

BBSRC AND MRC REVIEW OF VULNERABLE SKILLS AND CAPABILITIES

EXECUTIVE SUMMARY – UPDATED DECEMBER 2017

The Biotechnology and Biological Sciences Research Council (BBSRC) and the Medical Research Council (MRC) have consulted with the bioscience and biomedical research communities in order to identify vulnerable capabilities and skills within the UK bioscience and biomedical research base. A community consultation took place in 2014 (in collaboration with the former Society of Biology) and a light-touch refresh of the review took place in 2017.

In 2014, over 120 submissions were received from academic research organisations, BBSRC and MRC institutes, centres and units, businesses, professional societies and other organisations with an interest in research skills. In 2017, BBSRC and MRC consulted with its Doctoral Training Partnerships and advisory bodies in order to understand the extent to which the vulnerable skills identified are still relevant, particularly in relation to postgraduate research skills, and to identify any new vulnerable areas.

2014 consultation

Respondents were invited to provide evidence for one or more vulnerable skills and capabilities. A total of 242 'vulnerable' areas were raised in the original consultation; these were grouped into the following categories:

- Interdisciplinarity
- Maths, Statistics and Computation
- Physiology and Pathology
- Agriculture and Food Security
- Core Research and Subject Specific Skills

Respondents were asked to indicate at what level(s) and in what way(s) they had identified vulnerability within the last five years; these varied for the different areas and are described in more detail in the main report.

2017 update

A number of interventions have been implemented since the publication of the Review in 2015.

These include:

- Creation of BBSRC's Strategic Training Awards for Research Skills ([STARS](#)) and associated [GCRF-STARS](#) programmes
- Increased Research Council engagement with Training Partnerships regarding their support for vulnerable skills
- Support for fifteen MRC Doctoral Training partnerships across 29 institutions, aligned to vulnerable skills and capabilities highlighted in the 2014 review
- Establishment of cross-Research Council funded Centres for Doctoral Training in vulnerable areas, for example [Soil Science](#) and [Biosocial Research](#)
- Continued support for *in vivo* research skills via BBSRC [In Vivo Skills Awards](#)

- Provision of flexible financial support for high cost training, such as *in vivo* research skills and to support the transition of MRC studentships to first post-doc positions, via enhancements to MRC's Doctoral Training Partnerships
- Additional support for vulnerable areas, including [skills schools](#), PhD studentships and fellowships via the National Productivity Investment Fund (NPIF)

The 2017 consultation with BBSRC and MRC's Doctoral Training Partnerships and advisory bodies has revealed that the vulnerable research skills and capabilities published in 2015 remain areas of unmet need. A number of new / future vulnerabilities have been added, as provided in the paragraphs below.

Headline messages

The headline messages for each of the broad categories are as follows, [including new areas identified in 2017](#):

Interdisciplinarity (more detail in Annex 1)

- Many responses were received, reflecting a changing need for cross-disciplinary working in the biosciences and medical sciences, particularly across the chemical / physical sciences interface
- Interdisciplinarity is relevant to many areas of bioscience, but is particularly pertinent to the industrial biotechnology sector
- Vulnerabilities were noted at the postgraduate and postdoctoral levels (as a result of inadequate exposure at earlier stages), but also within researchers at the early stage of independence
- There is a need for both 'depth' of knowledge (e.g. pure biochemistry) and 'breadth' of knowledge (e.g. through working in multidisciplinary teams)
- There is considerable scope for working in partnership with other funders, industry and professional bodies
- [The 2017 update highlighted the following areas where there is a particular need for doctoral level training:](#)
 - [Cell and gene therapy bioprocessing](#)
 - [Enzyme biochemistry and fundamental biochemistry](#)
 - [Metabolic biochemistry \(also relevant to maths, statistics and computation\)](#)
 - [Research software engineering \(also relevant to maths, statistics and computation\)](#)
 - [Artificial intelligence \(also relevant to maths, statistics and computation\)](#)
 - [Bioscience-physics interdisciplinarity \(e.g. reaction kinetics and thermodynamics\)](#)
 - [Advanced cell therapies \(cell, gene and tissue engineering\)](#)
 - [Skills required to address global challenges](#)
 - [Lichenology \(of relevance to industrial biotechnology\)](#)
 - [Social science, health economics / econometrics](#)

Maths, Statistics & Computation (more detail in Annex 2)

- Data analytics, especially bioinformatics, appear to be particularly vulnerable
- Informatics skills are applicable to many areas of both the biosciences and the medical sciences
- Maths, statistics and computational biology skills are lacking particularly at the postgraduate and postdoctoral levels, with many respondents reporting difficulties in recruiting adequately skilled researchers at these levels; shortages are not just restricted to the UK
- [The 2017 update revealed that these areas continue to be vulnerable. New / specific areas of particular relevance to doctoral level training include:](#)

- Sophisticated analysis and interpretation of the complex data generated by genomics, proteomics, lipidomics and metabolomics
- Machine learning, Artificial Intelligence (AI), big data visualisation, programming and use of high performance computing
- Technology development for health data research and data analytics

Physiology, pathology and pharmacology (more detail in Annex 3)

- There were concerns about the future supply of individuals with skills to work with whole animals and with an holistic understanding of the physiology of laboratory and farmed animals
- *In vivo* work has unusually high costs required for infrastructure, welfare regulations, safety and maintenance; such costs inhibit the development of these skills at undergraduate levels
- There are strong academic and industrial needs for all areas
- Veterinary pathology is a 'niche' research skill that lacks an adequate career structure for these highly skilled individuals
- MRC and BBSRC have collaboratively provided considerable support for the development of these individuals and now that funding commitments are coming to an end there is concern that supply will 'dry out': there is a strong desire for sustainable, long-term support
- There is a general lack of expertise, capacity and career structure in the UK and worldwide in many aspects of microbiology, including physiology and taxonomy, from basic through to applied research and training
- There are links with other technologies including data analytics, genomics, host-pathogen interactions (including plant pathology), biology-chemical interface
- **New areas of particular relevance to doctoral level training include:**
 - Classical neurophysiological methods, including techniques applicable to whole animals, cells and invertebrates
 - Systems biology, particularly the development of integrated optical, electrophysiological, computational, molecular and behavioural approaches to study complex systems *in vivo*
 - Clinical pharmacology; drug metabolism, pharmacokinetics and pharmacogenomics
 - Translational medicine; particularly toxicology, pharmacology, ethics and regulatory approval, drug discovery, clinical trial design

Agriculture and food security (more detail in Annex 4)

- There is a long term decline and shortages in plant- and field-based studies
- The skilled population in this area is ageing and there is a lack of succession planning
- Shortages are worldwide, not just in the UK
- There is a need for continued building of links between academia and industry
- This area includes several 'niche' research skills where there is high strategic importance but only a small number of individuals are needed; these include forestry, plant breeding and entomology
- **New areas of particular relevance to doctoral level training include:**
 - Agronomy
 - Horticulture
 - Specialist knowledge applicable to the understanding of the food system, with an ability to communicate with industry

Core research and subject specific skills (more detail in Annex 5)

- There is some on-going concern about levels of core research skills, including those relating to interdisciplinarity (described in more detail in Annex 1) and numeracy (which underpin but are separate from maths, statistics and computational biology skills described in Annex 2)

- The inadequacy of numeracy skills in researchers results from a lack of sufficient input at the school and undergraduate levels. This view was reinforced during the 2017 update. Mathematical and computational skills remain a prominent and growing skills gap.
- Taxonomy skills continue to be a concern, with a lack of future supply of individuals; intervention is needed at the school and undergraduate levels
- Several respondents described the need for better training and career structure for (academic) early career researchers. Such support would be at the expense of funding for postgraduates.

BBSRC AND MRC REVIEW OF VULNERABLE SKILLS AND CAPABILITIES

Introduction

The Biotechnology and Biological Sciences Research Council (BBSRC) and the Medical Research Council (MRC), in collaboration with the Society of Biology, held a consultation in summer 2014 regarding emerging or existing strategic research skills and capabilities that are vulnerable or potentially vulnerable. The survey built on previous reviews of skills gaps in 2009 (BBSRC) and 2011 (MRC), which helped inform the development of the funders' studentship and training portfolios.

The survey aimed at identifying vulnerable capabilities and skills within the UK bioscience and biomedical research base¹. Vulnerability may be due to a number of reasons, including:

- A small or decreasing number of individuals with expertise in a particular area, with or without adequate succession planning
- Limited training opportunities for individuals
- The lack of career paths to preserve skills
- New and emerging areas of research
- Local changes in support for areas without due consideration of the wider impact

Response to survey

Responses to the online survey were welcomed from universities, groups, organisations or other representative bodies from across the bioscience and medical science sectors. Responses from individuals were discouraged. Over 120 submissions were received as shown in **Table 1**:

Type of organisation	Number of organisations	Proportion of responses
Academic ² (including intramural ³)	97	83%
Industry	5	3%
Other	4	2%
Society ⁴	17	12%
Grand Total	123	

Table 1: Respondents to skills consultation

Vulnerable skills and capabilities

Respondents were invited to provide evidence for one or more vulnerable skills and capabilities.

A total of **242** 'vulnerable' areas were raised in responses received and have been grouped into the categories shown in **Table 2**:

Area	More detail	Responses	% of total	BBSRC relevant	MRC relevant
Interdisciplinarity	Annex 1, p. 7	67	28%	81%	90%

¹ The consultation question set is provided in **Annex 6**, page 35

² 'Academic' includes responses on behalf of: whole Universities, University Groups or Departments, Research Council and non-Research Council academic Institutes as well as academic-led networks which might include non-academic partners, such as BBSRC Networks in Industrial Biotechnology and Bioenergy (NIBBs).

³ Intramural includes BBSRC and MRC Institutes, Centres and Units

⁴ 'Societies' includes responses on behalf of societies and 'society-like' organisations, such as charities.

Maths, Statistics and Computation	Annex 2, p. 13	63	26%	97%	100%
Physiology and Pathology	Annex 3, p. 16	42	17%	88%	98%
Agriculture and Food Security	Annex 4, p. 23	33	14%	100%	15%
Core Research and Subject Specific Skills	Annex 5, p. 29	37	15%	76%	86%
Grand Total		242	100%	88%	83%

Table 2: Responses to the consultation by overall areas

Respondents were asked to indicate at what level(s) and in what way(s) they have identified vulnerability within the last five years (see **Table 3**). It is noteworthy that respondents often raised vulnerability or shortage of skills at post-doctoral, as well as at PhD and independent researcher levels. Far fewer responses raised concern about numbers of current or future undergraduate or MSc students. The most cited reasons for vulnerability were identified as the ability to recruit, concerns about current numbers and about future supply.

	Under-graduate	MSc	PhD	Post-doc. Res	Independent Res.	World leading Res.	Other	Total by reason
Age	12	16	23	37	52	51	5	196
Career paths	34	47	87	101	80	40	10	399
Current numbers	49	56	114	127	106	91	10	553
Diversity	15	15	28	41	36	29	3	167
Future supply	56	62	120	134	121	109	12	614
New area	28	36	52	68	59	47	9	299
Recruitment	60	64	132	147	127	107	9	646
Retention	19	27	63	106	82	59	8	364
Training	77	85	119	103	57	36	11	488
Other	3	4	5	6	3	2	4	27
Total by level	353	412	743	870	723	571	81	3753

Table 3: Level and reason for 'vulnerability' across all areas

Summaries of free text responses concerning evidence of vulnerabilities, reasons for requiring interventions in the UK, current interventions and suggestions for potential solutions, are provided in **Annexes 1 to 5**.

ANNEX 1: INTERDISCIPLINARITY

Headline messages:

- Many responses were received, reflecting a changing need for cross-disciplinary working in the biosciences and medical sciences, particularly across the chemical / physical sciences interface
- Interdisciplinarity is relevant to many areas of bioscience, but is particularly pertinent to the industrial biotechnology sector
- Vulnerabilities were noted at the postgraduate and postdoctoral levels (as a result of inadequate exposure at earlier stages), but also within researchers at the early stage of independence
- There is a need for both 'depth' of knowledge (e.g. pure biochemistry) and 'breadth' of knowledge (e.g. through working in multidisciplinary teams)
- Considerable scope for working in partnership with other funders, industry and professional bodies

Responses by organisation type:

Organisation type	Responses
Academic	60
<i>Of which HEI</i>	34
<i>Of which Intramural</i>	6
<i>Of which Network</i>	20
Society	7
Industry	0
Other	0
Grand Total	67

Subject areas of concern within this category:

- **Chemical, physical and engineering interface (36 responses):** including biochemistry and chemical biology, industrial biotechnology (including fermentation technology and microbial physiology) and medicinal chemistry
- **Clinical interface (10 responses):** including translational research
- **Social / economic interface (8 responses):** including health economics
- **Imaging (13 responses):** including applied imaging techniques, microscopy and image analysis

Respondents cited the following reasons for and levels of vulnerability

Darker colours indicate higher numbers of respondents citing reason / level

	Under-graduate	MSc	PhD	Post-doctoral researcher	Independent researcher	World leading researcher	Other	Total by reason
Age	3	4	8	13	10	15	1	54
Career paths	10	12	25	27	21	13	3	111

	Under-graduate	MSc	PhD	Post-doctoral researcher	Independent researcher	World leading researcher	Other	Total by reason
Current numbers	11	9	31	37	27	21	2	138
Diversity	5	5	8	11	8	7	1	45
Future supply	17	13	31	38	30	28	4	161
New area	7	8	11	18	14	10	4	72
Recruitment	19	14	36	39	33	29	3	173
Retention	8	9	19	31	18	16	3	104
Training	20	18	32	29	14	9	3	125
Other	2	2	3	4	1	1	2	15
Total by level	102	94	204	247	176	149	26	998

Chemical, physical and engineering interfaces

Respondents cited the following reasons for vulnerability:

- General:
 - Can fall between remits of Research Councils, especially BBSRC and EPSRC
 - Strong industrial need, e.g. in pharmaceutical, industrial biotechnology and agrochemical sectors
 - Research does not tend to be 'blue skies' and is not as highly valued as some other areas (e.g. published in lower impact journals)
 - Loss of REF Biochemistry panel and many joint Chemistry / Biology degrees
- Lack of skills:
 - Widespread focus on 'omic technologies has led to lack of basic understanding of how microorganisms work in biomanufacturing and in health and disease processes – will result in reduced ability to make novel bioproducts and to anticipate spread of disease
 - Lack of holistic training in physiology of microbes
 - Strategy for microbial physiology and fermentation technology is lacking – not included in current Industrial Biotechnology focus
 - Difficult to recruit fermentation technology specialists to industry – impact on commercial production
 - Lack of development of interdisciplinary skills at undergraduate and postgraduate levels – results in difficulty in recruiting postdocs with appropriate skills
 - Students with physical sciences background require MSc to understand application to bioscience / biomedical sciences
 - Doctoral Training Partnerships do not allow for in-depth training at biology-chemistry interface – very few PhDs work at interface
 - Some rapidly developing / emerging areas require these skills (e.g. glycosciences, synthetic biology)
 - Specific need for formulation scientists, especially within industry
 - Some specific areas such as fermentation technology are not taught in undergraduate practical classes due to high cost and need for skilled technical support
 - The majority of training opportunities tend to be technique specific – little of a general physical biochemical nature

- Careers issues:
 - 'Pure' biochemists reaching retirement
 - Lack of coherence in teaching and research of pharmaceutical sciences
 - Difficulty in retaining overseas researchers in the long term

Respondents identified the following needs for training in the UK:

- Should take advantage of good pool of UK undergraduates
- Risk of international companies moving manufacturing abroad
- UK is strong enough to support industry base in an holistic way
- Without a strong chemical biology research base, industries cannot flourish in the UK – there will increasingly be competition from abroad
- UK will struggle to maintain competitive edge without strong academic / industrial base

Respondents cited the following current interventions:

- Strategy and workshops:
 - Some roadmaps / strategies being developed in specific areas (e.g. in US for glycosciences)
 - The Biochemical Society and Royal Society of Chemistry have held a joint symposium on computationally aided drug design that brought together a range of scientists to cross pollinate ideas relating to novel approaches in drug design (~50 places at symposium)
 - EMBO / Trends in enzymology: Enzyme mechanisms by biological systems (biannual conference, two conference series merged in 2014)
 - Bioscience Knowledge Transfer Network and the Institution of Chemical Engineers have investigated UK training provision for the bioindustries, and concluded that significant intervention is needed to provide the supply of trained manpower needed to drive future innovation in IBBE
- Continuing Professional Development (CPD):
 - Potential for Biochemical Society to provide CPD in metabolic biochemistry
- Training courses and workshops:
 - Most companies train staff in-house
 - MSc in formulation science offered by Science Industry Partnership
 - MSc courses run by various pharmacy / pharmaceutical science departments
 - Professional organisations such as the Academy of Pharmaceutical Sciences, the Royal Society of Chemistry, the Royal Pharmaceutical Society, the Joint Pharmaceutical Analysis Group and the Institute of Chemical Engineering provide workshops and training courses in various aspects of the pharmaceutical sciences, notably around materials science, formulation and analysis
 - Biochemical Society / University of Kent summer school in kinetics
 - University of Strathclyde provides a Medicinal Chemistry PhD programme which is used by GSK to train staff
 - Biochemical Society early career research awards
 - Skills-based practical training course in fermentation technology run by UCL

Respondents' suggestions for possible interventions included:

- Industry-linked training:

- Support training in applied areas of industrial biotechnology e.g. through Industrial CASE studentships
- Support interdisciplinary PhDs, e.g. from BBSRC Networks in Industrial Biotechnology and Bioenergy (IBBE)
- Targeted Modular Training Partnership call, e.g. for biofuels, synthetic biology
- Basic / specific training:
 - Encourage specific training within Doctoral Training Partnerships (DTPs)
 - MSc scholarships in bioprocessing / other areas
 - Cluster training in niche areas (e.g. glycoscience) – virtual, theme-based multi-institutional DTPs
 - Cross-DTP and –Centre for Doctoral Training (CDT) training where there is a general requirement, e.g. in enzymology, or technique specific training
- Post-doctoral / established researcher support:
 - Encourage movement of postdocs
 - Sandpit type events
 - Be explicit about inclusion of physical biochemistry in committee remits and fellowship calls
 - Establishment of Centres of Excellence and Networks of Excellence
 - Support for Industrial Biotechnology and Bioenergy (IBBE)-related infrastructure, equipment and technicians
 - More attractive mid-career and professorial fellowships (5 years), as an incentive for discipline hopping and for engagement in IBBE and synthetic biology research
- Collaborations:
 - Biochemical Society / Academy of Pharmaceutical Sciences / others
 - Joint strategy between BBSRC and EPSRC, e.g. for development of a specific cross council funding call; EngD equivalent linked to EPSRC centres

Social and economic interfaces, including health economics

Respondents cited the following reasons for vulnerability:

- Specialised area with requirement for strong quantitative background in statistics, econometrics and epidemiology – limited number of individuals with those skills
- Difficulty in both recruitment and retention – due to scarcity of individuals with the right skills combination
- Very limited supply of more senior applicants but also lack of suitable candidates for support in health economics at early post-doc stage. Potential loss of individuals between undergraduate and PhD – potential requirement for intervention at PhD level (although differences in opinion in responses).
- Lack of suitable candidates at early, mid and senior career stage even for centres of excellence
- Salaries in academic research not attractive to individuals with this background

Respondents identified the following needs for training in the UK:

- Improve retention in UK by training at early career stage
- Limited global market of individuals, difficulty in recruiting from UK and overseas, even for centres of excellence

Respondents cited the following current interventions:

- Good postgraduate training available at UK universities (discrepancies in responses)
- UK Health Economics Study Group – biannual conference for health economists
- MRC early career fellowships in economics of health at early post-doctoral level
- NIHR support at Masters level
- Co-funding of PhD students by industry

Respondents' suggestions for possible interventions included:

- National network for early career researchers to support retention
- More early career support to attract individuals to this career path
- MRC and NIHR to partner to maintain early career support, including at masters level
- Support interdisciplinary training for researchers (in both directions)

Clinical interface, including translational research**Respondents cited the following reasons for vulnerability:**

- General
 - Limited individuals to bridge gap between basic and clinical interface due to limited numbers who have experience of both basic and clinically applied approaches (example cognitive neuroscience)
 - Translational interface unattractive career path due to high failure rate of research
 - Lack of career structure, not attractive career pathway
 - Limited representation on evaluation panels of people with integrative background and knowledge of both basic and applied research. Concern that research evaluation does not value applied research.
 - Reduction in industry support for clinical trials
- Clinical
 - Clinicians constrained by regulatory approach to training within the NHS – difficulty to secure time out of programme to pursue research
 - Reduction in clinical pharmacology and therapeutics registrars from 54 in 2010 to 34 in 2011 and 2013
 - Limited research opportunities for early career clinicians

Respondents identified the following needs for training in the UK:

- Difficulty in recruiting clinicians from outside of the UK due to regulatory requirements
- Local skills in this area key to attract pharmaceutical investment to the UK
- Similar challenges outside of the UK

Respondents cited the following current interventions:

- National Institute for Health Research (NIHR) integrated academic training programme
- EU funding for industry linked research
- PhD programme in palliative care at Lancaster
- MRC clinical pharmacology programme

Respondents' suggestions for possible interventions included:

- Targeted clinical research training fellows linked to key investments
- Increase representation of translational expertise on evaluation panels
- Internships/placements for students to experience applied research
- Expansion of existing training programmes

Imaging, including applied imaging techniques, microscopy and image analysis**Respondents cited the following reasons for vulnerability:**

- Quickly developing field requiring people to advance new developments
- Lack of career structure and support makes attraction/retention of well-qualified staff difficult, particularly for technical/methodological specialists who will not pursue Principle Investigator (PI) route.
- Lack of interdisciplinary staff required to develop new techniques/equipment
- Lack of support/experienced staff and teaching equipment to train new researchers.

Respondents identified the following needs for training in the UK:

- Limited pool of expertise internationally
- Require crucial mass locally to respond to new opportunities and retain talented individuals in the UK

Respondents cited the following current interventions:

- Some capacity building taking place (post-doc training courses, across networks of excellence, via EuroBioImaging, summer schools) but more needed.
- Some success of training via networks of excellence (e.g. SINAPSE)
- Attempts to recruit individuals with mixed research/technical development role and training position – funding such posts currently challenging

Respondents' suggestions for possible interventions included:

- Targeted interdisciplinary studentships as part of broader capacity building programme (e.g. MRes, summer placements, industry links)
- Better definition of career paths, more support and recognition, particularly for 'non-PI' staff.
- Focussed funding for research and training across Centres of Excellence

ANNEX 2: MATHS, STATISTICS & COMPUTATION

Headline messages:

- Data analytics, especially bioinformatics, appear to be particularly vulnerable
- Informatics skills are applicable to many areas of both the biosciences and the medical sciences
- Maths, statistics and computational biology skills are lacking particularly at the postgraduate and postdoctoral levels, with many respondents reporting difficulties in recruiting adequately skilled researchers at these levels; shortages are not just restricted to the UK

Responses by organisation type:

Organisation type	Responses
Academic	56
<i>Of which HEI</i>	37
<i>Of which Intramural</i>	15
<i>Of which Network</i>	4
Industry	1
Other	3
Society	3
Grand Total	63

Subject areas of concern within this category:

- **Statistics (12 responses):** including statistical methodology development, statistical genetics, statistical support and underpinning statistical skills.
- **Bioinformatics (26 responses):** including bio(medical) informatics, neuroinformatics and bioinformatics with wet lab skills
- **Other data analytics (25 responses):** including computational biology, modelling, software development, data linkage as well as general skills required to utilise large data sets (interpretation, storage, programming).
- These skills could be applied to a variety of data sources, including 'omics' data, health records, biophysical data, imaging data. (Fields also mentioned: epidemiology and neuroscience)

Respondents cited the following reasons for and levels of vulnerability

Darker colours indicate higher numbers of respondents citing reason / level

	Under-grad	MSc	PhD	Post-doc. Res	Independent Res.	World leading Res.	Other	Total by reason
Age	2	5	4	5	7	6	0	29
Career paths	5	10	17	20	17	9	1	79
Current numbers	4	14	37	38	33	29	3	158
Diversity	2	3	9	11	10	9	1	45
Future supply	4	12	30	32	32	30	1	141

	Under-grad	MSc	PhD	Post-doc. Res	Independent Res.	World leading Res.	Other	Total by reason
New area	7	14	23	26	23	18	2	113
Recruitment	7	17	36	42	38	31	2	173
Retention	3	7	20	30	25	17	0	102
Training	13	23	32	22	15	8	1	114
Other	0	1	1	1	0	0	0	3
Total by level	47	106	209	227	200	157	11	957

- Concern about recruitment, retention, current numbers and future supply from PhD to world-leading research across the category of maths, stats and computation.
- Both statistics and bioinformatics require operational and research support roles – concern was raised about quality and provision of both.

Respondents cited the following reasons for vulnerability:

- New fields and increase in data availability (e.g. from genomics) provides new opportunities and need for more trained individuals.
- Competition for skill set from other high-throughput industries, such as banking.
- Lack of clear career path for 'core' staff making this an unattractive career path.
- PhD positions receive healthy numbers of applications, but with limited UK applicants with right experience for PhD in informatics areas and able overseas applicants often not eligible for RCUK studentships.
- Limited well-qualified applicants to post-doctoral and senior positions. Salary restrictions, particularly in MRC Units, make it difficult to offer attractive posts to most qualified candidates.
- Concern that undergraduate debt will deter undergraduates considering Masters training. Limited Masters funding to up-skill undergraduates ahead of PhD. Undergraduate courses not delivering the skills required.
- Need for increased knowledge within existing principle investigators and post-doctoral staff. Training courses at post-doctoral level limited in high demand and limited supply.
- Need for more interdisciplinary knowledge across the area, with individuals able to understand data analytics, mathematics, informatics and statistics as well as wet lab and clinical research.

Respondents identified the following needs for training in the UK:

- At training level:
 - Individuals from overseas may not be retained in the UK following training
 - Restrictions on eligibility for international candidates on RCUK studentships
- At researcher level:
 - Significant international recruitment already occurring, but international shortage in this area means international recruitment not viable
 - Shortage recognised by inclusion of bioinformatics on Home Office's Shortage Occupation list.

Respondents cited the following current interventions:

A range of interventions are already offered, but there was overall concern about the low scale of interventions offered and their integration into the biological and medical sciences. Interventions mentioned include:

- Training awards:
 - MSc programmes to reskill
 - PhD programmes
- Post-doctoral training at a number of different research institutions
- Short courses developed by the European Bioinformatics Institute (EMBL-EBI), Wellcome Trust, EMBO and others, including local and international training programmes
- Broader/Larger scale programmes:
 - ELIXIR-UK – planning UK-wide genomics training
 - GOBLET – international coordination of bioinformatics learning
 - MRC FARR Institute, networks and Trial Hubs

Respondents' suggestions for possible interventions included:

- Early training/support
 - Support for training at early stage via bursaries for short course/Masters/PhDs to increase pool of entrants
 - Widen eligibility criteria for training positions to EU/international students
 - Encourage more training provision internationally to build global pool of candidates
 - Increase support for early post-doctoral positions to retain those in the field
 - Provide increased support to enable change of field (e.g. from numerical to biological disciplines)
- Centres and training courses
 - Establish national Centres of excellence / hubs that can provide long term support and training, e.g.:
 - Online/e-learning resources
 - 'Lecturers' dedicated to area of training
 - Modules of training that can be incorporated into degrees or provided to more senior users
 - Workshops and courses
- Career interventions
 - Provide better defined career paths and highlight at an earlier age
 - Audit skills of the workforce to develop strategy to address gaps
- Other
 - Recognition/reward of training provided by active scientists
 - Embed core numerical skills earlier (schools, undergraduate) and throughout career.

ANNEX 3: PHYSIOLOGY, PATHOLOGY AND PHARMACOLOGY

Headline messages:

- Concerns about the future supply of individuals with skills to work with whole animals and with a holistic understanding of the physiology of laboratory / farmed animals.
- In vivo work has unusually high costs required for infrastructure, welfare regulations, safety and maintenance. Such costs inhibit the development of these skills at undergraduate levels.
- Strong academic and industrial needs for all areas.
- Veterinary pathology is a 'niche' research skill that lacks an adequate career structure for these highly skilled individuals.
- MRC and BBSRC have collaboratively provided considerable support for the development of these individuals and now that funding commitments are coming to an end there is concern that supply will 'dry out'. There is a strong desire for sustainable, long-term support.
- General lack of expertise / capacity and career structure in the UK and worldwide in many aspects of microbiology, including basic through to applied research and training, physiology and taxonomy.
- Links with other technologies including data analytics, genomics, host-pathogen interactions (including plant pathology), biology-chemical interface.

Respondents by organisation type:

Organisation type	Responses
Academic	37
<i>Of which HEI</i>	22
<i>Of which Intramural</i>	11
<i>Of which Network</i>	4
Industry	1
Society	3
Other	1
Grand Total	42

Subject areas of concern within this category:

- **Whole animal and in vivo physiology (22 responses):** including veterinary pathology
- **Microbial physiology (8 responses):** including fundamental microbiology, virology, environmental microbiology
- **Other aspects of physiology and pathology (12 responses):** including reproductive biology, behavioural biology, immunology, toxicology, wound healing, molecular pathology, mouse pathology

Respondents cited the following reasons for and levels of vulnerability

Darker colours indicate higher numbers of respondents citing reason / level

	Under-grad	MSc	PhD	Post-doc. Res	Independent Res.	World leading Res.	Other	Total by reason
Age	2	2	2	4	11	10	3	34
Career paths	6	9	19	23	17	8	3	85
Current numb.	7	9	14	17	15	12	3	77
Diversity	1	3	4	4	5	3	1	21
Future supply	7	8	18	21	21	19	5	99
New area	3	4	5	7	7	6	1	33
Recruitment	6	7	20	29	25	20	4	111
Retention	1	1	4	17	15	10	4	52
Training	12	12	17	17	11	7	5	81
Other	0	0	0	0	0	0	0	0
Total by level	45	55	103	139	127	95	29	593

Working with whole animals and in vivo physiology

Respondents cited the following reasons for vulnerability:

- Pressure on HEIs:
 - Very high costs and increasingly stringent regulations affecting facilities, welfare and safety for the maintenance of animal models or for human experimentation
 - Change to UK pharmaceutical industry, which was a major training environment, puts onus now on Universities
 - Lack of skills reduces capacity for *in vivo* teaching
- Lack of skills needed by both academia and industry:
 - People trained in industry (1-2 people p.a.) rarely move to academia
 - Very few students gain experience of hands-on *in vivo* science at either undergraduate or masters level
 - Lack of understanding of integrated systems
 - Integrative Mammalian Biology (IMB) Centres built capacity in the short term – still a shortage of researchers at all levels with skills
 - Specific lack of skills and training in: small animal surgery; recovery surgeries; microsurgery and microinjection; *in vivo* electrophysiology; generation of complex mouse models; systems neuroscience (animals)
 - Skills required for new and emerging areas of research, e.g. regenerative medicine
- Lack of training opportunities:
 - No issue with lack of interest but not enough funded studentships, workshops, courses or lab visits in the area – at all levels
 - Limitations in numbers of suitable trainers
 - Studentships not funded to required level to allow for *in vivo* projects
 - Lack of major industry investment
 - Training for veterinary pathologists in the UK is *ad hoc* and mostly within vet schools or on the job
- Lack of career structure:
 - No clear career paths for researchers or technicians; few full time posts in research pathology

- Very small number of PhD students are veterinarians – even fewer will become future research leaders
- Lack of longer term funding means trained researchers move to industry roles rather than stay in academia
- Lectureships in universities (to retain qualified researchers) are becoming increasingly competitive
- Several key researchers in this area have retired recently or are approaching retirement age - lack of succession planning
- Stigma around use of animals in research
- Need for an integration between veterinary and medical pathologists

Respondents identified the following needs for training in the UK:

- *In vivo* sciences are a critical part of the UK biopharmaceutical, academic and health sectors – the quality of translational research in the UK would drop if researchers with these skills diminish
- UK has excellent infrastructure to provide highest levels of skills and ethics
- Worldwide shortage so difficult to recruit from abroad; researchers rarely have adequate levels of skills, especially in certain areas such as histopathology
- People trained in the UK are often recruited to the US – if there were more UK trained individuals they would be more likely to stay in the UK and build up expertise over a prolonged period of time
- Staff recruited from abroad require a period of training to familiarise them with UK legislation and working practices
- Loss of expertise will hamper translational research – cannot rely on external supply

Respondents cited the following current interventions:

- Integrative Mammalian Biology (IMB) Centres (including funding from BBSRC, MRC and others); this funding has now come to an end
- British Pharmacological Society (BPS) administered the IPF (Integrative Pharmacology Fund), a £4m donation from AstraZeneca, Pfizer and GSK with the aim of supporting high quality research and training in UK universities. It has supported the following:
 - *in vivo* teaching courses, co-funded PhD research students and academic fellows
 - bursaries for MRes programmes with a particular focus on *in vivo* research at 3 universities
 - pump priming grants which enable early careers researchers to pioneer new *in vivo* techniques and therefore gain other grants as a result
- Joint BPS and Physiological Society Short courses in *in vivo* Pharmacology and Physiology techniques – established in 2004 for training at undergraduate and postgraduate levels. Three intensive (hands-on) courses run each year (at Bristol, Glasgow and KCL) and until 2011 trained a total of 27 students per annum. The scheme was expanded to 5 courses in 2012 to train approximately 50 students per annum. The funding (from BBSRC, MRC, Wellcome Trust and the Integrative Pharmacology Fund) is ending this academic year (2014/15).
- Vesalius Clinical Training Centre at the University of Bristol provides CPD training to up to 50 individuals at a time in surgical and non-surgical techniques
- British Association of Psychopharmacology has started a scheme offering up to £500 for summer interns to work on a short project involving behavioural-pharmacological studies in experimental rodents.

- Training for mouse genetics: establishment of Harwell Training Facility (HaTF) - Mouse Models for Human Disease. Development of current training for PhD students and early career researchers, both within MRC Harwell and more widely in the UK.
- Royal Veterinary College (RVC) / Wellcome Trust intercalated veterinary pathology BSc course
- 10 training posts in veterinary pathology in the UK p.a. – all funded *ad hoc* and mainly in the vet schools focussing on diagnostic pathology
- British Society of Toxicological Pathology (BSTP) provide continuing professional development (CPD) workshops to augment training in toxicological pathology and the Wellcome Trust has supported a biannual workshop at Hinxton
- Development by University of Edinburgh of a Centre for Comparative Pathology – to provide comprehensive training for both vet- and human-pathologists
- Small number of UK charities offering support for veterinarians to undertake PhDs (e.g. Horserace Betting & Levy Board)
- Wellcome Trust offers a scheme to support clinicians, veterinarians and dentists wishing to undertake PhDs.
- Wellcome Trust Intermediate Clinical Training Fellowship – supports vets at the postdoctoral level.

Respondents' suggestions for possible interventions included:

- Sustainability and long term planning:
 - Renew Research Council funding to maintain current programmes of training
 - Support training packages in partnership with the Wellcome Trust, learned societies, industry and NC3Rs
 - Underwrite the costs of Home Office license training and renewal for PhD students
- Apprenticeships, internships and technical training:
 - Consider a degree accreditation or certification scheme, with learned Societies
 - Targeted apprenticeship schemes with support for follow on posts, potentially via the Science Industry Partnership
 - Offer competitive, structured 3-month internships in industry for postgraduates
 - Support for technical training in animal histology/necropsy and a similar career path at NVQ level for staff
- Postgraduates:
 - Ring fence cohorts of focused research studentships within training centres
 - Provide research expenses to supplement studentships; guarantee top-up funding prior to recruitment rather than having to apply for it afterwards
 - Provide funding for others to run workshops, conferences and lab visits, aimed at PhD and post-doctoral researcher level researchers at reduced (subsidised costs)
 - In partnership with funding councils, learned societies and industry, support priority area PhDs, summer placements and MRes
 - Joint funding initiative for funded studentships and/or research collaborations which address the pathology skill gap
 - Call for a national agreement that full economic costs for use of animal facilities are not routinely charged for training, particularly at those institutions holding RCUK-funded studentships and/or doctoral training grants
- Research capability and senior positions:
 - Create academic posts (Lectureships / Chairs) devoted to *in vivo* experimentation and the skills required for the target testing in complex models

- Reinstate studies of brain-behaviour relations in animal models as a strategic priority
- Provide 1-2 year “pilot” grants (including staff support) to generate preliminary data / establish key methodological approaches for project grant applications for studies of brain-behaviour relations in animal models
- Improve representation on research committees of people with adequate integrative background to be able to assess mechanism-based translational research proposals
- More support for veterinarians to undertake MSc, PhD and post-doctoral research
- Postdoctoral support for veterinary researchers: bulk funding to institutions, personal awards for promising individuals or thematic funding for specific research questions
- Support career structures for researchers with veterinary expertise
- A career path of competitive Professional/Technical Career Development Fellowships in parallel with research fellowships
- Support for establishment of a UK Centre for Comparative Pathology
- Other support mechanisms:
 - Public engagement activities highlighting the positive effect of work to date on the UK economy
 - Develop a high profile internationally relevant job vacancies web site to attract in the best people from abroad
 - Put pressure on Home Office to reduce the burden of the regulations on researchers
 - Help 'de-stigmatise' animal research as an essential component of new medicines development
 - Targeted support for training posts in laboratory animal pathology, probably as collaborations between research organisations and the veterinary schools
 - Discuss needs with end users (industry)

Microbial physiology

Respondents cited the following reasons for vulnerability:

- Difficulty in recruiting microbiologists at all levels
- Lack of coherent career structure beyond PhD
- Environmental microbiology and other niche areas not seen as attractive area to specialise; little content in undergraduate courses so lack of interest at early stage
- Reliance on long-term commitment e.g. for culture collections – they cannot be replaced once gone
- Microbiology underpins many areas including food security, environmental research (such as bioremediation), all levels of biotechnology
- Decreasing number of both clinical and non-medical academic virologists in the UK – shift to general infectious disease training

Respondents identified the following needs for training in the UK:

- Lack of expertise worldwide
- UK talent and infrastructure needs nurturing
- Developing collaborations outside the UK will also be important

Respondents cited the following current interventions:

- Professional societies are aware and incorporate issue into scientific meetings and conferences where appropriate
- EU Horizon 2020 programme has highlighted microbiology and infectious disease as a priority for future research

Respondents' suggestions for possible interventions included:

- Create longer term stability and support for career structures through:
 - General increase in capacity – specific call for grant applications in microbial physiology and other basic microbial research (including virology)
 - Support of early- to mid-career researchers to help establish new groups in the longer term (at expense of PhDs if necessary)
 - Re-training opportunities to increase numbers of PIs, including senior fellowships
- Need for community of vets and medics in area of zoonotic threats; career development opportunities including senior fellowships; work in partnership with private and public sector diagnostic labs.
- Long-term career opportunities will attract people
- Increase emphasis on basic research, including for molecular biology of viruses; ensure coverage of research that risks falling between remit of MRC and BBSRC

Other aspects of physiology and pathology**Respondents cited the following reasons for vulnerability:**

- Toxicology: large reduction in MSc and PhDs; lack of postdocs with toxicology skills; difficult to recruit and retain experienced toxicologists
- Reproductive biology: little knowledge in human embryology which is substantially different from mouse embryology; those trained in human embryology work in human infertility sector and do not engage in research; retirement of senior scientists has resulted in complete lack of semen cryopreservation research in the UK
- Wound healing: reduced funding including cuts from government in science, technology, engineering and mathematics (STEM); lack of funding to provide adequate training at PhD level; requirement of interdisciplinarity
- Behaviour: loss of basic laboratory facilities leading to cessation of training opportunities at undergraduate and postgraduate levels
- Immunology: recruitment difficulties at early career stages

Respondents identified the following needs for training in the UK:

- Toxicology: Need to nurture excellent UK skills base; worldwide lack of skills; students trained in UK are recruited abroad; support for re-growth of UK pharmaceutical industry
- Reproductive biology: worldwide shortage; visiting scientists unlikely to establish long-term research groups in the UK
- Behaviour: loss of UK expertise will contribute to brain drain in neuroscience more generally, with many postdocs taking positions in the US
- Immunology: worldwide shortage

Respondents cited the following current interventions:

- Wound healing: The British Skin Foundation have a fellowship scheme but a shrinking pot of money and increased applications makes them very competitive
- Reproductive biology: The British Andrology Society runs an annual course for technicians working in infertility laboratories, aimed at maintaining operating standards (about 8 people p.a.)
- Behaviour: the British Association for Psychopharmacology (BAP) runs annual workshops in preclinical behavioural pharmacology but (reflecting the reduction in PhD students and Postdocs) attendance has declined in recent years. Publication in 2013 of an advisory booklet entitled 'Guiding Principles for Behavioural Laboratory Animal Science'.

Respondents' suggestions for possible interventions included:

- Toxicology: more interdisciplinary PhDs relating to toxicology; interaction with industry through Industrial CASE; support for career pathways through creation of postdoctoral positions
- Wound healing: support for fellowships in partnership with British Skin Foundation
- Reproductive biology: increase grant funding; support the strengthening of quality assurance mechanisms for infertility clinics; provide financial support for trainers on British Andrology Society course
- Behaviour: greater support for the high costs associated with behavioural research involving animals, including dedicated laboratory facilities and high animal maintenance costs; infrastructure funding specifically for the reinstatement of behavioural research labs and/or the modernisation of existing behavioural facilities; ring-fenced research studentships for projects that are predominantly behavioural in focus
- Immunology: balance between numbers of PhDs and fellowship / postdoc opportunities; increase support costs of PhDs

ANNEX 4: AGRICULTURE AND FOOD SECURITY

Headline messages:

- Long term decline and shortages in plant- and field-based studies
- Ageing population and lack of succession planning
- Shortages are worldwide, not just in the UK
- Need for continued building of links between academia and industry
- Includes several 'niche' areas where there is high strategic importance but only a small number of individuals are needed, e.g. forestry, plant breeding, entomology

Responses by organisation type:

Organisation type	Responses
Academic	18
<i>Of which HEI</i>	11
<i>Of which Intramural</i>	7
Industry	6
Other	1
Society	8
Grand Total	33

Subject areas of concern within this category:

- **Agricultural and plant sciences (12 responses):** including agri-engineering, agronomy, crop science, plant breeding, plant physiology
- **Pests and diseases (11 responses):** including acarology, entomology, mycology, plant pathology, weed biology
- **Forestry (4 responses):** including tree pathology
- **Food and nutrition (6 responses):** including sensory science, human and livestock nutrition

Respondents cited the following reasons for and levels of vulnerability

Darker colours indicate higher numbers of respondents citing reason / level

	Under-graduate	MSc	PhD	Post-doctoral researcher	Independent researcher	World leading researcher	Other	Total by reason
Age	2	2	4	8	18	14	1	49
Career paths	7	7	13	16	11	3	2	59
Current numbers	15	10	18	20	16	17	2	98
Diversity	6	2	4	10	8	7	0	37
Future supply	15	16	22	24	18	16	1	112
New area	3	2	4	7	5	3	1	25
Recruitment	18	13	20	19	16	14	0	100
Retention	5	3	7	15	14	8	1	53

	Under-graduate	MSc	PhD	Post-doctoral researcher	Independent researcher	World leading researcher	Other	Total by reason
Training	18	17	18	18	4	3	2	80
Other	0	0	0	0	1	0	1	2
Total by level	89	72	110	137	111	85	11	615

Agricultural and plant sciences

Respondents cited the following reasons for vulnerability:

- Long-term decline in crop sciences – little capacity within HEIs to teach, many senior academics have now retired and not been replaced
- Difficulty in attracting students and early career researchers, especially to field-based studies
- Many people who are trained in the UK do not stay in academia or move to work abroad
- Current Advanced Training Partnerships do not meet the needs of academia or industry in certain highly specialised areas such as plant breeding
- Much evidence has been provided in the UK Plant Sciences Federation’s “UK Plant Science” status [report](#) (published Jan 2014)
- Concerns over lack of development of new agrochemicals – move to development of novel biologics but lack of core skills such as product chemistry and bioinformatics

Respondents identified the following needs for training in the UK:

- Shortage is worldwide, not just UK
- For plant breeding in particular there is a global shortage (only about 200 in the UK) and the few people who are trained are often recruited in / to the US. The UK needs about 12 new plant breeders each year.
- EU employment laws make it difficult to recruit people from USA / Asia

Respondents cited the following current interventions:

- In-house training and work based learning
- There are a few existing short courses but there are not many of them and there are few opportunities at more senior levels
- MSc in Plant Genetics and Crop Improvement (at University of East Anglia and John Innes Centre) includes plant breeding – but is at risk of losing support as it currently relies on charity
- Current plant science summer schools are helping attract younger people in
- Gatsby Charitable Foundation provides PhD studentships across the plant sciences
- New Phytologist Trust sponsors a next generation science conference for graduate students in the plant sciences

Respondents’ suggestions for possible interventions included:

- Create clear career pathways for crop and plant scientists: wider consultation with industry; support work based learning; attract and retain high calibre research leaders
- Specific training: MSc in plant breeding; basic agronomy training at research institutes
- Support and increase (publication) impact of field experimentation, sites and facilities

- Sustain current funding (e.g. AgriNET, SARIC and CIRC) longer term
- Work with other organisations to promote plant science in the UK, especially at schools level
- Fund apprenticeships, employer-led training, industrial studentships and teaching fellowships

Pests and diseases

Note that plant pathology is also relevant to agriculture and plant sciences described above, and tree disease is included under forestry research.

Respondents cited the following reasons for vulnerability:

- Grave shortage of appropriately trained scientists – few places that can offer the training needed and few people being trained
- Substantial long-term decline in undergraduate teaching of these areas and disinterest due to lack of exposure at earlier levels
- Age profile a major concern
- Increased demand for expertise because of evolution of pesticide resistance
- Need for more stringent regulation
- Research often does not lead to high impact publications or highly competitive grant proposals
- Research Council committee structure is biased against whole organism biology
- Need for combined expertise of microbiology and zoology

Respondents identified the following needs for training in the UK:

- UK should have the capacity in scientific expertise it needs to fulfil social and economic targets
- UK has an unusual climate in relation to its latitude and therefore unusual growing conditions for crops, therefore need relevant expertise within the UK
- New EU regulations which affect sales or use of pesticides will require greater specialist expertise – already resulting in increased demand for plant pathology expertise throughout Europe
- In acarology, other countries have same problem

Respondents cited the following current interventions:

- Gatsby Summer School and British Society of Plant Pathology support for undergraduate summer vacation bursaries – have attracted several PhDs to plant pathology
- Royal Entomological Society awards three scholarships at MSc level and supports travel and outreach activities including international symposia
- Horticultural Development Company awards three scholarships at MSc level in Integrated Pest Management
- Agriculture and Horticulture Development Board is supporting weed science with funding the remaining active research groups (including relevant engineering) and attempting to develop a training fellowship by way of succession
- The British Mycological Society has a small number of guides to practicals in mycology for primary, secondary, and university students; they also run scientific meetings on various topics in mycology

- The Wellcome Trust has given a strategic award to the Medical Mycology and Fungal Immunology Consortium to promote medical mycology research and increase public understanding of the clinical importance of fungal infections

Respondents' suggestions for possible interventions included:

- Broaden life science teaching in UK universities
- Encourage updated policy to reflect legislative changes
- Strengthen industry-academia links
- Support accredited MScs in Plant Pathology
- Ring fence appropriate training money including fellowships
- Provide funding for fundamental entomological science, especially in areas like taxonomy/systematics, including molecular taxonomy, population genetics studies and functional genomics studies
- Fund international collaborations at full grant level or more grants to develop collaborations that may lead to full funding
- Targeted capacity building through establishment of a multidisciplinary research / training centre

Forestry

Respondents cited the following reasons for vulnerability:

- Very little HE research in forestry and what there is mostly relates to overseas forestry
- Recruitment of undergraduates is a concern
- Shortage of postdoctoral level research skills
- Concern that consolidation in the HE sector is leading to generic qualifications that do not differentiate forestry – has implications for the profession as well as for recruitment of researchers
- Forestry Commission's forest research agency is the smallest Government Research Institute and faces an uncertain future as the Forestry Commission is undergoing institutional change
- Need for postdoctoral specialists rather than multidisciplinary. In-house training no longer possible due to Forest Research Agency's budget cuts.

Respondents identified the following needs for training in the UK:

- UK forestry has particular characteristics related to the history of post-glacial colonisation and also socio-economic factors
- European countries also have recruitment and retention difficulties

Respondents cited the following current interventions:

- Institute of Chartered Foresters is trying to co-ordinate better communication and resource-sharing in the HE sector and to help with recruitment e.g. through accreditation and promotion
- Some attempts at Continuing Professional Development (CPD) but there are limited resources for this

- Some highly applied PhDs are sponsored by the wood-processing sector at Napier University and Herriot Watt and historically a few CASE studentships dealing mostly with social science issues
- No forestry-specific initiatives aimed at the doctoral and postdoctoral level to encourage potential researchers

Respondents' suggestions for possible interventions included:

- Forestry-specific PhDs
- Support careers by recognising impact of forest research
- Intervention at EU level – support collaboration

Food and nutrition

Respondents cited the following reasons for vulnerability:

- Becoming harder for industry to recruit at undergraduate or masters level – not seen as an attractive career choice at the undergraduate level
- Insufficient individuals available to meet requests for placements opportunities and jobs in industry
- Lack of suitably qualified UK postdoctoral / senior researchers; general lack of capacity

Respondents identified the following needs for training in the UK:

- Increasingly difficult to recruit a UK student who meets eligibility criteria
- Career progression can become dependent on ability / willingness to relocate to other research centres, e.g. in a multinational company
- Global placements are rare – need to sustain skills & expertise irrespective of origin of individual(s) participating to progress the expertise
- Companies have nowhere to go in the UK for high quality nutritional research in well-equipped facilities on a scale that is necessary
- Deficit of active livestock nutrition research in the UK - commercial work is undertaken overseas and may not be directly relevant to the UK
- Some recruitment from abroad currently

Respondents cited the following current interventions:

- Summer placements in industry
- Tailored training programmes and networking events
- A very small number of PhD studentships (hard to fill), one-year placements and graduate placements
- Some aspects are covered by training programme at University of Nottingham
- An attempt under the Agri-Tech Centres for Agricultural Innovation to establish a capability for both ruminants and monogastric species

Respondents' suggestions for possible interventions included:

- Continue supporting links with industry, e.g. student participation in Modular Training Partnership and Advanced Training Partnership programmes; early involvement of research

students in collaborative projects; subsidies for training courses and studentships part funded with industry; continued support for Industrial CASE Partnership awards (ICPs)

- Capacity building in university sector, especially with key institutions that have some remaining legacy of capability: targeted grants / initiatives
- Assessment of industry/commercial requirement with a long-term perspective and linked to health, welfare and particularly realising the benefits of advances in genetic potential.

ANNEX 5: CORE RESEARCH AND SUBJECT SPECIFIC SKILLS

Headline messages:

- There is some on-going concern about levels of core research skills, including those relating to interdisciplinarity (described in more detail in Annex 1, page 7) and numeracy (which underpin but are separate from maths, statistics and computational biology skills described in Annex 2, page 13).
- The inadequacy of numeracy skills in researchers results from a lack of sufficient input at the school and undergraduate levels.
- Taxonomy skills continue to be a concern, with a lack of future supply of individuals; intervention is needed at the school and undergraduate levels.
- Several respondents described the need for better training and career structure for (academic) early career researchers. Such support would be at the expense of funding for postgraduates.

Respondents by organisation type

Organisation type	Responses
Academic	29
<i>Of which HEI</i>	19
<i>Of which Intramural</i>	4
<i>Of which Network</i>	6
Society	7
Industry	0
Other	1
Grand Total	37

Subject areas of concern within this category:

- **Core research skills (13 responses):** including numeracy, experimental design, research conduct/ethics, science communication, team working, core research skills for clinicians, entrepreneurship
- **Subject specific skills (17 responses):** including those which do not fit within other categories, such as those for research in dentistry, mental health, malaria, single cell genomics, stroke, taxonomy (5 responses), flow cytometry, pre-mRNA splicing, genetic epidemiology, oncology
- **Other vulnerabilities within the bioscience and medical sciences (7 responses):** including vulnerabilities in the career pipeline, fundamental research and public health

Respondents cited the following reasons for and levels of vulnerability

Darker colours indicate higher numbers of respondents citing reason / level

	Under-graduate	MSc	PhD	Post-doctoral researcher	Independent researcher	World leading researcher	Other	Total by reason
Age	2	2	4	5	5	5	0	23
Career paths	4	6	8	12	12	7	1	50
Current numbers	6	8	7	9	8	6	0	44

	Under-graduate	MSc	PhD	Post-doctoral researcher	Independent researcher	World leading researcher	Other	Total by reason
Diversity	1	2	3	5	5	3	0	19
Future supply	6	6	10	12	13	10	1	58
New area	2	2	3	5	5	5	1	23
Recruitment	4	7	12	13	12	10	0	58
Retention	0	4	10	11	8	7	0	40
Training	5	6	10	11	9	5	0	46
Other	0	0	0	0	0	0	0	0
Total by level	30	43	67	83	77	58	3	361

Core research skills

Respondents cited the following reasons for vulnerability:

- Numeracy and experimental design (including design of complex clinical trials): fewer students are obtaining A-level maths – more maths training is needed at schools level. Emerging areas such as systems biology and bioinformatics require underpinning mathematical skills; there is a need good experimental design in research relating to animal welfare and the 3Rs. Lack of training opportunities to support this.
- Very few medical technology entrepreneurship training programmes in all of Europe, yet this knowledge base is crucial for anyone working in the area.
- Lack of researchers with ability to articulate purpose and impact of their research to policymakers, the public and others.
- Lack of interdisciplinary / team-work training at undergraduate / postgraduate levels.
- Success measured on numbers of individual successes rather than working with a large team on a project.
- Lack of emphasis on research training at undergraduate / postgraduate levels for clinicians.
- No requirement for 3Rs training beyond the modules needed for the Home Office licence.

Respondents identified the following needs for training in the UK:

- Worldwide shortage of numerate graduates. Implications for both academia and industry – lack of skill affects UK competitiveness.
- Lack of communication skills in UK researchers creates a barrier to wider engagement, understanding, collaboration and advocacy.
- Need for research skills among all clinical staff within NHS – cannot be addressed by recruiting from abroad.
- Risk of UK falling behind other European and international countries that are proactively addressing shortage of skills in experimental design.

Respondents cited the following current interventions:

- Summer schools and internships:
 - BCA/CCP4 Summer School every year at Diamond and St Andrews (alternate years). This course is targeted to PhD students who have completed ~1 year of basic crystallography and offers about 40 places.

- Research Council and learned society support for undergraduate research experience placements involving underpinning mathematical skills.
- Research Council Policy Internships help address communication skills.
- Technical training:
 - University of Bristol is now running a series of four free tutorials to provide training in computational simulations through CCP-BioSim.
 - National Institute for Health Research (NIHR) acknowledges the strategic importance and shortage of clinical trial expertise. However, this funding stream only applies to existing NIHR Trainees and further training within the setting of a Clinical Trials Unit (in receipt of NIHR CTU Support Funding).
 - EU-wide consortium of universities beginning to train the next generation of medical technology entrepreneurs. UK members include Imperial College, Newcastle University and Bristol University.
 - RSPCA have received approval to run a pilot two-day course entitled 'Animal Research: Critical, Challenging and Creative Thinking' as part of the Doctoral Skills Development Programme at UCL. This pilot will take place in February 2015. Production by RSPCA of a complete set of educational materials suitable for tertiary and Higher Education (including postgraduate).
- Use of up to 10% of EPSRC DTP for Doctoral Prize Fellowships.
- Europe PubMed Central Access to Understanding science writing competition and development of a web-based resource for researchers and the public.
- CLOSER longitudinal studies programme (backed by MRC and ESRC), which aims to enhance training and capacity building in interdisciplinary life-course research, with a particular focus on equipping researchers to demonstrate impact.

Respondents' suggestions for possible interventions included:

- Support and develop maths skills for Higher Education (HE) students:
 - Work with HE funding bodies to convey importance of developing maths skills prior to undergraduate study
 - Continue to fund current SysMIC online course (currently oversubscribed), although some adaption of content may be required
 - Develop additional online resources (e.g. statistics, recorded lectures) where students can enhance their maths-based training
 - Support interdisciplinary training of PhD students with an emphasis on the development of maths skills
 - Support the development and retention of workshops that enhance or train individuals in these skills
 - Expand the length of Research Experience Placements to help support interdisciplinary projects
 - Incorporate interdisciplinary training at undergraduate level, e.g. through Society of Biology Degree Accreditation Scheme
- 'Topic specific' Centres for Doctoral Training of the sort currently being offered by NERC (but in the area of mathematical / quantitative biology, statistics, modelling) – rather than making it a mandatory requirement of a more general Doctoral Training Partnership.
- Individually tailored CASE studentships, and ring-fenced fellowships, involving high levels of numeracy.
- New degree programmes in medical technology entrepreneurship.

- Fellowship funding for non-degree programmes in the model of Stanford's BioDesign programme.
- Development of researcher training days that help define the framing of research purpose and impact that is mutually beneficial to the consumers, practitioners and decision-makers, particularly in an interdisciplinary context.
- Further training for researchers on methodology, research design, bioinformatics, quantitative skills and computing analytics, as well as management and entrepreneurial skills is needed to capture the broad range of requirements of the medical research sector. Joint working between MRC, NIHR and HEFCE to create a research-ready NHS workforce.
- Continue to support MRC Methodology Fellowships and the MRC Hubs for Trials Methodology Research.
- Collaboration with charities or other partners to provide specialist education and training initiatives, including by influencing existing funding streams.

Subject specific skills

Respondents cited the following reasons for vulnerability:

- Taxonomy – 3 reviews by the House of Lords Select Committee on Science and Technology concluded that more needed to be done to ensure the future health of the area; only one provider of field identification qualifications, the Botanical Society of Britain and Ireland Field Desertification Skills Certificate (FISC). The Natural History Museum offer very limited numbers IdQs. There is no obvious career path in taxonomic research. General lack of funding in the UK for research and training. Taxonomists are ageing and few new people coming through.
- Flow cytometry technicians – difficulties in recruitment and retention
- Pre-mRNA splicing – difficulty in securing funding and suitably qualified postdocs; taught in very few HEIs leading to poor recruitment at PhD level; lack of applicants with physical / mathematical background
- Single cell genomics – new and emerging area
- Dentistry – need for clear career pathways for research in the UK
- Genetic epidemiology – limited training opportunities at MSc, PhD and postdoc levels
- Mental health – decreasing numbers of clinical academics and preclinical researchers; reduction in investment
- Stroke research – lack of senior clinical academics and few trainees
- Drug resistance in malaria parasites – reduced UK capacity, insufficient to address threat of drug resistance.

Respondents identified the following needs for training in the UK:

- Taxonomy – skills needed for UK are species / habitat specific; need for UK career path
- Flow cytometry technicians – currently recruit from abroad
- Pre-mRNA splicing – most research done in the USA, not seen as attractive career in UK
- Single cell genomics – UK needs to build quickly on recently established research leadership in the area
- Dentistry – retention of overseas researchers is difficult; need to create career pathways in the UK

- Genetic epidemiology – even individuals recruited from abroad lack the necessary skills and require in house training
- Mental health – substantial regulatory requirements to practice in the UK; very few junior clinicians are from the EU
- Stroke research – recruiting from abroad won't address need for UK expertise
- Drug resistance in malaria parasites – similar loss of capacity in Europe

Respondents cited the following current interventions:

- Taxonomy – New MSc Course, Edgehill University (approx 20 places per year on Conservation Management); existing MSc course, Manchester Metropolitan University (approx 20 places per year on Biological Recording); Field Identification Skills Certificate (BSBI) (approx 60 places per year); Field Studies Council (approx 600 courses per year); Field Studies Council (identification resources - keys and guides); BSBI - field meetings and training events (approx 120 per year)
- Pre-mRNA splicing – improving visibility through biennial meetings and formal networks
- Dentistry – NIHR Research Fellowships must include patient and public involvement and are extremely competitive; projects are usually clinical based and do not fund research solely focussed on underpinning science or development of clinical technologies
- Mental health – Academy of Medical Sciences has produced a report and recommendations

Respondents' suggestions for possible interventions included:

- Taxonomy – funding to ensure there are sufficient field schools to ensure first-hand experience in the environment; reinstate whole organism studies at undergraduate level; work with other funders to re-instate collaborative funding schemes. Use of genome sequence data has the potential to revitalise the area – develop novel funding streams for application of genomics to systematics
- Flow cytometry technicians – support professional technical management as a career choice for technically skilled post-doctoral scientists who do not wish to pursue a career as a PI
- Pre-mRNA splicing – should become a strategic priority for both Research Councils; fund training courses for non-specialists to learn how to teach the subject
- Single cell genomics – establish research and training centre
- Dentistry – more opportunities to fund training of clinical dental researchers whose interests lie in underpinning science and development of clinical technologies
- Genetic epidemiology – More training opportunities at MSc level and at PhD level which are more flexible and decoupled from 4 year PhD programs; suitable master's courses could include Master's in Medical Statistics with modules in genetic epidemiology
- Mental health – Targeted training schemes; infrastructure investment associated with training; increase mental health spend in responsive mode and intramural funding streams; need for political pressure
- Stroke research – support training activities to encourage interdisciplinary skills to be applied to this area; raise profile amongst research community
- Drug resistance in malaria parasites – provision for early- to mid-career researchers

Other vulnerabilities in the biosciences and medical sciences

Respondents cited the following reasons for vulnerability:

- Career pipeline – too many PhDs relative to postdoctoral positions; postdocs staying in post too long; independent researchers who fail to secure grants early are moved to teaching only roles; lack of permanent positions for areas requiring expensive instrument infrastructure
- Fundamental research – increasingly Research Council funding is focussed on programmatic research

Respondents identified the following needs for training in the UK:

- Career pipeline – individuals from abroad represent further competition to UK PhD students
- Fundamental research – need to promote both fundamental science and recruit from abroad; UK needs to retain top overseas scientists

Respondents cited the following current interventions:

- Career pipeline – Cardiff University run a number of courses for PhD students across all disciplines designed to enhance employability; Royal Society provides funding for equipment

Respondents' suggestions for possible interventions included:

- Career pipeline – allocate PhD studentships based on success of obtaining career development awards; additional funding for postdoc positions; further support for transferable skills at PhD level; invest in long term infrastructure / equipment grants
- Fundamental research – more support for basic research; fight to increase science budget to 2.5% of GDP; restore and strengthen PhD as a demanding research degree; emphasise creative fundamental research in grants, rather than top-driven programs; promote significant start-up packages at the Assistant Professor/ Lecturer level to foster new, ambitious, independent research.

ANNEX 6: CONSULTATION QUESTION SET

A. Respondent details

- Society or organisation on whose behalf you are responding
- Web link if possible
- Contact information

B. Vulnerable Research Skill

1. What is the research area or discipline for which you wish to highlight a skills/capability vulnerability?
2. To which funder(s) do you consider this research relevant [BBSRC, MRC, Both BBSRC and MRC, Other: ____]
3. For the identified area, what is the evidence for its strategic importance?
 - If the area addresses known strategic research priorities, please describe how, highlighting interdisciplinarity where relevant.
 - What are the impacts (economic, social, health or academic) of this research skill in the UK?L
4. Please indicate at what level(s) and in what way(s) you have identified a vulnerability in the research area within the last 5 years.
 - Please tick all that apply – options as shown in Table 3, page 6
 - Please provide evidence for your answers below, giving as much quantitative information as possible.
5. Why does this skill need to be enhanced in the UK, rather than by recruiting individuals from abroad? What would be the impact of losing UK expertise in this area?
6. Please tell us about any relevant interventions (that you are aware of) by institutions, companies or professional societies.
 - Please be as specific as possible and consider all appropriate intervention methods, including for example training courses and positions, workshops, networking events, Continuing Professional Development (CPD), summer schools, etc. Please indicate the scale of the intervention if possible (e.g. numbers of training positions available per annum).
7. For the identified area, describe what actions could be taken forward by BBSRC / MRC (in partnership with others, where appropriate) to support the efforts identified in question 6.

C. Option to complete section B for multiple areas