Chemical Biology and Biological Chemistry Theme Day Report

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2. Summary

The EPSRC Theme Day on Chemical Biology and Biological Chemistry took place in London on 3 December 2013. The Theme Day was an important opportunity for EPSRC to gain a better understanding of the EPSRC research portfolio in this area and to scope the future focus and shaping of the portfolio. A panel chaired by Professor Herbert Waldmann (Max Planck Institute Dortmund and Technische Universität Dortmund) reviewed the portfolio of research.

The key findings of the panel's observations and perceptions were:

- The science presented at the Theme Day was diverse and at a high level.
- EPSRC funded chemical biology research is particularly strong at method development in synthesis and spectroscopy, although further improvements in tackling important (chemical) biology problems could be made.
- The number of research groups in the area is impressive and has reached the critical mass needed for international leadership. Chemical biology research in the UK has undergone major development in terms of quality, breadth and diversity. It is in the top tier internationally with individual research groups in an internationally leading position.
- The relevance of the area to society is clearly established; the group of researchers is aware of it and voices it.
- Scientific grand challenges were identified (see Appendix D for a compilation), and there was the willingness and creativity in the community to tackle them.
- The following challenges identified by the researchers were important issues that chemical biology research could address: health/ageing/better living in later years, nutrition, sustainable resource management/biological resources.
- The area is covered by several funding agencies. The diversity of funding was seen as a strength by the panel. Given the quality and the leadership of chemical biology research in the UK and its impact on society, funding should at the very least be sustained, preferably increased by the relevant bodies.
- Although in the top tier, EPSRC-funded projects are often not perceived to be internationally leading (top 5%): more "beacons" are needed in the area. A challenge for the future of the area in the UK community is to create more innovation at the level of individual research groups and collaborations.
- In order to create additional global leaders the size of individual research grants should be increased, thereby enabling fully-fledged cutting-edge research, which truly integrates both chemistry and biology, in individual research groups and furthering sophisticated collaborations between groups.
- Interdisciplinary training of and access to a sufficient number of highly motivated excellent Ph.D. students is of utmost importance to reach and maintain a globally leading position, and needs to be bolstered.

The key recommendations of the panel were:

- Given the quality and the leadership of chemical biology research in the UK and its impact on society funding for chemical biology needs to be sustained or increased

- To raise the profile of research groups in chemical biology, in particular younger, starting researchers, to an internationally leading level, the size of individual research grants should be increased.
- Additional efforts should be made by the EPSRC chemical biology community to directly address biological hypotheses, making immediate use of the enabling techniques and research tools developed within the funded projects.
- Research Councils should facilitate the transition of projects from one Council to another as the nature of the work evolves (i.e. physical sciences through into life scenes and biomedicine).
- EPSRC, BBSRC and other funding bodies should review their joint funding arrangements. Joint panels could be formed to more reliably assess funding applications, and joint funding initiatives could foster interdisciplinary work from the start of a project. Research councils should truly collaborate in funding the best projects of chemical biology research and assure that all projects will receive an expert review. It needs to be assured that doctoral students with a multi-year research horizon receive efficient and high-quality research training among the diverse and large community of groups.
- The EPSRC should ascertain that CDTs will not restrict research in Chemical Biology to a very limited number of institutions and raise awareness of the EPSRC Doctoral Prize mechanism to extend the funding period for the best EPSRC-funded students.

3. Acknowledgements

EPSRC would like to thank the following people for helping with the success of the Chemical Biology and Biological Chemistry Theme Day:

- The members of the Panel for their hard work and enthusiasm under the chairmanship of Professor Herbert Waldmann (Max Planck Institute, Dortmund and Technische Universität Dortmund) and the Chair for his plenary lecture and chairing the panel.
- The grant holders and other researchers for their posters, discussions with the panel and constructive participation in the breakout sessions
- EPSRC colleagues for their help in organising the event and assistance on the day itself

4. Introduction

4.1. Theme – definition and sub-themes

EPSRC defines the Research Area of Chemical Biology and Biological Chemistry as:

“The application of chemical techniques for the understanding of biological processes and the synthesis of biologically active and biological molecules; it also covers biomimetic chemistry, including producing simplified chemical models of complex biological systems”

The EPSRC realises that this definition should be applied flexibly so that excellent research at the engineering and physical science/biology interface can be funded that is not strictly covered by this definition.

The theme was split into sub-themes defined as follows:

- **Application- or problem-led Chemical Biology** - Examples of research within this subtheme include agri-science, medicinal chemistry, therapeutics, materials, systems chemistry
- **Molecule-driven research** - This subtheme covers research into DNA and nucleotides, peptides and proteins, natural products and their synthesis
- **Development or improvement of tools/techniques for Chemical Biology** - This subtheme includes research into analytical techniques, imaging, probes, microscopy, biophysical, computational approaches
- **Areas of chemistry that contribute towards Chemical Biology research** - These include but are not limited to bioinorganic chemistry, supramolecular chemistry, and engineering
- **Biological Chemistry** - The synthesis of biologically active and biological molecules

4.2. Background

A Theme Day is a well-established mechanism used by EPSRC to evaluate the effectiveness of EPSRC's support for research in an area that cuts across its programme boundaries. In this case the Research Area cuts across the remit of several different funding bodies.

A secondary aim of the Theme Day mechanism is to provide advocacy by generating information on research achievements and successes that can be used to demonstrate the importance of research. Thirdly it provides an opportunity for individuals within a particular research community to network with others.

Chemical biology research in the UK, as elsewhere, is broad and disparate as noted in the 2008 Royal Society of Chemistry report Face to Face: the UK Chemistry Biology Interface, which was supported by the Research Councils and the Wellcome Trust. The rationale for the Theme Day was to gain a better understanding of the area for EPSRC and to allow us to scope the future focus and shaping of the EPSRC portfolio.

The objectives for this Theme Day in Chemical Biology and Biological Chemistry research were:

- To benchmark the Chemical Biology portfolio internationally, as a whole and as a collection of Sub-Themes, in terms of: research quality; creativity; academic impact; and, impact on the user community.
- To discuss with the assembled researchers the barriers to Chemical Biology research, and to share knowledge about the ways in which these barriers can be overcome.
- To identify with the assembled researchers areas of future opportunity for Chemical Biology research.
- To provide a forum for networking and community building across the Chemical Biology community.

- To establish uniqueness of chemical biology research in EPSRC portfolio, compared to other research councils

5. Key points and panel recommendations

The Theme Day consisted of three sessions in which each delegate participated. These sessions were:

- A poster session, where the panel members assessed a sub-set of posters against the assessment criteria given above to benchmark the portfolio of research
- A breakout session discussing challenges and opportunities in chemical biology and biological chemistry research
- A second breakout session where discussions were around societal, technological and cultural challenges and opportunities for chemical biology and biological chemistry.

The key points from the two breakout sessions were fed back to the panel in the post-event meeting on 4 December 2013. Further information on the selection of delegates and the Theme Day methodology is given in Appendix B.

5.1. Overall impressions and perceptions of the panel

The panel had the following observations and perceptions about the science presented to them at the Theme Day and about the outputs from the breakout discussions.

- The panel scored research projects falling under sub-themes “Areas of chemistry that contribute towards Chemical Biology research”, “Molecule-driven research” and ”Development or improvement of tools/techniques for Chemical Biology” consistently high. Whilst there were only two posters assigned to the sub-theme “Areas of chemistry that contribute towards Chemical Biology research” and the score may thus not be representative, the “Molecule-driven research” and ”Tools/techniques” sub-themes were the most popular, with 16 and 19 posters, respectively. Projects grouped in sub-themes “Application- or problem-led Chemical Biology” and “Biological Chemistry” on average were scored lower. A very limited number of research projects consistently received the highest scores.
  This general outcome reflects the usually more chemistry-driven motivation and character of the chemical biology research projects funded by the EPSRC (e. g. development of chemical enabling technologies; development of tool compounds), as opposed to more biological problem- and hypothesis-driven research projects, which are probably funded by more biology-focussed funding organizations, in particular the BBSRC.
  The panel suggests that additional efforts are undertaken by the EPSRC-funded community to directly address biological hypotheses, making immediate use of the enabling techniques and research tools developed within the funded projects. This could be facilitated by partnering with biology groups at the start, during and after completion of a project.
- Chemical biology research funded by the EPSRC is very diverse, ranging from relatively small individual group projects to local collaborations between groups to

address a particular subject to UK-wide networks. Similarly, the topics funded vary widely ranging from organic synthesis to medicinal chemistry, bioanalytical chemistry, computational investigations, peptide- and protein chemistry, biological imaging and nanoscience. Several Doctoral Training Centres are included as well.
This diversity adequately reflects the fact that Chemical Biology covers diverse areas of the modern biosciences and testifies that selection for funding by the EPSRC appears to be flexible and responsive to the manifold interests of the corresponding UK research community.

- The panel noted and strongly supports the integration of computational approaches and synthesis into the context of chemical biology and their combination with experimental work at the chemistry-biology interface by the UK chemical biology community.
- In general, the scientific quality of the EPSRC-funded projects is high or very high. The leading funded scientists are internationally fully competitive. The number and diversity of the research groups are impressive, and the critical mass required to reach international leadership has been established in the UK. During the last 10 – 15 years chemical biology research in the UK has undergone major development in terms of quality, breadth and diversity. Today, it can rightfully be rated as in the top tier internationally with certain individual research groups clearly in an internationally leading position.
- UK chemical biology researchers are fully aware of and voice the relevance of their science to society. The community has identified grand scientific challenges and is willing to take the undeniable risk to tackle them. These areas of relevance include, in particular, health and ageing, personalized medicines and diagnostics, as well as better living in later years, nutrition and sustainable management of resources, in particular energy and biological resources.
- Given the quality and the leadership of EPSRC-funded chemical biology research, its impact on society and its future development, the panel recommends that funding by the EPSRC should at the very least be sustained, preferably increased. In taking such an initiative it is recommended that the size of individual research grants should be increased. Chemical biology research by definition is multidisciplinary and very cost-intensive since it has to match the financial and infrastructural demands imposed by both chemistry and biology research and often analytical and physical science.
- Interdisciplinary training and funding of Ph.D. students as a core group of researchers with a multi-year vision and horizon for their work is of particular relevance to research in chemical biology. Due to their interdisciplinary nature, cutting edge research projects in chemical biology often require multiple years of investigation (4 – 5 years of bench research is not an exception).
  Therefore, interdisciplinary training of and access to a sufficient number of highly motivated excellent Ph.D. students is of utmost importance to chemical biology research in the UK. Lack of appropriate student funding may ultimately severely impair competitiveness of the UK in this highly important area.
  However, postdocs are critical as well, and means are needed to extend their projects too.
- Although in the top tier internationally, only a few of the EPSRC-funded chemical biology projects can be seen to be truly innovative or productive at a world-leading

level. It would be highly desirable to increase the number of “scientific beacons” among the EPSRC-funded chemical biology research groups.
In order to establish individual groups on such a level, funding on a different scale than currently accessible by means of EPSRC-grants is required. Such funding will enable the establishment of larger interdisciplinary research groups which can truly integrate internationally competitive chemistry and biology research.

- Several of the leading chemical biology groups in the UK do not have EPSRC-funded projects, probably because they receive funding from other organizations, in particular the BBSRC and the Wellcome Trust.
  Given the intricacy of chemical biology funding in the UK, an increase in the number of worldwide leaders in chemical biology might be spurred and mediated by setting up a well-coordinated joint funding initiative between the different relevant funding organizations, in particular the EPSRC, the BBSRC and the Wellcome Trust.
  Notwithstanding the potential strength of funding chemical biology from different perspectives, the panel noted that numerous participants expressed their advocacy of a joint EPSRC/BBSRC funding initiative. They expect that in such a joint program their applications would undergo a review process by a broad scientific field and appropriate experts with matching expertise, reflecting the diverse core disciplines of the individual funding bodies.
- In light of these arguments, there is a need for the research councils to truly collaborate in the funding of chemical biology research. They should not, for example, compete for funding of the best projects or demarcate areas so strictly that certain areas are not funded by any research council

5.2. Recommendations

Following discussions after the Theme Day about the panels' observations and review of the area, the panel made the following recommendations:

- Given the quality of science and the societal impact funding for chemical biology needs to be sustained or increased.
- The size of individual research grants should be increased.To raise research groups to an internationally leading level, individual funding on an expanded scale is required to run the big, interdisciplinary groups needed to address the research challenges in chemical biology. Currently this may be possible for a very few UK groups, but for true international leadership this number should be increased. Further, younger, starting researchers in chemical biology in the UK require internationally competitive start-up packages and the EPSRC should devise a means to contribute substantially to such packages. The community also should raise their ambition and ask for more when writing their proposals if they need larger grants.
- To better orchestrate funding on such a scale, EPSRC, BBSRC and other funding bodies should review their joint funding arrangements. Many delegates suggested to the panel that a EPSRC/ BBSRC joint panel would assess their applications more reliably. Another possibility could be to encourage joint funding between funding bodies for Fellowships to foster interdisciplinary work from the start of a project.
- Research Councils should consider mediating the transition of projects as the remit progresses from one council to another.
- The panel strongly recommends that the research councils should truly collaborate and not compete in funding the best projects of chemical biology research. The

councils need to assure that all projects will receive an expert review, and that no areas should be prejudged to be out of scope for funding.

- Assure that doctoral students receive efficient and high-quality research training among the diverse and large community of groups. Ph.D. students with a multi-year research horizon are the core group of researchers in chemical biology. However, postdocs are critical as well, and means are needed to extend their projects too.
- The EPSRC should ascertain that CDTs will not restrict research in chemical biology at the graduate level to a very limited number of institutions. In this regard, the amount of DTP funding, the way it is distributed and whether any is expected to support chemical biology should be clarified. EPSRC should raise awareness of the EPSRC Doctoral Prize mechanism for extra funding of up to two years for the best EPSRC-funded students once they have completed their PhD.(Further information on the prize can be found here http://www.epsrc.ac.uk/skills/students/dta/Pages/doctoralprize.aspx).

6. Conclusions

Chemical biology research in the UK has undergone major development and today is in the top tier internationally with individual research groups clearly in an internationally leading position. In the past, research at the chemistry/ biology interface in the UK has been creative and has given rise to innovative discoveries. The opportunity to conduct pioneering research needs to be kept open, especially to up and coming young academics. Funding by the EPRSC has been instrumental to foster the development of chemical biology and to reach this superior standing. Sustained investment into funding of this interfacial area will be of major importance to assure the competitiveness of the UK's science base in the life and health sciences and will be an excellent investment into the future development of the country.

Within the UK, infrastructure and funding to raise chemical biology research to an even higher level are in principle available. The community needs to take advantage of these opportunities, and the best use of them needs to be promoted.

Appendix A. Panel membership

Panel Member	Organisation
Prof. Herbert Waldmann (Chair)	Max Planck Institute Dortmund and Technische Universität Dortmund
Prof. Luc Brunsveld	Eindhoven University of Technology
Dr Lyn Jones	Pfizer
Prof. Rob Field	John Innes Centre
Prof. Hagan Bayley	University of Oxford
Dr David Lathbury	Albany Molecular Research Inc. and Physical Sciences Theme Strategic Advisory Team member
Dr Anne-Kathrin Duhme-Klair	University of York

EPSRC would like to thank all the panel members for their time and dedication for this Theme Day.

Appendix B. Methodology

A Theme Day is a well-established mechanism used by EPSRC to evaluate the effectiveness of EPSRC's support for research in an area that cuts across its programme boundaries. A secondary aim of the Theme Day mechanism is to provide advocacy by generating information on research achievements and successes that can be used to demonstrate the importance of research. Thirdly it provides an opportunity for individuals within a particular research community to network with others.

During the Theme Day, an independent panel of experts provide their opinions and perceptions on a representative sample of grants from across the portfolio and draw conclusions about the portfolio as a whole. Notably, a Theme Day is not concerned with constructing league tables of grants or researchers, nor to isolate individual failures.

To provide a representative sample but a manageable volume for a one-day event, there were 65 posters due to be presented the event, although 56 researchers presented on the day. The majority of these were EPSRC grant holders (~50 posters) and the rest were suggested by the panel, MRC, BBSRC, RSC and Wellcome Trust or nominated themselves through an open invitation on the EPSRC website (advertised twice). The posters were selected from the portfolio by choosing projects that had recently finished or are current and were chosen to give a spread of grant types, career stages and institutions. Posters from outside the portfolio were chosen to give the panel a broader view of UK research in the area.

Each poster was allocated a pair of panel members to spend 10 minutes at an allotted time discussing the contents of the poster with the presenter. Both of these panel members were asked to assess each poster against an international benchmark, across the following primary criteria:

- **Research quality** - Quality of the research proposed and undertaken
- **Creativity** - The originality of the research proposed and undertaken; the degree of adventure required to produce a high return in terms of knowledge advancement and impact on the academic and user communities; the incremental nature of the research.

- **Academic impact** - For example, as indicated by refereed journal and conference publications, book chapters, citations, conference presentations, and invited keynote speeches.
- **Impact on the user community** - For example, as indicated by patents, direct dissemination of outputs (e.g. consultancy and training courses), exhibitions, involvement of non-academic project partners, and project partner contributions.

Panel members provided a score (from 1 to 5) for each criterion as well as an overall score for each poster. These scores were aggregated to provide information for the panel discussion after the theme day event to help the panel to make their recommendations.

Appendix C. Analysis of panel scores

The following data from the panel review of poster presentations were presented to the panel at the post theme day panel meeting to facilitate discussion of the panel's views and recommendations for the research area. The graphs are created from the scores that panel members provided for each assessment criterion. Panel members gave posters a score from 1 to 5 for each criterion and an overall score, with 1 being poor and 5 being internationally leading. The average overall score for all posters presented was 3.6.

The distribution of posters presented in terms of sub-theme is given below (Figure 1). There were only two posters presented for the ‘areas of chemistry that contribute’ sub-theme so scores in this area are not statistically significant, both posters scored 5/5 overall. 65 presenters had agreed to attend, although on the day only 56 researchers presented posters.

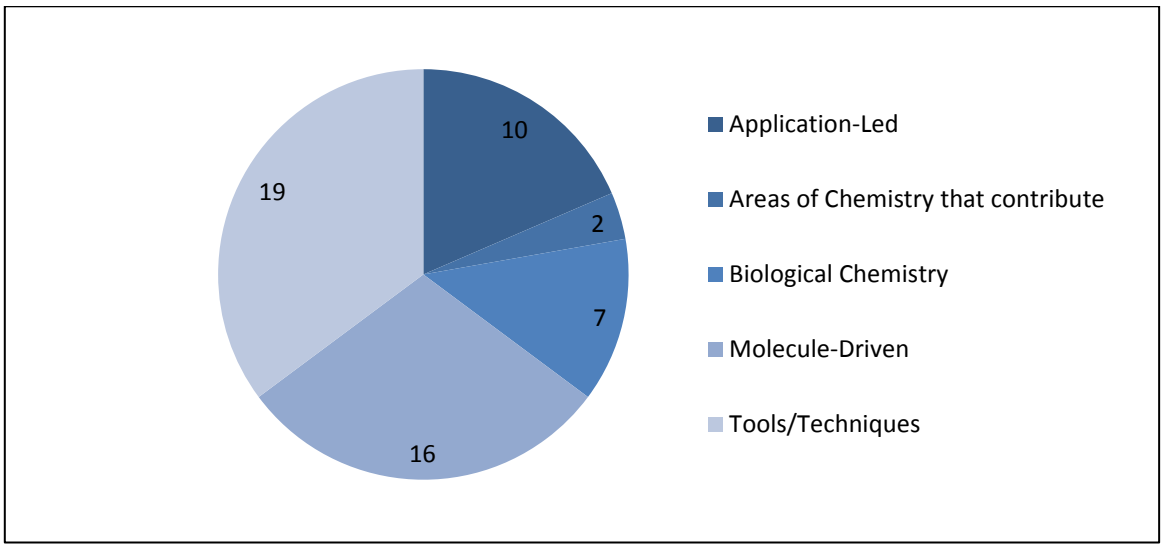

Figure 1: Posters presented at the Theme Day by sub-theme area. The number of posters in each sub-theme is indicated. The total number of posters at the day was 56.

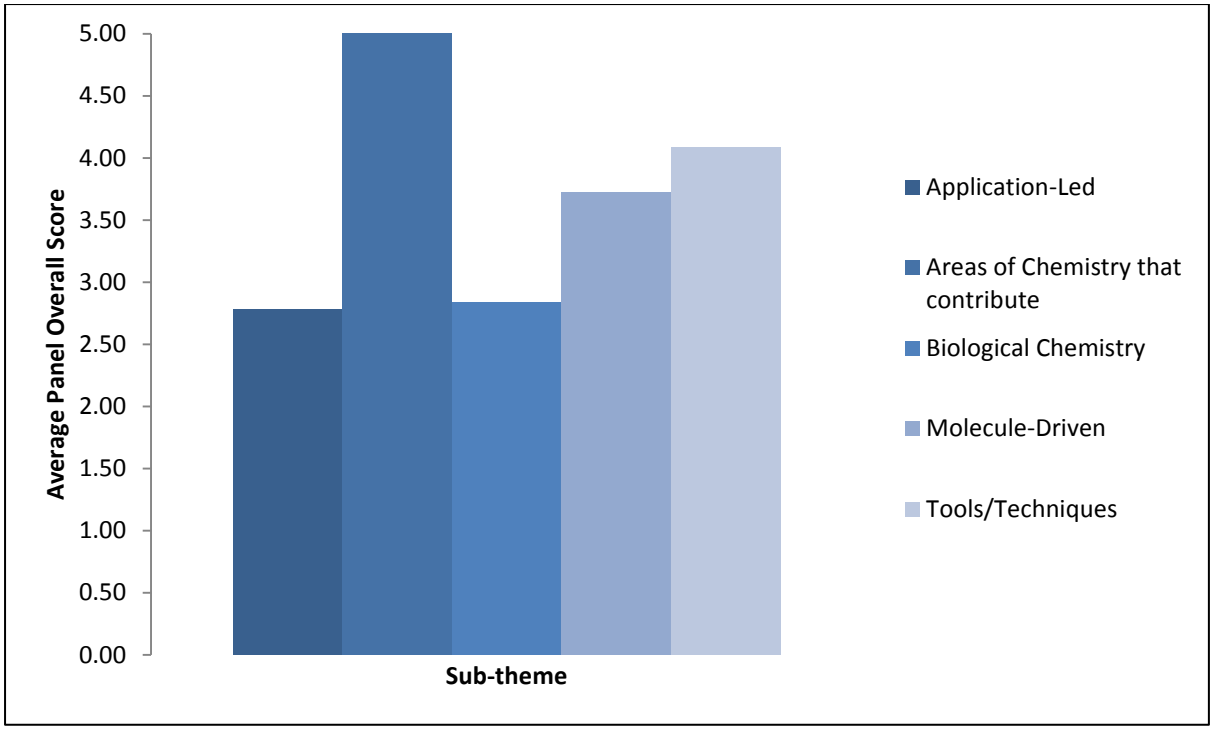

Figure 2: Average panel overall scores for posters viewed in each sub-theme. The number of posters presented in each sub-theme is given in Figure 1.

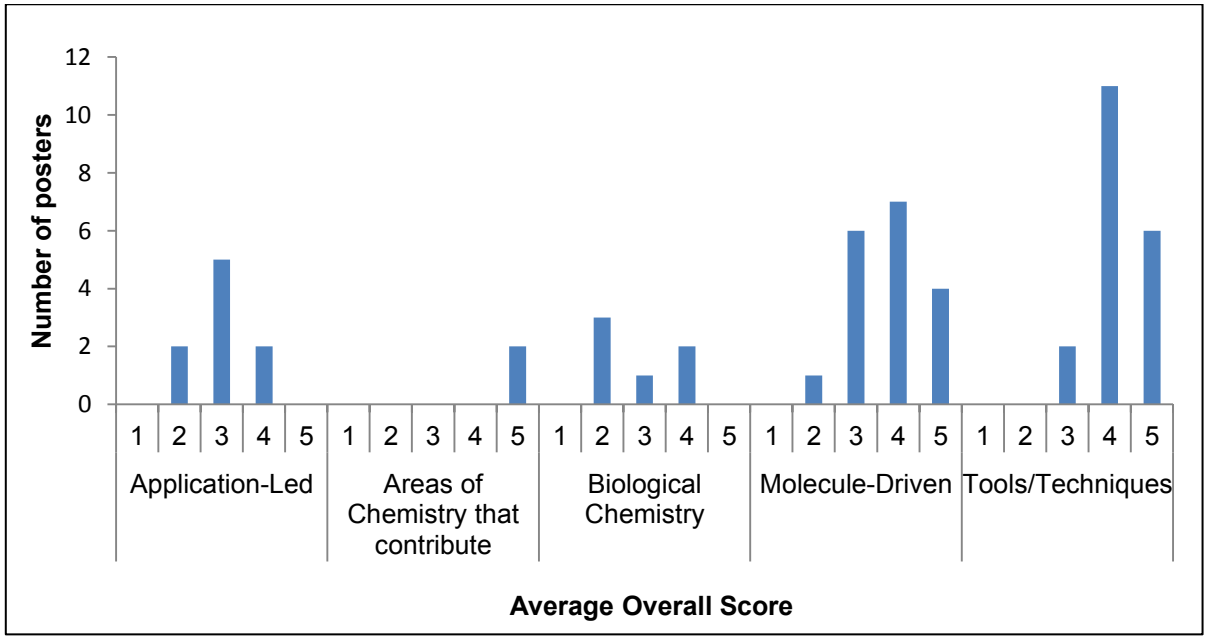

Figure 3: Distribution of average panel overall scores for posters in each sub-theme. The number of posters presented in each sub-theme is given in Figure 1.

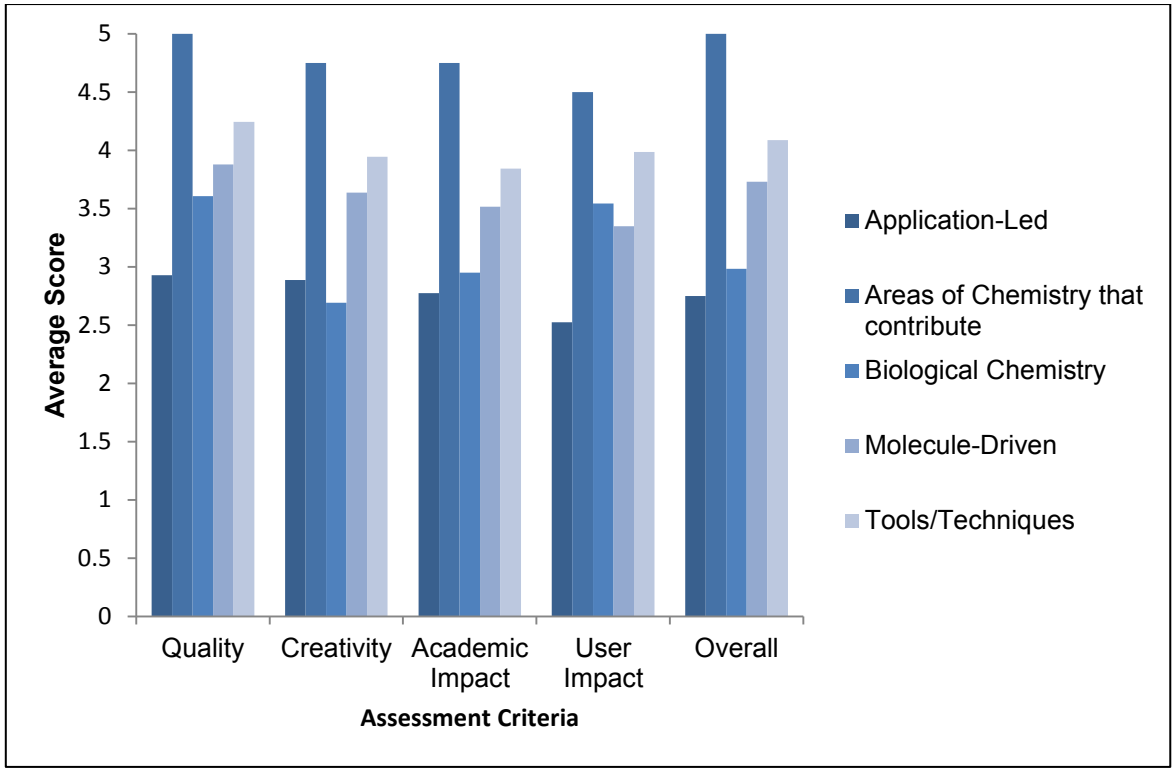

Figure 4: Average panel score for each assessment criterion in the various sub-themes. The number of posters presented in each sub-theme is given in Figure 1.

Appendix D. Breakout sessions

Breakout session 1

This facilitated session was focussed around challenges and opportunities in chemical biology and biological chemistry research – what the current important and emerging areas of research are and how the UK is placed to address them.

Delegates were asked to think about the following around each key challenge they identified:

- What is needed to tackle the challenge? What can the community do? What can EPSRC do?
- What would success look like?
- Is there any overlap with other research areas?
- Identify the associated barriers

Further details of the challenges identified by delegates during this session are given below.

Challenge: Protein-Protein Interactions
Understanding the biological relevance of protein-protein interactions (PPIs) remains an important research challenge. Many biological functions are instigated by multiple proteins binding together such as cell regulation and inactivating proteins. Abnormal PPIs are the cause of many human diseases, so in order to aid in the design of potential treatments these interactions need to be understood at a molecular level. There are several barriers that are inhibiting progress in this area. Studying PPIs is a problem on a grand scale as many PPIs are currently not structurally defined and their biological functions are even less well understood. Tackling such a problem requires the

assembly of a large and adaptable team with expertise covering synthesis, modelling, informatics, structural molecular biology and cell biology, which can be difficult to do in the UK. Powerful computational techniques are needed, including software that non-experts can use. Advances in this area could lead to new medicines and probes for disease diagnosis, as well as advances in agri-science.

Challenge: Cell Technologies

This challenge is a combination of several similar challenges identified in the breakout sessions. These were: New Technologies for Molecular Interactions in the Cell; Control and Manipulation of Molecular Systems (Molecular Robots) and Understanding, visualising and manipulating cell machinery.

Being able to understand and visualise the interactions within the cell and manipulate the cell's machinery would allow researchers to better understand and control biochemical pathways. Improved understanding at the cellular level could lead to better knowledge of the mode of action of a drug or allow you to track a single molecule through the cell. Other possibilities include the ability to shut down diseased cells at will or develop a completely synthetic cell. Being able to manipulate an entire molecular system could enable the development of "personalised molecular robots" which have the ability to repair damage caused by toxins. Success in any of these research challenges could lead to the development of better therapeutics.

In order to tackle the cell technologies challenge, a number of scientific and cultural barriers need to be overcome. The complexity of large cellular components and how they assemble needs to be investigated and the limitations of current in vivo techniques need to be improved to single molecule sensitivity. New probes and imaging techniques are needed as well as time and spatially resolved "-omics". . As this is such a broad challenge, large consortia/networks of researchers are needed with multidisciplinary overlap. Both short-term funding for speculative ideas and flexible longer term funding are required. Expertise from across the engineering and physical sciences and into the biological sciences is needed and includes but is not limited to: physicists, optics experts; chemical biologists, analytical scientists; nanotechnologists; cell biologists; synthetic biologists.

Challenge: Post-Translational Modification (endogenous and exogenous)

Understanding the post translational modification (PTM) of proteins is an important research challenge for Chemical Biologists as such modifications perform crucial roles in the regulation of a cell's biology. PTMs are responsible for changing a protein's chemical or physical properties, activity and stability.They play a role in every disease and the pathology of the cell, so it is important that these modifications are identified and understood so that their role in cell regulation and disease can be better realised.

In order to be able to study PTMs in a more comprehensive manner, improved analytical techniques are required, for example, high-throughput AFM/STM; single molecule vibrational spectroscopy; single molecule protein mass spectrometry; single molecule diffraction and single molecule NMR. This lack of fundamental techniques is a major barrier to success in this area. The development and synthesis of chemical tools to probe these interactions goes hand in hand with technique development. Improved techniques will allow for the identification of PTMs and quantify their distribution on a single molecule basis. Higher resolution techniques will also aid studying perturbation of PTMs and monitor their affects, which in turn will aid understanding of the mechanisms of disease. In order to tackle this challenge efforts are needed from both analytical scientists and synthetic chemists.

Challenge: Molecules to Man

The chemists that synthesise drug molecules and the clinicians who trial these compounds are very disparate communities. In order to accelerate the transition "molecule to man", better integration of these two communities is needed. This challenge could be tackled by students, postdocs and academic staff with overlaps in expertise and by flexible funding for chemical biology that includes the translation stage. The current barriers include the perceived gap between the different Research Councils and the different culture of chemists as compared to other disciplines. The Research Councils must cooperate, rather than strive

to maintain unique research areas, and the chemists must collaborate to make molecules that will actually be used in biological investigations.

Breakout session 2

This facilitated session was focussed around societal, technological and cultural challenges and opportunities for chemical biology and biological chemistry. It is key for EPSRC to understand why the research area is important

Delegates were asked to think about the following around each key challenge they identified:

- Specific examples of how Chemical Biology/Biological Chemistry can help for each challenge
- Within this example identify the EPSRC research contribution
- Identify the barriers that need to be overcome in order to tackle this challenge (e.g. lack of new technology, lack of expertise). Alternatively identify how the research/technology could be accelerated.

Further details of the challenges identified by delegates during this session are given below.

Challenge: Effective & affordable healthcare, quality of life and long term health	
Why is it important?	- Ageing population - Sustainable costs - Viral infections - Resistant strains - Developing world demands - Diseases of affluence
How can chemical biology/biological chemistry help?	- Diagnostics and monitoring for early warning - More effective drug discovery - Better understanding of the biology of ageing
What is the EPS contribution?	- Chemical methods (synthesis, analytical methods computational methods)
What are the barriers?	- Cultural/language barriers between research communities, - Not enough communication between funding bodies
Challenge: Quantifying disease mechanisms and treatment	
Why is it important?	- Improved quality of life - Prevention of adverse drug reactions
How can chemical biology/biological chemistry help?	- Develop better diagnosis - Better validate drug targets - Use a quantitative approach - Small molecule sensors - High through-put imaging
What is the EPS contribution?	- Use small molecules to elucidate disease mechanisms - Quantitative imaging technologies - Chemical analysis to understand biomarkers - Using chemical tools in primary humans cells and animal modelling - Chemical proteomics
What are the barriers?	- Complexity in biology - Cultural resistance to quantification - Lack of analysing tools - Running multi-disciplinary projects - Universities are discipline based

Challenge: Chemical synthesis using biological systems (in-vivo or in-vitro)	
Why is it important?	- Ecology - Finite resources - New material design - Chemical industry replacement - Petro-chemical industry - Wealth creation
How can chemical biology/biological chemistry help?	- Understand biological networks so they can be reverse-engineered (top-down approach) - Development of bio-catalysis (including artificial enzymes, bottom up approach) - Process engineering - Artificial chassis/artificial cell construction
What is the EPS contribution?	- Process engineering - Understanding complexity - Mathematics/systems biology (engineering interpretation)
What are the barriers?	- Complex and multi-disciplinary - Scale up - Ethical issues - 'frankencell' - Energy / resource costs - Change in world economy/political infrastructure
Challenge: Going to the Doctors and getting it right	
Why is it important?	- Better healthcare and quality of life - Sustainability – better more efficient use of resource and time
How can chemical biology/biological chemistry help?	- Better understanding of chemical space to biological space - Better understanding of biological mechanisms - Instrument development and techniques - Data and analysis - Identification of unlabelled molecules in cells - Better more sensitive, selective and responsive probe molecules
What is the EPS contribution?	- Instrumentation and technique development - Data analysis (not simplistic) - Device engineering - Point-of-care (or close to)
What are the barriers?	- Managing political expectations from scientists to doctors to public, advocating on part of the scientist - Theory/experiment culture divide
Challenge: Speed and parallelization in the discovery of functional molecules	
Why is it important?	- Reduce impact of attrition in drug discovery - Route to developing personalised medicines - Faster route to sustainable manufacture and lower costs – e.g. catalyst discovery
How can chemical biology/biological chemistry help?	- Biomimetic strategies - Chemical tools - Harnessing information-carrying molecules - Functional molecules are chemicals
What is the EPS contribution?	- Molecular robotics and molecular manufacture - Technologies for molecular evolution - Improved technologies for screening, amplification and analysis
What are the barriers?	- Lack of analytical tools for pmol scale - Inability to amplify molecules other than nucleic acids

	- Inability to mimic the efficiency of nature (e.g. catalysis information transfer) - Engaging and fostering effective interdisciplinary teams – lack of mechanisms to enable networking to deliver effective outcomes
Challenge: Energy Sustainability	
Why is it important?	- A fundamental need for everyone
How can chemical biology/biological chemistry help?	- Chemical methods used to understand biocatalysts of fuel transformations – inspiration from nature for ways of making/using fuel - Biocatalysts for making added-value chemicals from bio-mass waste - Learning from energy generation/utilisation in nature
What is the EPS contribution?	- Biochemistry – Discover completely new chemical conversions - Chemistry – Synthetic biomimicry; chemical techniques applied to understanding enzymes, cells and biological systems; interfacing materials and chemistry with biological systems to make hybrid approaches; catalysis - Engineering – Technology delivery
What are the barriers?	- Short termism (nature is complex), - Molecular understanding of whole systems, lack of UK infrastructure, - Scale up of fermenters, enzymes production etc.
Challenge: What do we do with all of the (unpublished) data?	
Why is it important?	- Paid for by the public - Untapped resource - Ensures maximal use of funded work - Might allow complementary data analysis (across unrelated projects)
How can chemical biology/biological chemistry help?	- We have lots of data and compounds - Communication between groups can ensure good use of data - Sharing expression constructs, reporter strains etc. (iGEM, PCOMP etc.)
What is the EPS contribution?	- Enforce standards/electronic notebooks - Encourage data deposition - Set up appropriate framework
What are the barriers?	- IP - Ethics (toxicity, carcinogen etc. of compounds) - Human trial ethics - Data volume and standardisation - Getting credit – why bother? - Efficient extraction of data from theses/electronic notebook
Challenge: Food production/security	
Why is it important?	- Growing population - Poor distribution - Food/energy competition - Climate change - Over consumption - Environmental impact - Food waste
How can chemical biology/biological	- Understand fundamental biology - Plant engineering

chemistry help?	- Increase productivity - Crop/pest interactions - Target identification for small bioactive molecules - Ligand design - Membrane translocation - Enhancing photosynthesis - Resistance - Tools and tech for quantitative sensing - Quantitative 'omic' tools - Predictive design of agrochemicals, multi-scale from molecule to farm
What is the EPS contribution?	- Money - Training - Facilitate industrial partnerships - Support to encourage networking - Funding core expertise
What are the barriers?	- Short-termism, - CDTs - Funding - Research groups too small - University IP policy - Difference in language - Networks are making great progress in building links with agrochemical industry – need to support this - Not always clear where/how to support research at the chemical biology/agri-science interface as it falls at the EPSRC/BBSRC interface.
Challenge: Impact of molecules on biological systems	
Why is it important?	- It underpins diagnosis prevention and cure of disease - Food security and energy
How can chemical biology/biological chemistry help?	- Target I. D. and development - Technology to facilitate I.D. - Chemical probes - Lead discovery - Manipulation of pathways - Chemical biology underpins synthetic biology (more than just engineering)
What is the EPS contribution?	- Molecularly-trained scientist interested in biological problems
What are the barriers?	- Risk averse(UK) - Excessive data required - Difficult to get interdisciplinary funding

Appendix E. List of attendees and List of posters

Name	Organisation	Poster Title
Laura Barter	Imperial College London	Agri-Science Chemical Biology Network: AGRI-net
Maya Thanou	Kings College London	Enzyme-Triggerable Stealth Release (ETSR) of targeted nanoparticles for cancer gene therapy
Weng Chan	University of Nottingham	Cell Control in a Petri Dish (CCPD) Collaborative Network
Clifford Taggart	Queen's University	New strategies for the inhibition of Infection and

	Belfast	Inflammation in Cystic Fibrosis Lung Disease
Jennifer Borthwick	GSK	The Identification of high quality inhibitors for target validation of BCATm
Ed Tate	Imperial College London	Drug target discovery and validation driven by chemical biology
Matthew Powner	University College London	An Investigation of Multicomponent Azole Chemistry within a Generational System for the Expression the Canonical Genetic Structures
Christopher Abell	University of Cambridge	Microdroplet technology - the next stage
James Tucker	University of Birmingham	Functional DNA-based assemblies
Paul Wyatt	University of Dundee	3D Libraries Consortium
Matthew McConville	University of Nottingham	A Photochemical Approach to Dimeric Diazoparaquinones Inspired Through Biosynthetic Speculation
Ali Tavassoli	University of Southampton	Genetic Selection of Protein-Protein Interaction Inhibitors
Paola Borri	Cardiff University	Shedding new light on cells with coherent multiphoton nanoscopy
Andrew Turberfield	University of Oxford	Molecular Motors
David Spring	University of Cambridge	Restricted Diversity; Constrained Diversity-Oriented Synthesis
Adam Nelson	University of Leeds	Realising lead-oriented synthesis
Mike Shipman	University of Warwick	Bioactive Natural Product Assembly Using Precious Metal Catalysis: Total Synthesis of Phyllostictine A
Nigel Scrutton	The University of Manchester	Catalysis in motion: accessing how fast motions facilitate catalysis through pump-probe and fast time resolved spectroscopies.
Helen Hailes	University College London	Chemical Techniques and Tools to Study and Manipulate Biological Systems for Molecule Assembly
David Klug	Imperial College	Next Generation Analytical Tools: Application to Protein Oxidations that affect Human Health and Wellbeing
Adrian Mulholland	University of Bristol	Computational biochemistry: predictive modelling for biology and medicine/ Adaptive Multi-Resolution Massively-Multicore Hybrid Dynamics/ CCP-BioSim: Biomolecular simulation at the life sciences interface
Oscar Ces	Imperial College	LSI Doctoral Training Centres - The doctoral training centre in chemical biology
Mark Bagley	University of Sussex	Alignment of Synthesis, Medicinal Chemistry and Structural Genomics to Accelerate UK Drug Discovery: Network SMS-Drug
Sebastien Campos	GSK	The synthesis & optimisation of irreversible ITK inhibitors as a potential new treatment for severe asthma
Robert Mart	Cardiff University	Intracellular Biophotonic Nanoswitches
Richard Harvey	Kings College London	Molecular mechanisms of antimicrobial peptides: phase changes induced in endotoxic

		bacterial lipopolysaccharide.
Michael Webb	University of Leeds	Synthetic probes of histidine phosphorylation: new reagents for systems biology and proteomics
Gail Bartlett	University of Bristol	Electron Delocalization in Polypeptide Structure and Stability
Alethea Tabor	University College London	Self –assembling nanoparticles for therapeutic delivery and multimodal imaging
Nicholas Westwood	University of St Andrews	Clean Catalysis for Sustainable Development and globalisation grants at EaStCHEM
Mike Hannon	University of Birmingham	LSI DTCs 2007: Physical sciences of imaging in the biomedical sciences (PSIBS)
Nikos Doltsinis	Kings College London	Phototriggered polypeptide unfolding dynamics: a nonadiabatic multiscale simulation study
Carmen Galan	University of Bristol	Novel ionic-based tools for glycoscience
Alison Hulme	University of Edinburgh	Triazole biotin: A tight-binding biotinidase-resistant conjugate
Emma Raven	University of Leicester	-
Jason Micklefield	The University of Manchester	Manchester Chemical Biology Network
John Overington	EBI	ChEMBL - An Open Data resource for Chemical Biology
David O'Hagan	University of St Andrews	Extending fluorinase [C-18F]-bond biocatalysis for Positron Emission Tomography (PET)
Steve Meech	University of East Anglia	Photodynamics in Second Generation Fluorescent Proteins/International Collaboration in Chemistry: BLUF Domain blue light photosensors - a paradigm for optogenetics
Chris Coxon	Durham University	Regiospecific, Controlled Synthesis of Structurally Defined Peptide Scaffolds
Andrew Wilson	University of Leeds	Protein-Protein Interaction Inhibitors: From Design and Synthesis, Through Biophysics to Cell Permeable Inhibitors
Kylie Vincent	University of Oxford	INSPIRE: Robust Biocatalysis for Energy Solutions(2)
Glenn Burley	University of Strathclyde	New molecular tools for the 21st century: Molecular design of new DNA-based devices
Fiona Meldrum	University of Leeds	Crystallisation in Confinement - A Biological Perspective
Beining Chen	University of Sheffield	Stem Cells, Prion Proteins and Alzheimer's Diseases: A Prion Chemical Biology Network (PCBNet)
Hawa Diallo	GSK	Synthesis and optimisation of H3K27 demethylase inhibitors: Effects on the modulation of the pro-inflammatory macrophage response
Philip Howes	Imperial College	'Bio-functionalised Nanomaterials for Ultrasensitive Biosensing'.
Duncan Graham	University of Strathclyde	In Vivo Reporting using Nanosystems Chemistry and Optical Spectroscopy

Phil Gale	University of Southampton	Selective Receptors for the Transmembrane Transport of Bicarbonate Anion
Alison Rodger	University of Warwick	LSI Doctoral Training Centres - Molecular organisation and assembly in cells (MOAC) doctoral training centre
Lu Shin Wong	The University of Manchester	Biocatalytic Nanolithography: Nanofabrication of High Chemical Complexity Surfaces
Andrew Jamieson	University of Leicester	-
Rudi Marquez	University of Glasgow	New Chemistry Approaches for the Next Generation of Healthcare
Stuart Conway	University of Oxford	International Collaboration in Chemistry: The development of Chemical Probes for Hopanoid Function
Alison Parkin	University of York	Electrochemical Technique Development to Learn How to Re-wire Biological Catalysis
Andrew Glidle	University of Glasgow	LSI Doctoral Training Centres - Doctoral Training Centre in Cell & Proteomic Technologies
Jody Mason	Essex	Truncated and Helix-Constrained Peptides with High Affinity and Specificity for the cFos Coiled-Coil of AP-1
Russell Cox	University of Bristol	Chemical Analysis of Hybrid Fungal Megasynthases
Tim Cullingford	MRC	-
Harp Minhas	RSC	-
Jim Iley	RSC	-
James Hutchinson	RSC	-
Victoria King	Wellcome Trust	-
Feodora Rayner	BBSRC	-
Alex Berry	EPSRC	-
Andrew Bourne	EPSRC	-
Claire Higlett	EPSRC	-
Emma King	EPSRC	-
Ellie Gilvin	EPSRC	-
Helen Niblock	EPSRC	-
Sue Carter	EPSRC	-

Appendix F. Agenda

Time	Session
10.00	Tea/Coffee
10.30	Introduction from Andrew Bourne, Physical Sciences Theme Lead
10.50	Plenary lecture – Herbert Waldmann, Max Planck
11.30	Poster Session 1 (Group A)
	Breakout 1 (Group B)
	Breakout 2 (Group C)
12.40	Working Lunch/Networking
14.00	Poster Session 2 (Group B)
	Breakout 1 (Group C)
	Breakout 2 (Group A)
15.10	Tea/coffee

15.40	Poster Session 3 (Group C)
	Breakout 1 (Group A)
	Breakout 2 (Group B)
16.50	Wrap up
17.15	Close

Appendix G. Funding bodies for UK Chemical Biology research

In addition to the EPSRC, the following funding bodies may alternatively support Chemical Biology research:

EPSRC, BBSRC, MRC, Wellcome Trust, Cancer Research UK, EU funding, Leverhulme Trust, Royal Society (Fellowships).