Higher Education in STEM Subjects

A response from The Physiological Society to the House of Lords Science and Technology Sub-Committee 1

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The Physiological Society is a learned society which brings together over 3000 scientists from over 60 countries. Physiology is the study of the normal functioning of genes, cells, tissues and organs and how these in turn influence the whole animal or person. Consequently some physiological research needs to be undertaken on living animals or people so as to integrate the insights that come from studying isolated cells and tissues. Working with living animals or people requires additional skills in the care and welfare of the experimental subjects, on top of the underlying investigative skills needed by all researchers. For animals that combination is generally referred to as 'in vivo skills'.

Since its foundation in 1876, the Members of The Physiological Society have made significant contributions to the knowledge of biological systems and the treatment of disease. Our aims are to support physiologists - from researchers starting out in the field to those that are more established in their career, promote the discipline to ensure it remains at the forefront of biological and medical research, and to raise awareness of physiology among non-specialists. A key focus of our work is to ensure physiology remains an attractive career option and we work with teachers, lecturers and researchers from both academia and industry to achieve this.

Summary

- Physiology is a laboratory based research discipline, involving the study of the normal functioning of genes, cells, tissues and organs and how these in turn influence the whole animal or person, and should always be included with definitions of STEM. As a translational discipline which links work carried out on the cellular level to a whole organism, physiology is crucial aspect of the biomedical and life sciences sector.
- Some specific areas of the biomedical and life sciences sector are vulnerable, and should be considered as 'Strategically Important and Vulnerable Sciences'. This includes training in the use of whole animals in biomedical research including physiology. The specific provision in these areas for Masters and PhD level training, including financial support, need urgent review so as to put this training on a sustainable footing.
- The standard of numeracy and literacy at school leaver stage is far below desirable and with the current funding and length of degree courses it is difficult to catch up to achieve standards of laboratory skills suitable for future careers, especially in research.
- There are number of substantial reforms taking place in Higher Education, and the impacts of these changes are interlinked. As such, it is not easy to predict the outcome and there is concern in the sector relating to the impact these reforms may have upon the national skills base.

General questions

What is the definition of a STEM subject, and a STEM job?

1) This definition can vary in different contexts and organisations, and it is regrettably not always clear what is considered a 'STEM subject'. It is of considerable concern that the term 'biological sciences' may itself not be used in a consistent manner. For instance, biomedical sciences such as physiology are often excluded.
2) HEFCE categorises physiology as a STEM discipline[1], but in other contexts it may be categorized under 'health-sciences', disciplines usually associated with medicine and dentistry and health practice. Physiology is a laboratory based research subject that aim to understand how cells, tissues and organs interact in living systems, and should always be considered a STEM subject.
3) In addition it is of note that physiology, whilst identified by HEFCE as a 'STEM' subject, has never been classified as one of the 'Strategically Important and Vulnerable Subjects' (SIVS)[2]. HEFCE provided additional funding to support STEM based SIVS on the basis that they were "very high cost, strategically important to the economy and society, but vulnerable due to low student demand".
4) Despite the 2009 BBSRC report 'Strategically important and vulnerable area of UK Bioscience Expertise'[3] identifying 'Animal Physiology', including *in vivo* skills[4], as a strategically important skills area that was likely to become vulnerable, HEFCE have not provided additional support to whole animal physiology or to courses that provide training in *in vivo* techniques.
5) Several reports, including from industry[5, 6] and government have highlighted a skills shortage in this area and the need for explicit funding to cover the considerable costs of the training needs.
6) We would urge there to be joined-up and transparent thinking by all institutions involved in the issue of support for STEM subjects from various institutions, including the Government and Higher Education Funding Councils such as HEFCE, as well as other organisations such as the Higher Education Academy (HEA).
7) The Physiological Society has a particular concern about the inconsistent inclusion of biomedical sciences such as physiology. In particular we urge that these laboratory-based disciplines be consistently included under the STEM umbrella.

Do we understand demand for STEM graduates and how this could be used to influence supply?

8) There is widespread agreement on the lack of basic numeracy and literacy skills among graduates of many disciplines. This is of particular concern in vulnerable science areas because of the need for such well-qualified graduates to enter the research profession. There is a need for pressure on both schools and universities to address these failings.

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[1] Strategically Important and Vulnerable Subjects (HEFCE, 2011) http://www.hefce.ac.uk/pubs/hefce/2011/11_24/

[2] http://www.hefce.ac.uk/learning/funding/201213/DefinitionofSIVS_byJACS30.xls

[3] Strategically Important and Vulnerable Capabilities in UK Bioscience, BBSRC Bioscience Skills and Careers Strategy Panel (2009): http://www.bbsrc.ac.uk/web/FILES/Reviews/0905_bioscience_research_skills.pdf

[4] *In vivo* is here taken to refer to research involving the use of living animals, techniques that require a high degree of training to be conducted in a scientifically and ethically appropriate manner

[5] Sustaining the Skills Pipeline (ABPI, 2005): http://careers.abpi.org.uk/your-career/undergraduates/Documents/_publications_pdfs_2005-STEM-Ed-Skills-TF-Report.pdf

[6] Skills Needs for Biomedical Research (ABPI, 2008): http://www.abpi.org.uk/our-work/library/industry/Documents/skills-biomedical-research.pdf

9) More specifically, the bioscience sector has identified some specific gaps in the skills pipeline. Training in the use of living animals in biological and biomedical sciences is one such area of concern to this Society (see below).

Graduate supply

Is the current number of STEM students and graduates (from the UK, EU and overseas) sufficient to meet the needs of industry, the research base, and other sectors not directly connected with STEM? Is the quality of STEM graduates emerging from higher education sufficiently high, and if not, why not?

10) It is not merely the current number of STEM students and graduates that needs to be considered, but also the numbers of STEM students and graduates there are likely to be in the future. Additionally, it is crucial to take into account the skill set of those entering the work-force, as a shortage situation is created if there is a skills gap.
11) Two areas of skills shortage of particular concern to this society are those required for investigating function in whole animals (referred to here as *in vivo* skills) and those required for linking work on the cellular level with the whole human body, a field termed 'integrative human physiology'.
12) Reports produced by ABPI in 2005 and 2008[7], [8] and by the BBSRC in 2009[9] identified undergraduate and graduate skills shortages in physiology and *in vivo* sciences, recommending additional financial support for courses in these areas. These reports, produced before the tuition fee cap was raised identified key concerns specific to physiology that the proposed Higher Education Reforms will only exacerbate.
13) Some exposure to animal based protocols is crucial to inform undergraduates of the options and need for research careers in whole animal physiology, and but there are high financial and administrative burdens associated with providing such exposure. These burdens have been the cause of the substantial decrease in the number of HEI's offering any such practical work as well as in the number of classes by those HEIs still providing some exposure. Those courses with such content that still operate can only do so because of additional funding from industry and/or learned societies, but such support is always short-term, precluding a sustainable basis for the skills provision.
14) As the HEFCE teaching fund is cut and HEI's are encouraged to become more 'efficient', market forces make it very likely that HEI's will chose to cut animal practical classes and *in vivo* training. In addition, with the pharmaceutical sector currently undergoing contraction in the UK, HEI's will find it increasingly difficult to source funds from this sector.
15) Since the release of the reports by ABPI and BBSRC, *in vivo* sciences have seen increased support from central funds. An example of this has been the Integrative Mammalian Biology Initiative (IMBI), in which Research Council (BBSRC and MRC) funding was used in association with charity (Wellcome Trust) and industry funding. However, these programmes and their funding have always been short-term; IMBI funding will be ending in 2012, and the funding shortfall, will leave the sustainability of these centres of specialist expertise very much in doubt.

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[7] Sustaining the Skills Pipeline (ABPI, 2005): http://careers.abpi.org.uk/your-career/undergraduates/Documents/_publications_pdfs_2005-STEM-Ed-Skills-TF-Report.pdf

[8] Skills Needs for Biomedical Research (ABPI, 2008)http://www.abpi.org.uk/our-work/library/industry/Documents/skills-biomedical-research.pdf

[9] Strategically Important and Vulnerable Capabilities in UK Bioscience, BBSRC Bioscience Skills and Careers Strategy Panel (2009): http://www.bbsrc.ac.uk/web/FILES/Reviews/0905_bioscience_research_skills.pdf

16) The skill set associated with integrative human physiologists was also identified above as an area which is currently at risk. Due to a reductionist molecular approach over the last few decades, it is becoming increasingly difficult for integrative human physiologists to get research funding. As PhD students can only be trained in active research laboratories which receive funding, it is becoming increasingly difficult to train this specific type of scientist in the UK. This is problematic as integrative human physiology is crucial for translational work in humans.
17) There is anecdotal evidence from both industry and academia stating that the numeracy and literacy skills of too many bioscience graduates are inadequate for many employers, particularly those involving research, whether in academia or industry. The roots of this are widely perceived to lie in school-level education, where core ability and confidence in numeracy and literacy are lacking in too many university entrants.

What effect will higher education reforms have on the quality of teaching, the quality of degrees and the supply of STEM courses in higher education institutions?

18) The large number of significant Higher Education reforms taking place simultaneously leave many within the sector feeling that it is not possible to safely predict the outcomes for the long-term supply of the graduate skills that the UK needs.
19) The Government announced that it wishes funding to follow students; raising the tuition fee cap to £9,000 whilst simultaneously decreasing the teaching funding supplied through HEFCE. This creates a severe shortfall in finance for laboratory based biomedical sciences, especially *in vivo* science, even when taking into account the additional HEFCE supplement of £1,500 for students taking Band B subjects.
20) High-standard scientific courses with significant levels of advanced practical and laboratory work for students provide the laboratory skills required for research. Therefore these courses are exactly what employers in industry and academia require, and yet without sufficient funding, it is these courses which are likely to suffer. Indeed there is already anecdotal evidence of many HEI's planning to 'rebalance' degree provision from costly laboratory programmes towards courses with a wider profit margin, such as humanities.
21) Providing incentive for HEI's to rebalance away from laboratory based bio-sciences is in direct contrast to statements released by this Government, such as the recently launched 'Strategy for Life Sciences'[10]. Statements such as this recognise that the life sciences is an area in which the United Kingdom is a world leader, and an area from which the Government believe economic growth will come.
22) Physiology is a translational discipline and its practical adoption is a core requirement for research into drug development and other clinical developments, as well as providing an integrative approach which enables understanding of how genomic insights translate into a better understanding of whole organism phenotypes. Without sufficient funding for degrees such as those containing substantial practical physiology and *in vivo* components, the UK's position as a world-leader in life sciences will come under threat. This threat is significant as BRIC countries invest increasingly in building their STEM capacity.
23) We support the call from the Society of Biology for the Government to perform longitudinal studies on the impact of the HE reforms on the willingness of graduates to study STEM subjects at undergraduate and post-graduate levels, as well as the number of those entering into research careers This will provide hard data for the future, and enable Government to monitor

[10] Stragey for Life Sciences (2011): http://www.bis.gov.uk/assets/biscore/innovation/docs/s/11-1429-strategy-for-uk-life-sciences.pdf

any potential loss in skills. This ought to be initiated within this academic year so as to capture data from students prior to the raising of the tuition fee cap.

What effect does "research assessment" have upon the ability to develop new and cross-disciplinary STEM degrees?

24) Many HEIs are reacting already to the Research Excellence Framework, before the final criteria have been set, and it is of concern that many appear to be acting against statements released in the REF documentation. One example of this is that there is anecdotal evidence from our membership that managers within HEI's are putting pressure on academics to publish in high impact journals. This is despite a statement within HEFCE documentation that "No panel will make use of journal ranking or journal impact factors in the assessment"[11]. Given the other changes within the HE sector, it is unsurprising that HEI's are very nervous about the introduction of REF.
25) Neither teaching nor laboratory-based project supervision is recognised within RAE or the new REF, and this is to the detriment of academic departments. With REF being instrumental in the allocation of QR funding, a substantial income source for many HEI's, there is the risk that the perceived importance of teaching will decrease, at exactly the time when Government states it wishes for an increase in teaching standard.
26) Research-informed teaching is beneficial to STEM graduates, both so as to promote a high level skill-set (e.g. critical thinking and problem-solving) and to inculcate an appreciation of practical research gained through exposure to an active research environment.

What is the relationship between teaching and research? Is it necessary for all universities to teach undergraduates and post graduates and conduct research? What other delivery model should be considered?

27) Not all STEM subject teaching needs to take place in a research-active environment. However, where the aim is to produce the next generation of researchers, then it is vital that there is exposure to researchers and first-hand experience of research at undergraduate level. This is so as to (a) train students appropriately and (b) provide them with the insight into research required to guide their future career choices.

What is being done and what ought to be done to increase the diversity of STEM graduates in terms of gender, ethnic origin and socio-economic background?

28) Public perceptions of the new fee structure are such as to dissuade those from less affluent backgrounds from undertaking more arduous and/or longer courses that will both accrue more loans and limit time for part time working. STEM subjects are often both longer, with increased movement towards 4 year MSci degrees, and are likely to be more time consuming (eg. placements requiring full time attendance).
29) Recruitment to STEM subjects from those normally more reluctant to engage will therefore be difficult - especially if there is no major salary incentive for graduates of that subject, as is the

11 Consultation on draft panel criteria and working methods (HEFCE, 2011): http://www.hefce.ac.uk/research/ref/pubs/2011/03_11/03_11.pdf

case for those who enter academia. The future is hard to predict here, but the new system certainly doesn't help.

Post-graduate supply

Is the current training of PhD students sensitive to the range of careers they subsequently undertake?

30) PhD students can only be trained in active research laboratories receiving funding for their facilities from competitive sources. The range of PhD topics on offer, and the techniques used within the course of study, are therefore influenced by the policies of research funders such as research councils and charities.
31) The balance of such research support may or may not align to the specific needs of employers; for instance academic research may look to new techniques that may take many years to be incorporated into industry. However, the core research skills acquired are largely independent of the specific techniques utilised, so the bigger issue is to ensure that PhD training is undertaken in high quality research environment. That is currently broadly the case.
32) A separate issue is that the standard 3 year UK PhD programme is substantially shorter than equivalents in other countries, and UK graduates are therefore sometimes found to be inexperienced compared to their international counterparts, both in terms of research and teaching experience. This can impact adversely on international employment prospects.
33) Some areas of research are more sensitive to this than others, and the *in vivo* sciences are one such. The higher than normal level of training in practical and technical competence cannot adequately be achieved in 3 years, and funders are increasingly (but not universally) recognising that some such areas merit 4 year PhD programmes. This is to be welcomed and encouraged.

Are we currently supporting the right number of PhD studentships to maintain the research base and are they of sufficient quality?

34) The Research Councils are reducing the number of doctorate studentships they offer in STEM subjects, moving towards an increased resource spend per student. Whilst this may be a positive consideration, possibly resulting in an increased skill set acquired by students, and therefore higher quality researchers, there is the risk that the decreased numbers of PhDs will result in a reduction of people looking to enter research careers.
35) Unless closely monitored, any gaps in numbers embarking upon research careers won't be noticed for a few years, by which time it will be a struggle to regain the relevant competency in the national skills base.
36) Achieving a national skills base takes many years. It cannot realistically be adjusted to match the economic cycle and short-term fluctuations in employment prospects. This causes a difficulty, but it is high risk to reduce training whenever there is a downturn in the economy because while the economic bounce-back may be fast (a year or two), replenishing a depleted skills base takes many years.

What impact have Doctoral Training Centres had on the quality and number of PhD students? Are there alternative delivery models?

37) As indicated above, it is essential that PhD training is undertaken in quality research laboratories. Doctoral Training Centres (DTCs) should provide that. However it is a mistake to

assume that there are no high class laboratories outside those with DTC status, and training potential will be seriously curtailed if PhD training is limited to DTCs. [There is also a wider issue of researchers denied funding potential being driven out of low research environments, to the detriment of the teaching and training in those institutions.]

Should state funding be used to promote Masters degrees and is the balance right between the number of Masters degree students and PhD students?

38) This is a large topic that will vary substantially between subject areas and employment prospects.
39) Where an area is accepted as a SIVS, there is a strong case for state funding for Masters level training so as to promote an adequate supply of graduates with subject-specific training either for direct employment or entry onto PhD programmes. The Physiological Society therefore supports the idea of state funding being used to support students undertaking Masters courses, in vulnerable subject areas such as *in vivo* science, although not at the expense of PhD funding.
40) It should be noted that whilst integrated masters qualifications are increasingly being provided at HEI's, these courses are typically 120 credits points, as opposed to the 180 provided by a stand-alone Masters course. Whilst many HEI's in the UK are satisfied these courses provide sufficient training to embark upon a doctoral research degree, it is at the bottom of the Bologna requirements, and therefore seen across Europe as second best.

What impact will higher education reforms have on the willingness of graduates to pursue a research career?

41) Prediction is a dangerous game, and we will only be able to determine actual outcomes quite a few years hence. However, with the undergraduate fee cap raised substantially, there are strong concerns that many students will feel unable to afford to enter into the post-graduate study required for a research career.
42) As mentioned above, many students require a Masters degree before entry on to a PhD. With limited funding available for research Masters and none for taught Masters, many students currently fund these courses themselves. With higher undergraduate tuition fees, many students may feel unable to take on more student debt.
43) The funding situation for Masters level training will affect several interlinked aspects. If the costs are excessive then fewer students are likely to apply. The resulting reduced intake is quite likely to render the course uneconomic to run, leading either to its withdrawal or to an increase in the, at present, unregulated fees charged. Consequently there may be a serious loss of stand-alone Masters training provision.
44) The increased costs to students is compounded because research careers are (a) insecure for the first few years at Masters and PhD level, and in postdoctoral posts; (b) the period of a PhD adds years during which a former student is not earning above the threshold to begin to pay back tuition fees, thus adding to the interest and increasing the total debt; and (c) even long term research scientists are typically not well paid relatively to those with equivalent abilities in other professions.
45) It should also be borne in mind that the restructuring of grant support for academic research will concentrate funding and reduce the number of well-funded laboratories in which quality postgraduate training can be provided. Particularly in the life sciences sector there are areas of research that do not require 'big science', and the changes in research support scarcely support

the Government's claim of wanting to create a thriving science, and specifically "Life Sciences" sector.

46) In conclusion, it is important to be aware that anything which affects student choice now will affect the skills supply many years ahead. The down-stream impacts of this are difficult to predict accurately but seem likely to be substantial.

Industry

What steps are industry and universities taking together to ensure that demand for STEM graduates matches supply in terms of numbers, skills and quality of graduates?

47) There currently seems no means by which the numbers of graduates being trained is matched to the number required. The removal of restriction on subjects studied by students gaining AAB+ at A level, and the right of universities unilaterally to 'rebalance' to non-STEM subjects that are more profitable under the new funding arrangements, both motivate against balancing supply with demand.

48) Despite this there are some moves in a few vulnerable STEM areas. For instance, the Society of Biology are currently conducting pilot studies for Degree accreditation. One of the pilot areas are degrees containing a substantial in vivo component. The Physiological Society will help the Society of Biology to engage with the in vivo community, and provide links to the expertise stored within HEI's. This Degree Accreditation Programme will require HEI's to work with industry (SMEs, CROs etc) to find placements for students, thus helping to forge links between the two.