The Physiological Society

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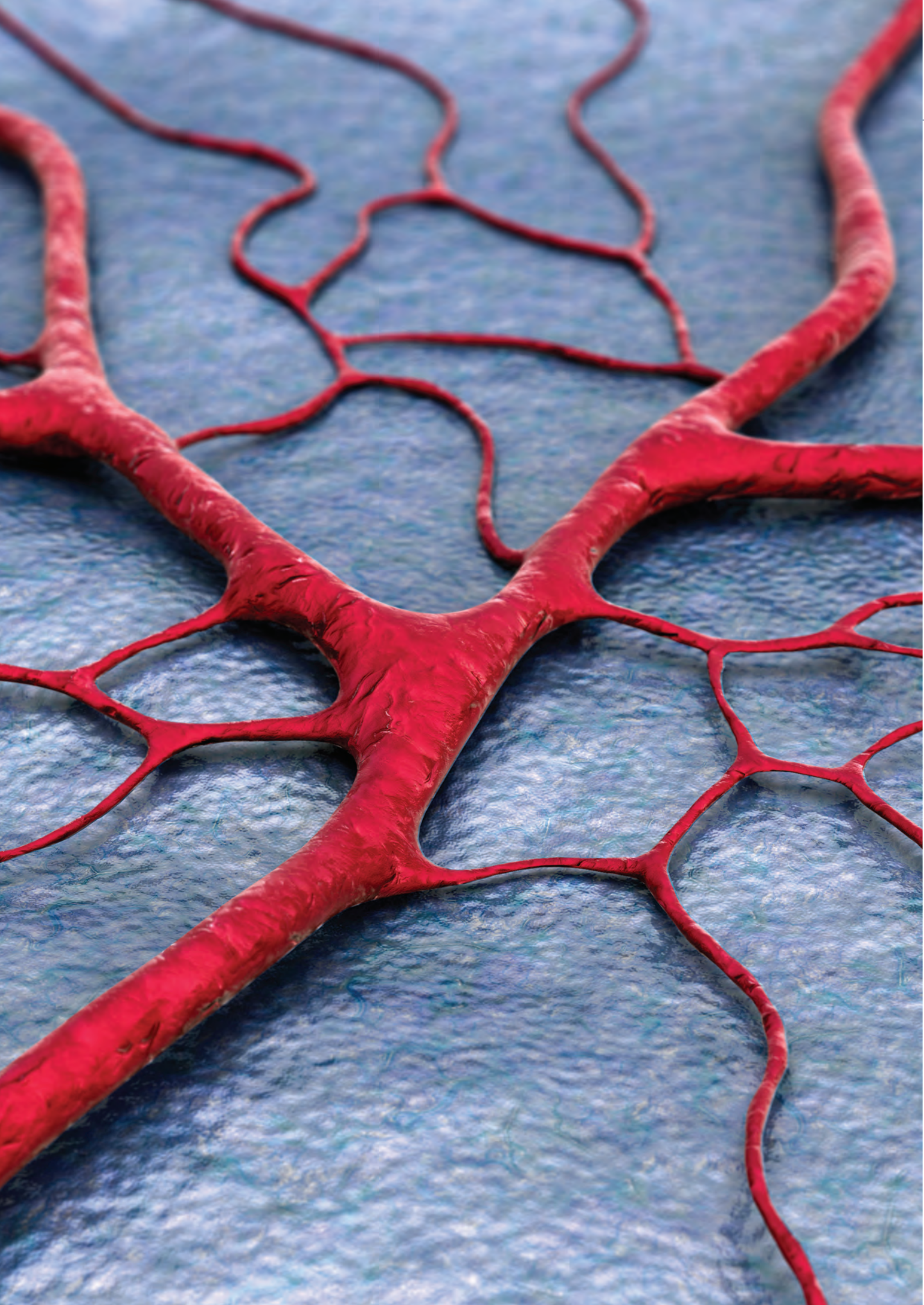
Health of Physiology



The Physiological Society

Health of Physiology

Contents

Professor Richard Vaughan-Jones

President, The Physiological Society

President's Foreword

This review addresses the question: How healthy is the discipline of physiology?

Is physiology in 2016 now in a similar position to anatomy, which has largely run its course as a research discipline and has seen its departments closed, becoming primarily a subject taught to medical students?

Did physiology peak in 1963 with the award of the Nobel Prize to Eccles, Hodgkin and Huxley for their work on nerve cell conduction, just as Francis Schmitt was founding the Neuroscience Research Program at MIT?

Has physiology been so successful that its sub-disciplines – neuroscience, biophysics and systems biology – are now fully-fledged disciplines in their own right, pushing physiology out of the nest?

Or, is physiology being revitalized, fuelled by the need to interpret knowledge of the human genome, new imaging modalities, and big data? A strength of physiology is its long history of multidisciplinary collaboration. In a world of specialisation, is it now time to work even more closely together?

This report, commissioned by The Physiological Society in 2014, considers the health of physiology as a research discipline, particularly in the UK. It considers the place of physiology in government science strategy*, assesses the skills pipeline producing the physiologists of the future, analyses research funding and output, and looks forward to the future of physiology.

The Health of Physiology concludes with a series of recommendations to promote the wellbeing of Physiology, outlining measures that will ensure that the UK continues to produce world-class physiologists and that physiology as a discipline continues to play a central role in biomedical research.

As President of The Society, I am in a privileged position to see the work that goes on to understand and support Physiology in the UK and beyond. I feel this report gives useful insight that can direct our actions and priorities in future. I am grateful to all those who contributed to it and to the Physiological Society staff who produced it. I look forward to seeing the burgeoning future of Physiology for many years to come.

Professor Richard Vaughan-Jones

President, The Physiological Society

*Note: The Referendum on EU membership was conducted shortly before this report went to press. The consequences of the result will have a large effect on all domestic policy, not least science and universities. The response of The Society to these developments will be informed by our goals and charitable objectives in the best interests of the discipline, but cannot yet be fully detailed in this volatile political climate.

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Executive summary

Key findings

Physiology is a core and fundamental scientific discipline that underpins our knowledge of medicine and veterinary science. It is central to our ability to detect, prevent and treat disease.

However, there has been a perception in recent years that the visibility of "physiology" as a term has been in decline, the result of the merger of dedicated departments of physiology with other biomedical departments, coupled with the emergence of new disciplines. It is far more common now to see larger departments or faculties of "Biomedical Sciences" or "Life Sciences". Further, this diminished visibility may have had an effect on the funding and appeal of science identified as physiology.

Education and skills pipeline

The findings of this report are that the number of students graduating with undergraduate physiology degrees has slightly increased over the course of the last ten years, while the number of postgraduate physiology students has increased significantly. This is very encouraging for the sustained health of physiology.

Research

The UK and Ireland continue to be among the world's leading nations in physiological research. However, the visibility of physiology has declined in recent times and the reported level of funding for physiological research in the UK has fallen in real terms over the past ten years.

It must be noted that the broad scope of physiology makes it difficult to collect accurate data on funding. It is possible that the underlying support for research continues at much the same level, but the research is funded under a different umbrella. Even so, the funding environment in the UK and Ireland is challenging, with government support for research considerably lower than in other countries. The greater investment in other G20 nations and the growth of research in emerging nations such as China, South Korea and Brazil pose a further threat to the world-leading status of the UK and Ireland.

Diversity

Issues of diversity in academic science disciplines are widely recognized and much progress has been made recently through the Athena Swan Initiative. The number of female early career researchers has increased throughout the biomedical sciences, but this change has yet to be reflected at the highest academic levels.

Visibility

Physiology, as a discrete discipline, is falling in visibility, both among potential students and researchers of the discipline. Much research which would previously have come under its banner is now regarded as belonging to a sub-discipline or multidisciplinary endeavour, or is rebadged as biomedical science.

Recommendations

The skills pipeline

- Physiology teaching at all levels should include effective practical content, and assessment of practical skills
- Universities and learned societies should ensure that career advice and development is available to those pursuing physiology (or to physiology students taking their skills elsewhere)
- Schools and universities should promote physiology so it is something that students are aware of, can identify with and want to study

The value of research

- The value of animal research should be consistently and openly communicated, with support for the 3Rs (reduction, replacement, and refinement of animals in research)
- Government should commit to a long-term increase in the science budget. Further, it should ensure the formation of UK Research and Innovation and reorganisation of the Research Councils allows flexibility of funding for fundamental, applied and interdisciplinary research covering all branches of physiology and associated subjects

Diversity

- Diversity should be promoted in the STEM subjects, and learned societies must increase diversity within their leadership and membership

Visibility

- Physiology research and teaching should be identified and defined as such in order to retain the academic community of physiologists
- Organisations representing physiology should strengthen national and international collaborations to communicate a united vision for the future of physiology

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Introduction

What is physiology?

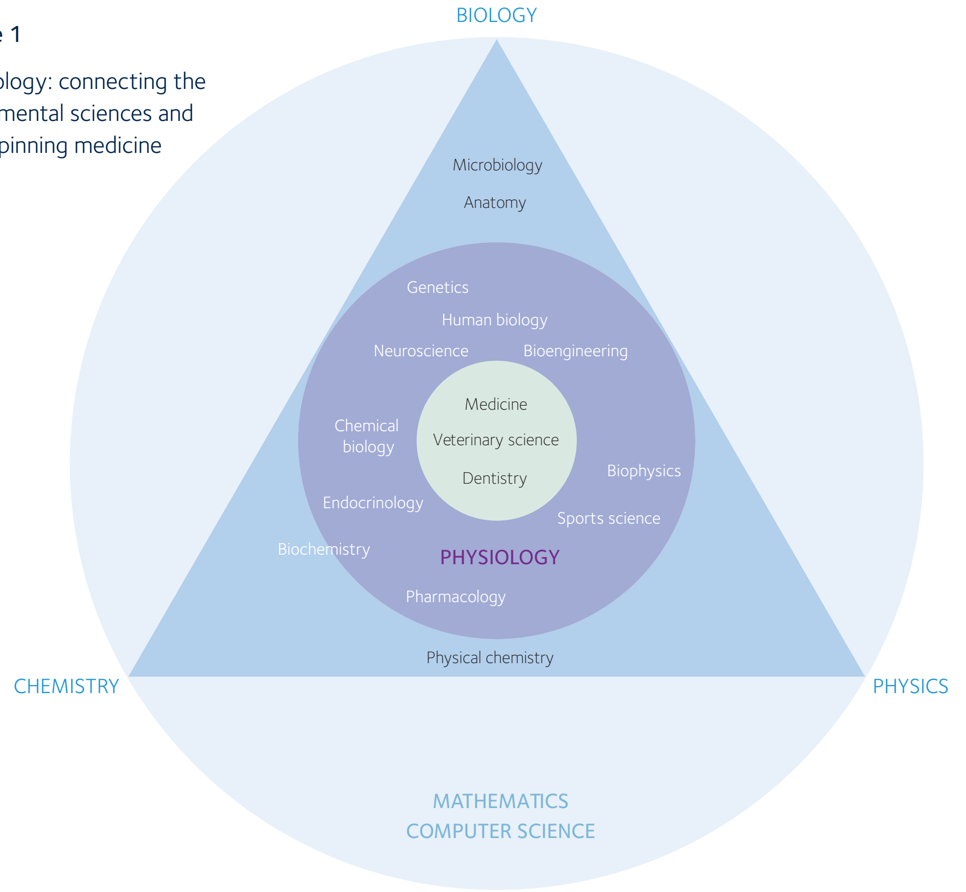
The Oxford dictionary defines physiology as ‘the science of the functions of living organisms and their parts’.[1] As such, physiology is a very broad scientific discipline, spanning from the molecular and cellular level through to the organ, tissue and whole system levels. In effect, it provides a bridge between the basic sciences and the applied medical sciences (Figure 1).

The situation of physiology as a discipline has changed dramatically over the last 15–20 years, as both the scientific and funding environments have evolved. The emergence of new areas of biomedical sciences (including some that were historically part of physiology), coupled with a shift from dedicated ‘Departments of Physiology’ to integrated biological, medical and life science faculties, has reduced the visibility of science identified as physiology, despite the research still going on. This in turn may have affected both the teaching of physiology and the research environment.

Here we evaluate these changes and examine their effect on education and research in physiology.[2] Led by a steering group chaired by The Physiological Society’s President, Professor Richard Vaughan-Jones (Annex 1), the report is based on specially conducted surveys and stakeholder meetings and on a comprehensive review of information from other sources.

Figure 1

Physiology: connecting the fundamental sciences and underpinning medicine



[1] The Concise Oxford Dictionary of Current English - 8th edition.

[2] As the focus of The Physiological Society and its members is human and “model” animal physiology, the review does not cover plant physiology or comparative animal physiology

The importance of physiology

The aim of physiology is to understand the mechanisms of life, from the molecular basis of cell function to the integrated behaviour of the whole body. Further, physiology underpins medicine and veterinary science and is key to the detection, prevention and treatment of disease.

As a science, physiology is both integrative and reductionist. Without an understanding of physiology, progress in other areas of research – such as the sequencing of the human genome – can be of only limited value, because every advance in biological research must ultimately be translated to the behaviour of the whole organism if advances are to be made in areas such as medicine and health care.

The Nobel Prize in Physiology or Medicine recognizes the most important developments in physiology. The 2014 Nobel Prize was awarded jointly to John O’Keefe, May-Britt Moser and Edvard I. Moser for their work in the field of neurophysiology on “the discovery of cells that constitute a positioning system in the brain.”

While the broad scope of physiology and the connections it makes are central to its value as a scientific discipline, in organizational terms this breadth may be both a strength and a weakness.

The growth and fragmentation of physiology

The volume of the scientific space occupied by research under the banner of physiology has led to major areas of study, such as cell biology, neuroscience and biophysics, developing their own identities to the point where they are often considered separate disciplines, with their own societies, conferences and journals. This challenges the standing of physiology as a coherent and unified subject, although of course it is the immensity of physiology that allows it to have sub-disciplines large enough to stand on their own.

Segmentation into sub-disciplines blurs the lines of what is and is not considered to be physiology.

Perhaps the best way of looking at physiology is as an umbrella discipline, with core and non-core sub-disciplines. Areas such as cell signalling and systems physiology form the core of the discipline, while bioengineering and sports science are examples of related disciplines overlapping with physiology at its perimeter (Figure 2).

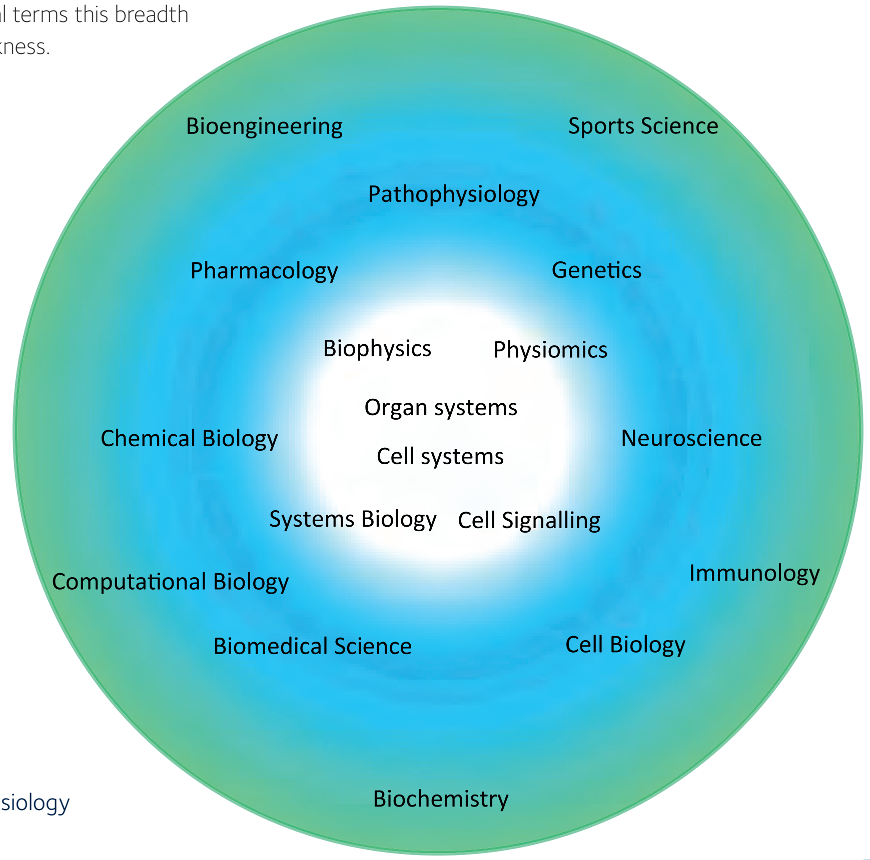


Figure 2

Core and related disciplines of physiology

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Physiology is a key scientific discipline and, as such, is taught and researched all around the world. However, as approaches to biomedical research have changed, the visibility of 'physiology' as a discipline has waned. The number of university departments with the word 'physiology' in their name has fallen considerably, from 23 departments in the UK and Ireland in 1996 to 14 in 2013 **(Table 1)**. Most have been integrated into larger departments or faculties of biomedical sciences, along with former departments of pharmacology, anatomy, genetics and even biochemistry.

Departments of Physiology	1996	2013
UK	18	10
ROI	5	4

Table 1 The number of named 'Departments of Physiology' in the UK and Republic of Ireland has fallen considerably since 1996

The Physiological Society membership, too, reported more diversity in the naming of their university departments in 2014, compared to 2001. In 2001 the proportion of The Society's membership registered to a department with the word 'physiology' in the title was 28.4%; this fell to 18.2% in 2014 **(Figure 3)**.

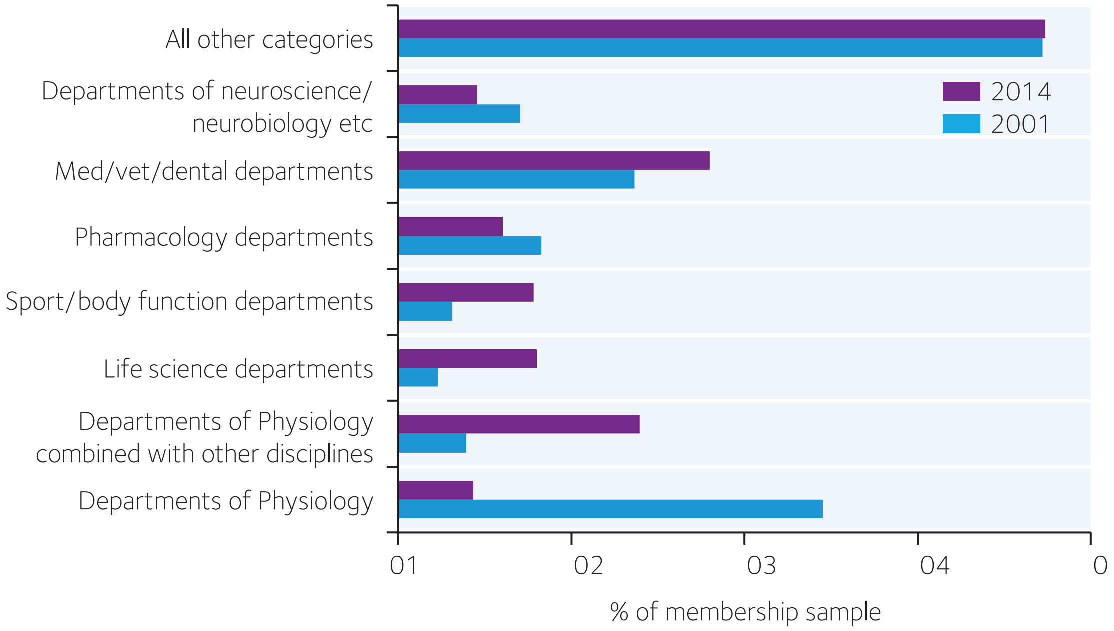

Figure 3 Fewer members of The Physiological Society are working in named Departments of Physiology. (Sample of ordinary members, 967 members from 2001 and 1012 from 2014)

If physiology as a departmental masthead is disappearing from the UK, does that extend below the surface to physiology as a research discipline? Are academics still happy to call themselves physiologists? Is work badged as physiology still being funded and conducted?

The numbers of postgraduate students **(see Chapter 5)** and the output of physiology journal articles both strongly suggest that the science is in good health. However, to retain a dedicated community intent on the continuation of physiology as an academic discipline, effort and collaboration is needed for it to keep its identity.

[3] 1996 Data sourced from the membership directory of The Physiological Society and 2013 data sourced from university websites.
[4] Data sourced from the membership directory of The Physiological Society

CASE STUDY

Physiological Society Theme: Cardiac and Respiratory Physiology

Professor Denis Noble FRS
University of Oxford

Discovery of i_f and the development of Ivabradine

In 1979, Hilary Brown, Dario DiFrancesco and Susan Noble[1], members of Professor Denis Noble's research team in the Department of Physiology, Oxford, reported the discovery of a then new cardiac membrane ion channel, which conducted what they called the 'funny current', i_f. This electric current helped to set to the rhythmic beating of the heart. Subsequent work revealed the channel to be a member of the "HCN family" of hyperpolarizing-activated non-specific cation channels.

Computer models of cardiac pacemaker rhythm, developed by the Noble team[2,3], predicted that blocking if would produce a slowing of the heart and might therefore be a safe method to achieve deceleration in patients in which reduction of the metabolic load on the heart would be therapeutic.
This insight led to the development by the French pharmaceutical company Servier, of the drug Ivabradine that is now used to treat patients for whom a frequency limiter of this kind is necessary. For the scientific basis of this development Dario DiFrancesco was awarded a prestigious prize by the French Academy of Sciences. Thus physiological research into the heart's own biological pacemaker led to a life-saving drug therapy for heart disease.

[1] Brown, H, DiFrancesco, D & Noble, S, 1979, How does adrenaline accelerate the heart? Nature, 280, 235-236.
[2] DiFrancesco, D. and Noble, D. (1985). A model of cardiac electrical activity incorporating ionic pumps and concentration changes. Philosophical Transactions of the Royal Society B 307: 353-398.
[3] Noble, D. and S. J. Noble (1984). A model of S.A. node electrical activity using a modification of the DiFrancesco-Noble (1984) equations. Proceedings of the Royal Society B 222: 295-304.

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UK life science policy

The health of physiological research is, at least in part, shaped by the surrounding policy environment. Government decisions impact upon current and future physiologists at every level. The breadth of legislation affecting physiology covers school curricula/assessment, student financing, funding/regulation of research, and the tax and regulatory environment for industry.

The policy environment is itself further affected by the incorporation of European legislation, and by differences across the UK under the devolved administrations. Additionally, local policies in schools and universities, as well as decisions made by funding organisations, publishing organisations, healthcare organisations and others can have a profound impact on physiology.

If physiological research is to retain its strength in underpinning developments in the modern life sciences, its legislative framework must be carefully considered to achieve the most effective outcome.

Government actions

A casual observer may feel that elements of the policy landscape are almost completely disconnected and developed in isolation, with the overall effect on science not fully considered. However, successive governments have tried to develop overarching strategies for science and innovation. In this respect, it is important to think of science as an integrated ecosystem, rather than of physiology specifically, with change at one point likely to have knock-on effects elsewhere within the system.

The period of the 2010-15 Coalition government saw the release in 2011 of a 'Strategy for UK Life Sciences',[5] then in December 2014 came the strategy for science and innovation 'Our plan for growth: science and innovation'.[6] Over this period the Science Minister changed from David (now Lord) Willetts to Greg Clark; in 2015 the incoming Conservative government appointed Jo Johnson to the post.

While the 2011 life science strategy focussed on the applied and commercial side of the life sciences, both documents proposed measures to address the complete breadth of science, from teaching in schools through to the commercialisation and application of science. They also included efforts to increase the diversity of science students and the research workforce, and to improve regulation of the use of animals in research.

Both Coalition strategies recognised the world-leading nature of UK science and reflected the critical role it has to play in the future health and prosperity of the nation. They comprised an acknowledgement from the Government that co-ordinated action is required for the UK to maintain its world-leading status in science and innovation. Unfortunately, this was not matched by recognition from the Treasury that science required an enhanced investment to maintain its strength. The resource budget was frozen in cash terms over the course of the Parliament.

Unlike research, innovation has traditionally not been seen as a strength of this country. Government policies have attempted to support and improve innovation and commercialisation of new developments. Innovate UK (previously the Technology Strategy Board) provides funding to advance the commercialisation of new technologies, while the Catapult centres (including a number working in the life sciences) concentrate expertise in research and innovation on specific topics. The Dowling Review[7] of 2015 was commissioned to analyse the relationship between universities and business, in order to strengthen collaborations between these sectors and improve research commercialisation. A response is currently being considered by the Government as part of their overall changes to science and higher education.

The skills pipeline attracts contentious, conflicting comments. On the one hand, there is rightful pride in the quality of UK higher education and its ability to attract overseas students; on the other, industry commonly complains of the difficulty of finding workers with the right skills and training.

The life science strategy pledged the introduction of a higher-level apprenticeship programme for the life sciences, alongside measures to increase the number of undergraduate placements within the life sciences. Although these measures were designed to address the need for skilled technicians and research workers, the calls for stronger graduates have not abated. The economic downturn in 2008 led to an increase in graduates going on to study for higher degrees, rather than entering the workforce, leading to an influx of qualified researchers looking for jobs in industry and academia, but there are still claims that recruitment of good candidates is hard. It remains to be seen whether policy changes will reconcile the provision of and demand for better (or differently) trained workers.

Current situation and future measures

After the 2015 general election the Conservative government took stock of national finances and, under strong pressure from the science sector, committed in their Comprehensive Spending Review to increase science resource funding in line with inflation until 2020.

The government has not released a new overarching science strategy, but has signalled changes that will have a significant effect on the sector. On the back of Sir Paul Nurse's recently released review[8] of the Research Councils, a new umbrella body (UK Research and Innovation) is to be formed to oversee all government-funded research in the UK. Higher education will also undergo change, with the Research Excellence Framework being overhauled and the introduction of a Teaching Excellence Framework to assess and improve the quality of university teaching.

These measures aim to push higher education towards a marketised model where universities compete for students through their ratings for research and teaching.

The success of these measures and their effect on the research sector remain to be seen. However, the signals coming out from Government suggest an understanding of the importance of science to our 21st Century economy. Support for research and innovation are widely discussed, both generally and in the context of specific initiatives such as the "Northern Powerhouse". There is recognition of the UK's strength in the life sciences, reflected in headline projects such as the Crick Institute and 100,000 Genomes initiative. As discussed previously, physiology is a key aspect of all this research, providing a bridge between the fundamental sciences and the medical applications that the UK aims to make its particular strength. Acknowledging the need for robust support of physiology as a key player underpinning the life sciences economy, the government should work to ensure the strength of the discipline.

As this report went to press, the "Out" vote in the referendum on EU Membership was newly revealed. Clearly, the status of the UK in relation to EU funding, movement of labour, regulation, and many other facets has a massive bearing on science. We do not yet know how this landscape will look in the coming months and years, but this does not change the overall goal of supporting the prominence of physiology and the strength of research.

5 Department for Business Innovation and Skills (2011) International Comparative Performance of the UK Research Base – 2013, Available at: http://tinyurl.com/ldqkstb

6 Her Majesty's Treasury (2014) Our plan for growth: science and innovation, Available at: http://tinyurl.com/l6e6vuq

7 http://www.raeng.org.uk/publications/reports/the-dowling-review-of-business-university-research

8 Ensuring A Successful UK Research Endeavour, Sir Paul Nurse, http://tinyurl.com/nm5ccb4

CASE STUDY

Physiological Society Theme: Epithelia and Membrane Transport

Professor Dame Frances Ashcroft FRS

University of Oxford

Oral drug therapy transforms life for patients with neonatal diabetes

Research undertaken by Professor Dame Frances Ashcroft at the University of Oxford and her collaborator Professor Andrew Hattersely at the University of Exeter has led to several hundred neonatal diabetes (ND) patients worldwide being able to switch from daily insulin injections to oral sulphonylurea tablet therapy since 2008. ND is a rare but potentially devastating monogenic form of diabetes that presents soon after birth. Patients were previously assumed to have type 1 diabetes, and thus were treated with insulin injections: transfer to sulphonylurea treatment has transformed their quality of life and led to marked health improvements.

Sulphonyl treatment of ND is based on discoveries made in the 1980s and 1990s, by Ashcroft and colleagues at Oxford, that closure of a plasma-membrane ion channel in the endocrine pancreas (the KATP channel) is a key link between glucose metabolism and insulin secretion. Hattersely at Exeter subsequently identified that mutations in KATP channel genes are associated with ND. Joint studies then showed that the mutant KATP channels are not closed by metabolically generated ATP but remain sensitive to inhibition by sulphonylurea drugs. Thus basic-science studies of integrative cellular physiology, combined with molecular genetics, led to development of a highly effective oral tablet treatment for ND.

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The skills pipeline

The health and success of physiology depends on a number of factors, but perhaps none is more important than a continuing supply of talented physiologists. The pipeline for physiologists begins at school. At this stage physiology is taught as biology. It is only once students reach university that they have the opportunity to study physiology as a stand-alone subject, or in combination with other subjects.

School

The supply of future physiologists begins when pupils make their post-16 (senior cycle in Republic of Ireland) subject choices. The entry requirements for undergraduate physiology degrees vary by institution, but a requirement for at least two science and/or maths A-Levels (or equivalent) is common, with biology often a mandatory subject.

Across the UK and Ireland, biology continues to be among the most in-demand subjects. It was the third most popular A-Level subject in England in 2014[9] (behind only maths and English), the third most popular Higher in Scotland[10] and the sixth most popular Leaving Certificate subject in the Republic of Ireland.[11] Along with biology, large numbers of school pupils opt to take maths, chemistry and physics. It is clear that not every school pupil studying biology, or science more generally, will go on to take a degree in physiology. However, the continued popularity of the sciences and maths as post-16 subjects ensures a healthy supply pool of potential physiologists, who should certainly be made aware of physiology as an option for their university studies.

The most concerning aspect of school-level science education is the provision of practical work to demonstrate concepts and provide experimental skills. The Office of Qualifications and Examinations Regulations (Ofqual) announced in March 2015 that assessment of practical work in GCSEs will be by written questions rather than direct observation.[12] There are fears this will have a negative effect on the provision of practical training for pupils in England and Wales.[13]

In Scotland, a recent report by The Learned Societies' Group on Scottish Science Education raised concerns about the resourcing for science education in Scotland.[14] The report, based on a survey of 39 primary and 46 secondary schools, highlighted a perceived shortage of lab equipment and consumables, with 98% of secondary schools who responded having to draw on additional funding to provide for normal curriculum activities. The sample size of the Learned Societies' Group report was relatively small, but the results are worrying nonetheless.

University

Undergraduate numbers

The large numbers of students taking sciences at post-16 education and the promotion of science, technology, engineering and maths (STEM) careers have been reflected in increases in the number of students choosing STEM degrees over the ten years 2003-13. There is a large choice of undergraduate degree subjects in the biological and medical sciences. Physiology competes with pharmacology, microbiology and biochemistry to name but a few. Data collected by the Higher Education Statistics Agency (HESA) shows that the number of students in UK universities gaining degrees in either physiology, or physiology in combination with another subject, has remained relatively stable over the period 2003–2013 (Figure 4).[15] While there was a 10% fall in graduates in 2009/10 compared with the previous year, numbers then rebounded, hitting a ten-year peak in 2012/13.[16] The number of institutions awarding physiology degrees also remained fairly stable.

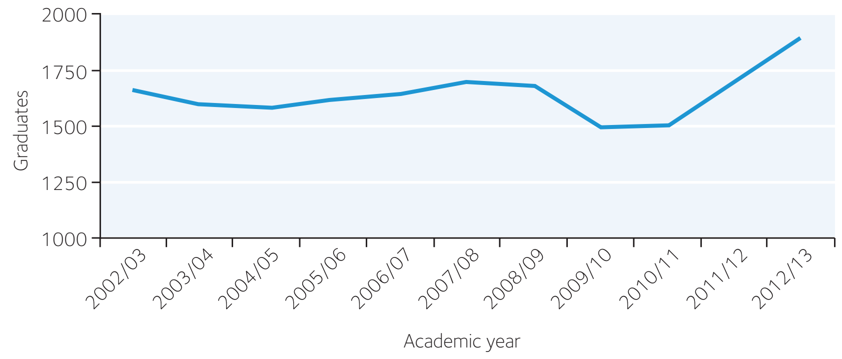

Figure 4 The number of students qualifying with a degree in physiology in the period 2003–2013 has remained stable

During this period, the overall number of students graduating has increased considerably in both STEM (science, technology, engineering and maths) and non-STEM subjects.

The growth in STEM students has outstripped the small rise in physiology students. This decline in proportion of STEM students gaining degrees in physiology is shown in Figure 5. However, on closer examination of the data it becomes clear that the increase in STEM student numbers is heavily concentrated within a small handful of subjects (namely nursing, psychology and sports science). Indeed, the picture for other traditional biomedical degree subjects like biology, microbiology and genetics is similar to that for physiology.

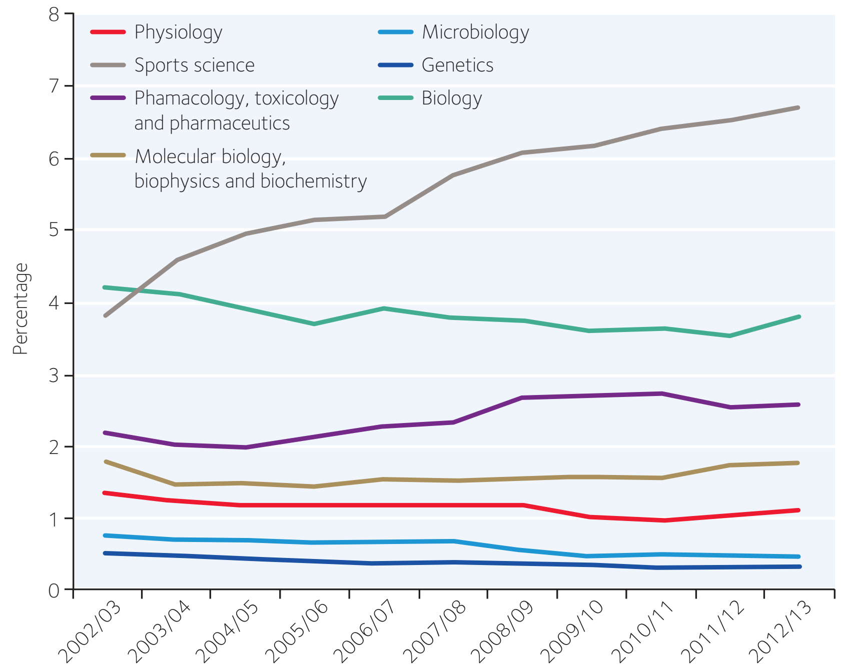

Figure 5 The proportion of first degree STEM qualifiers graduating with a physiology degree has fallen over the period 2003–2013

[9] Joint Council for Qualifications. 2014. A level and AS entries 2014 http://tinyurl.com/jrgfvpg

[10] Combined data for biology and human biology. Scottish Qualifications Authority. Attainment Statistics (August) 2014 http://www.sqa.org.uk/sqa/files_ccc/Attainment_Statistics_(August)_2014.xls

[11] Department of Education and Skills. 2014 Education Statistics Database. http://tinyurl.com/zrm4ddk

[12] https://www.gov.uk/government/news/a-new-approach-to-gcse-science-practical-assessment

[13] Science Community Representing Education letter to Ofqual – http://tinyurl.com/go6edby

[14] The Learned Societies' Group on Scottish Science Education http://www.royalsoced.org.uk/1076_LearnedSocietiesGrouponScottishScienceEducation.html

[15] Source: HESA Student Record 2002/03-2012/13. Copyright Higher Education Statistics Agency Limited 2013. HESA cannot accept responsibility for any inferences or conclusions derived from the data by third parties. All data subjected to standard HESA rounding methodology.

[16] While we can have confidence in these overall trends in student numbers, some caution is required when working out the absolute number of UK graduates qualifying with degrees in physiology. The accuracy of the data relies on individual institutions assigning students to the correct Joint Academic Coding System (JACS) subject code and difficulties arise when course content falls under several subject codes. There will be students whose courses have included a substantial physiology component but who are not classified as studying physiology.

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During discussions with stakeholders, a recurring theme came up: physiology is a degree course that many stumble across. The majority of the undergraduate students consulted during this review were not aware of physiology as a discipline when beginning their search for their degree course. Typically, these students 'discovered' physiology while searching for bioscience and/or biomedical degree courses. This relates to the wider issue of the visibility of physiology, and its identification as such when being taught, especially in schools.

Sports and exercise science degrees have seen student numbers increase more than two-fold over the past ten years. Many of these contain a significant physiology component, especially around macro-scale topics such as muscle, organ and whole-body physiology. Consequently, increasing numbers of students are learning about physiology. However, they may not be aware of this fact. It is worth considering whether some of these students potentially could have been recruited to 'Physiology' degrees, especially if these courses included more vocational aspects or better-defined routes into work outside of academia.

This is reflected in the fact that, while recognising that sports and exercise science courses would contain physiology components, the undergraduate stakeholders questioned were of the opinion that the student cohorts were very different between physiology and sports science degrees.

Student financing

During the period covered by the data in this review, student tuition fees were increased in England, Wales and Northern Ireland. Indeed, the 2006/07 increase in tuition fees from £1,000 per annum to £3,000 (England and Wales) might account for the observed fall in physiology graduates in the 2009/10 academic year, since it coincided with an economic down turn; the decline was observed across various subjects. The effect of the most recent, significant increase in tuition fees in England has yet to filter through to physiology graduate numbers. When this fee regime came into force in 2012, the numbers of students accepted onto UK university courses dipped, although numbers rebounded in 2013.[17]

The undergraduate students who attended the stakeholder meetings all started their degree after the £9,000 fee cap was introduced. Within this sample, no students had been put off further study due to the debt they had accrued from their undergraduate degree. However, a lack of funding for masters degrees and PhD courses was cited as a reason why some would not pursue further study within physiology.

It will be important to monitor how changes to tuition fees and postgraduate loans affect the number of students opting to study physiology at both undergraduate and postgraduate level in the future.

Funding for course provision

Physiology is a relatively expensive course for Higher Education Institutions (HEIs) to deliver, with significant costs for practical provision. Clearly, the level of funding available for HEIs will have a direct impact on course delivery. Within the UK, funding for undergraduate taught courses is a devolved responsibility. The financing for course provision is split between the fees paid by students and government funds provided to HEIs. The balance between government and student financing varies considerably among the UK nations and Republic of Ireland. Across the UK, additional funding is provided to HEIs to enable them to provide high cost subjects, such as clinical medicine and STEM subjects.

There is considerable variation within the UK nations over the classification of physiology as a high cost subject, and therefore whether physiology courses are eligible for this additional funding. In England, physiology is assigned to 'price group B' along with Pharmacy and Pharmacology, Biosciences, and other STEM subjects such as physics and chemistry. This results in HEIs in England receiving additional funding to provide physiology courses, on top of the tuition fees they receive from students.

Physiology was placed in this price group after the Higher Education Funding Council for England (HEFCE) carried out an analysis of the cost provision, using data collected over a three-year window.[18] The average cost of provision per full time student in 'Anatomy and Physiology' was deemed to be £9,130 (based on the cost of provision for 19,119 students). The figure for 'Biosciences' was £9,190 per student (123,150 students). This is a relatively minor difference of £60 per full time student.

Conversely, in Scotland and Wales physiology is not classified in the same cost groups as other science subjects. In Wales it is classified as a subject allied to medicine and in Scotland under a broad category of 'Other Health and Welfare'. Consequently, HEIs receive less funding per student for physiology than they would for 'Biosciences' or 'Pharmacy and Pharmacology' students.

As tuition fees in Scotland and Wales vary, depending on whether the student is a resident of that nation, the calculations for determining the level of teaching grants received by HEIs are more complex than those used in England. This makes it extremely difficult to put an exact figure on the difference in teaching grants received by HEIs in Scotland and Wales per physiology student vs. a 'biosciences' student. However it is certainly higher than the £60 difference in actual cost of provision of a 'bioscience' course. This is likely to de-incentivise the provision of physiology courses vs. other bioscience courses.

Undergraduate practical provision

Physiology is a practical discipline and the opportunity for students to develop practical skills is key to the pipeline. To find the current levels of practical provision for undergraduate students a questionnaire was sent to members of The Physiological Society based at universities across the UK and Ireland, with 34 separate responses received.[19]

Institutions were asked how many hours of practical classes students attended throughout their undergraduate degree, distinguishing between hands-on, demonstration-based and computer-based learning.

The level of practical provision varies among universities but, on average, undergraduate physiology students receive around 100 hours in total of practical training in the first year of their degree, increasing to around 120 hours in the second year (Figure 6).

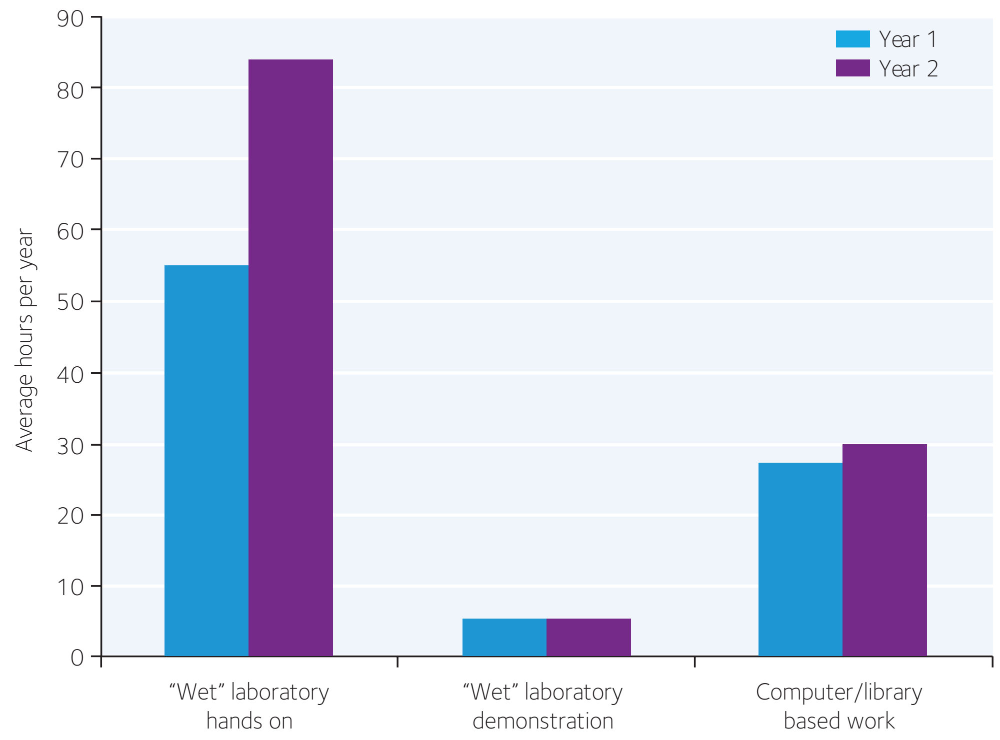

Figure 6 Laboratory work continues to be the largest component of practical provision for physiology students

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The majority of respondents (57%) believe that the amount of practical provision their institution provides is sufficient for students.

There were mixed views on how practical provision had changed over the previous 5–10 years, with an equal number of respondents (32% each) believing that it has improved or deteriorated and the remaining 36% considering that there was little change.

Looking to the future, there was again an equal number of respondents (21% each) who felt that provision would improve/deteriorate over the next five years, with the remaining 58% less sure of what would happen.

The advancement of physiology, along with biomedical disciplines more generally, continues to depend on a range of practical experimental approaches, requiring in some cases the use of animals in research. The limited opportunity for undergraduate students to experience animal research was raised as a concern by both physiology academics and students. Most commonly, this lack of exposure is attributed to the high cost and regulatory hurdles involved. The use of animals for scientific purposes is strictly regulated in both the UK and Ireland, and more broadly across Europe, under the European Union Directive 2010/63/EU.

Students also reported anxieties that their options to continue with a career within physiology have been restricted by the research specialism within their institutions. They spoke of their interest in specialising in their final year of their degree in areas of physiology that were not offered in their institutions.
This discouraged them from continuing their careers within physiology, as they felt they would be unable to be gain a PhD place with their perceived lack of experience. Similarly, increasing specialisation is causing a reduction in the number of postgraduates who can teach systems physiology for biomedical courses such as medicine and dentistry.

Some of the undergraduate students consulted felt that some of their courses tutors were overly focused on their research, and that this was detrimental to their teaching responsibilities. The Physiological Society has long maintained an interest in the balance between research and teaching within universities. In 2014, The Society produced a joint report with the Academy of Medical Sciences, the Society of Biology and the Heads of University Biosciences entitled 'Improving the status and valuation of teaching in the careers of UK academics'. The Society is continuing to work on the promotion and recognition of good teaching and is getting some traction with government efforts to address this topic.

When considered in conjunction with the lack of animal research training today's undergraduate students receive, these concerns pose a broader question around the provision of physiology skills within the UK and Ireland: are there key physiology skills that are under threat of dying out? It is a question we cannot answer at present. The vulnerability of key physiology skills within the UK and Ireland requires further investigation.

[17] http://www.bbc.co.uk/news/education-25432377

[18] Higher Education Funding Council for England (2012) High cost subjects analysis using TRAC(T) data: detailed commentary http://tinyurl.com/gs37rr9

[19] Details of universities responding to the survey are listed in appendix III.

Postgraduate student numbers

The number of students graduating in the UK with postgraduate taught degrees and with doctorates in physiology has increased rapidly over the ten years 2012–2013 (Figure 7). This growth rate has outstripped the general upward trend seen within STEM disciplines over the period. Most encouragingly, the proportion of physiology undergraduates who proceed to obtain a PhD in physiology has more than doubled from 7% to 15%.

As undergraduate numbers have remained stable or slightly increased over the same period, the number of physiology doctorates in absolute terms has increased significantly. It is from this group that the next generation of world leading researchers and inspiring teachers will emerge. However, there are concerns among these students, and the research sector more widely, about the sustainability of the general trend of expanding numbers of PhD graduates. It is clear that a large proportion will not proceed into a career in academia or industry. The Royal Society's report 'The Scientific Century – securing our future prosperity' found that only 3.5% of PhD students will progress into, and stay as, permanent research staff in academia. Of the remaining 96.5%, some will take up research careers outside of university, in industry, government etc., but the majority will end up in careers outside of science. This trained workforce is still important, as it brings the advantage of a better understanding of evidence and scientific analysis among businesses and the general population. Nevertheless, many of those who wished to go into academia or research will find themselves disappointed.

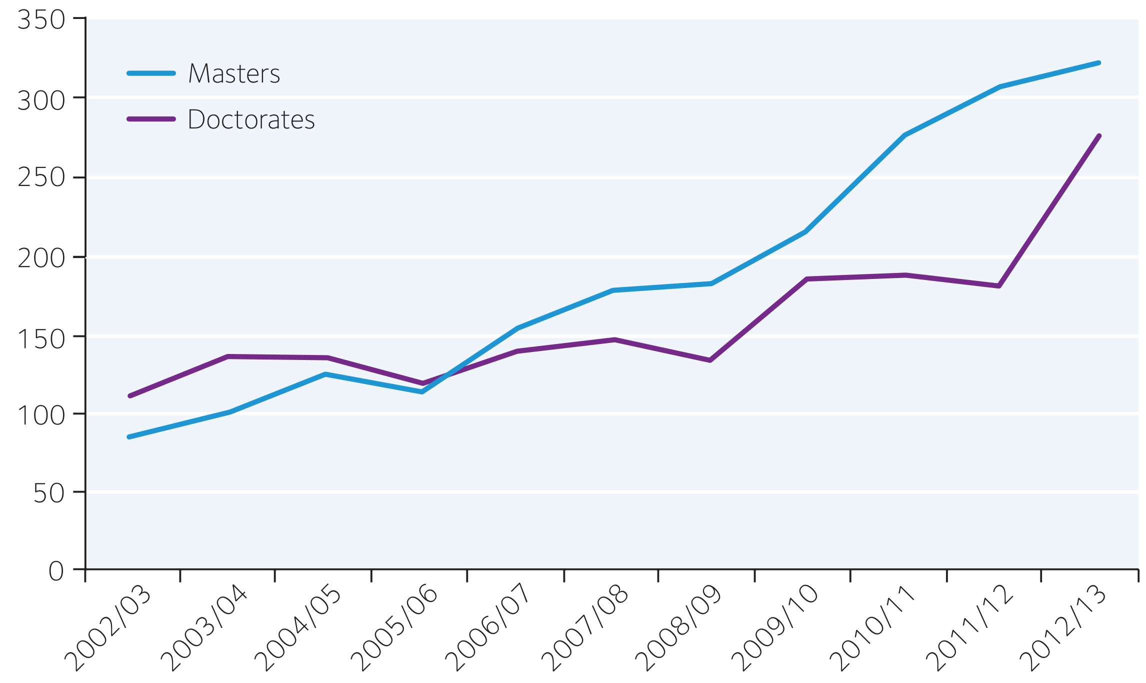

Figure 7 The numbers of physiology postgraduate qualifiers has increased substantially over ten years

[20] Directive 2010/63/EU of the European Parliament and of the Council, of 22 September 2010, on the protection of animals used for scientific purposes - http://tinyurl.com/kong2ud

[21] http://tinyurl.com/hfn5saj

[22] The Economist, 2010. The disposable academic. The Economist, http://www.economist.com/node/17723223

[23] The Royal Society. (2010) The Scientific Century, http://tinyurl.com/jry3hms

CASE STUDY

Physiological Society Theme: Metabolism and Endocrinology

Doctor Kevin Murphy

Imperial College London

Physiology in obesity treatment

Obesity is a major global health problem, affecting not just developed countries, but increasingly developing countries, and associated with serious metabolic disease including diabetes and cardiovascular disease. Current pharmacological treatments are at best modestly effective, and have side effects; bariatric surgery is highly effective, and results in long term weight loss, but is impractical to address the growing numbers of the obese- two thirds of UK adults are now overweight or obese. Our best option for developing new safe and effective therapies lies in understanding the physiology of energy and glucose homeostasis, to reveal potential novel pharmacological targets. Genome wide association studies have identified dozens of genes associated with obesity and diabetes, but the function of many is unknown. We have some knowledge of the gut-brain signalling mechanisms and the central neuronal circuits that regulate food intake, but much is still to be learned. Physiology and physiologists are therefore crucial to our understanding of these systems, and the best hope for discovering novel treatments.

The Physiological Society

6

Academic output

Published research

Number of publications

The UK is a world-leading research nation for many disciplines, including physiology. The UK's output as measured by the number of physiology journal articles published has remained fairly stable through 1996–2012, with the UK consistently ranked in the top five countries (Table 2).[25,26]

Europe and North America continue to lead the world in the number of physiological research articles produced, though their combined share of the global total has fallen from around 80% in 1996 to 70% in 2012 (Figure 8). This has mainly been due to a rapid increase in output from China. Notably, the number of physiology publications has seen little growth in India over the same period, where growth in publications in other STEM disciplines such as pharmacology and biochemistry has been considerable. Whether this will change in the short- to medium-term remains to be seen.

	1996	1998	2000	2002	2004	2006	2008	2010	2012
Number of publications	1101	1077	966	1049	1043	1180	1143	1087	1116
Share of global publications	8%	7%	6%	7%	6%	6%	6%	6%	5%
Rank	3	3	3	3	3	3	3	5	4

Table 2 The UK has maintained a place in the top 5 most prolific producers of physiology journal articles

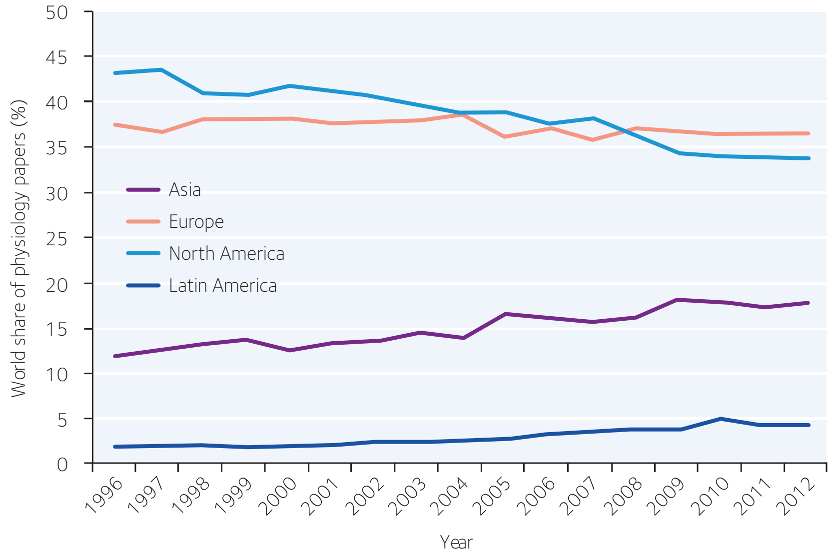

Figure 8 Europe and North America continue to dominate in terms of number of physiology research articles published, but with Asia increasing its share

[24] Department for Business Innovation and Skills (2013) International Comparative Performance of the UK Research Base – 2013 http://tinyurl.com/ldqkstb

[25] SCImago. SJR – SCImago journal & country rank. Retrieved 1 October 2013, from www.scimagojr.com

[26] These values should not be taken as absolute, and instead should only be used as relative Figures to compare year-to-year performance, or country-to-country performance.

Quality of publications

Although there is no perfect methodology for judging the quality of a nation's research output, measuring the average number of citation per paper is often used as a proxy measure.[27]

It is important to note that citation rates vary considerably by discipline and by time since publication. By normalising the number of citations an article receives by the world average for the discipline and by the year the paper was published, it becomes possible to compare research papers from different years.[28]

The data show that publications from the UK and Ireland, for any given year between 1996 and 2012, performed better than the world average for that year. The performance of the UK and Republic of Ireland is matched only by Canada and the United States (Figure 9).

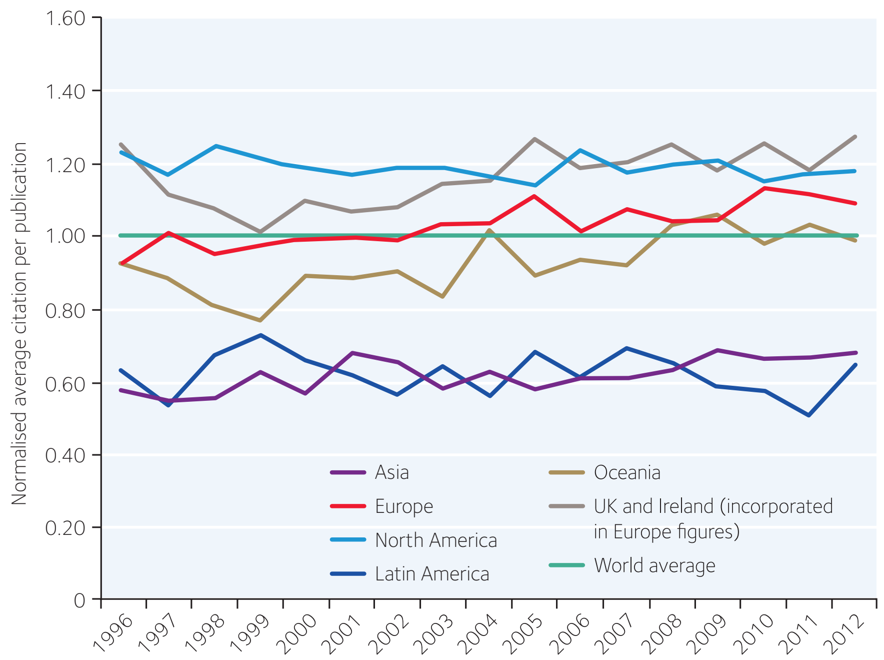

Figure 9 Research publications from the UK and Ireland are world leading for number of citations per paper

[27] Department for Business Innovation and Skills (2013) International Comparative Performance of the UK Research Base – 2013 http://tinyurl.com/ldqkstb

[28] While there will be outliers, which either generate their citations either very quickly or very slowly, these should be averaged out across the relatively large data sets.

6

Research funding

Reported funding for academic physiological research within the UK has remained relatively flat over the previous ten years (Figure 10). When viewed as a share of overall science funding it has fallen considerably. The major caveat to this data is that it is based on the disciplines to which universities attribute funding income. Given the decreasing visibility of physiology and the nature of interdisciplinary research, it is likely that these figures are not a true representation of the actual level of funding for physiology within the UK. Given the number of physiology publications, the discipline cannot be in the state of decline that these funding data suggest. It is difficult to assess accurately how the level of funding physiology vs comparator subject funding has changed over the years. Nonetheless, it is impressive that the UK continues to be amongst the leading nations in both the quantity and quality of research output in physiology, given the general stagnation of science funding in the period of the last government. It is worrying that this period saw the UK become the lowest spender on science as a proportion of GDP among the G8 nations.[29]

Over this period, the overall level of funding for science has increased significantly, with the clinical medicine research field the biggest benefactor (Figure 11).

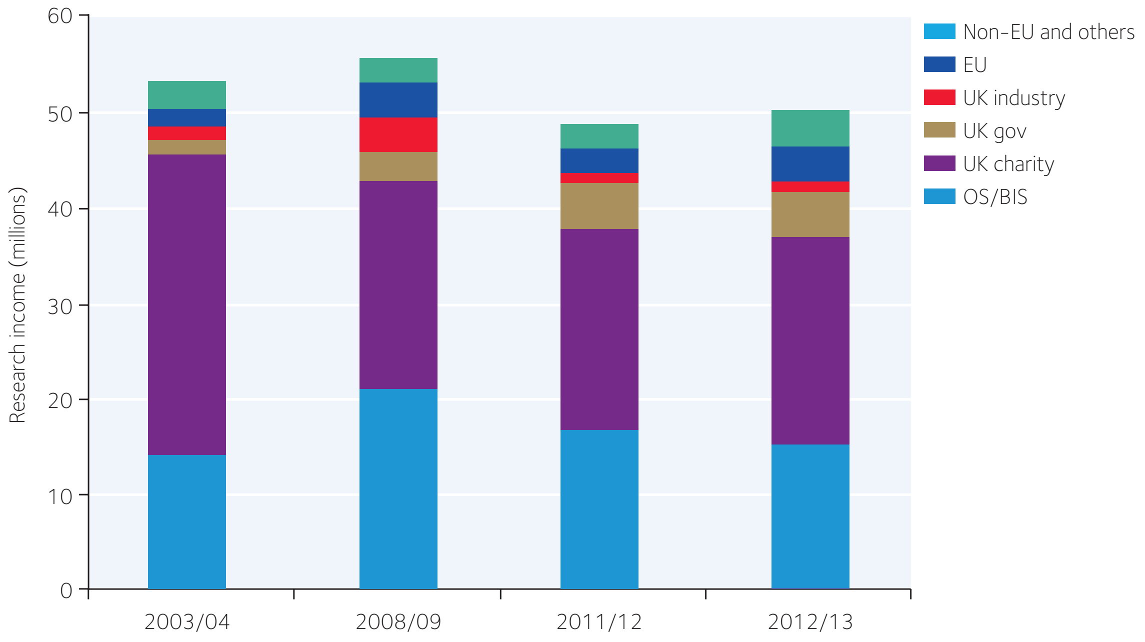

Figure 10 UK university research income for physiology and anatomy has remained flat over the period 2003–2013

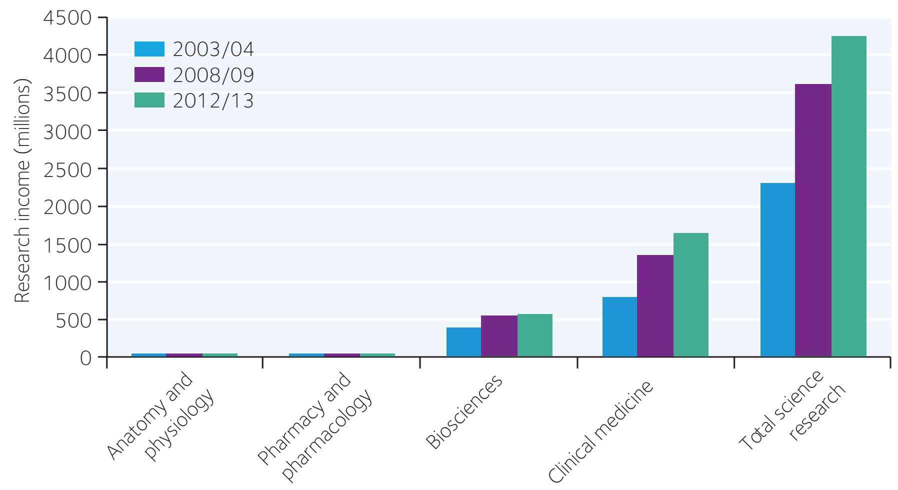

Figure 11 Clinical medicine receives the largest share of research income in the UK

The UK and Irish governments are investing at a much lower proportion of GDP (gross domestic product) in research and development than the majority of EU and OECD (Organisation for Economic Co-operation and Development) nations. The UK invests approximately 0.6% of GDP and the Irish government 0.5%. The EU28 average is around 0.7% and competitor nations such as Germany and the USA are investing closer to 0.9%. While the UK science budget was ring-fenced with a flat-cash settlement in 2010, it is estimated that in real terms the science budget has been eroded by a figure of £1.1bn by 2015/16, from the 2010 total.[30]

Recognition from the Irish Government in January 2015 that investment in science and research would need to rise significantly to keep pace with other nations must be welcomed.[31] Deeply worrying, however, is the move of the Irish Government to focus funding on applied research and 'orientated basic' research in prioritised areas, to the detriment of fundamental research in disciplines such as physiology.[32] Over 900 Irish scientists recently sent an open letter to the Irish Times highlighting their concerns.[33] This policy has the potential to impact significantly upon the health of physiology and scientific research in Ireland.

The UK's 2015 Comprehensive Spending Review brought the welcome news that the science resource budget would be increased in line with inflation over the course of this Parliament, as well as an affirmation of the already-announced science capital fund. While this is, of course, good news, the small print must yet be examined, as there are risks of this budget being forced to stretch further than ever before.

Animal research

The progression of physiology as a scientific research discipline, and its ability to contribute to the advancement of human and animal health, continues to require the use of animals in research in many cases.

Animal research is a controversial area of science and is strictly regulated across the EU. It is illegal to use an animal for research if a viable alternative technique exists. Although the most recent Ipsos-MORI survey, commissioned by the UK Government in 2014, found that the majority of the public continues to support the use of animals in research, it is right to acknowledge that some opposition exists.[34]

[29] http://scienceogram.org/blog/2015/03/uk-science-bottom-gdp-g8/
[30] http://sciencecampaign.org.uk/CaSESR2015Response.pdf
[31] http://www.rte.ie/news/2015/0115/672804-research-minister-says-science-spend-has-to-rise/
[32] http://www.nature.com/news/irish-government-under-fire-for-turning-its-back-on-basic-research-1.17132
[33] http://www.irishtimes.com/opinion/letters/funding-basic-research-in-science-1.2142827
[34] Attitudes to animal research in 2014: A report by Ipsos MORI for the Department for Business, Innovation & Skills https://www.ipsos-mori.com/Assets/Docs/Polls/sri_BISanimalresearch_NONTRENDreport.pdf

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Public understanding and awareness of animal research remains low, with only 30% of those surveyed by Ipsos-Mori feeling well-informed. The survey highlighted that the majority of the public is unaware of the efforts of the research community and UK government to implement the 3Rs –reduction, replacement, and refinement (of animals in research). The Physiological Society works closely with the UK's National Centre for the 3Rs (NC3Rs), most recently co-funding a research project to advance the 3Rs.

This lack of public understanding may be partially attributed to the often one-sided nature of media coverage of this topic. Many scientists who are involved in animal research do not feel comfortable in talking publicly about their work, creating an information void subsequently filled by groups opposed to animal research. Many such groups operate within the UK; in the past some groups employed violent measures, including letter and car bombs, to intimidate scientists working in this area. While extremism on this level has not been seen in the UK for a number of years, its legacy continues to impact on today's researchers.

The Physiological Society, along with the wider bioscience sector, is aware of the general public's limited understanding of animal research. In October 2012 over 40 organisations, including The Physiological Society, came together to launch the 'Declaration on Openness on Animal Research', which committed signatories to develop a concordat which would set how bodies involved in animal research would be more open and transparent. The 'Concordat on Openness on Animal Research', which The Society played a significant role in developing, was launched in May 2014, with The Society as a signatory. The full impact of the Concordat will not be known for some time yet, however it is hoped that the Concordat will enable the public to access accurate and up-to-date information on animal research within the UK.

The Society also works with sectoral and governmental bodies to ensure that the regulatory environment for carrying out research involving animals is effective, balanced and responsive.

CASE STUDY

Physiological Society Theme: Neuroscience

Professor David Wyllie

University of Edinburgh

Brain physiology leads to new treatments

The human brain is the most complex entity we know of and the activity of its hundreds of billions of cells control and give rise to our every thought and action. In 2011 the European College of Neuropsychopharmacology indicated that 164.8 million of the EU's population suffers from a disorder that affects brain function. For example these include diseases that affect the normal development of the brain through to neurodegenerative disorders. These numbers exclude those whose brain function is compromised following stroke or traumatic brain injury. Indeed the burden in terms of financial cost to the EU of treating individuals with brain dysfunction is estimated to be around €400 billion. While successful therapeutic interventions exist for many conditions it is unfortunately the case that disorders of brain function are very difficult to treat. Physiologists play a key role in our understanding of brain function through their experiments which use multidisciplinary approaches to record and image brain activity in vitro and in vivo. Using preclinical models of brain disorders neurophysiologists identify novel targets for therapeutic intervention together with assessing the potential of cell-replacement, protein and gene therapy technologies to allow the translation of basic research to clinical benefit.

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Sances S, Bruijn LI, Chandran S, Eggan K, Ho R, Klim JR, Livesey MR, Lowry E, Macklis JD, Rushton D, Sadegh C, Sareen D, Wichterle H, Zhang SC, Svendsen CN. (2016). Modeling ALS with motor neurons derived from human induced pluripotent stem cells. Nat Neurosci. Mar 29;16(4):542-53. doi: 10.1038/nn.4273. Review. PMID: 27021939

7

Diversity in physiology

Diversity among physiologists

The gender diversity in science has been widely reported and investigated.[35] In the life sciences, women outnumber men at the early stages of the academic career ladder. Despite this, the gap narrows at each subsequent stage of the ladder, with men significantly outnumbering women at the highest levels.[36]

The data for UK physiologists reflects this wider picture. Women outnumber men by almost 2:1 at undergraduate level, with the gap narrowing considerably by the masters level, and still further among PhDs. Upon reaching academic posts, the gap closes entirely and then reverses, with professorships dominated by men (Figure 12).[37] This makes Physiology within UK academia little different to other STEM subjects, academia in general or the wider business world, with significant gender imbalance at the top of the sector. The imbalance in STEM is widely recognised. A number of reports have been produced,[38] and initiatives launched, to address this issue, such as Athena SWAN,[39] which the Physiological Society strongly supports.

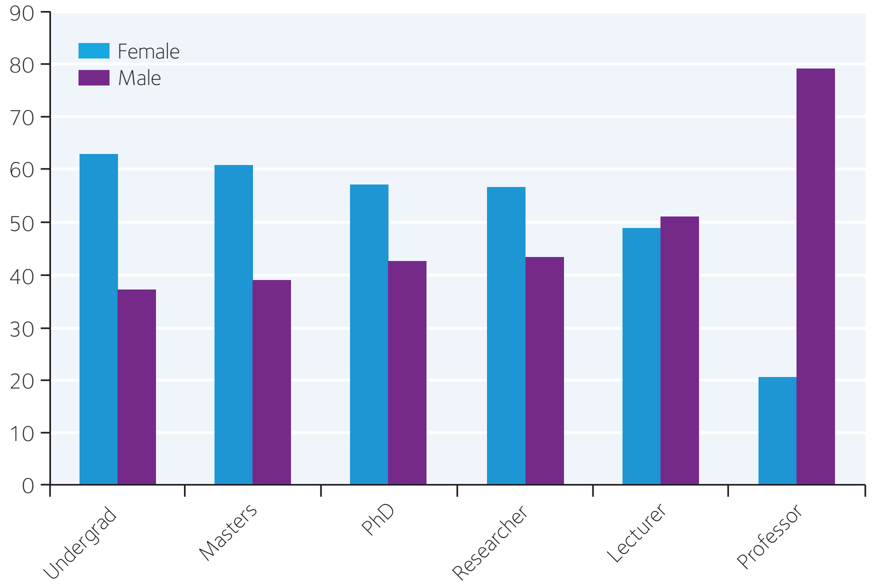

Figure 12 Gender split (%) of physiologists at all levels from undergraduate to professor

The proportion of female academics is considerably higher in physiology and anatomy than the average figure for science, engineering and technology (SET) subjects, which is 40%. Generally, across the SET disciplines, the proportion of female academics drops down significantly to 16% at the professorial level. The situation within physiology (and wider life sciences) is arguably more complicated than that faced by physics, for instance, where men significantly outnumber women at every level from post-16 education upwards. While continuing to address the gender imbalance at the top of the academic career ladder, the life science community should continue to encourage men to enter the life sciences at the undergraduate level to maintain balance in both directions.

[35] House of Commons Science and Technology Select Committee (2014) Women in Scientific Careers, http://tinyurl.com/o33d6wr
[36] Royal Society, (2014). A picture of the UK scientific workforce, http://tinyurl.com/h79rxwp
[37] Equality Challenge Unit, (2014). Equality in higher education statistical report 2013 http://tinyurl.com/jp7ovcv
[38] House of Commons Science and Technology Select Committee (2014) Women in Scientific Careers, http://tinyurl.com/o33d6wr
[39] http://www.ecu.ac.uk/equality-charter-marks/athena-swan/

Disability

The data from the Higher Education Statistics Agency (HESA) show that the percentage of UK first-degree STEM qualifiers recorded as having a disability has steadily increased from approximately 5% in 2002/03 to just under 10% in 2012/13. This trend is apparent in the data for physiology, where the figure has gone from 4% in 2002/03 to 9% in 2012/13.[40] The proportion of physiology graduates, and STEM graduates more widely, recorded as having a disability broadly matches data collected by the Royal Society in its report 'A picture of the UK scientific workforce'.[41] The proportion of physiology graduates registered as disabled has steadily increased over the past ten years, and this increasing inclusivity is very encouraging.

However, only 2.8% of physiology and anatomy academic staff are recorded as having a disability. While this figure is around the average across the SET subjects (2.5%), this is considerably lower than the figure of 13.5% reported by the Royal Society in the wider scientific workforce. Removing both the physical and societal barriers to disabled people succeeding in science is a significant issue. Importantly, the scientific community is actively taking steps in this area, with the STEM disability committee formed in 2011 to consider steps to remove barriers faced by disabled people in STEM.[42]

Ethnicity

Ethnicity within the UK undergraduate population is a very complex picture, as revealed in the Equality Challenge Unit's higher education statistical report.[43] The data sourced from HESA allows a partial analysis of the ethnicity of physiology students in the UK.[44] In 2012/13, 61% of UK university physiology degree qualifiers were white, 29% BME black and minority ethnicities (BME) and 10% were non-UK domiciled students (for whom ethnicity data is not available). These proportions have changed notably since 2002/03, when the undergraduate population was 74% white, 21% BME, and 5% non-UK domiciled. In the overall undergraduate STEM population the proportion of BME and non-UK students has also increased, albeit at a slower rate.

These data show that UK-domiciled black and minority ethnic (BME) students are proportionally overrepresented at undergraduate level in physiology, in comparison to the national population.[45] Further up the academic career ladder, 88% of UK academic staff in anatomy and physiology are white and 12% BME, which broadly reflects UK national demographics,[46] though closer inspection shows that black academics are underrepresented within physiology and anatomy. To fully assess the situation, more detailed data are required, along with a comparison of the changing demographics between generations.

[40] Note that this data is compiled on the basis of student self-assessments. Students are not obliged to report a disability.
[41] Royal Society, (2014). A picture of the UK scientific workforce, http://tinyurl.com/h79rxwp
[42] http://www.stemdisability.org.uk/about/default.aspx
[43] Equality Challenge Unit, (2014). Equality in higher education statistical report 2013 http://tinyurl.com/jp7ovcv
[44] HESA collects the data for only a sub-set of the overall student population. Data is collected from students domiciled in England, Wales, Scotland, Northern Ireland, Guernsey, Jersey and the Isle of Man, so excludes for instance visiting and exchange students.
[45] Office of National Statistics 2011 Census: KS201UK Ethnic group, local authorities in the United Kingdom, http://tinyurl.com/ovrkfds
[46] Equality Challenge Unit, (2014). Equality in higher education statistical report 2013 http://tinyurl.com/jp7ovcv

7

The Physiological Society

Diversity of The Society's membership

Currently The Society only holds diversity data relating to the gender of its membership; this makes it harder to determine how well The Society's membership reflects the community it seeks to serve.

Across all of The Society's membership categories there is a gender balance of approximately 40:60, female to male. However, the proportion of women within The Society's 'Member' category, which is for established physiologists, falls to approximately 25%. This may be due partly to the proportion of women staying in physiology past the postdoctoral stage reducing; indeed analysis of available data on the gender diversity of new entrants to the 'Member' category shows that in every year since 2008, more men joined the 'Member' category than women did. What is more encouraging in this case is that, over this period there has been a clear trend of this gap narrowing, and it appears to be steadily approaching a 50:50 balance. Moreover, in the younger generation (affiliates, undergraduates), there are more women joining than men. We may therefore expect the gender balance in the 'Member' category to improve over the next period. Honorary membership is also skewed, although in the past year the proportion of female honorary members has increased from 7.8% to 12.3%. We would hope to maintain this upward trend, thus reflecting the significant contributions of female physiologists.

The Society has recently celebrated 100 years of Women in Physiology, with 2015 being the centenary of the admission of female Members. However, it must be noted that during this period there has never been a female President of The Society.

With respect to ethnicity and disability, the current lack of data makes it very difficult to assess how The Society is performing in relation to these diversity indicators. This is currently being addressed by The Society's Diversity and Equality team. As part of the commitment of The Society to the Science Council's declaration on diversity, equality and inclusion, surveys of both staff and the membership have been carried out in the past year. Part of this addressed whether members feel that they are fully supported by the Society and have the opportunity to engage with Society activities, irrespective of gender, ethnicity or disability. Results from this were encouraging since over 98% of respondents felt that The Society was addressing these issues.

CASE STUDY

Physiological Society Theme: Education and Training

Professor Judy Harris

University of Bristol

Society work on recognition for teaching

In 2014, The Society produced a joint report with the Academy of Medical Sciences, the Royal Society of Biology and the Heads of University Biosciences entitled 'Improving the status and valuation of teaching in the careers of UK academics'.

In 2015, The Society produced a booklet 'Recognising Teachers in the Life Sciences' that includes case studies of 32 inspirational life scientists, including 18 physiologists, for whom achievements in teaching have been an important aspect of their career progression/promotion.

The Society held events at the Labour and Conservative Party Conference fringes to bring attention to the reward and recognition of teaching in higher education, and the validity of a career path being a teaching academic.

8

Conclusions and future direction

Fundamentally, this review shows an optimistic future for physiology, as a discipline. It is in a position where, with concerted effort from the sector, it can show its relevance and utility in the modern age.

There is a healthy pipeline of physiologists in training, though more should be done to make this representative of societal demographics and to continue this diversity into higher levels of academia. Further, physiology and research skills are being exported into the workplace leading to a greater degree of critical thinking and scientific understanding. Funding for research is protected, in theory, for the period of this Government, but physiologists must make the case loudly for fundamental and multidisciplinary research to be supported and understood. Overall, The Physiological Society and sister organisations must work across institutions to collaborate and improve the recognition of physiology among students, researchers, policymakers and the public, in order to ensure the discipline and the name continues into the future.

The skills pipeline

School

Schools are producing a growing number of students interested in going on to further study in STEM disciplines. That physiology is not benefitting from this growth is an issue that needs to be addressed. Schools should help students understand the various sub-disciplines of science to a broader degree than simply biology, chemistry and physics. They should retain practical provision across the spectrum of disciplines to engage as many students as possible in a specialisation that will continue to interest them throughout their education and career.

While the practical skills of current and future physiology undergraduate students are an area of concern, the changes to practical assessment in England and Wales, with increased emphasis on demonstration, have yet to come into force. This is clearly a pan-science issue and the community will need to monitor what, if any, effects these changes will have on future science students.

The Physiological Society has developed a number of high quality teaching and careers resources, primarily targeted at those studying and teaching physiology within the 11-19 age group. The Society hosts all of these resources on a bespoke educational website – 'understanding-life.org/'. Given the seemingly widespread lack of awareness of 'physiology' among prospective degree students, it would be sensible to review the content of the website and the underlying strategy behind it to determine whether it is targeted appropriately. Overall focus on the name 'physiology' in schools and beyond should be considered.

University

An increase in the awareness of physiology among school-leavers would likely lead to more students proactively looking to study physiology and related degree courses, rather than ending up on them when initially searching for something else.

Of course, the future of the discipline is not only reliant on the number of students studying physiology, but also on the skills they possess. It is therefore reassuring that in our survey a majority feel that current practical training is sufficient for their undergraduate physiology students. These findings were mirrored in a 2014 Royal Society of Biology and Biochemical Society review of practical provision for undergraduate bioscience students.[47] Students too echoed this view, with most feeling that the amount of practical provision was suitable. However, it remains to be seen if this level of practical provision can be continued given the straitened financial circumstances for many university departments.

Practical experience of physiology must include training in experiments on animal models. The provision of this is limited for undergraduates due to cost and regulatory burdens, leaving students inadequately prepared for this area of academic research. These concerns are not new, and The Society already collaborates with the British Pharmacological Society, the Wellcome Trust, the Medical Research Council and the Biotechnology and Biological Sciences Research Council in running short courses in mammalian in vivo research techniques for undergraduate and postgraduate students. However, these courses have limited capacity and realistically are not a long-term solution to providing the next generation of physiologists with opportunities to experience animal research. These skills are not only necessary for future physiologists but are also important for training in medicine, dentistry and veterinary sciences where a good understanding of biological structures is crucial.

Over 80% of the 113 PhD- and postdoctoral-level physiologists surveyed stated that they wished to remain in academia, while less than 1% of respondents intended to seek a career outside science. However, the fact remains that there are insufficient positions available in academia to satisfy all these career intentions. The scientific community must recognise this and provide appropriate information and training for PhD students. The Royal Society published a set of principles and responsibilities in 2014, to help manage both career expectations and development of PhD students.[48] They contain a number of measures for students, supervisory teams, careers/training services and HEIs to take to help address this issue.

Student financing

The cost of a degree is an ever-changing area of policy. Tuition fees have been raised by successive governments, and the incumbent Conservatives have released plans to allow fees to rise in line with inflation for universities providing effective teaching. Additionally, maintenance grants have been converted to loans, leading to concern that candidates from lower-income backgrounds will face greater debt and be put off studying. This uncertain environment makes it hard to offer advice on how best the physiology community can respond. Departments must continue to do their best to widen access routes in order to bring in a strong and diverse cohort of students.

Plans are in place for a postgraduate loans scheme, allowing masters students to borrow up to £10,000 (starting in the 2016-17 academic year) and PhD students up to £25,000 (starting date unconfirmed) to fund their studies. It is hoped this will lead to a greater take-up in postgraduate studies.

Recommendations

- Physiology teaching at all levels should include effective practical content, and assessment of practical skills
- Universities and learned societies should ensure that career advice and development is available to those pursuing physiology (or to physiology students taking their skills elsewhere)
- Schools and universities should promote physiology so it is something that students are aware of, can identify with and want to study

8

Physiology research

Physiology research in the UK and Republic of Ireland is world leading. However, this situation is under threat due to the continuing under-investment in science. Although numbers of publications from this country, and their rate of citations, present a picture of a strong discipline, due to the slow pace of scientific investigation the adverse effects of cuts may be experienced years or even decades down the line. An assumption that efficiency savings will not impact on the quality of research due to the inherent strength of the research base is misguided.

The 2015 Spending Review ring-fenced the science resource budget and promised to raise it in line with inflation. However, if the budget did not include the Global Challenges Fund it would remain flat in cash terms, falling in value with inflation. Existing research projects may meet criteria for overseas development, especially those with medical applications, allowing the most flexible use of this money. Otherwise, new projects face additional administrative hurdles to receive this additional support. Scientists and research organisations must hold the government to account over their promises of support to the sector.

During consultation with stakeholders, specific concerns were raised over the research funding structure within the UK's Research Council system. It was perceived that some areas of physiological research fall between the disciplinary boundaries of the Biotechnology and Biological Sciences Research Council (BBSRC) and the Medical Research Council (MRC), which is affecting the ability of researchers to obtain funding for these areas of work. These concerns are being addressed by the government, which has recently announced that it will implement the changes proposed by Sir Paul Nurse in his review of the Research Councils.[49] This will bring together the Research Councils under an umbrella organisation, Research UK, which has a specific remit including greater understanding of and funding for multidisciplinary research. Learned societies must ensure that the creation of Research UK is well thought-out and addresses the main concerns of the research community, particularly in terms of the future relationship with European Union science funding and the global movement of scientists and students.

Animal research continues to be an emotive topic that demands political attention, especially with new techniques for gene and cell manipulation becoming mainstream within biological research. The UK and EU both have legislation in place covering the use of animals in research, but this is constantly being challenged and amended. The Society must remain alert to changes to this legislative landscape and ensure they are made by informed bodies on a rational basis. Domestically, The Society must continue to support the effective use of animals in research within the principles of the 3Rs. It must also promote the Concordat on Openness on Animal Research and encourage organisations involved in animal research to become signatories.

Recommendations

- Government should commit to a long-term increase in the science budget. Further, they should ensure the formation of UK Research and Innovation and reorganisation of the Research Councils allows flexibility of funding for fundamental, applied and interdisciplinary research covering all branches of physiology and associated subjects
- The value of animal research should be consistently and openly communicated, with support for the 3Rs (reduction, replacement, and refinement of use of animals in research)

[49] https://www.gov.uk/government/collections/nurse-review-of-research-councils

Diversity in physiology

In October 2014, The Physiological Society signed up to the Science Council's Declaration on Diversity, Equality and Inclusion, making a public commitment to ensure The Society's activities help and support increased diversity and inclusion within physiology and the wider science community. As part of this commitment The Society has launched a significant diversity, equality and inclusion project.

The challenges relating to all of these diversity issues are not unique to physiology, and are seen across the STEM disciplines. The Physiological Society must lead the way within physiology, but it is important to recognise that a collective approach across not only the scientific community but within wider society and government is needed to address these challenges.

Indeed, the UK government could do more to promote diversity within science. Only four of the nineteen government departmental Chief Scientific Advisers are female (as of March 2015).[50]

Recommendation

- Diversity should be promoted in the STEM subjects, and learned societies must increase diversity within their memberships

[50] Government Office for Science. 2015. Chief Scientific Advisers. http://tinyurl.com/zgj2soa

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Visibility of physiology

The fall in the number of departments of physiology from 1996 to 2013 is reflected in the proportion of the membership of The Physiological Society registered as working in named departments of physiology. An example of the declining prominence of the name "physiology" is highlighted further by the common referral to the Nobel Prize in Physiology or Medicine as the "Nobel Prize in Medicine", including by the official website of the Nobel Prizes.[51] Anecdotal evidence from stakeholders representing cognate learned societies suggests that this trend is not unique to physiology but applies to other specialised scientific disciplines as well.

While use of the word "physiology" seems to be in decline, reviewing the data shows that metrics relating to student numbers and research output remain strong and healthy. The amount of funding registered as going to 'physiology' has fallen in UK universities, but the picture may not be as bad as it first appears. It is probable that funding for physiological research in the UK is holding up, simply under a different label.

Clearly, the underlying appeal and value of physiology as a scientific discipline remains strong. As long as society wishes to further its understanding of living systems, physiology will remain a core scientific discipline. Students will continue to have a desire to learn about the workings of living systems. Physiological research will continue to uncover and explain the nature and nuances of human and animal health.

With the continuing fragmentation of physiology into new, more fashionable sub-disciplines, the future visibility and identity of 'physiology' is less clear, as is the potential impact any further loss of visibility this may have upon skills, funding and the community.

These problems are not confined to the UK. Scientific research is a globalised endeavour, and we have many sister Societies overseas representing other communities of physiologists (not to mention a significant proportion of international members of The Physiological Society). Effective collaboration with these Societies and other bodies representing biomedical disciplines is necessary in order to advance a unified strategy for the future strengthening of physiology. This must be communicated to physiologists worldwide and actioned through meetings and conferences, journals and public activities.

Recommendations

- Physiology research and teaching should be identified and defined as such in order to retain the academic community of physiologists
- Organisations representing physiology should strengthen national and international collaborations to communicate a united vision for the future of physiology

[51] http://www.nobelprize.org/

CASE STUDY

Physiological Society Theme: Human and Exercise Physiology

Professor Stephen Harridge

King's College London

Exercise and ageing physiology

Exercise, ageing and space flight conflate a number of areas of human physiology which are pertinent to human health in the context of a growing older population and the recent endeavours of the first astronaut to fly under the UK flag, Tim Peake. It is now being recognised that being physically active is one, if not the key pillar underpinning health across the lifespan. Evidence showing that increased sedentary behaviour, as quantified by increased sitting time, is itself an independent risk factor for all course mortality. Whilst the likelihood of developing cardiovascular disease, obesity, or type II diabetes all increase with physical inactivity. Muscular work is essential for maintaining metabolic health as well as maintaining muscle mass for contractile function. Furthermore, our understanding of the physiology of human ageing is confounded by the interaction of ageing per se with inactivity- mediated processes. A six month stay aboard the International Space Station has been likened to be an acceleration of this ageing process, with cardiovascular deconditioning, loss of bone mineral density, deterioration in immune function and a loss of muscle mass all finding similarities with a sedentary aged phenotype. Importantly, the countermeasures undertaken to ameliorate the effects of micro-gravity are not pharmacological, but physiological in the form of daily exercise regimens. Likewise, for older people, as well as for patient groups, with conditions such as COPD, the interventions shown to most effective are often exercise based. The challenge remains to understand the mechanisms by which the "exercise pill" exerts its poly-pharmaceutical powers across the physiological systems to maintain and enhance health throughout life and indeed to understand how personal this exercise effect might be.

Reference

Pollock RD, Carter S, Velloso CP, Duggal NA, Lord JM, Lazarus NR, Harridge SDR (2015) An investigation into the relationship between age and physiological function in highly active older adults.

J Physiol. 593(3):657-80

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Appendices

Appendix I: Membership of steering group

Chair

Professor Richard Vaughan-Jones, University of Oxford (President, The Physiological Society)

Membership

Professor Dennis Brown	Harvard Medical School
Professor Blair Grubb	University of Liverpool
Dr Michael Evans	Keele University
Professor Mary Morrell	Imperial College London
Professor Ken O'Halloran	University College Cork
Keith Siew	University of Cambridge
Sir Patrick Sissons FMedSci	University of Cambridge
Professor Lucia Sivilotti	University College London
Professor Godfrey Smith	University of Glasgow
Professor Melanie Welham	Biotechnology and Biological Sciences Research Council
Dr Keith Wafford	Eli Lilly and Company

Project Secretariat

Dr Philip Wright, Chief Executive	(Ex) The Physiological Society
Dr Ed Hayes, Policy Officer	(Ex) The Physiological Society
Saranjit Sihota, Head of Policy, Education and Outreach	(Ex) The Physiological Society
Henry Lovett, Policy and Public Affairs Officer	The Physiological Society
Simon Rallison, Director of Publications	The Physiological Society

The Steering group would like to thank the Physiological Society Staff who have taken a large part in researching, writing and producing this report. We have learned a lot during the process and the staff involvement has been key – specific thanks go to Ed for all his work on the data, and to Ed, Saranjit, Simon and Henry who have written and produced the report.

Appendix II: Review methodology

This review is based on a combination of primary and reported research. The steering group organized four stakeholder meetings, ran two surveys of The Society's membership and conducted an extensive review of existing datasets.

Meetings were held with undergraduate physiology students at Bristol and Leicester Universities, with 30 Society members and with representatives of The Society's sister organisations.

An electronic survey was sent to The Society's membership of PhD students and postdoctoral researchers, with over 100 responses. A second survey was circulated to Society Representatives in universities in the UK and Republic of Ireland, to gauge the levels of undergraduate practical provision in their universities.

Appendix III: Stakeholder meetings

Organisations and universities represented at stakeholder meetings

University
Kings College London
Barts and The London, School of Medicine and Dentistry
University of Bristol
Kingston University School of Pharmacy and Chemistry
University of Sheffield
University of Aberdeen
University of Leeds
University of Nottingham
Brunel University
University of Surrey
Anglia Ruskin University
University of Cambridge
University of Liverpool
University of Manchester
University Of Reading
University Of Southampton
University Of Brighton

Organisation
Academy of Medical Sciences
British Neuroscience Association
Biochemical Society
British Pharmacological Society
Medical Research Council
Society of Biology
Understanding Animal Research
Wellcome Trust

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Appendix IV: Universities responding to practical provision survey

Univerity name
Bangor University
Barts and The London, QMUL
Imperial College London
Machester Metropolitan University
National University of Ireland Galway
Queen's University Belfast
St George's Hospital Medical School
Swansea University
University College Cork
University College Dublin
University College London
University of Aberdeen
University of Bath
University of Bristol
University of Cambridge
University of Durham
University of Edinburgh
University of Hertfordshire
University of Huddersfield
University of Keele
University of Kent
University of Leeds
University of Leicester
University of Manchester
University of Newcastle upon Tyne
University of Nottingham
University of Portsmouth
University of Reading
University of Sheffield
University of Southampton
University of Ulster
University of Warwick
University of Wolverhampton
University of York