contact in their Department.

Provides broad research themes that cross school boundaries and offer financial support through these themes

Formation of larger schools, e.g. chemistry, pharmacy and food biosciences. Provision of University research themes with associated funding, e.g. biomedical and pharmaceutical research

Makes contacts between people in different fields

It established an institute in 1986.

By establishing interdisciplinary research institutes and by facilitating funding to these institutes.

Research office offers help and advice; cross-departmental seminars; cross-departmental collaborations highly encouraged; "virtual" institutes

Encourages cross department research programmes, helps to identify access routes to seed funds, organises meetings

Research led university with access to ALL departments

Joint grant applications with biology groups, e.g. tissue engineering. Use of facilities to carry out collaborative work and joint lectures/symposia.

Bioincubator building Refurbished facilities -- purpose built space Equipment procurement Staffing strategy

Multi-disciplinary working is encouraged

Some medicine/chemistry joint funding

Physical proximity

Built the Centre building housing biologists and chemists

Being a smaller University we tend to know each other, we also have joint buildings

Biologists and chemists inhabit the same interdisciplinary lab

They established the Centre

Simple understandable funding models. Pump priming initiatives.

Providing opportunities to develop new teams and supporting success by longer term commitment.

By operating in an atmosphere that encourages cross-discipline studies and through senior academics leading by example.

Brings people together across boundaries Provides specific funding (small) Establishes non-departmental research units

We have chemistry/biology interface meetings. Joint bids for funding

Interdisciplinary structure of faculties

Supporting joint seminars/research group meetings/away days to discuss opportunities at the interface of disciplines

We have invested appointments in key inter-phase areas and in joint infrastructure under SRIF.

As an environmental science faculty both chemists and biologists are employed and encouraged to collaborate

The initiatives on Campus are multidisciplinary which encourages joint projects to lever funds which has stimulated further application to RCUK and research work

My University encourages multidisciplinary work by the generation of various centres, including doctoral training centres that bring together people from different disciplines.

The provide interdisciplinary research centres and appoint biochemists in the Chemistry Department

Encourages inter departmental collaboration by facilitating joint ventures

Minimal administrative hurdles no nothing gets in the way

No specific enabling measures, just few barriers to collaboration. Inter-disciplinary doctoral training programmes have provided real stimulus for inter-disciplinary work.

Interdepartmental collaborations seen positively by Departments & University Researchers can access facilities/equipment in other Departments Joint degree between Chemistry & Biological Sciences, joint project students Doctoral training centre involving Chemistry & Biological Sciences University has supported cross-Departmental centres

Joint grant applications and doctoral training centres

Co-location of structural and theoretical chemists with biologists. Coordination of research and teaching activities between Biology and Chemistry departments through a joint planning group that meets regularly. Funding of interdisciplinary PhD studentships given a high priority in both departments. Joint seminar programmes and occasional afternoon symposia focused on interdisciplinary research between departments. Provides SRIF support for interdisciplinary Biology-Chemistry ventures; for example, establishing a new Centre and funding a joint appointment in and establishing high-throughput expression/purification laboratory.

Joint courses for undergraduates and graduates; joint appointments between departments; jointly funded PhD students; jointly organised research days; joint committees overseeing interactions between biology and chemistry departments

Has joint planning groups between chemistry and biology departments

## Appendix 5: Research funding

### EPSRC, BBSRC and MRC

#### Getting advice on remit

It would seem from the case studies that not all applicants are either aware of, or see the need to, seek advice from the Research Councils on remit. More importantly, applicants do not always agree with the decision as to which Research Council should lead on a proposal.

Research Councils state that grant applicants can seek advice directly from BBSRC, EPSRC and MRC at any time and it is part of the role of the programme teams / committee secretariats to advise on both scientific remit and procedure prior to submission of a formal application.

BBSRC, EPSRC and MRC respond to many requests for advice from potential applicants on a regular basis. Within EPSRC, the Cross-disciplinary Interfaces Programme (C-DIP) enables the engineering and physical sciences research community to engage with the life sciences. As part of this, the programme operates an informal "outline service" which allows researchers to seek advice prior to submitting a formal application. When BBSRC, EPSRC or MRC provide advice on research that spans remits, that advice should have been discussed and agreed between relevant Research Councils prior to being conveyed to applicants. Following this advice, subsequent applications may be led by the EPSRC, BBSRC or MRC with appropriate co-funding from other funders.

Despite advice available from the BBSRC, EPSRC and MRC, and for a range of different reasons, applications are not always submitted to the correct research council. The case study interviews revealed that moving applications between Research Councils can cause delays and additional work for researchers. An example was given of an applicant for whom delay had meant that the researcher with the relevant expertise had moved on and the expertise has been lost to the applicant's group. Another example was cited where the work had been done elsewhere during the delay and was no longer relevant.

#### Reviewing grant applications

The UK Research Councils and the Wellcome Trust mainly draw their peer reviewers from national and international academic experts in the relevant fields but industrial experts are also used.

The EPSRC states that it selects most reviewers and members of prioritisation panels from a College of peer reviewers that is nominated by the research community. At the time of accepting their nomination, College members indicate their research expertise. The EPSRC does not use standing panels, instead panels are convened in order to review the set of proposals received. Written reviews are received to support decision-making at the panel meeting, in the same way that the other Research Councils and the Wellcome Trust obtain written reviews in advance of committee meetings. In cases where an application is considered to cross Research Council boundaries, the lead Council will seek suggestions for referees from the co-funding Council, in order to ensure applications are assessed by referees with appropriate expertise. Each proposal is considered in the most appropriate responsive mode panel, based on the predominant relevant Programme area within EPSRC remit, for example Chemistry, Physics or ICT. Panel members with relevant expertise in the life sciences are included in the Programme panel membership to facilitate this process and speak on proposals, where appropriate. Proposals are considered within the Programme panels to ensure the quality of both the engineering/physical science research and the multidisciplinary life-science elements.

This report finds that it is not clear to successful applicants whether they had received LSI funding or standard EPSRC Programme funding and this seems to be causing confusion.

Some respondents thought that EPSRC's system worked well enough but others felt that because any panel meets only once, it left the panel members unable to develop any strategy or to implement EPSRC's strategy of supporting the chemistry-biology interface. The EPSRC advise that Programme Strategic Advisory Teams (SATs) as opposed to peer review panels provide strategic advice to EPSRC on the research and training elements of the respective programmes, paying particular attention to multidisciplinary opportunities.

In contrast, project applications submitted to BBSRC are reviewed by a number of referees with appropriate

expertise. They are nominated by the applicants and committee members, and also selected from BBSRC's referees database. Applications at the chemistry-biology interface are then, in most cases, assessed by the Biomolecular Sciences Committee. While conducting research for this report we were told of a situation where an application requested two post-docs but only one was funded and that the researcher considered that the application was falling in a gap. BBSRC's research committees do occasionally reduce the staff resources on a project application but this is based on expert judgement, and reflects the committee's role in advising on the allocation of funding.

Information on funding available from the **EPSRC** can be found at <http://www.epsrc.ac.uk/ResearchFunding/HowToApply/default.htm>

EPSRC Programmes

<http://www.epsrc.ac.uk/ResearchFunding/Programmes/default.htm>

Contact: Zoe Brown

Email: [Zoe.Brown@epsrc.ac.uk](mailto:Zoe.Brown@epsrc.ac.uk)

Information on funding available from the **BBSRC** can be found at <http://www.bbsrc.ac.uk/funding/apply/index.html>

BBSRC Engineering and Biological Systems

[http://www.bbsrc.ac.uk/funding/grants/engineering\\_biological/index.html](http://www.bbsrc.ac.uk/funding/grants/engineering_biological/index.html)

Contact: Sophia Abbasi

Email: [sophia.abbasi@bbsrc.ac.uk](mailto:sophia.abbasi@bbsrc.ac.uk)

BBSRC Biomolecular Sciences

[http://www.bbsrc.ac.uk/funding/grants/biomolecular\\_sciences/index.html](http://www.bbsrc.ac.uk/funding/grants/biomolecular_sciences/index.html)

Contact: David McAllister

Email: [david.mcallister@bbsrc.ac.uk](mailto:david.mcallister@bbsrc.ac.uk)

Information on funding available from the **MRC** can be found at

<http://www.mrc.ac.uk/OurResearch/TheResearchBoards/MolecularandCellularMedicineBoardMCMB/index.htm>

### **The Wellcome Trust**

Information on funding available from the Wellcome Trust can be found at

<http://www.wellcome.ac.uk/Funding/index.htm>





