BRITISH PHARMACOLOGICAL SOCIETY

AN EVALUATION OF THE INTEGRATIVE PHARMACOLOGY FUND: LESSONS FOR THE FUTURE OF *IN VIVO* EDUCATION AND TRAINING

DECEMBER 2016

TODAY'S SCIENCE TOMORROW'S MEDICINES

THE INTEGRATIVE PHARMACOLOGY FUND EVALUATION TEAM

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FOREWORD

Animal research is currently essential for the development of new and safe medicines, and the UK is a world leader in this regard. In the future, *in vivo* education and training will be vital if the UK is to remain at the forefront in championing standards and best practice internationally, as well as attracting global biomedical research.

On behalf of the British Pharmacological Society, I am pleased how ambitious and forward-thinking the evaluation of the Integrative Pharmacology Fund has proven to be – in keeping with the spirit in which funding was originally launched in 2004. Many thanks to the report's evaluation team for developing such targeted, specific and realistic recommendations, and to the many individuals who participated and provided feedback during the course of this important project.

The British Pharmacological Society is proud to be a leader in the *in vivo* sciences, both in terms of driving long-term collaborative, cross-discipline partnerships and providing funding where appropriate. However, the Society is also mindful of the important contributions of other organisations and networks with an interest and a role in the future of *in vivo* education, training and research. The Society supports the recommendations made in this evaluation and will commit resource to exploring their implementation with the wider community.

If you identify any further opportunities as you consider the evaluation's findings, you are invited to get in touch with the Society's Education Team at **education@bps.ac.uk**

Professor David Webb MD DSc FRSE FMedSci FBPhS

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EXECUTIVE SUMMARY

This report is the product of an evaluation of the Integrative Pharmacology Fund (IPF) conducted by the British Pharmacological Society in collaboration with the University of Exeter between October 2015 and July 2016. The purpose of the evaluation was to identify the outcomes of the IPF and assess the extent to which it has supported sustainable solutions to the *in vivo* skills gap, in the context of a changing landscape for the demands and delivery of *in vivo* research.

The IPF was launched in 2004 to sustain the capacity for *in vivo* education, training and research in higher education, and to foster improvements to animal welfare, the 3Rs (replacement, reduction and refinement of the use of animals in research) and research outcomes. In this report, we evaluate the outcomes of the IPF against the following criteria:

- To what extent has the IPF contributed to improving **community capacity** for *in vivo* education, training and research?
- To what extent has the IPF contributed to individual **career development**?
- To what extent has the IPF contributed enhancements to **research practice and outcomes**?
- To what extent has the IPF contributed to development of research **networks, dissemination and collaboration**?

The findings of this report are based on quantitative and qualitative analyses. A quantitative survey was used to compile key metrics concerning the use of *in vivo* skills in the subsequent careers of undergraduates, postgraduates and postdoctoral researchers who received IPF-funded education, training or grants. Data were also compiled from undergraduate end of module/course evaluations. In-depth qualitative interviews were then conducted with participants involved in different strands of the IPF-funded activities, in order to acquire a fine-grained understanding of the local impacts of the IPF intervention, compare research needs, organisational contexts and requirements in relation to *in vivo* training across institutions and groups, and identify ways forward for the future.

The key findings of the evaluation are as follows:

- The IPF initiative successfully **increased the capacity** of *in vivo* education, training and research in academic institutions, at least partially off-setting projected losses due to retirement;
- There are enduring **concerns about the retention of *in vivo* skills** and how best to build sustainability through local investments in people with those skills;
- The careers of **those supported by the IPF continue to benefit** from the support received, with notable levels of follow-on grant success, collaborative network-building and growth in personal reputations;
- The **education and training received by students was of high quality**, and contained substantial material on experimental design, animal welfare and the 3Rs;
- The *in vivo* researchers appointed as a result of the IPF have **enabled colleagues who are not *in vivo* scientists to pursue new lines of research**, including some of a more translational nature;
- The Integrative Mammalian Biology (IMB) centres were **strong local networks** of researchers and students that helped foster collaborations and the sharing of current good practice;
- The **the Experimental Officer role at The University of Manchester provides a novel and successful model** for skills retention, training, monitoring of animal welfare, forging collaborations and sharing of current good practice.

The report makes recommendations on how *in vivo* research skills in the UK can be best supported in the future, drawing lessons from the implementation and impact of the IPF. These recommendations are summarised here, accompanied by key principles that emerged from the evaluation and which should inform future initiatives and their conduct. Throughout the evaluation section, we have identified recommendations that derive from the conclusions we reached. At the end, there is a detailed examination of each recommendation, and the further steps we propose to work towards fulfilling them.

The recommendations build upon the lessons learned from the evaluation to suggest efficient methods of assessing and conducting *in vivo* training and education, and fostering new collaborations and the adoption of good practice. Reflecting on the model of the IPF itself, we make proposals based upon a partnership approach to funding, coordination and delivery. Potential partners are suggested but other organisations or individuals are invited to contribute.

The recommendations comprise a mix of proposals that can be easily achieved in the short term, proposals that depend on the development of partnerships and initiatives and will bear fruit on a medium-term timescale, and proposals for the long term. The recommendations listed here are discussed in full in Section 5.

1. **Develop core learning outcomes.** Educators and employers in the *in vivo* community should work together and lead the development of clear core learning objectives for the *in vivo* sciences, including experimental design, statistics, animal welfare, cultures of care, ethics and the 3Rs. These outcomes should be integrated across the biosciences, and should be reinforced throughout a student's undergraduate and postgraduate career.

2. **Conduct research on educational outcomes.** Higher education institutions and learned societies should conduct research on the educational outcomes of different education and training routes and methods, and should forge ways to ensure that data collection and analysis are supported and based on common standards.

3. **Support undergraduate education modules.** The British Pharmacological Society should continue to provide part-funding for undergraduate education modules, to foster stability and security for the continuation of entry-level *in vivo* skills education.

4. **Create innovative resources and approaches.** The community of educators and educational institutions should cooperate towards developing innovative education and training resources and approaches to prepare students for postgraduate research and/or employment. These approaches and resources should be developed in alignment with agreed learning outcomes and set up with impact assessment in mind.

5. **Nurture networks of good practice.** The *in vivo* sciences cross a range of disciplines, and networks of good practice should be cross-cutting but deal with specific areas of need:

    - Higher education institutions, employers and learned societies should build and/or encourage participation in *in vivo* research and education networks, signposting them to people first as undergraduates and then throughout their careers.

    - Higher education institutions, learned societies and other relevant organisations should encourage and support the development of online open access repositories to collect and showcase course materials that use innovative approaches to learning in *in vivo* pharmacology.

    - National knowledge-sharing networks sharing good practice to advance excellent research with high welfare standards should be maintained and developed by the research community. This should be aided by individual higher education institutions, networks of and between named persons and other relevant individuals, the National Centre for the 3Rs (NC3Rs) and learned and professional societies.

    - Learned societies and partners should make grants available to support PhD students learning a particular *in vivo* technique in another laboratory.

6. **Provide support for early career researchers.**

    - Learned societies and partners should make a new strategic commitment to fund pump-priming grants for early career researchers. Such grants would support the development of new or adapted animal models and techniques to advance standards of animal welfare, the 3Rs, make research more potentially translatable, and provide data that recipients can use to apply for further grants.

    - Higher education institutions, research councils, learned and professional societies should recognise the importance of explicitly *in vivo* research fellowships, and should work together to ensure that these positions can be financially supported and sustained.

7. **Support integrated pathways for technicians and animal technologists.** There should be strong institutional support for career progression, skills training and job security for technicians and animal technologists, which takes account of their key roles in laboratory animal research. Laboratory animal technologists should be more integrated into the planning and conduct of academic research and preclinical research and development, both in industry and academic research.

8. **Establish apprenticeships for *in vivo* sciences.** Higher education institutions, the British Pharmacological Society, the Association of the British Pharmaceutical Industry, and industrial and clinical partners should collaborate in the development of pharmacology apprenticeships, including degree apprenticeships.

9. **Foster collaborations across academia, industry and the NHS.** Research collaborations involving *in vivo* researchers in academia, industry and the NHS need to be supported, with obstacles to cooperation identified and addressed. Academics, higher education institutions and industry should work together, supported where appropriate by research councils and learned and professional societies, to conduct studies and evaluations to inform and facilitate long-term links, collaborations and relationships between academic education, training and research, industry and the NHS.

10. **Recognise and support engagement work.** Public engagement and student outreach should be supported and encouraged by higher education institutions and learned societies as a core activity of academic researchers, advancing the commitments contained in the Concordat on Openness on Animal Research.

From the findings of the evaluation and related recommendations, we have extracted four common principles to underpin future work and initiatives:

1. INTRODUCTION

This report evaluates the outcomes of the Integrative Pharmacology Fund (IPF), which was launched by the British Pharmacological Society and partners in 2004 in response to concerns about the shortage of scientists with the skills and expertise to conduct *in vivo* research using mammals.

This problem had been highlighted by skills surveys conducted by the Association of the British Pharmaceutical Industry (ABPI) and the Biosciences Federation.[1] A survey by the British Pharmacological Society and The Physiological Society demonstrated that fewer than 2% of graduates of relevant biological sciences received any *in vivo* education in the UK, while 25% of the academic staff qualified to provide this education and training were due to retire within five years.[2] As the IPF drew to a close, an evaluation was commissioned by the British Pharmacological Society in order to assess the outcomes of the scheme. The evaluation was carried out by a joint project team from the British Pharmacological Society and The University of Exeter (see the inside front cover for full details).

The aim of this report is to evaluate the IPF and use the results of the evaluation to inform recommendations for the future, targeted at a variety of stakeholders. The report is structured as follows. First we introduce the history and initial aims of the IPF, contextualising these through discussion of the current landscape of *in vivo* education, training and research. Section 3 describes the methods used and outline the criteria with which we have assessed the outcomes of the IPF. Section 4 details the empirical findings on the IPF that are pertinent to each of these criteria. We use these results to inform the recommendations that are summarised throughout the evaluation section. The final section focuses on recommendations for supporting teaching and learning of *in vivo* skills and *in vivo* research itself in the future.

Definition of key terms:

***In vivo* skills** are broadly defined as including any skills that are required to conduct research that uses live animals and is regulated under the auspices of the Animals (Scientific Procedures) Act 1986 (the A(SP)A, and subsequent revisions). The definition is not restricted, however, to only the activities specified in the legislation. *In vivo* skills also include the competence to perform particular procedures, such as stereotaxic surgery or the administration of anaesthesia, the ability to handle animals, to ensure that they are cared for in a species-appropriate way, to have relevant knowledge of the physiology and behaviour of relevant species, and to be able to design, conduct and analyse experiments to ensure that animal welfare is considered and high quality data are produced.

***In vivo* education** is defined as any intervention that occurs within the taught curriculum, with the content primarily designed by academic staff.

***In vivo* training** is defined as any hands-on experience undertaken as part of Home Office modular training courses or the acquisition of vocational/technical skills during a programme of research. This includes 'on the job' training as part of participation in research conducted under a supervisor's project licence.

1 ABPI and Biosciences Federation (2007) In vivo sciences in the UK: sustaining the supply of the skills in the 21st century. Available online at: http://www.abpi.org.uk/our-work/library/industry/documents/in-vivo-report.pdf. See also: ABPI (2005) Sustaining the Skills Pipeline in the pharmaceutical and biopharmaceutical industries. Available online at: http://careers.abpi.org.uk/your-career/undergraduates/Documents/_publications_pdfs_2005-STEM-Ed-Skills-TF-Report.pdf ; and ABPI (2008) Skills Needs for Biomedical Research: Creating the Pools of Talent to Win the Innovation Race. Available online at: http://www.abpi.org.uk/our-work/library/industry/Documents/skills-biomedical-research.pdf

2 British Pharmacological Society (2004) A survey of integrative physiology/pharmacology teaching undertaken by the BPS and The Physiological Society, *pA2 Online* Vol. 3 No. 2: 10–11. Available online at: http://www.pa2online.org/articles/article.jsp?volume=5&issue=2&article=31 (Note that '*in vivo* education' here involved practical work conducted that required a personal licence.)

2. THE INTEGRATIVE PHARMACOLOGY FUND

2.1. BACKGROUND AND AIMS

The IPF was intended to address the need for *in vivo* training identified by the ABPI and Biosciences Federation reports and was supported by contributions totalling £4 million from AstraZeneca, GlaxoSmithKline (GSK) and Pfizer.

The aim of the IPF was to develop strategies to support *in vivo* research and training in Pharmacology, Physiology and Toxicology in the UK. It was led by a steering group comprising representatives of the funders: Dr Martin Todd (AstraZeneca); Dr Malcolm Skingle (GSK); Dr Mike Collis (Pfizer); and Professor Sue Brain (British Pharmacological Society).

A strategic decision was made by the steering group that the IPF would work with national funding bodies (the Biotechnology and Biological Sciences Research Council, BBSRC; the Medical Research Council, MRC; and the Higher Education Funding Council for England, HEFCE) to support *in vivo* education and training. This collaborative approach resulted in the £4 million contributed to the IPF leveraging total support of £22 million for *in vivo* research, education and training.

The IPF sought to sustain the complete academic pipeline of *in vivo* training and development – from undergraduate to Master's, PhD, fellow and lecturer – through the funding of Master's courses, PhD studentships, academic fellowships, project (pump-priming) grants and permanent lectureship positions. The rationale for this approach was that funding only one phase of the development of the next generation of *in vivo* scientists would not succeed in rebuilding the expertise base, as the phases are mutually dependent. The British Pharmacological Society and The Physiological Society already supported undergraduate *in vivo* education and the IPF offered financial support to these existing schemes (see Figure 1 and Table 2).

Initial offers of funding from the IPF were made jointly with Research Councils UK (RCUK; for Academic Fellowships) and the BBSRC and MRC (for targeted *in vivo* PhD studentships, Master's courses and industrial partnership grants). The IPF grants were distributed to 20 different academic institutions in the UK.

The high cost of the facilities and infrastructure required for animal research and training led the steering group to favour a targeted approach, rather than providing small awards to a large number of academic institutions. A strategy was therefore developed to establish a small number of Centres of Excellence.

Discussions were initiated with the BBSRC, MRC, HEFCE, the Scottish Funding Council (SFC) and the Department of Trade and Industry (DTI) to establish a funding partnership to provide five-year grants of £3 million for up to four centres of *in vivo* excellence (Integrative Mammalian Biology Capacity Building Centres, or IMB centres). The centres were selected for their world-class expertise in *in vivo* integrative pharmacology, physiology and toxicology, high-quality infrastructure, well-defined strategy for *in vivo* research and their long-term commitment to support animal welfare and public outreach.

Aims of the IMB Centre awards:

- Provide 'springboard' funding to enhance high quality research and training in integrative mammalian biology
- Provide 'seed-corn' funding to enhance the higher education institution's strategy in integrative mammalian biology
- Foster an environment that attracts and supports the required diversity of top-quality scientists, who conduct research at the highest level, and train and develop the next generation of researchers in good practices in integrative mammalian biology
- Equip the next generation of researchers with the expertise and skills in understanding the ethics surrounding the use of animals in research, high quality experimental design and the application of a broad range of techniques and approaches in integrative mammalian biology
- Promote awareness of the importance of this area of science

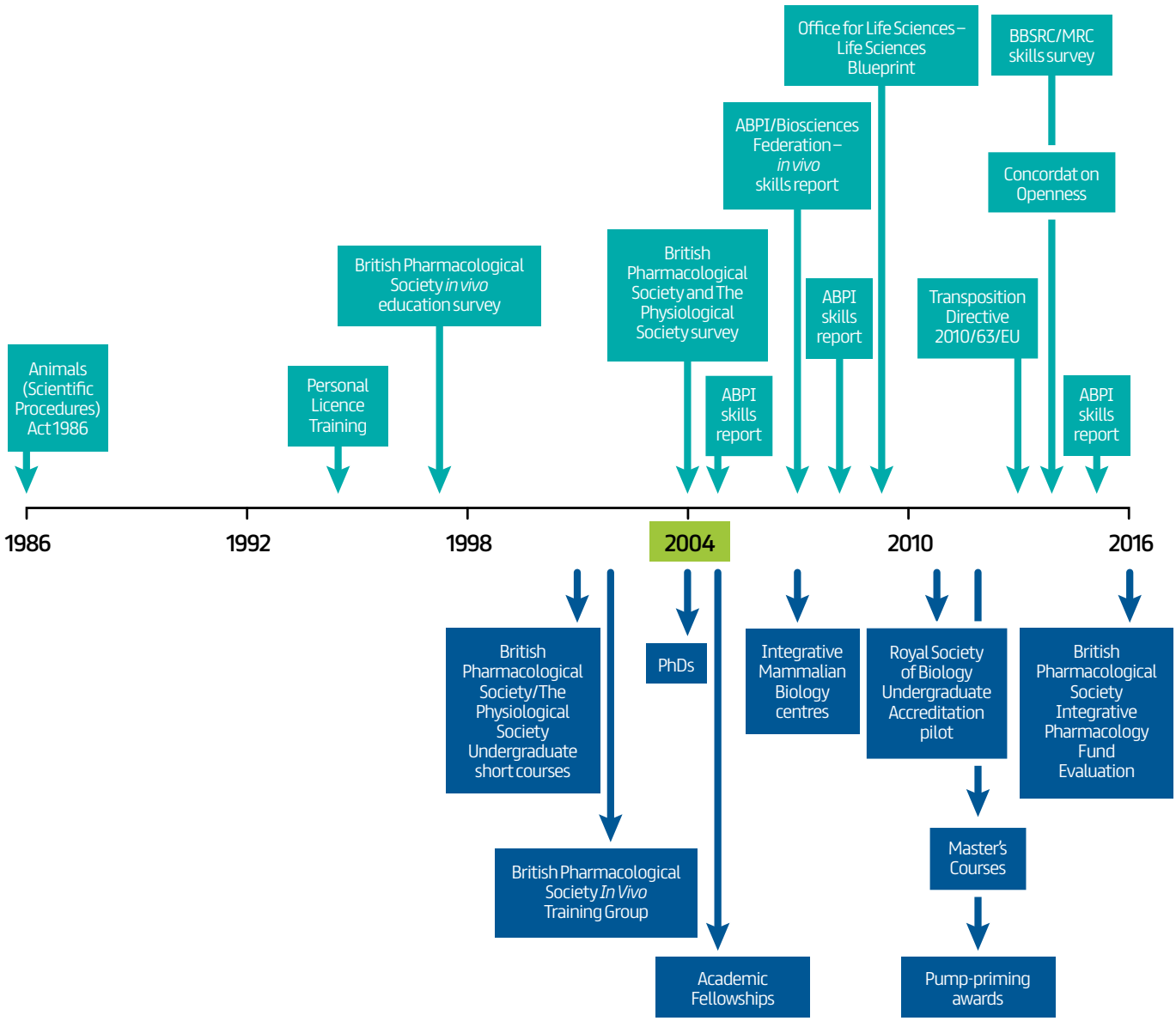

Figure 1 – Timeline of drivers of the IPF and changes in animal research (turquoise boxes above the timeline) and elements of the IPF intervention (blue boxes below the timeline). 2004 marks the start of the IPF initiative. Acronyms: BBSRC – Biotechnology and Biosciences Research Council, MRC – Medical Research Council. Image credit: Dave Lewis

IMB centre awards were made to Imperial College London and King's College London individually and to two consortia of universities: the Universities of Manchester and Liverpool, and the Universities of Glasgow and Strathclyde. Within the guidelines of building capacity and sustainability of high quality research, education and training, institutions were given flexibility to propose how they would use the IMB centre awards. The recipients all provided (and in most cases established) Master's courses and/or new undergraduate modules, funded a number of *in vivo* PhD studentships, recruited postdoctoral staff as lecturers to build teaching capacity, and established management boards. The University of Manchester IMB centre appointed an Experimental Officer to provide expertise in *in vivo* studies.

The IMB centres reported on their activities to the steering committee each year. The IPF-supported members of staff had to report on their *in vivo* education, training, research and outreach activities. In addition to this more formal monitoring, there was informal tracking of the progress of the centres and individuals by members of the steering committee.

The remaining money left in the IPF after these major grants had been awarded was used for pump-priming grants, aimed to enable *in vivo* scientists to conduct the preliminary studies necessary to develop major project grant applications. With the end of the IPF funding, evaluation of the use of its funds and the outcomes generated is required to guide activity and support post-IPF. This also requires consideration of how the general landscape of *in vivo* research has changed in the UK since the IPF was launched in 2004.

2.2. CURRENT LANDSCAPE

In vivo techniques are used primarily in universities, medical schools and commercial organisations. According to Home Office statistics on the number of scientific procedures conducted in 2015 under the auspices of the amended A(SP)A, 48% of the total 4.14 million procedures (a small increase since 2014) are conducted in universities and medical schools, 25% in commercial organisations, with the rest of the procedures primarily conducted in other public bodies and non-profit organisations.[3]

Figure 2 shows the number of licensed procedures in the university-medical school sector and the commercial sector over the last decade, showing an increase in procedures in academic institutions, and the initial increase in the commercial sector up to 2008, which declined and levelled over the following years.

Half of the procedures in 2015 involved the creation or breeding of genetically-altered animals not used in further procedures. Continued small increases overall, and a somewhat larger increase over the last decade in the number of procedures in academic research, indicates a continuing need to ensure the highest possible quality science and animal care for all recorded procedures on animals.

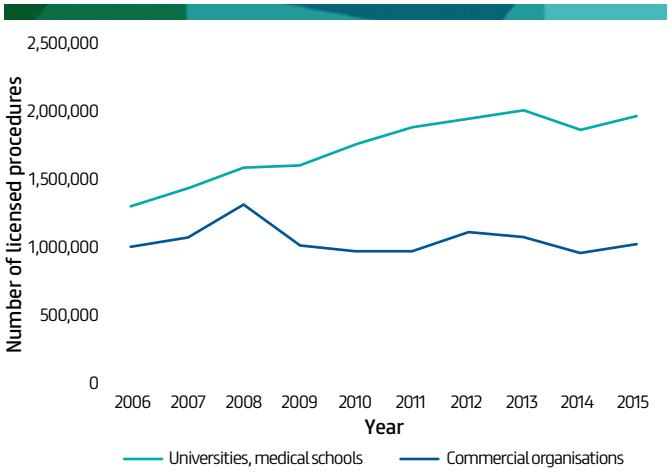

Figure 2 – The number of licensed procedures in universities and medical schools and the commercial sector, from 2006 to 2015 inclusive. From 2013, new reporting systems have been used. Source: Home Office[3]

Since the start of the IPF, there have been significant shifts in the landscape of *in vivo* research in the UK. The regulatory framework has changed with the transposition of EU Directive 2010/63/EU into UK law. Institutions that have establishment licences must appoint named individuals to take responsibility for ensuring: that people working with animals are properly educated, trained and competent (the Named Training and Competency Officer, NTCO); that they have access to relevant information concerning their work with animals (the Named Information Officer, NIO); that standards of welfare and care of animals are upheld (the Named Animal Care and Welfare Officer, NACWO), and that the requirements of the A(SP)A and licence conditions are upheld (the Named Compliance Officer, NCO). Additionally, at least one Named Veterinary Surgeon (NVS) should be appointed to advise on the health and welfare of the animals. Further, in addition to the initial provision of education and training, there is now a legal requirement to assess and ensure the technical competency of personal licence holders throughout their career and for both personal and project licence holders to engage in Continuing Professional Development.

There has also been a renewed focus on advancing the 3Rs, and the creation of the National Centre for the 3Rs (NC3Rs) has been a catalyst for new work (by funding PhD projects, for example), collecting and disseminating good practice, and developing tools such as the Experimental Design Assistant (EDA). The EDA in part is intended to address perceived problems with the quality of results produced in areas of biomedical research. The concerns have focused on the design and conduct of experiments, and the analysis and interpretation of data generated in them.

There has been a period of considerable change in higher education in the UK, with the introduction of student fees, and strategic review for funding councils, with a general emphasis on demand management and the co-ordination of research around grand challenges. Support for *in vivo* research has been through initiatives such as the Strategic Skills Awards, and amendments to Doctoral Training Partnerships to allow for additional funds for more expensive *in vivo* research for students.

In higher education more broadly, the introduction of the impact agenda through the Research Excellence Framework (REF) encourages researchers to demonstrate the impact of their research. Impact is considered "an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia".[4]

3 Home Office (2016) Annual Statistics of Scientific Procedures on Living Animals Great Britain 2015. Available online at: https://www.gov.uk/government/statistics/statistics-of-scientific-procedures-on-living-animals-great-britain-2015

4 Research Excellence Framework (2012) Assessment framework and guidance on submissions. Available online at: http://www.ref.ac.uk/media/ref/content/pub/assessmentframeworkandguidanceonsubmissions/GOS%20including%20addendum.pdf

As well as potentially incentivising translational research, impact can also include affecting or changing "the activity, attitude, awareness, behaviour, capacity, opportunity, performance, policy, practice, process or understanding… an audience, beneficiary, community, constituency, organisation or individuals".[5] This can therefore include outreach and public engagement, as well as contributing to policy development.

The growing movement towards a more open science has also influenced the *in vivo* research landscape. Concerns about the reproducibility of data produced in biomedical research have led to the development of new guidelines on the publication of methods and data.[6] Separately, a new approach to increasing transparency and facilitating public engagement was pioneered by Understanding Animal Research and members of the UK biosciences community through the 2012 Declaration of Openness on Animal Research. The launch of the subsequent Concordat on Openness on Animal Research[7] in 2014 has encouraged organisations and individuals to commit to be more open about the use of animals in their research, and to engage constructively with members of the public.[8] Alternative metrics to include public engagement activity may need to be developed to encourage this in addition to the impact case studies, see Recommendation 10.

The industry landscape has changed, with a decline in the research base of large pharmaceutical companies and growth in small to medium sized enterprises (SMEs) in the UK.[9] According to the latest set of figures from the Office for National Statistics, research and development spending in the pharmaceutical industry declined in real terms in successive years from 2011 to 2014, at a time when overall UK research and development spending increased according to the same measure.[10] Smaller biotechnology companies and Contract Research Organisations (CROs) are now increasingly important for conducting or sponsoring *in vivo* studies in the UK.

There is also additional sub-contracting of projects and tasks by large pharmaceutical companies to university-based laboratories, in part through the development of partnerships and collaborations such as GSK's 'Discovery Partnerships with Academia', Pfizer's 'Centers for Therapeutic Innovation' and AstraZeneca's research partnerships.[11]

The closure of some of the larger pharmaceutical company research facilities means that there is, temporarily at least, a large number of scientists with *in vivo* skills available, but this may not always be the case.

Training within the large pharmaceutical companies has also changed. Whereas previously large companies would employ school-leavers who could then complete a BSc and perhaps a PhD while in post, this is no longer the case. The introduction of degree apprenticeships in 2015, in addition to the existing model of apprenticeships, may provide an alternative pathway for individuals to receive ongoing *in vivo* skills education and training, as well as career progression. It may also be a space for the development of new forms of cooperation between academia and industry.

In addition, the referendum vote for the UK to leave the European Union is expected to impact upon the pharmaceutical sector and research more broadly.[12] The possible implications of this include barriers to obtaining grants and collaborating with colleagues in Europe, but also potential staffing problems, with a high proportion of laboratory staff in some institutions coming from non-UK EU countries. The UK research and development landscape is therefore characterised by uncertainty, and the task of those concerned with the future of *in vivo* skills and research is to ensure that there is sufficient flexibility and resilience to ensure that short-term changes and events are managed or capitalised upon.

Organisations such as the British Pharmacological Society, other learned societies and Research Councils have a responsibility to safeguard the future of *in vivo* research, in the context of wider challenges in the political, economic, industrial or academic landscapes.

5 Research Excellence Framework (2012) Assessment framework and guidance on submissions. Available online at: http://www.ref.ac.uk/media/ref/content/pub/assessmentframeworkandguidanceonsubmissions/GOS%20including%20addendum.pdf

6 Institute for Laboratory Animal Research (2015) Reproducibility Issues in Research with Animals and Animal Models. Available online at: http://www.nap.edu/catalog/21835/reproducibility-issues-in-research-with-animals-and-animal-models-workshop

7 Understanding Animal Research (2016) The Concordat on Openness on Animal Research. Available online at: http://www.understandinganimalresearch.org.uk/policy/concordat-openness-animal-research/

8 Leonelli S *et al* (2015) Sticks and carrots: encouraging open science at its source, *Geo: Geography and Environment*, Vol. 2: 12-16.

9 ABPI (2016) The Changing UK Drug Discovery Landscape. Prepared by TBR's Economic Research Team and CBSL. Available online at: http://www.abpi.org.uk/our-work/library/industry/Documents/the-changing-UK-drug-discovery-landscape.pdf

10 See: Office for National Statistics (2015) Business Enterprise Research and Development: 2014. Available online (with accompanying data) at: https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/businessenterpriseresearchanddevelopment/2014

11 Information on these partnerships are available at: www.dpac.gsk.com www.pfizer.com/research/rd_partnering/centers_for_therapeutic_innovation www.astrazeneca.com/partnering/partnering-case-studies.html

12 British Pharmacological Society (2016) The European Union Referendum. Available online at: https://www.bps.ac.uk/about/the-european-union-referendum.

3. METHODS AND EVALUATIVE CRITERIA

3.1. METHODS

The evaluation was based on a mixed methodology. We collected and analysed quantitative and qualitative data to inform the evaluation of the immediate outcomes and longer-term impacts of the IPF investments. The evaluation team worked collaboratively with the IPF participants and wider stakeholders to add further data and interpretation at a workshop based on the interim draft of the evaluation report.

The sources, samples and contribution of the data collected for the evaluation are summarised below, and described further in the remainder of this section.

Source	Sample	Data/Contribution
Questionnaire[a] (online)	Link to online questionnaire sent by email to Master's/PhD students who received the IPF support and fellows/staff appointed with the IPF support.	Quantitative and qualitative data for evaluation. Informed development of methodology for selection of interviewees and content of interviews.
Grant Questionnaire[b] (emailed)	Sent by email to recipients of pump-priming grants funded by the IPF.	Qualitative data for evaluation. Informed development of methodology for selection of interviewees and content of interviews.
Education Surveys (administered by institutions)	Undergraduate students who took education modules or short courses supported by the IPF	Mainly quantitative data analysis (but also some qualitative analysis) for evaluation and to inform potential recommendations.
Interviews (interviewed by James Lowe)	Master's/PhD students who received the IPF support, fellows/staff appointed with the IPF support, senior figures at IMB centres.	Recorded, transcribed and coded data used to analyse and evaluate the various facets of the IPF and pick up on potential areas of recommendation.
Roundtable Meeting (facilitated by the British Pharmacological Society)	Senior figures at IMB centres.	Data from recordings and notes used to assess and evaluate the work of the IMB centres, their legacy and the sustainability of *in vivo* education, training and research in those institutions.
Stakeholder Workshop (facilitated by the British Pharmacological Society)	Stakeholders from academia, industry, learned societies, animal welfare organisations, industry bodies, research councils.	Data from recordings and notes used to assess and provide further evidence for the evaluation.
Follow-up Interviews (interviewed by James Lowe)	Non-IPF supported researcher, industry figures, *in vivo* educators.	Data from recordings and notes used to assess and further shape recommendations.

a See appendix 3, available online at www.bps.ac.uk/futureinvivo
b See appendix 4, available online at www.bps.ac.uk/futureinvivo

Table 1. Overview of research methods

In December 2015, the team circulated a questionnaire by email to two groups of recipients of support from the IPF: Master's/PhD students and fellows/staff. The questionnaire gathered quantitative and qualitative data concerning the effect of the IPF support on their careers and their views of the future prospects of *in vivo* research. For the Master's/PhD group, 70 individuals with active contact details were identified and contacted by email, of whom 32 responded (46%), and 25 completed the questionnaire (38%). For the fellows/staff group, 21 were contacted, of whom 17 responded (81%), 16 of these fully completed the questionnaire (76%), and 1 partially completed it. The response rates, aided perhaps by personalised emails to potential respondents, was high for an online survey.

In addition to this questionnaire (see appendix 3 online), a separate questionnaire was distributed to 6 recipients of pump-priming grants (see appendix 4 online), the team also reviewed exit feedback from undergraduate modules and short courses supported by the IPF, and analysed a more substantive survey of students who took the Level 6 undergraduate education module 'Integrative Biomedical Science' at the University of Leeds from 2005 to 2015.

Data from a questionnaire circulated in December 2015 was used to identify potential follow-up interviewees, sampling for different exposures to the initiative (i.e., position and type of support, presence at an IMB centre or non-IMB centre), involvement in education and training (including being able to offer insights about the education and training they have received), and the status and progress of an individual's research career. In-depth interviews were carried out with 20 people supported by the IPF in a variety of capacities, including: undergraduate attendee at a short residential course, Master's student, PhD student, appointed Fellow, appointed Lecturer, appointed Experimental Officer, and existing staff member at one of the IMB centres established through the initiative. The interviewees also encompassed different areas of work: neuroscience, immunology and cardiovascular research, as well as research support. Furthermore, there were interviewees who are no longer involved in academic research or training.

Qualitative interviews produced:

1,406 minutes of interview recordings

328 pages of transcripts

The interviews were conducted by James Lowe, as an evaluator external to the British Pharmacological Society. Interviewees were offered a choice of different levels of confidentiality, including complete anonymity, disclosure of role and/or organisation and full disclosure. The interviews were recorded and transcribed, and the qualitative research software package NVivo was used to code the transcripts using evaluative criteria developed over several iterations of initial analysis.

Subsequent to the interviews, a roundtable meeting was organised at which senior members of staff associated with IMB centres were present, and were able to share their reflections on the initiative, its legacy, and future challenges and opportunities for *in vivo* research.

In May 2016, a workshop was held with invited stakeholders from research councils, industry and industry bodies, academia, and learned societies. This stakeholder workshop included presentations from selected participants and discussions on the data collected so far. The discussions and proposals emanating from this workshop were fed into the evaluation, and also informed a set of recommendations which were then developed and made more specific. Further interviews and conversations followed the stakeholder workshop in order to finalise the evaluation and recommendations.

3.2. EVALUATIVE CRITERIA

The outcomes of the IPF were assessed against four evaluative criteria, each of which can be exemplified through a question, as follows:

To what extent has the IPF contributed to improving community capacity for *in vivo* education, training and research?

This includes evaluation of the overall contribution of the IPF to addressing the identified skills gaps, enhancing capacities for providing education and training, strengthening the quality and effectiveness of training, and developing a legacy and sustainable future for *in vivo* education, training and research. By legacy we mean the structures, skills and research culture which endure in institutions beyond the cessation of the IPF support.

To what extent has the IPF contributed to individual career development?

This includes evaluation of the contributions of the IPF training, funding and positions to individual career advancement, the development of group and grant activities, and the direct and indirect contribution of *in vivo* skills education and training to both careers and the wider scientific community.

To what extent has the IPF contributed enhancements to research practice and outcomes?

This includes evaluation of the contributions of the IPF education, training, funding and positions to changes in research practice, including experimental design, potential for translational research, and advancements in terms of the 3Rs (especially improving practices through reduction and/or refinements).

To what extent has the IPF contributed to the development of research networks, dissemination and collaboration?

This includes evaluation of the contribution of the IPF investments in networks, hubs and outreach activities to the development of collaborative links and research projects, the sharing of current good practices in research and the 3Rs, dissemination of results and public engagement with research.

These criteria were developed by considering three main groups of drivers:

1. The **original aims** expressed for the IPF and subsequent IMB centre awards;
2. The **interpretation and development of aims** by participants involved in the activities of the IPF and IMB centres;
3. **Emerging issues** for the future of *in vivo* education, training and research that were identified by participants during interviews and at the roundtable discussion.

Discussions of all three provide valuable information for this assessment. Because the IPF was not narrowly prescriptive in what it demanded from bids for IMB centres or for other support such as funds for fellowships and studentships (beyond the requirement for high standards of research, education, training, animal welfare and outreach), many additional aims were generated by those in receipt of support from the IPF, whether institutions or individuals. This report seeks to capture these.

In addition, the evaluation criteria reflect a range of issues that have emerged since the inception of the project and are now important for any consideration of the future *in vivo* education, training and research. As indicated above, these include, but are not limited to: the decline in the R&D base of large pharmaceutical companies in the UK; the advent of the Concordat on Openness which has changed the way researchers and institutions approach communications and public engagement; the development of the work of the NC3Rs, with an increased focus on animal welfare and the 3Rs; legislative changes as a consequence of the transposition of the EU Directive 2010/63/EU into UK law; and changes to doctoral training schemes, including the creation of Doctoral Training Partnerships (DTPs).

4. THE INTEGRATIVE PHARMACOLOGY FUND OUTCOMES

4.1. COMMUNITY CAPACITY

Interviewee perspectives on meeting community capacity:

"It raised the profile of *in vivo* biology and to some extent has offset that tendency to lose those skill sets."
(Interviewee FS7, IMB centre)[c]

"Without the framework to hold onto the people, you're just going to lose them long-term."
(Interviewee MP5, IMB centre)

These two quotes encapsulate the overarching theme of this section. The IPF trained large numbers of people in a range of *in vivo* research skills. The concerns expressed by those who were supported by the IPF or who worked at IMB centres relates to the long-term retention of those skills, and therefore the sustainability of the results of the IPF intervention.

Establishing the IPF and building community capacity

The IPF successfully brought together multiple stakeholders to leverage the initial £4 million into a sum of £22 million, and to fund eight Academic Fellowships, 102 PhD studentships, 106 Master's students, five *in vivo* short courses, between six and eleven undergraduate modules (the figure varied over time), and twelve pump-priming grants. Four centres of excellence were established across six universities (Table 2).

Level	Number supported	Funding partner
Pump-priming grants	12	None
Lectureships	12	IMB centre funders
Academic fellows	8	RCUK
PhDs	102	BBSRC/MRC CRUK IMB centre funders
Master's students	106	BBSRC/MRC IMB centre funders
Short residential courses	5	British Pharmacological Society/ The Physiological Society BBSRC MRC Wellcome IMB centre funders
Undergraduate courses	6–11	Pharmaceutical companies, CROs, Resource Suppliers, British Pharmacological Society

Table 2 – The number of people/courses supported by the IPF and funding partners.

c Codes have been used for interviewees to preserve anonymity while still signalling their role. FS is someone who was appointed as a fellow or staff with IPF support or otherwise in that position and at an IMB centre, MP denotes someone who was an IPF-supported postgraduate student.

The IMB centre of excellence model supported by the IPF leveraged the initial funds provided by the IMB centre funding consortium producing outcomes that were, in quantitative terms, in excess of the initial expectations, as the figure below indicates. This increased productivity was due to the success of the IMB centres in gaining additional non-IMB centre funding to support additional students and staff (including a Business Development Manager at Manchester/Liverpool and an Industrial Impact Fellow at King's College London). The IMB centres acted as "honey pots" for additional grant funding, illustrating the advantages of establishing virtual centres of excellence for *in vivo* research and training.

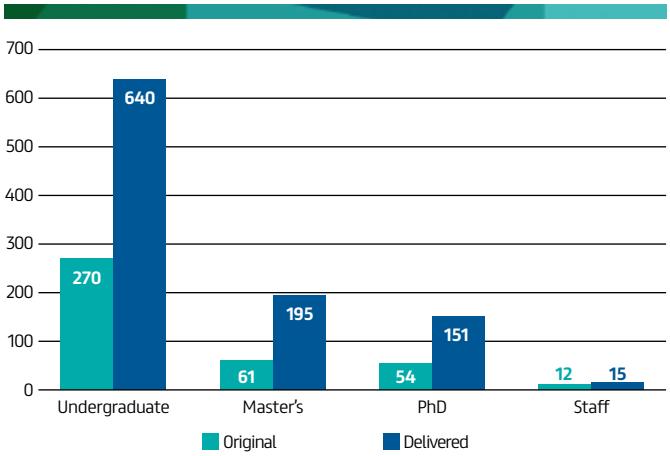

Figure 3 – Graph depicting numbers of people originally envisaged to be supported by the IMB centres, and those actually supported through additional non-IMB centre grants.

The focus of the IPF was on the provision of courses and training at research-intensive universities. One of the key aims was to replace lecturers nearing retirement. The original loss of academic teaching staff was projected to be 56. This figure comes from the assessment by the British Pharmacological Society and The Physiological Society in 2004 of those projected to retire within the following five years. There is evidence that not all who have formally retired have ceased teaching, for example at The University of Manchester and King's College London. Through the appointment of new lecturers, and of fellows with a gradually increasing teaching load who would become lecturers after five years (pending satisfactory performance), undergraduate education capacity has been preserved. Based on the results of the questionnaire, 21 new academic staff were appointed as a result of the IPF, of whom at least 15 are still involved in *in vivo* education and training in the UK. Based on interview responses, staffing levels do not currently appear to be a limiting factor for undergraduate or postgraduate *in vivo* education and training. Rather, it is the cost of this education and training that limits provision. Of the courses supported by the IPF, the Master's at the Imperial College London IMB centre has ceased, and the standalone Master's degree at the University of Manchester has ended. Lack of funds to run courses were cited as the reason for both of these closures.

Additional funds from the research councils are not likely to be forthcoming, but the Strategic Skills Awards were valued by researchers. The Strategic Skills Awards (funded by the MRC and BBSRC) provided additional funds to support the running costs of *in vivo* PhD studentships. The Awards were originally made for individual projects following review by the IPF steering committee and the NC3Rs. Additional top-up funding for *in vivo* research is now incorporated into DTP funding.

Taught courses and PhD studentships

New undergraduate and Master's courses were developed, and old courses continued. Eleven of the new staff appointed have been involved in the setting up of new courses. 640 undergraduates received *in vivo* training at the IMB centres. One lecturer commented in an interview that, *"the number of undergraduates and Master's students that I trained was as a consequence of British Pharmacological Society involvement. I would have done far fewer if people weren't expecting me to do in vivo."*

One new course, at King's College London, was pioneered by two IPF-supported fellows. The way in which they approached teaching statistics to biology and biomedical sciences undergraduates has led to a new online method for teaching statistics to the whole school (up to 1,200 students).

Although those employed on permanent contracts will remain after the cessation of the IPF and related funds, and therefore constitute an ongoing legacy in terms of teaching capacity, the sustainability of some of these courses, or at least the training of *in vivo* practical skills in them, was thought to be in doubt at some institutions. A variety of funding issues contribute to this uncertainty, including debate over the relative cost and value of personal licences for students' *in vivo* education.

The IPF fellows and lecturers have contributed significantly to Master's training, which was a key part of the education and training operations of the IMB centres. The IPF directly funded PhD studentships, and the IPF fellows and staff were able to successfully obtain grants or leverage their positions in other ways to obtain additional PhD studentships and top-up funds.

Skills gap and ongoing skills concerns

A review of 'vulnerable skills' conducted by the BBSRC and the MRC in the summer of 2014 highlighted continuing concerns about the training, career pathways, recruitment and future supply of people with *in vivo* research skills. In its November 2015 report entitled 'Bridging the skills gap in the biopharmaceutical industry,' the ABPI downgraded *in vivo* sciences as no longer being an area of 'high priority' concern, but "*although concerns over in vivo pharmacology and animal technology have reduced slightly, they are still medium priorities*".[13] A caveat here is that the ABPI considered *in vivo* pharmacology to consist of safety pharmacology, and areas that might be considered to be pharmacology were included under *in vivo* physiology, which was deemed to be an area of major concern. This in itself is evidence of the different definitions used by industry and by academic researchers, and points to a need for improved dialogue between the sectors.

13 ABPI (2015) Bridging the skills gap in the biopharmaceutical industry. Available online at: http://www.abpi.org.uk/our-work/library/industry/Documents/Skills_Gap_Industry.pdf

The same report concluded that interventions such as the IPF and the IMB centres "*have been effective and it is essential that, as funding for some such initiatives approaches its end, activity in these areas continues to avoid recurrence of skills gaps in these areas*". It is a strong possibility, however, that the reduction in in-house research capacity in large pharmaceutical companies in the UK has resulted in significant numbers of scientists with *in vivo* skills entering the labour market, thus reducing the pharmaceutical industry's concerns about supply. In contrast to industry, demand for *in vivo* scientists in academia is increasing. Thus, any perceived increased availability of people with *in vivo* training and skills may only be temporary.

The concerns about sustainability raised in both reports were shared by interview respondents. The expense of *in vivo* training and research means that there are concerns that these gains may be lost without specific and targeted funding that supports the improvements in teaching and research capacity.

In particular, concerns were raised that without guaranteed top-up funds, Principal Investigators (PIs) are not putting forward PhD studentships. Without a guarantee of extra funding on top of a stipend and small additional budget, a PhD student may not be able to conduct *in vivo* research, or may only do so at considerable cost to the laboratory. Since many *in vivo* research groups are small, and may not have the money to absorb these costs, there is a disincentive to put forward *in vivo* PhD studentships.

The Doctoral Training Partnerships (DTPs) grants, available to universities from RCUK, have been criticised for not taking account of the elevated costs of *in vivo* training and research. Subsequently, the scheme has been modified to allow for DTPs to apply for top-up funding for more expensive *in vivo* research. At the stakeholder workshop, representatives from the BBSRC and MRC explained that they sought the "best return" on their investment in research, which could mean funding more expensive projects with better outcomes and impact than less expensive projects.

Other stakeholder workshop participants noted the importance of other ways of training for *in vivo* skills. These include being trained by industry, for example through the hiring of graduates and apprentices. Degree apprenticeships, in which apprentices work in a relevant company while also studying for a degree-level qualification, offer a potential route towards the development of *in vivo* skills that may not require additional funding of courses or staff at universities.

RECOMMENDATION

Establish apprenticeships for *in vivo* sciences

Higher education institutions, the British Pharmacological Society, the ABPI, and industrial and clinical partners should collaborate in the development of pharmacology apprenticeships, including degree apprenticeships.

In bids from institutions to host IMB centres, the IPF explicitly required guarantees of institutional support for *in vivo* work and the aims of the initiative. In particular, they sought evidence of higher-level institutional support. At the stakeholder workshop, this higher-level support from senior colleagues, as well as the continued involvement of senior IMB centre staff, was emphasised as an important factor in ensuring that certain parts of the initiative continue to run, such as undergraduate courses or *in vivo* Master's courses. During roundtable discussions, there was concern about the legacy of the IMB centres, and this was strongly associated with the sustainability of the initiatives established at the IMB centres. Permanent members of staff were cited as the only ongoing legacy beyond this year by a senior member of one IMB centre, and in that sense specific individuals embody the legacy. At other IMB centres, courses remain and some of the institutional architecture and networks put into place during the period of the IMB centre persist.

Research grants

Grant success for the 17 fellows and staff:

15 (88%) held non-IPF grants. Of these, **14 (93%)** believe that their prior IPF-supported work enabled them to win these grants.

Having been appointed, fellows and lecturers have been able to use the limited funds allotted to them as part of the IPF scheme and the work of the IPF-supported PhD students (and, to a lesser extent, Master's students on rotation in their laboratory) to leverage further grant funding, for instance by producing pilot data that was then used in grant applications. Although some have found obtaining grant funding difficult, a majority has been able to obtain grants to fund several generations of PhDs and postdoctoral researchers through their laboratory.

Technical skills, technicians and technologists

There is considerable concern about non-research skills capacity; in particular, that funding is insufficient to appoint and retain animal technologists and/or research technicians. Researchers noted several benefits of having technicians or animal technologists, namely performing procedures and allowing research to continue in the absence of the PI, undergraduate education, training of researchers and postgraduates, and providing stability and continuity of skills, amidst losing skills acquired by PhDs and postdoctoral researchers when they move on. The responses of multiple interviewees concurred with the view that, while individual researchers value technicians and technologists, institutions tend not to.

Many of the researchers and other stakeholders pointed out that, when institutions (be they academic or industrial) have technicians or animal technologists trained in procedures such as blood pressure monitoring and telemetry, there is a considerable impact in terms of research productivity. They are able to optimise and standardise procedures, and also have closer access to some knowledge-networks concerning welfare and experimental practices that researchers may not.

The role of the Experimental Officer appointed to the IMB centre at The University of Manchester is an instructive example of how someone appointed to a non-research role – in this case a postdoctoral position – can enhance the research and training capacity of a university. This individual has become a repository of *in vivo* skills and current good practice; delivers Home Office training not just at the University of Manchester but more widely as well; is involved in ensuring that current good practice is disseminated to the appropriate people, and coordinates animal research. The role of the Experimental Officer has evolved since its inception, and is now underwritten by the University as a University-wide role. The Experimental Officer serves as the Named Information Officer (NIO) and the Named Training and Competency Officer (NTCO) under the auspices of A(SP)A. The role works because of the institutional support for the position (including, but not restricted to, the salary), the holder's experience and training in conducting *in vivo* techniques, clear lines of management, and the fact that being appointed to a University-wide role helps to break down the academic silos inhibiting joint-work between different faculties.

RECOMMENDATION

Support integrated pathways for technicians and animal technologists

There should be strong institutional support for career progression, skills training and job security for technicians and animal technologists. Laboratory animal technologists should be more integrated into the planning and conduct of academic research and preclinical research and development, both in industry and academic research.

In industry, there is less of a fundamental divide between laboratory animal technologists and scientists, with technologists in some companies encouraged to contribute towards the design of experiments, as well as conducting procedures and analysing data. Career progression and development is in some cases geared not towards the academic background of the individual or the job on entry, but to the aptitude and interests of the individual. In some companies, the title of 'technician' or 'technologist' has been dispensed with altogether, with people traditionally regarded as such being treated instead as research support. Discussion at the stakeholder workshop indicated that the organisation of academic research around specific costed projects can make this kind of ongoing core support difficult to fund within higher education institutions.

Student progression and retention

Interviewees who were on the Master's at Imperial College London cite many colleagues who are no longer in research, but attribute this to the natural attrition in academic research. A commenter at the University of Glasgow believed that many who had gone through the Master's and the PhD were no longer using their *in vivo* training. The picture at the University of Manchester is different, with high levels of progression from Master's to PhD, and even from PhD to postdoctoral researcher reported. A member of staff at Imperial College London reported a higher progression to postdoctoral researcher positions from the IPF-funded PhD students. There may not be a contradiction between these experiences, as the conversion from PhD to postdoctoral researcher (and beyond) is notoriously low in general.[14,15] The higher progression rates could be explained by the advantages possessed by students who took Master's courses, which provided them with a personal licence and research training and experience, as well as matching them up with potential PhD supervisors. As one former postgraduate at an IMB centre put it: "*Different labs have got different feels, it can be very difficult to get a feel for that until you're actually in it.*"

Of the 25 respondents to the questionnaire who had taken Master's degrees and/or PhDs with the IPF support, 23 (92%) are in science-based careers or training, and 14 (56%) use *in vivo* skills in their current role. Those that do not use *in vivo* skills practically cite their training as useful in providing a better appreciation of data and assessing the practical *in vivo* work of others. 12 of the 25 (48%) train others in *in vivo* skills.

Evidence of student progression (2012 data IMB Centres):

58 of 67 Master's Students **(87%)** had gone on to a PhD.

17 of 25 PhD students **(68%)** now held postdoctoral positions. 3 **(12%)** had jobs in the pharmaceutical industry.

Further study for taught Master's students for 2011/12: **27%** for biomedical sciences and **21%** for biological sciences.* 2009 study of 2007 biology PhD awardees, **61%** in university and other research.**

*Universities UK (2014) Taught Postgraduate Employability and Employer Engagement: Masters with a purpose. Available online at: http://www.universitiesuk.ac.uk/policy-and-analysis/reports/Pages/masters-with-a-purpose.aspx

**Vitae (2009) What do researchers do? First destinations of doctoral graduates by subject. Available online at: https://www.vitae.ac.uk/vitae-publications/reports/what-do-researchers-do-wdrd-by-subject-vitae-jun-2009.pdf/view

4.2. CAREER DEVELOPMENT

A key part of the IPF's aim of increasing *in vivo* skills capacity was ensuring that sustainable and successful careers and career pathways were secured for those trained in *in vivo* research. An important part of this evaluation therefore concerns the career development of individuals. The main focus will be on fellows, staff and postgraduates, as this was the main focus of the IPF intervention. Fellows and staff supervise and secure funding for PhD students, and in turn Master's and PhD students contribute to the research of the PI's group as a whole.

In the section on Master's and PhD students, attention

14 Cyranoski D *et al* (2011) Education: The PhD Factory, *Nature*, Vol. 472: 276-279.

15 Powell K (2015) The future of the postdoc, *Nature*, Vol. 520 No. 7546: 144-147.

will be focused on career progression and the quality of education and training, thus raising some relevant issues for postdoctoral career progression and undergraduate education.

Fellows and staff

Reflections on career development from fellows and staff:

"It gave us lectureships, and the chance for independence, at a time when we wouldn't have got them otherwise."

(Interviewee FS2, non-IMB centre)

"The fellowship, again, it just…it helps people that have *in vivo* skills get themselves established, which is really important, and again, *in vivo* research is so extremely expensive that just any support you can get is vital."

(Interviewee FS8, IMB centre)

"I'm currently at lecturer level, my grant is coming to an end and I don't have any… so my postdoc has finished and I don't have any PhD students. My research is at risk of failing entirely if I can't get another grant."

(Interviewee FS4, IMB centre)

The quotes above illustrate the positive effect of the IPF on individual careers, but also the challenges that face *in vivo* researchers. All three of these interviewees (and many others) were grateful that the IPF initiative had enabled them to obtain positions that they believe they would not have obtained otherwise. Due to the challenges of *in vivo* research, an intervention that specifically appointed *in vivo* researchers was invaluable in allowing those appointed to acquire fellowships and lectureships.

Challenges include: the financial cost, regulatory requirements and ethical concerns of *in vivo* research, and that it is perceived to be unfashionable (compared with molecular biological research for example) and has lower outputs in terms of publications compared to other areas of biological research. These challenges make ongoing support to maintain this work vital. Interviewee FS4's problems highlight this, and they also express the difficulties of starting a research group if the continuity of postdoctoral researchers and PhD students in the lab is broken.

Two staff interviewees commented on the importance of the IMB centre as a support network, in terms of helping them to navigate the UK regulatory system and mentorship to boost their confidence as a researcher. One interviewee who had moved to the UK believed that the more competitive research environment in the UK helped improve their research.

The fellowships have been praised by those who held them for providing security and freedom to conduct research. The graduated increase in teaching time meant that by the end of the five years of the fellowship the holders were fully prepared for the transition to the teaching load expected of a lecturer, and felt able to make the transition without their research suffering.

RECOMMENDATION

Provide support for early career researchers

Learned societies and partners should make a new strategic commitment to fund pump-priming grants for early career researchers. Higher education institutions, research councils, learned and professional societies should recognise the importance of explicitly *in vivo* research fellowships, and should work together to ensure that these positions can be financially supported and sustained.

PhD students attached to new fellowships and lectureships enabled the holders of these positions to produce data for publications and to obtain new grants. PhD students funded in part by the IPF were also attached to laboratories where the PI was not appointed by the IPF initiative, and were able to add to the research of the laboratory and leverage further funds. Additional competitive training grants were received by IMB centres from the MRC, BBSRC, British Pharmacological Society, Wellcome, the British Heart Foundation (BHF) and Cancer Research UK (CRUK).

Of the 15 respondents who hold grants, 14 (93%) believe that their prior IPF-supported work enabled them to win these grants. Many interviewees attributed their later grant success to the initial IPF support: "*they believe that we're capable of doing in vivo research because we've had grant funding to support that previously*" (interviewee FS5, IMB centre).

Master's and PhD training

Feedback on Master's and PhD training:

"It was a really broad skill set, it was quite comprehensive as well, and I didn't think we probably quite realised that until we finished and we were working with other people who had done Master's and various different bits and pieces, and we're working alongside them, and you realise you've actually got far more skills than they do."

(Interviewee MP4, IMB centre)

"It did produce five papers, three of which were very high impact, so that's obviously facilitated my career thereafter."

(Interviewee MP1, non-IMB centre)

In the questionnaire responses, 16 out of 25 respondents (64%) considered their *in vivo* training to have been important in securing their current role. Respondents agreed that the IPF encouraged their skills in experimental design (19 out of 25, 76%), new *in vivo* techniques (23 out of 24, 96%) and animal welfare and the 3Rs (21 out of 25, 84%). For those for whom it is applicable, 50% (7 out of 14) have grants to support their research.

RECOMMENDATION

Create innovative resources and approaches

The community of educators and educational institutions should cooperate towards developing innovative education and training resources and approaches to prepare students for postgraduate research and/or employment. These approaches and resources should be developed in alignment with agreed learning outcomes and set up with impact assessment in mind.

The training received by Master's students was highly rated by them, with a broad-based education in the different areas of *in vivo* research accompanying a strong focus on experimental design and animal welfare. The laboratory rotations in the Master's courses enabled students and prospective supervisors to assess each other in advance of working in a laboratory during a PhD. This was thought to be valuable by students and PIs alike, and aided progression from Master's to PhD. Furthermore, it was felt that the *in vivo* skills Master's training helped students to acquire competitive PhD places. Visits to industrial sites and speakers from industry were valued by former Master's students..

The PhD training at IMB centres was thought by those who received it to be an excellent preparation for research: "*the training was very clearly motivated towards making you a very useful PhD student to the research group you went to, which on reflection I think was very good*" (interviewee MP5, IMB centre). It also enabled researchers like interviewee MP1 to establish a track record of publications, which helped them to obtain positions after completion. Some supervisors offered the view that it would be valuable for PhD students to be provided with funding to enable them to learn techniques from experts.

There are examples of researchers appointed as a result of the IPF initiative who have brought new *in vivo* skills that they learned during their Master's and/or PhD to laboratories, providing the laboratory and other researchers in it with new collaborative possibilities and new modes of conducting research.

RECOMMENDATION

Support undergraduate education modules

The British Pharmacological Society should continue to provide part-funding for undergraduate education modules, to foster stability and security for the continuation of entry level *in vivo* skills education.

Of the Master's and PhDs students who have not gone on to careers in research, many are in a position where they are using either some of the *in vivo* skills that they learned in their postgraduate training, or the more generic skills (for example, communicating to a lay audience or writing) that they learned as a result of doing a PhD.

Postdoctoral Researchers

A large number of concerns were raised about the transition from postdoctoral research to independence, though this is not confined to *in vivo* research. These concerns were raised by both female and male interviewees, and yet the instability of post-PhD academic employment disproportionately discouraged female PhD holders from pursuing further research in academia.

Pump-priming grants were relatively small sums of money that allowed holders to develop and use new models, in one case with the effect of being able to form a collaboration that has led to the awarding of a fellowship and a permanent lectureship.

Undergraduates

The IPF support for undergraduate modules with *in vivo* education components was another example of the leverage enabled by relatively small amounts of funding. Departments used this external funding as validation for the course to justify its continuation and the maintenance of university support for it.

The short residential courses run by the British Pharmacological Society and The Physiological Society were highly rated by students who participated in them, and the researchers involved in running them are enthusiastic about their value. Similarly, academics involved with undergraduate *in vivo* modules as part of the taught curriculum are effusive about them. Data from one such undergraduate course, at King's College London, indicates that many of the students who participated have gone on to intra-mural year projects with *in vivo* content. Unfortunately, there are wider concerns about the supply of industry placements for undergraduate students.

Students of both the short-courses and *in vivo* undergraduate modules reported that these enhanced their employability.[d] Depending on whether the undergraduate module was run under delegated authority or an educational project licence, the undergraduate education courses cost the British Pharmacological Society roughly six to nine times less, per student, than the cost of the short residential courses.[e]

d In data obtained from 65% (93 out of 143) graduates enrolled on the University of Leeds Level 6 *in vivo* education module BMSC3126 from 2005–2015, 77% of all respondents agreed or strongly agreed that the practical skills gained through the module had been beneficial to their subsequent career, and 99% agreed or strongly agreed that the employability skills developed during the module had been beneficial to their subsequent career.

e This estimate uses figures from 2013–14, the final year of full funding. For modules run under delegated authority, full animal and consumables costs were covered. For modules run under an education project licence, a contribution was made to the cost, but the rest was covered by the university.

What is delegated authority?

The guidance to A(SP)A permits licensees to: "Delegate tasks which form an integral part of the regulated procedures that you are authorised to perform to assistants under your control who do not themselves possess the requisite personal licence authority. The tasks must not require technical knowledge or skill."

As such, students can participate in, and gain hands-on *in vivo* practical experience of, most procedures currently undertaken under educational project licences through the use of delegated authorities. These include the use of freely moving animals, anaesthetised animals and *ex vivo* preparations, for example:

- **Psychopharmacology:** Student placement of animals in behavioural arenas and their scoring of animal behaviours; any pharmacological agents being administered by the supervising licensee.
- **Diuretic modulation of renal function:** Student placement of animals in metabolic chambers, collecting and analysing the excreted urine; any pharmacological agents being administered by the supervising licencee.
- **Pharmacological modulation of physiological responses in anaesthetised preparations:** Student injection of pharmacological agents through previously implanted cannulas and their measurement of changes in physiological parameters or reflexes. The supervising licensee is responsible for the surgical preparation of the animal, insertion of catheters and other measurement devices, and the induction and maintenance of anaesthesia.
- **Assessment of physiological function and reflexes in *ex vivo* preparations.** Once the supervising licensee has set up the preparation, it falls outside of the Act. Students can, for example, administer pharmacological agents, electrically stimulate nerves and record changes in physiological parameters or reflex function.

These can be complimented by hands-on training in procedural skills performed using models or cadavers, for example:

Injection technique: Using a model animal or cadaver, students inject intraperitoneally, subcutaneously, intravenously or by gastric gavage. When using a cadaver, students can inject dye and then undertake a dissection to check the location of their injection. This can be useful for relating the anatomy of the animal to potential complications associated with injection procedures.

Training in surgical techniques (e.g. blood vessel cannulation and tracheotomy): Students are given a cadaver and following guidance undertake cannulation of an artery and vein and perform a tracheotomy. Students are taught about aseptic technique and good practice for surgical procedures.

Acknowledgement: With thanks to Dr Emma Robinson (University of Bristol) and Dr Dave Lewis for their input.

Students who participated in the undergraduate *in vivo* modules supported by the IPF were invited to complete a feedback survey after their courses. Free text responses from students indicate they valued taking part for a range of reasons, including feeling more confident, gaining insight on a potential career working in animal research, improved awareness of the ethical considerations of *in vivo* work and gaining knowledge of research techniques and animal physiology. However, the two most commonly cited reasons were the opportunity to get hands-on experience and to develop practical skills.

RECOMMENDATION

Develop core learning outcomes

Educators and employers in the *in vivo* community should work together and lead the development of clear core learning objectives for the *in vivo* sciences, including experimental design, statistics, animal welfare, the culture of care, ethics and the 3Rs.

The IPF support for undergraduate modules contributes towards the cost of animals and Home Office licence training and licences (where applicable) and the costs of running the courses. Exposure to licenced procedures, whether hands-on or via delegated authority, is not primarily about producing people with *in vivo* skills but about exposure to *in vivo* work, to ensure that students can make an informed decision about embarking on further *in vivo* education and training. It is not clear whether continued support for licences for undergraduates is necessary to maintain high-quality *in vivo* education. Several interviewees suggested that the same educational learning outcomes are achieved through the use of a combination of delegated authorities, demonstrations, cadavers and e-learning tools to provide the exposure to *in vivo* work. As this would cost considerably less, it may help retain courses with some kind of *in vivo* component allied to some hands-on practical experience. It would also advance the aims of the 3Rs by using fewer live animals to achieve similar learning outcomes.

The evaluation has opened up the issue of undergraduate education as a key factor in the future development and sustainability of *in vivo* research. At the stakeholder workshop, several participants raised concerns that in relevant undergraduate degrees such as pharmacology and biomedical sciences, there was not sufficient introduction to the nature, principles and practices involved with *in vivo* research. The importance of exposing students to *in vivo* research and explaining its purposes was emphasised by multiple participants, albeit for different reasons. Some stressed the importance of making students aware of the possibilities of *in vivo* research, thereby exposing them to an area of research that they may have otherwise not been properly aware. Others saw undergraduate education as a suitable place for intervening to address the perceived problems concerning experimental design and practice in biomedical research, and further improve standards

of animal welfare in research.[16,17,18] There was broad agreement that *in vivo* work and principles of good experimental design, statistics and animal welfare should be introduced earlier into undergraduate studies, and be returned to throughout the course of the degree.

4.3. RESEARCH PRACTICE AND OUTCOMES

Pump-priming grant recipient on how the money was useful:

"This sum of money actually made me do what I wanted to do and what I think is translationally relevant, rather than go for the cheap way to do things, but not proper way of doing things."

(Interviewee FS11, non-IMB centre)

Support by the IPF enabled many of the recipients to develop innovative programmes of research, with some developing new animal models of disease and injury, or adapting existing ones to new purposes. Researchers supported by the IPF have published widely, and some have published papers with high numbers of citations in journals that encompass *in vivo* and non-*in vivo* work. In surveys of academic fellows (conducted by the IPF in 2009) and lecturers (conducted by the IPF in 2011), 7 out of 20 had received prizes for their research or teaching.

The fellows and staff questionnaire respondents from 2015–16 worked across many areas of research, mainly neuroscience or electrophysiology but also cardiovascular research, endocrinology and immunology, with two respondents each working in two different fields. While the researchers who responded mainly worked with rats and mice, they also worked with (non-human) primates, humans, guinea-pigs, pigs, rabbits, zebrafish and amphibians, such as *Xenopus laevis*.

Fellows attributed the development of productive new models and research to the security of the fellowships. This security enabled them to take risks, for instance, conducting research that might not have guaranteed publishable results. The pump-priming grants also enabled researchers to develop new experimental models. The extra funding available allowed them to design experiments that produced results with more translational potential than more limited experiments may have done.

Research quality and the 3Rs

13 out of 16 (81%) questionnaire respondents who were appointed as a fellow or staff agreed that the IPF had enabled them to work towards the aims of the 3Rs. The transposition of EU Directive 2010/63/EU and the rewriting of the guidance to A(SP)A, along with the establishment of the NC3Rs make it difficult to identify the precise role that the IPF intervention has played in improving standards of animal welfare and care. There are, however, numerous concrete examples of IPF-funded researchers or researchers within IMB centres who have made improvements to research practices that have improved the 3Rs. These include the development of rodent handling techniques to lower their stress levels by a group at the University of Liverpool IMB centre, and the introduction to a laboratory of imaging techniques that reduce the number of animals used in experiments by a former Imperial College London IPF-supported PhD student. A fellow supported by the IPF has participated in the development of the Experimental Design Assistant pioneered by the NC3Rs. Another has replaced the use of wires to track neural activity in rats with wireless transmitters that are less stressful for the animal, and generate considerably more data which enables a reduction in the number of rats used. At one IMB centre, a new animal model was developed which replicates the co-morbidity associated with human manifestations of a disease: the model was developed by one of the lecturers appointed as a part of the IMB centre bid, in conjunction with a PhD student supported by the IPF.

19 out of 25 questioned (76%) who received IPF support as a Master's and/or PhD student, agreed that the IPF enabled them to develop their skills and competency in experimental design, 23 out of 24 (96%) agreed that the IPF enabled them to develop their skills and competency in new *in vivo* techniques, and 21 out of 25 (84%) agreed that the IPF enabled them to develop their skills and competency in animal welfare and the 3Rs. 24 out of 25 respondents (96%) affirmed that their training had helped them work towards the aim of the 3Rs: "*The 3Rs were instilled in us from the very start and we received continual training and communications via the course tutors, the animal units and the named vets.*" Interviews have confirmed this focus on experimental design and the 3Rs, particularly in Master's courses, although these elements were not a key feature of the Master's offered at the University of Glasgow. One dissenting questionnaire respondent commented, "*There is still an over-reliance on employing large scale animal studies, often with limited rationale.*"

Examples have been given of an approach to *in vivo* education provided by IPF-supported staff at undergraduate and Master's level, which sets particular research problems to students, who then have to design appropriate experiments. As a former Master's student at an IMB centre put it, "*We usually had to design our experiments with the idea of animal welfare and numbers and the whole process behind it, which helped a huge amount during the PhD*" (interviewee MP4). A lecturer at a non-IMB centre institution relates: "*In particular practical designs I wanted students to understand the design of in vivo experiments, power calculations and so forth. So I gave them a question which was actually a part of my research I had done*" (interviewee FS11). Another lecturer at an IMB centre institution commented that teaching the 3Rs to students prompted personal reflection: "*[Teaching] made me go back and revisit the things that I'd gone through and maybe got me a little more 3Rs orientated*" (interviewee FS7).

16 Begley CG and Ellis LM (2012) Drug development: Raise standards for preclinical cancer research, *Nature*, Vol. 483 No. 7391: 531–533.

17 Begley CG and Ioannidis JP (2015) Reproducibility in Science: Improving the Standard for Basic and Preclinical Research, *Circulation Research*, Vol. 116 No. 1: 116–126.

18 Macleod MR *et al* (2015) Risk of Bias in Reports of *In vivo* Research: A Focus for Improvement, *PLoS Biology*, Vol. 13 No. 10: e1002273.

Sources of expertise

As well as being the hub for animal research and sitting on the Animal Welfare and Ethical Review Body, the Experimental Officer at The University of Manchester has been involved in various projects, including a tissue-sharing resource which seeks to maximise the use of tissues from euthanized animals, and running an experimental design course with a colleague. They described a key part of their job as, "*Ensuring that everybody who's using animals has an absolute knowledge of experimental design, and they are therefore able to refine their experiments as far as possible.*" The Experimental Officer at the University of Manchester was a conduit for all animal work. As a consequence, clinicians approached the IMB centre at Manchester to conduct translational research, and collaborations were established to test treatments in animal models. Several interviewees noted the importance of non-research technical staff or technologists as an actual or possible source of expertise for effective practice concerning procedures and welfare, and believed that in their institutions (with the exception of the University of Manchester) some form of intervention to support the technical side was missing from the IPF. As universities rather than research councils fund technical staff, a different model of collaborative funding would be required to support them.

Translational research

Having *in vivo* researchers alongside non-*in vivo* researchers has enabled those researchers to take their research closer to the clinic. The capacity of a laboratory to do *in vivo* work has therefore enabled groups to take the next step towards working with clinicians. Having a teaching hospital with researcher clinicians nearby is an advantage to researchers in terms of the informal discussions which can guide research design and improve the chances of clinically-relevant knowledge being produced. One interviewee cited the transformation of their perspectives towards a more translational approach over the course of the period that their IMB centre existed.

Improving standards

Staff appointed as a result of the IPF have been involved in community-wide efforts to improve standards of research, for instance by participating in NC3Rs projects and the setting of journal standards. These standards include requirements on the reporting of methods, experimental design, use of power calculations to identify proper sample sizes, and the use of statistics.

4.4. NETWORK, COLLABORATION, DISSEMINATION

Networks and hubs

There were strong networks fostered at the level of individual IMB centres within institutions. Deliberate and successful attempts were made to create communities of Master's and PhD students trained within IMB centres. Researchers in some cases continue to identify with them even after they have formally ceased. A number of joint courses were established between centres, for example a joint telemetry course involving King's College London and Imperial College London. These two centres, together with University College London and the Universities of Cambridge and Oxford, formed a 'Global Medical Excellence Cluster', which works closely with the pharmaceutical industry to support integrative physiology and pharmacology.

Nationally, there was little sense of a common identity or network of the IPF-supported researchers, although three national events were held.[f] The lack of a national network inhibited the fostering of a stronger *in vivo* community.

RECOMMENDATION

Nurture networks of good practice

The *in vivo* sciences cross a range of disciplines, and networks of good practice should be cross-cutting but deal with specific areas of need such as: building and/or encouraging participation in *in vivo* research and education networks, signposting them to people first as undergraduates and then throughout their careers; supporting the development of online open access repositories showcasing course materials that use innovative approaches to learning in *in vivo* pharmacology; maintaining and developing national knowledge-sharing networks sharing good practice to advance excellent research with high welfare standards; making grants available to support PhD students learning a particular *in vivo* technique in another laboratory.

The IMB centres did not operate as hubs in terms of formal arrangements with nearby universities. This was at least in part due to the lack of funds for this, and the difficulty of getting universities to work together. Two London-based interviewees noted that the IMB centres were too short-lived to properly establish themselves as longer-term hubs. Dual-institution arrangements worked to a certain degree over the lifespan of the IPF but, some limited training and research collaboration aside, have not been sustained.

The Experimental Officer role provides a point through which all *in vivo* work in the institution flows. They are therefore able to establish collaborations, advise on good

f These events included a meeting and visit to a GSK facility in Stevenage in 2007, a two-day meeting in London in 2009, and a meeting at The University of Manchester on welfare involving all IMB centres and run in collaboration with the NC3Rs in 2011.

practice, and try and ensure adherence to the highest standards of research and animal welfare. As the Named Information Officer (NIO) and Named Training and Competency Officer (NTCO), the Experimental Officer is in a good position to ensure as much as possible that current good practice is adopted as well as disseminated.

The Business Development Manager (funded by the North West Regional Development Agency) at Manchester-Liverpool and the Industrial Impact Fellow (funded by BBSRC) at King's College London were successful in forging collaborations between individual researchers and groups and industry, in addition to obtaining Collaborative Awards in Science and Engineering (CASE) studentships, which are PhD projects run in collaboration with industry.

Disseminating good practice

Many interviewees expressed the view that current good practice is not well shared on a national level. A few expressed the view that it is not adopted well, rather than disseminated poorly. A few meetings aside, the IPF missed an opportunity to develop a network of animal researchers across the UK, which may have assisted in the dissemination of effective practice.

Dissemination of current good practice by Fellows and Staff:

11 out of 16 (69%) agreed that the IPF initiative had encouraged them to disseminate current good practice in experimental design.

12 out of 16 (75%) agreed that the IPF initiative had encouraged them to disseminate current good practice in animal welfare and the 3Rs.

12 out of 16 (75%) agreed that the IPF initiative had encouraged them to disseminate current good practice for *in vivo* techniques.

The Master's courses and other courses which operated in large part due to the IPF support enabled the education of students in current good practice, both in experimental design and the 3Rs, and also encouraged them to think about the best way to conduct experiments rather than simply apply a rote method or protocol. In establishing centres of excellence with strong internal networks and a high concentration of *in vivo* researchers, the IPF was successful in establishing the means for strong local sharing of current good practice.

Facilitating collaboration

All 17 fellows and staff who responded to the questionnaire had established collaborations with scientists from other groups and disciplines. Eight respondents (47%) specifically cited collaborations with researchers at pharmaceutical or biotechnology companies, four (24%) specifically cited collaborations with clinicians or other healthcare providers, and one with another industry (food). In interviews, some researchers commented that it was their visibility as *in vivo* researchers appointed by the IPF initiative that initially fostered collaborations. The prominence of the IMB centre also directed attention towards the researchers working in it. As one senior member of staff in an IMB centre put it, "*Everybody knew what [the] IMB centre was within the university, everybody knew who to go and ask.*" In some cases, the collaborations came about because they had *in vivo* skills that could contribute towards a specific project.

As cited above, the Business Development Manager at The University of Manchester and the Industrial Impact Fellow at King's College London were successful in helping academic researchers to establish collaborations with people and companies in the private sector. Additionally, the Experimental Officer helped to forge collaborations between life science researchers and clinical researchers. Responding to concerns about the cost to industry of engaging with academic researchers (such as the cost of funding a PhD studentship which may not provide the results desired by the industrial funder), and the institutional barriers towards formal collaboration, the Industrial Impact Fellow developed several initiatives. One initiative deemed to be a success was 'Find Your Ideal Partner,' in which funds were provided to academic researchers to conduct small projects that could serve as feasibility experiments for potentially larger projects in collaboration with industry. One less successful initiative was developing a 'fee-for-service' model for services provided to industry by academics, which has so far not generated regular business, but is still ongoing.

RECOMMENDATION

Foster collaborations across academia, industry and the NHS

Research collaborations involving *in vivo* researchers in academia, industry and the NHS need to be supported, with obstacles to cooperation identified and addressed. Studies and evaluations should be conducted to inform and facilitate long-term links, collaborations and relationships between academic education, training and research, industry and the NHS.

Initiatives focusing on particular problems faced by industry, involving discussions between academic researchers and industry researchers, offer the potential for lowering the barriers to cooperation and collaboration. One example comes from the University of Bristol, where 'Industry Day' events were organised in 2015 and 2016, at which industrial and academic researchers participated in sessions focusing on industry challenges and how academic researchers could help.

Clinical collaborations cited by researchers, which enabled them to alter the way in which they designed their research to make it potentially more translatable, tended to depend upon proximity. This is especially true for the more informal collaborations based on the sharing of expertise. Academic researchers found formal collaborations with clinicians and the NHS less easy to initiate than with industry, but one of the IPF-supported fellows did secure a fellowship concerning translational research from the NHS.

Supporting outreach

Participation in outreach activities was a key stipulation for the receipt of support from the IPF. 12 out of 16 fellows and staff questionnaire respondents (75%) had engaged in outreach activities, many of which involved school visits. 9 out of 16 (65%) are still involved in outreach activities; time constraints and the lack of value placed on such activities by the university were a limitation for some. 76% (19 out of 25) of Master's and PhD students participated in outreach activities of varying types, which are listed in the following boxes:

RECOMMENDATION

Recognise and support engagement work

Public engagement and student outreach should be supported and encouraged by higher education institutions and learned societies as a core activity of academic researchers, advancing the commitments contained in the Concordat on Openness on Animal Research.

Activities of postgraduates supported by the IPF:	Activities of fellows and staff supported by the IPF:
Supervision of sixth form students for a summer project	Drug testing at the London 2012 Olympic Games
Helping out with open days by talking about research and explaining complex ideas	Involvement in science on the International Space Station initiatives
Involvement in scientific policy: communication with government and the public about animal research	BBSRC Schools Regional Champion
Volunteering for Understanding Animal Research (UAR)	School visits
School visits and talks	Running small workshops at science fairs and museums
Participation in careers fairs on studying science (women in Science, Technology, Engineering and Mathematics or STEM)	Giving public lectures
Involvement in 'Pint of Science' event	Made videos for UAR
Social media based campaigning	Putting on work experience weeks for year 10 students
Involvement in museum events	STEM ambassador
Giving public talks or lectures	Volunteer for UAR
Serving as a STEM ambassador	Pint of Science
Scientific advisory committee member	Organising IMB centre showcase event

Table 3. Description of outreach and engagement involvement reported by students and staff supported by the IPF.

5. RECOMMENDATIONS

PRINCIPLES

The IPF successfully brought together multiple stakeholders to leverage the initial £4 million into a sum of £22 million. The steering committee approach incorporating stakeholders enabled a consensual approach to strategic decision-making. Future initiatives, including those recommended in the course of this report, should be based on these principles of partnership and collaboration. From the findings of the evaluation and related recommendations, we have extracted four common principles to underpin future work and initiatives:

Lessons from the IPF: guiding principles for future initiatives

We now explore the ten recommendations in more detail, explaining the context and evidence for their proposal, and detail the follow-up actions suggested for their implementation.

RECOMMENDATION 1: DEVELOP CORE LEARNING OUTCOMES

Educators and employers in the *in vivo* community should work together and lead the development of clear core learning objectives for the *in vivo* sciences, including experimental design, statistics, animal welfare, cultures of care, ethics and the 3Rs. These outcomes should be integrated across the biosciences, and should be reinforced throughout a student's undergraduate and postgraduate career.

Contexts

The Master's courses provided by the IMB centres featured a strong focus on experimental design and the 3Rs. Students were set particular research problems, and were tasked with designing appropriate experiments. Multiple respondents emphasised the need for these aspects to be included in undergraduate education to ensure that students are able to make informed choices about their futures, as well as being aware of the principles of *in vivo* research, animal welfare and good experimental design and practice, ahead of entry into postgraduate study or employment.

In the case of statistics, the Level 5 Animal Models of Disease and Injury module at King's College London led to a new way of teaching statistics to biological sciences undergraduates being developed that made learning the principles and practice of statistical analysis more accessible to them.

Actions

There is ongoing debate about the kind of education and training that should play a role in undergraduate pharmacology. There is agreement that undergraduate exposure to *in vivo* research is vital for making students aware of what it entails and for helping them to make the emotional and intellectual steps required of prospective *in vivo* researchers. Education about *in vivo* science needs to be provided earlier in undergraduate studies, with a wider introduction of animal research and *in vivo* techniques to Level 4 undergraduates, so that they understand the concepts and practicalities of *in vivo* research, and to improve employability. Employability should not just focus on prospective academic researchers, but should also equip students to navigate the current industry environment.

The British Pharmacological Society, in collaboration with multiple partners, should therefore develop learning objectives that encompass these aspects and other needs of relevant stakeholders, for instance with academic, technical, industrial, clinical and learned society input. The learning objectives should be congruent with (and, possibly, cross-referenced to) the Subject Benchmark Statements outlined by the Quality Assurance Agency (QAA). The learning objectives should be broad enough to ensure that there is enough commonality or core objectives in Level 4 and Level 5 undergraduate programmes to allow the development and sharing of resources (see Recommendation 5), but allow individual institutions to develop bespoke courses suited to their own strengths and areas of application. The development of the learning objectives should draw upon the experiences of those who have previously participated in efforts to establish core curricula in pharmacology (see the examples to the right).

Undergraduate education on topics such as experimental design and animal welfare should be particular to the skills needs and disciplinary content being taught. For example, like the King's College London module mentioned, statistics teaching should be adapted to needs of life sciences undergraduates, rather than starting from a high level of statistical theory.

Examples of prior initiatives to develop core curricula:

2007–2008: Formulation of MSc in Safety Pharmacology post-2007 ABPI/Biosciences Federation *in vivo* sciences report – most of courses that adopted this have now ceased due to lack of demand and/or funds.

2011: Development of Integrated 4-year Master's in Integrative Physiology & Pharmacology for Research, which is still running at King's College London.

2011: Royal Society of Biology pilot accreditation of *in vivo* sciences undergraduate degree (post-"Blueprint for the Life Sciences" report of the Office for Life Sciences) – these accreditation criteria are now broader and not explicitly *in vivo*.

2013–2014: Development of Royal Society of Biology accreditation criteria for *in vivo* MSc – this did not proceed beyond planning stage.

A potential model that could form the basis for the development of these learning outcomes is for all Level 4 undergraduate students taking relevant degrees (such as pharmacology and biomedical sciences) to receive education about what *in vivo* research involves and is for, and the importance and principles of experimental design, welfare and ethics. Online resources such as videos may be used, and data from real experiments (perhaps those depicted in the videos, also simulations on websites such as www.virtualpharmacologylab.com) could be used in class exercises. The smaller number of Level 5 students may then participate in a course operated under delegated authority, and thus have more hands-on experience. For Level 6 students, a course run under delegated authority may be run, or if there is a sufficiently robust rationale, one involving education or training that requires them to obtain a personal licence.

Higher education institutions should be asked to make explicit to students the opportunities to gain a robust education in *in vivo* sciences, for example by providing

key information on their courses, such as how much money they provide for Level 6 projects, employability data, contact time (including time in the laboratory) and data relating to placements. The British Pharmacological Society and other learned societies could encourage course organisers and admissions tutors to use such data in undergraduate recruitment. Clarity around learning outcomes from educators and employers would help tailor appropriate resources and inform their delivery.

RECOMMENDATION 2: CONDUCT RESEARCH ON EDUCATIONAL OUTCOMES

Higher education institutions and learned societies should conduct research on the educational outcomes of different education and training routes and methods, and should forge ways to ensure that data collection and analysis are supported and based on common standards.

Contexts

The importance of, in particular, undergraduate education and training to achieve the aims of improving the supply and quality of people trained in *in vivo* techniques, was a feature of responses from interviewees and participants at the stakeholder workshop. There was disagreement, however, on the models of education and training that are most effective. These disagreements cannot be resolved in the absence of systematic data collection and analysis of the outcomes of different models and examples of education and training. The Wakeham Review of STEM Degree Provision and Graduate Employability[19,20] has called for "a greater degree of granularity around data on graduate outcomes so that we can construct a more nuanced understanding of the factors that really make a difference," and in response the British Pharmacological Society has made suggestions about ways to improve data collection. Additionally, the Higher Education Statistics Agency is conducting a review of the data it collects on graduate destinations and outcomes.[21]

Actions

The effectiveness and outcomes of Level 5 and Level 6 undergraduate courses that incorporate personal licences and those that do not should be evaluated, and there should be sharing of experiences on the role delegated authority could play in undergraduate education.

There should be regular curriculum reviews and formalised exit surveys and follow-ups with students supported by the British Pharmacological Society and others in conjunction with relevant university departments. The means to conduct this work and contact students should be in place from the start of their course, to enable the collection and analysis of quantitative data concerning the impact and outcomes of particular courses and initiatives. The British Pharmacological Society could assist in the efforts of relevant university departments to collect and analyse data, including providing some common platforms for data entry and analysis to ease the burden on universities and allow comparability of data. Issues around data protection and access to contact details will need to be explored.

Furthermore, the British Pharmacological Society and partners should support the conducting of a regular survey of *in vivo* education and training, track the careers of the IPF-supported students, and develop and publish career case studies.

RECOMMENDATION 3: SUPPORT UNDERGRADUATE EDUCATION MODULES

The British Pharmacological Society should continue to provide part-funding for undergraduate education modules, to foster stability and security for the continuation of entry-level *in vivo* skills education.

Contexts

Undergraduate education and training is a key point of intervention in the development of high quality researchers and scientifically-trained employees. It exposes students to *in vivo* research, which enables them to make a more informed decision about whether to pursue postgraduate study or employment in that field, as well as potentially equipping them with the knowledge and skills that will enable them to conduct research with high standards of welfare and reproducible results. Evaluations of short courses by participants rate them highly, but these courses are expensive to run. Additionally, well-resourced and organised undergraduate education modules supported by higher education institutions and learned societies provide a more integrated approach than short stand-alone courses.

Actions

Even small-scale funding of, for example, undergraduate modules by British Pharmacological Society helps the providers of those modules to validate and justify them to obtain and maintain institutional support for them. This is therefore an area where even limited resources can secure the future of undergraduate modules containing *in vivo* education and training.

19 Wakeham Review of STEM Degree Provision and Graduate Employability (2016). Available online at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/518582/ind-16-6-wakeham-review-stem-graduate-employability.pdf.

20 British Pharmacological Society (2016) Response to the Wakeham Review. Available online at: www.bps.ac.uk/about/policy-positions/consultation-responses/articles/response-to-the-wakeham-review.

21 HESA (2015) Review of Data on Destinations and Outcomes for Leavers from HE. Available online at: www.hesa.ac.uk/pr/3686-review-of-data-on-destinations-and-outcomes-for-leavers-from-he.

The British Pharmacological Society should continue to provide funding for undergraduate education modules, basing its support on the adoption and outcomes of the rest of the recommendations relevant to undergraduate education outlined in this report.

RECOMMENDATION 4: CREATE INNOVATIVE RESOURCES AND APPROACHES

The community of educators and educational institutions should cooperate towards developing innovative education and training resources and approaches to prepare students for postgraduate research and/or employment. These approaches and resources should be developed in alignment with agreed learning outcomes and set up with impact assessment in mind.

Contexts

The Master's degrees supported by the IPF were highly valued by staff and students. Stand-alone Master's degrees are now difficult for institutions to support, in part because of the policies of funding councils. The importance of a good grounding in knowledge and skills pertaining to *in vivo* research ahead of PhD research or entry into employment in industry was recognised.

Actions

The development of new educational and training approaches should be approached alongside the formation of learning objectives outlined in Recommendation 1 and in the light of the evaluative work suggested in Recommendation 2.

Learned and professional societies such as the British Pharmacological Society should leverage contacts to establish focus groups for employers and research groups centred on key *in vivo* skills areas in order to understand where innovative resources are most needed, and how they could be used.

Higher education institutions should establish faculty-based industrial advisory boards to advise on course content, required skills and course design.

There are potential alternatives, such as the development of distance e-learning. Such courses could help students understand key principles and equip them for entry to further study or employment in industry.

RECOMMENDATION 5: NURTURE NETWORKS OF GOOD PRACTICE

The *in vivo* sciences cross a range of disciplines, and networks of good practice should be cross-cutting but deal with specific areas of need:

- Higher education institutions, employers and learned societies should build and/or encourage participation in *in vivo* research and education networks, signposting them to people first as undergraduates and then throughout their careers.
- Higher education institutions, learned societies and other relevant organisations should encourage and support the development of online open access repositories to collect and showcase course materials that use innovative approaches to learning in the *in vivo* sciences.
- National knowledge-sharing networks sharing good practice to advance excellent research with high welfare standards should be maintained and developed by the research community. This should be aided by individual higher education institutions, networks of and between named persons and other relevant individuals, the NC3Rs and learned and professional societies.
- Learned societies and partners should make grants available to support PhD students learning a particular *in vivo* technique in another laboratory.

Contexts

There were strong networks fostered at the level of individual IMB centres within institutions. Deliberate and successful attempts were made to create communities of Master's and PhD students trained within IMB centres. The IPF-supported Master's courses were good at exposing students to a wide range of people from academia and industry, which provided them with the knowledge of potential future sources of information, assistance and collaboration, as well as an awareness of the range of activities for which *in vivo* skills and research is relevant.

On the national level, however, networks of knowledge-sharing and dissemination of good practice were weaker. The information to enable researchers to improve aspects of their research practice exists, but it is not always available to, or targeted at, the right people. Academic researchers voiced concerns that the dissemination of good practice concerning animal welfare and the 3Rs was not sufficiently well-targeted, but rather was placed in forums (such as journals and conferences) that were not consulted or attended by academic researchers, but

rather by technical staff. The targeted dissemination of information by NIOs to researchers and the informal network of NIOs were cited as examples of effective dissemination and communication of current good practice. In response to a question asking interviewees about potential uses for small pots of money, several respondents volunteered the suggestion that grants with the aim of ensuring that PhD students are able to learn techniques from those who exhibit the current good practice for a particular technique would be particularly valuable.

During the course of the evaluation, educators and trainers reported innovative and effective approaches to undergraduate and postgraduate education and training. The means for sharing of these resources are currently limited. Additionally, the increasing importance of lifelong learning and Continuing Professional Development heightens demand for education and training resources targeted towards researchers as well as students.

Actions

University departments should develop links with relevant people and organisations encompassing a variety of areas of work and research in which *in vivo* skills are used. Through these links, speakers should be invited to address undergraduates (certainly Level 6, but preferably also prior to a placement year). Additionally, site visits should be encouraged, and the British Pharmacological Society and other organisations that can provide links and support may have a role to play in establishing these.

Case studies should be developed, for example by the British Pharmacological Society, other learned societies and higher education institutions, to support students entering into networks of collaboration and knowledge and good practice-sharing.

The British Pharmacological Society and other learned and professional societies should invite relevant academic departments known for expertise in particular techniques to develop short course training in those specific techniques, in which people are posted into expert labs with some attached funding. Grants can be provided on the basis of partnership funding between learned societies, academic institutions, and possibly research councils, to support PhD students learning a particular technique in another laboratory, and then returning to their home laboratory to set up the technique and to train others.

Educators should be encouraged to submit some of their course materials that use innovative approaches (such as ways of teaching statistics) to online platforms. The British Pharmacological Society should work collaboratively with researchers and educators in higher education institutions to ensure that they receive the proper support and encouragement to deposit resources. Examples of repositories are provided in the box to the right. The British Pharmacological Society may wish to look at how it could host and disseminate resources that are particular to pharmacology education and training. Educators and trainers should be directed (for instance, by hyperlinks from the British Pharmacological Society website) towards the repositories most appropriate to the resources they wish to deposit, and a robust ecosystem of these repositories should be developed and sustained. Proper curation would have financial implications, and so the *in vivo* community could look into a consortium approach. For any repository in the ecosystem, the consortium should ensure that procedures are in place to properly vet uploaded resources.

Resources should be deposited with re-use and adaptation in mind, so that educators and trainers can take and adapt what they need for their own purposes. They should therefore be modular in construction, and enable the extraction of particular parts and re-incorporation into new resources. The resources should be accompanied by guidance notes.

Examples of repositories of free, open access e-learning resources:

ETRIS (Educational and Training Resources in *In vivo* Sciences): www.etris.leeds.ac.uk

OER Commons (Open Educational Resources): www.oercommons.org

LifesciTRC (Life Science Teaching Resource Community): www.lifescitrc.org

Merlot (Multimedia Educational Resource for Learning and Online Teaching): www.merlot.org/merlot/index.htm

Whereas previously issues concerning the ownership of resources made sharing between institutions problematic, new methods of assessment such as the Teaching Excellence Framework are likely to incentivise sharing, as this could be used to show impact. It will be important to understand intellectual property requirements to ensure that the community is appropriately rewarded for their engagement.

The British Pharmacological Society and other learned societies, the Institute of Animal Technology (IAT), the Laboratory Animal Science Association (LASA) and animal welfare organisations should support the organisation of informal events on a regular basis bringing together *in vivo* researchers, animal technologists and others interested in animal welfare, to enable colleagues to converse, establish contacts, exchange ideas, form collaborations, and also develop support networks.

Institutions should encourage the nomination of named statistical and experimental design consultants within relevant departments or schools, to provide advice on licence applications, experimental design, statistics and power calculations, with suitable compensation within workload allocation models. A national support network and training should be provided for these in-house consultants.

For conferences run by learned societies, papers dealing with good practice, especially concerning the 3Rs and animal welfare, should be explicitly included in the call for abstracts, and included as part of symposia for related research with well-briefed chairs. The British Pharmacological Society could produce guidelines to inform chairs. Researchers that participated in the IPF

evaluation have a variety of different research areas and approaches, and therefore what constitutes good practice cannot simply be stipulated across all *in vivo* pharmacology. Even if it could, a separate session dealing with good practice may not be the most effective way of ensuring its dissemination, as opposed to papers integrated into sessions themed by research area. This approach to conference organisation is allied to the current drive for documenting experimental design deriving from the open science movement and the push for more detailed reporting of research in response to criticisms of research practice and reporting in the biomedical sciences.

To add to existing Continuing Professional Development initiatives, residential workshops should be established to bring scientists together who are using a specific technique to develop current good practice. At these residential workshops, experts would demonstrate the technique, and scientists could discuss the challenges and limitations of that technique and possibly try it out on cadavers. An online database of technique workshops should be established, and this should be part of an *in vivo* skills training and dissemination network established in partnership between learned and professional societies, research councils, industry and representatives from higher education institutions.

The British Pharmacological Society and other learned societies should encourage greater sharing of good practice and training resources through open access repositories, and regularly draw members' attention to the repositories in general, as well as any items that might be specifically relevant to their research. This would not require the British Pharmacological Society to act as a curator for these resources, but to coordinate their dissemination.

The British Pharmacological Society and other learned societies should introduce dedicated prizes for models of good practice, which would encourage submissions and dissemination of these models.

The British Pharmacological Society should raise the profile of prizes such as the Drug Discovery of the Year Award, and use it as a source of examples and learning resources.

RECOMMENDATION 6:
PROVIDE SUPPORT FOR EARLY CAREER RESEARCHERS

- Learned societies and partners should make a new strategic commitment to fund pump-priming grants for early career researchers. Such grants would support the development of new or adapted animal models and techniques to advance standards of animal welfare, the 3Rs, make research more potentially translatable, and provide data that recipients can use to apply for further grants.
- Higher education institutions, research councils, learned and professional societies should recognise the importance of explicitly *in vivo* research fellowships, and should work together to ensure that these positions can be financially supported and sustained.

Contexts

Support for early career researchers is vital to their career development, and the maintenance and development of *in vivo* education, training and research capability and capacity. Pump-priming grants were relatively small sums of money that allowed holders to develop and use new models, in one case with the effect of being able to form a collaboration that has led to the awarding of a fellowship and a permanent lectureship. Fellowships have been praised by those who held them for giving them the security and freedom to conduct research.

Actions

Pump-priming grants are useful to fund small projects and specific initiatives, in particular for early-career researchers, as this work may enable them to successfully apply for larger grants, particularly to open up new areas of research and improve current practice, for instance by pioneering a refinement to an established animal model of disease. There may be several mechanisms to guarantee pump-priming grants. Higher education institutions could play a role, and innovative ways of funding should be explored, such as those used by drug discovery groups within academia. The British Pharmacological Society and other learned societies should contribute to efforts to fund these grants. Awards may be made conditional on institutional sign up to the Concordat on Openness on Animal Research, and the effective dissemination of the new techniques developed or 3Rs improvements.

The fellowship stage is most in need of intervention. While organisations such as the British Pharmacological Society are not in a position to fund fellowships themselves, they are in a position to communicate their value to career development and research capability. A

partnership approach may be able to leverage enough funds from other commercial partners and funding bodies to secure explicitly *in vivo* research fellowships in or across institutions.

Research councils, learned and professional societies and higher education institutions should explore and advance ways in which the supportive environment experienced by the fellows appointed with support from the IPF can be extended to all academic researchers, from early career onwards. This may involve valuing their work in a more multi-dimensional way, and acknowledging their broader contribution to research, education, training and public engagement (see Recommendation 10).

RECOMMENDATION 7: SUPPORT INTEGRATED PATHWAYS FOR TECHNICIANS AND ANIMAL TECHNOLOGISTS

There should be strong institutional support for career progression, skills training and job security for technicians and animal technologists, which takes account of their key roles in laboratory animal research. Laboratory animal technologists should be more integrated into the planning and conduct of academic research and preclinical research and development, both in industry and academic research.

Contexts

Researchers have noted several benefits of having technicians and animal technologists, which include performing procedures, allowing research to continue in the absence of the PI, contributing to undergraduate education, training of researchers and postgraduates, and providing stability and continuity of skills. There is considerable concern that funding to appoint and retain technicians is insufficient. Increased integration of laboratory animal technologists into academic research will allow academic researchers to make use of their expertise in husbandry, welfare and other aspects of practical experimental design and the conduct of experiments, as well as enhance the status and visibility of these individuals in their institutions, which would increase the likelihood of core funding for their position. There is evidence of this occurring in industry, but to a lesser extent in academic research.

Actions

The British Pharmacological Society should constructively participate in BBSRC, MRC and Science Council work on animal technologists and technical skills, alongside the IAT, LASA, Establishment Licence Holders, NTCOs and NACWOs. In particular, there is a need for a technical/technologist career pathway to ensure that skills are retained through the long-term employment of technicians and animal technologists, and that there is increased employment of permanent research infrastructure technicians.

The British Pharmacological Society and other learned societies should improve their offer for technical members, especially those working with animal welfare organisations. Spaces should be opened to enable these people to present at annual meetings, network, and highlight their role in institutions as part of the mission of 'creating strong research communities'.

Institutions should consider appointing someone with practical *in vivo* skills experience analogous to the Experimental Officer appointed as a postdoctoral research associate to the IMB centre at The University of Manchester, to the roles of NTCO and/or NIO, to perform or oversee similar functions such as: serving as a repository of *in vivo* skills and current good practice; delivering training and judging competency; ensuring that knowledge of current good practice is disseminated to the appropriate people; and, possibly, acting as an introducer to break down barriers between academic researchers and those in clinical or industry roles. The position or positions should not be restricted to one faculty or school, and should receive full institutional support.

The British Pharmacological Society needs to find new ways of collaborating with organisations such as the IAT and LASA to secure and advance the role of laboratory animal technologists in the research effort, both in higher education institutions and industry, including SMEs. This may include the establishment of a joint working group, associate membership of the British Pharmacological Society for IAT or LASA members, or cooperation around some of the initiatives proposed in this report. One common goal for the British Pharmacological Society, IAT and animal welfare organisations is to improve the welfare of laboratory animals, which in turn will reduce their suffering and lead to better and more reproducible data.

Higher education institutions should implement those sections of the Brown Report[22] that stipulate that senior laboratory animal technologists should be fully integrated with researchers and into research teams, and be given significant input into both the design and implementation stages of research projects.

Higher education institutions should consider adopting the industry practice of laboratory animal sciences units, which undertake all *in vivo* research regardless of the research area.

Animal welfare organisations and institutions such as the NC3Rs, the IAT and LASA also have a role in developing *in vivo* skills. They should support and participate in any initiatives to develop laboratory animal technologists and the technical capabilities of academic research institutions and industry.

22 The Brown Report (2013) Independent Investigation into Animal Research at Imperial College London. Available online at: http://brownreport.info/wp-content/uploads/2014/02/The-Brown-Report.pdf

RECOMMENDATION 8: ESTABLISH APPRENTICESHIPS FOR *IN VIVO* SCIENCES

Higher education institutions, the British Pharmacological Society, the ABPI, and industrial and clinical partners should collaborate in the development of pharmacology apprenticeships, including degree apprenticeships.

Contexts

The advent of degree apprenticeships was thought by stakeholder workshop participants to be a potential opportunity for the development of *in vivo* skills in the UK. Apprenticeships were cited as a way to help to break down the dichotomy between animal technologists and researchers, and provide an alternative pathway for skills training and the development of *in vivo* expertise.

Actions

A collaborative approach towards the development and validation of apprenticeships, including degree apprenticeships, between organisations such as the British Pharmacological Society, the IAT, LASA, higher education institutions, the ABPI and industry along the lines of the IPF initiative should be pursued to help ensure that high quality programmes are developed which meet the needs of various stakeholders.

RECOMMENDATION 9: FOSTER COLLABORATIONS ACROSS ACADEMIA, INDUSTRY AND THE NHS

Research collaborations involving *in vivo* researchers in academia, industry and the NHS need to be supported, with obstacles to cooperation identified and addressed. Academics, higher education institutions and industry should work together, supported where appropriate by research councils and learned and professional societies, to conduct studies and evaluations to inform and facilitate long-term links, collaborations and relationships between academic education, training and research, industry and the NHS.

Contexts

Existing initiatives such as CASE PhD studentships and BBSRC Industrial Partnerships as well as fellowships exist to foster and support collaborations. Concerns have been expressed, however, in particular at the stakeholder workshop, that certain barriers or obstacles are preventing more successful collaboration between academics and industry. Some of the main problems are the cost of formal collaborations such as the funding of PhD studentships, different priorities and ways of working, and a lack of understanding on the part of academic researchers as to the benefits of collaboration with industry. The IMB centres at The University of Manchester and King's College London had qualified success in forging collaborations between academic researchers and industry, in which a responsible member of staff was a vital component. The role of industry liaison is now a more common one in UK universities.

In a number of cases, collaboration between academic researchers and industry does not bear fruit immediately. It may take time for understanding of what each party can offer the other, and what they need from the interaction, to develop. An example of this is the relationship between the University of Leeds and the CRO Covance, which is detailed in the box to the right.

Example of an academic – industry collaborations for *in vivo* education:

Covance, a CRO, has contributed to the design and delivery of Level 5 and Level 6 undergraduate education modules in Drug Discovery, Toxicology, and *In Vivo* Pharmacology at the **University of Leeds** for over seven years.

Recently, they have identified a shortage of individuals equipped with the knowledge, skills and expertise to undertake biopharmaceutical research.

To address this skills gap, they are working with the Faculty of Biological Sciences at the University of **University of Leeds** to develop and co-deliver an MSc programme in Biopharmaceuticals, both for their own employees and the sector as a whole.

Actions

Models of lowering costs of industry-academia collaboration should be developed, taking inspiration from schemes such as 'Find Your Ideal Partner' at King's College London, and the Industry Impact Fellowship at the same institution.

There is a role for the British Pharmacological Society in promoting networking between academics and industry, and fostering potential collaborations. The British Pharmacological Society or alternative organisations have the potential to act as an introducer and facilitator, and can also provide training to academic researchers on how to manage networking opportunities, including the use of social media websites such as LinkedIn, to develop contacts with people in industry.

As a minimum, the British Pharmacological Society and other learned societies should produce information documents in collaboration with some university industry liaison officers to address key questions and concerns that academics might have, such as those relating to intellectual property, costs, publications, REF impact, and setting up partnerships.

Researchers in academia should be made better aware of the benefits of industrial collaboration, for example the access to drugs, facilities, and animal models. One way of doing this could be to provide a session at the annual British Pharmacological Society meeting, *Pharmacology*. This awareness of the importance of mutual benefits is particularly important where and when higher education institutions do not value the outputs of such collaborations.

Named individuals should be identified within universities and research institutes to broker connections between industry, clinicians and researchers. They should act as connectors, facilitating and fostering translational research collaborations.

The value of events to bring together people from academia and industry need to be shared and encouraged in universities and research institutes. Discussions between academics and researchers from industry centred on challenges and solving particular problems has the potential to make academic researchers more aware of the kind of data valued by industry, and industry more aware of the challenges faced by academic researchers, and the potential support they can therefore offer them.

There is a role for organisations such as the British Pharmacological Society, in collaboration with other learned societies, companies and industry bodies, to establish the means by which sabbaticals in industry might be established and made into a normalised part of academic careers. The advantage of sabbaticals such as these would be to give academic researchers, including but not restricted to those who work with *in vivo* models, exposure to the rationales, working practices and needs of industry.

There is a need for industry bodies to support and enable CROs and SMEs to take undergraduate students on placement, and ensure that they can provide a high quality placement. As CROs and SMEs do not necessarily have the temporal horizons or institutional means to commit to long-term placements, alternative placement models with different timescales will need to be explored. The British Pharmacological Society, in conjunction with other learned societies, industry bodies and higher education institutions (especially placement officers), can work to produce guidance to CROs and SMEs on placements, and how they can get the best out of students placed with them.

The ABPI should be invited to audit the proportion of studentships, project grants and industry placements that go to genuinely *in vivo* work. In future data-gathering and reporting, organisations such as the ABPI, research councils and learned societies need to identify more fine-grained categories of researcher and skills, to ensure that a more precise picture of skills needs and gaps is generated.

On the part of higher education institutions, academic researchers and industry, alternative means of collaboration and the different ways in which collaborations develop should be recognised. Case studies should be published on the different ways in which long-term collaborations develop.

More research on modes and pathways of collaboration in pharmacology needs to be conducted by social scientists, and disseminated to the relevant scientific and policy communities. A collaborative approach should be adopted to the development of research questions incorporating scholars from the humanities, social sciences, scientists from academia and industry, and clinicians. A possible model for this is the approach is the interdisciplinary group convened to deliberate on an agenda for humanities and social science research on laboratory animal science and welfare.[23]

RECOMMENDATION 10: RECOGNISE AND SUPPORT ENGAGEMENT WORK

Public engagement and student outreach should be supported and encouraged by higher education institutions and learned societies as a core activity of academic researchers, advancing the commitments contained in the Concordat on Openness on Animal Research.

Contexts

Public engagement activities were regarded positively by those who participated in them. They are a useful source of ideas and reflection for the researchers themselves, and for 3Rs improvements. Public engagement is now a major responsibility of institutions who have signed up to the Concordat on Openness on Animal Research and the individuals who work within those institutions.

Actions

Higher education institutions should ensure that researchers are provided with the time and resources, (including administrative support), to plan, conduct, and evaluate public engagement activities. In part this requires a shift from valuing people based on narrow metrics based on first/last author credits and towards valuing the overall contribution and role of individuals in their own institutions and communities of educators and researchers.

Learned societies such as the British Pharmacological Society should ensure that researchers receive advice and mentoring to engage in productive public engagement.

Researchers should ensure that public engagement involves a commitment to two-way dialogue with lay persons.

Institutional press releases regarding research in which *in vivo* research has played a part should mention that animals were involved, in line with the content guidelines published by the Concordat on Openness on Animal Research, which has to date been signed by representatives of over 100 organisations and institutions.[24]

23 Davies GF *et al* (2016) Developing a Collaborative Agenda for Humanities and Social Scientific Research on Laboratory Animal Science and Welfare, *PLoS One*, Vol. 11 No. 7: e0158791.

24 See http://www.understandinganimalresearch.org.uk/policy/concordat-openness-animal-research/signatories-to-the-concordat-on-openness-on-animal-research

Concordat on Openness on Animal Research
Headline commitments:

"We will be clear about when, how and why we use animals in research."

This includes a key commitment that "When we communicate about the use of animals in research, we should provide accurate descriptions of the benefits, harms and limitations of such research, be realistic about the potential outputs of such research, and be open about its impact on animal welfare and the ethical considerations involved."

"We will enhance our communications with the media and the public about our research using animals."

"We will be proactive in providing opportunities for the public to find out about research using animals."

www.understandinganimalresearch.org.uk/policy/concordat-openness-animal-research

APPENDICES

APPENDIX 1 – THE STEERING COMMITTEES

IPF steering committee:

Mike Collis (Pfizer and Chair)

Malcolm Skingle (GSK)

Martin Todd (AstraZeneca)

Sue Brain (British Pharmacological Society)

With additional input from **David Tattersall** and **Rebecca Dias** (both Pfizer)

IMB centre steering committee:

Aileen Allsop (Independent Chair)

Mike Collis (British Pharmacological Society and project co-ordinator)

Susan Fleetwood-Walker (University of Edinburgh)

Kevin Fox (Cardiff University)

Stephen Holgate (University of Southampton)

Malcolm Skingle (GSK)

Graeme Smith (AstraZeneca)

Funder representatives

Stuart Fancey (Assistant Director of Research and Innovation, SFC)

Kimberley Hackett (Higher Education Policy Adviser, HEFCE)

Simon Kerley (Strategy and Policy Manager, BBSRC)

David McAllister (Head of Skills and Careers, BBSRC)

Andrew Staphnil (Business Interface Manager, BBSRC)

Harriet Warburton (Programme Manager, Research Careers Awards, MRC)

Stephanie Williams-Blackwell (Strategy and Policy Officer, BBSRC)

APPENDIX 2 – LIST OF ACRONYMS

3Rs	Replacement, Reduction and Refinement of the use of animals in research
ABPI	Association of the British Pharmaceutical Industry
A(SP)A	Animals (Scientific Procedures) Act 1986
BBSRC	Biotechnology and Biological Sciences Research Council
BHF	British Heart Foundation
CASE	Collaborative Awards in Science and Engineering
CRO	Contract Research Organisation
CRUK	Cancer Research UK
DTP	Doctoral Training Partnership
EDA	Experimental Design Assistant
GSK	GlaxoSmithKline
HEFCE	Higher Education Funding Council for England
HESA	Higher Education Statistics Agency
IAT	Institute of Animal Technology
IMB	Integrative Mammalian Biology
IPF	Integrative Pharmacology Fund
LASA	Laboratory Animal Science Association
LAVA	Laboratory Animals Veterinary Association
MRC	Medical Research Council
NACWO	Named Animal Care and Welfare Officer
NC3Rs	National Centre for the 3Rs
NCO	Named Compliance Officer
NIO	Named Information Officer
NTCO	Named Training and Competency Officer
NVS	Named Veterinary Surgeon
OLS	Office for Life Sciences
PI	Principal investigator
PIL	Personal licence
RCUK	Research Councils UK
REF	Research Excellence Framework
SFC	Scottish Funding Council
SME	Small to Medium sized Enterprise
STEM	Science, Technology, Engineering and Mathematics
UAR	Understanding Animal Research

ABOUT THE BRITISH PHARMACOLOGICAL SOCIETY

Formed in 1931 the British Pharmacological Society is a charity with a mission to promote and advance the whole spectrum of pharmacology, including laboratory, clinical, and toxicological aspects. The Society now leads the way in the research and application of pharmacology around the world.

With over 3,500 members from more than 60 countries worldwide, the Society represents a diverse community working across academia, government agencies, industry and the health service.

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