Foreword

Physiology is the science of life and aims to understand the mechanisms of living things, from the basis of cell function at the molecular level to the integrated behaviour of the whole body.

Research in physiology helps us to understand how the body works in health and how it responds and adapts to the challenges of everyday life. It also helps us to determine what goes wrong in disease, facilitating the development of new treatments and guidelines for maintaining human health. This research is then translated into education and clinical practice which gives patients the best chance of making a full recovery.

Physiology as a whole, underpins clinical curricula and informs nurses and allied healthcare professionals performing holistic assessments of people in their care, assisting in the early detection of disease or the development of frailty syndromes. It is pleasing therefore, to see the proportion of students that study courses with a core physiology component who go on to qualify as frontline healthcare workers. As the COVID-19 pandemic has tragically demonstrated, we cannot rely on treatment protocols alone to create gold standard treatments for patients. When novel diseases emerge, the building blocks of a physiology degree equip healthcare professionals to quickly innovate to give patients the best care as quickly as possible. Clinically applied physiology has been a backbone of the science and technology used by medics, nurses, healthcare scientists and allied health professionals throughout the pandemic.

In research centres, physiologists are working collaboratively with other researchers and healthcare professionals on some of the biggest challenges facing the world. Examples of this interdisciplinary collaboration can be seen in responses to the climate emergency, to ageing populations and to the long-term impact of COVID-19.

As this report demonstrates, beyond the lab, physiologists are working in communities, elite sport settings, schools, universities, healthcare centres and hospitals to improve the ‘performance’ of human health.

We are delighted that the report’s case studies demonstrate the variety and breadth of courses with a core physiological component and the impact that they can have, and we would like to thank everyone that took the time to contribute to this report. This report’s findings demonstrate the inextricable link between education with a core physiological component and tangible benefits to patients, the public and the economy as a whole. Our hope is that this report will serve as a constant reminder of the importance and need for physiology to be at the heart of future-proofing university courses, public health and clinical care.
INTRODUCTION

Research in physiology helps us to understand how the body works; it also helps us to determine what goes wrong in disease, facilitating the discovery of new treatments. As such, it has a number of large subdisciplines which often include considerable sub-specialisations themselves. These sub-disciplines include, cardiovascular sciences, respiratory sciences, sensory sciences and gastro-intestinal physiology.

Other widely transferable health-related work undertaken beneath the umbrella of physiology includes the study of healthy ageing; the production of occupational fitness and health standards; the investigation of the health-related benefits of different supplements; and the examination of the causes of sport-related and other deaths and injuries including soft tissue injuries, sudden cardiac death, and drowning. Further, physiology also informs preventative medicine thus, by its very nature, physiology brings together researchers and healthcare professionals from across different specialties, universities, institutions and colleges throughout the UK to undertake research into human activity and health. As such, this report’s analysis not only includes physiology and its sub-disciplines, but also those roles beyond academia that have physiology as a core component of their education, skills or qualifications.

The aim of the work presented in this report is to independently and objectively assess the economic value of higher education provision to the UK that has physiology as a core component at its heart.

About this report

This analysis of the economic value of courses with a core physiological component provision to the UK economy was undertaken by Emsi Burning Glass, an independent economic modelling company that provides economic impact studies and labour market data to universities and institutions. The work was carried out on behalf of The Physiological Society, the largest network of physiologists in Europe, and the Academy for Healthcare Science (AHCS).
Methodology

Data and assumptions used in the study are based on several sources, including student completions, earnings, and demographic data from the Higher Education Statistics Agency (HESA) provided by JISC; industry and employment data from Nomis official labour market statistics; and Emsi Burning Glass’s input-output model. The higher education provision of which physiology is a core component is defined through the Joint Academic Coding System (JACS) codes. These are listed in the main report. The study applies a conservative methodology and follows standard practice using only the most recognised indicators of economic impact. As such, it is likely that the total contribution of graduates that studied courses with a core physiological component could be greater than calculated in this report.

The following two analyses are presented: 1) national economic impact analysis, measured in terms of graduate impact, and 2) benefits analysis to students, society, and the public purse. High-level methodology and results for both analyses are described more fully in each section later in this report. Student data reflect academic year 2018–19, the most recent year for which full data were available. Please note, a full breakdown of the methodology can be found in the long form report which can be accessed via The Physiological Society (www.physoc.org) or the Academy for Healthcare Science (www.ahcs.ac.uk) websites.

CASE STUDY | GRADUATE IMPACT

Promoting equity and diversity in physiology science communication

Alongside The Physiological Society, I developed Being Black in Physiology, Diversity for Scientific Excellence, an animated video which provides insights into the roles and career prospects of black scientists and the importance of equity and diversity in science. It has enabled me to contribute to an animation video where I discussed why equity and diversity is critical to scientific research for the benefit of the global population.

This gave me more confidence that not only as a research scientist I can inspire young scientists from minority background to become physiologists but also the realisation that I can contribute to the diverse, dynamic and competitive scientific environment both nationally and internationally. The confidence developed there led me to apply and obtain funding to host a “Microbiomes in Physiology” symposium where I coached a junior colleague to enhance his professional development and also my leadership skills.

Together we co-hosted the symposium, inviting international speakers with the aim to highlight the range of careers in microbiology. The students also took part in a programme of sessions designed to highlight the range of careers in microbiology. As well as carrying out primary research projects.

In turn, this gave me an opportunity to enhance my communication and networking skills and develop international collaborations with whom I aim to apply for collaborative grants in future. Having become a corresponding author in the review article arising from the work discussed at the symposium, I have the confidence to apply for the BBSRC early career fellowships. This will enhance my future employability in higher income scientific research positions ensuring that as a black scientist, I also can attain a top position in higher income scientific research positions ensuring that the total contribution of graduates that studied courses with a core physiological component could be greater than calculated in this report.

The importance of mentors was one of the most valuable lessons I took away from this programme.

The students gained valuable research skills and insight into research careers. Some quotes from the students who took part are as follows:

"After a month working at the Babraham Institute, my outlook on scientific careers has completely changed and I couldn’t be more optimistic about my future."

"This placement has reassured me that progressing to a PhD is possible for a person of my background."

"The importance of mentors was one of the most valuable lessons I took away from this programme."

CASE STUDY | BENEFITS TO STUDENTS

Providing placement experiences to students from underrepresented backgrounds during the pandemic through the Research Access Programme

The Research Access Programme aims to break down barriers that some students may encounter in obtaining opportunities to progress with a life sciences academic career. It provides students, from underrepresented backgrounds, the chance to undertake a five-week placement working within research groups to carry out primary research projects.

Nine students carried out projects in cellular physiology ranging from meta-analysis of proteostasis decline in senescent cells to researching immunologically relevant RNA binding proteins, all falling within the theme of better understanding ageing at a molecular cell level.

The placements were carried out online, owing to the pandemic preventing hosting of the students in person, further removing geographical barriers that would often prevent some students taking part in such a programme. A stipend was also provided to further support students throughout their participation in the project. As well as carrying out primary research, the students also took part in a programme of sessions designed to highlight the range of careers in bioscience, give insight into day-to-day life working at a research institute, and provide networking opportunities to help support the students in the next steps of their careers. At the end of the five weeks, the students presented their research projects and findings in a half-day, online conference to Institute staff.

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"This placement has reassured me that progressing to a PhD is possible for a person of my background."

"The importance of mentors was one of the most valuable lessons I took away from this programme."
Physiology’s importance in underpinning innovation and research in the health and wellbeing industry

Physiology has been a foundation for my career in children’s health, animal care and nutrition and now human health and wellbeing. Physiology connects all the biomedical disciplines and helps place other subjects like immunology and microbiology in the context of the wider body. Understanding physiological processes is also the foundation for understanding disease, and therefore the creation of innovative health prevention or treatment interventions.

My physiology training taught me problem solving and critical thinking, and I’ve applied these skills to creating innovative healthcare solutions. In my present job, my network across UK physiology academic teams provides me with project partnership opportunities to conduct high-quality research, to form new ideas and commercially successful innovation, through to consumer communications and education. The global health and wellbeing market is a crowded and competitive place. Having a holistic view and understanding the intricate mechanisms within the human body, physiology as a subject will help UK businesses successfully compete and grow.

Using physiology teaching to support pharmacists to assess patients in the community

The role of the pharmacist is rapidly evolving, with pharmacists increasingly involved in holistic patient-centred care. This is driven by a focus on community-based health services and the increasing use of the pharmacy workforce to fill gaps in other sectors. The Community Pharmacy Consultation Service (CPCS), commissioned in 2019 connects patients with minor illness with community pharmacists, with referrals coming from NHS111 and general practice. As part of this service, pharmacists need to be able to assess patients and be vigilant for acute illness presentation, understanding how to refer patients for whom they have concerns. Central to this is the application of the National Early Warning Score (NEWS), as developed by the Royal College of Physicians, an aggregated score allocated to physiological measurements that standardises and improves the detection and response to acute illness in adult patients.

NEWS, including the relevance of the physiological response has been taught in postgraduate pharmacy practice in recent years as part of non-medical prescribing studies. However, with the advent of the CPCS, and the recently revised initial education and training standards for pharmacists, which both

Glossary of terms

Graduate impact
Graduate impact refers to graduates’ higher wages, increased productivity, and associated multiplier effects in Academic Year (AY) 2018-19 as a result of undertaking a course with physiology at its core. This is an annual impact.

Multiplier effects
Multiplier effects refer to the additional income and jobs that are created due to the impacts of graduates. For example, as a graduate earns more money, they create additional demand for goods and services across the wider economy due to their increased spending.

Graduates and students
For the purpose of this study, ‘graduates’ and ‘students’ include anyone returned under JACS codes that were identified as having physiology as a core component of the course.

Social benefits
Social benefits, also referred to as benefits to society, are benefits accruing to the public purse and private UK citizens over time as a result of graduates receiving a physiological sciences education. They are measured in terms of higher earnings, added tax revenues, social savings, and public purse savings.

Present value
Present value refers to expressing projected future revenues and costs in today’s terms. In other words, £1 today is not worth the same as £1 five years from now.

Benefit-cost ratio
Dividing the benefits by costs yields the benefit-cost ratio. It demonstrates how many pounds are returned in increased earnings for each £1 invested.

Rate of return
The rate of return is the annual percentage return to graduates in terms of increased earnings over their career.
Graduate impact

**APPROXIMATELY 97%** of graduates included in the analysis at a UK institution stay in the UK after graduating. Their enhanced skills and abilities bolster the output of UK employers and public services, leading to higher income and a more robust, healthier economy.

The accumulation of graduates who study courses of which physiology is a core component currently employed in the workforce amounts to £22.6 BILLION in added income in the UK’s economy each year. This is equivalent to supporting over 777,200 AVERAGE SALARY JOBS ANNUALLY.

Benefits to students

Costs students in the Academic Year (AY) 2018-19 include £1.1 billion for tuition fees and books and supplies, and £3.1 billion in forgone earnings had they been working instead of learning.

IN RETURN, THEY WILL RECEIVE **£18.6 BILLION** in increased earnings (present value) over their working lives. For example, a Level 6 graduate (equivalent to a bachelor’s degree) will earn £685,200 (not adjusted for inflation) more in earnings across their working life compared with if they had a Level 3 education (equivalent to A Levels in England, Wales and Northern Ireland and Highers/Advanced Highers in Scotland).

Overall, every £1 that students included in this analysis invest in their education yields **£4.40 IN HIGHER FUTURE WAGES.** These graduates will enjoy an annual rate of return of 20.3% compared with their previous level of education.

Benefits to society and public purse

The social and public purse benefits to the UK from students included in the analysis from the AY 2018-19 equal a present value of £35.6 billion. These benefits include £27.8 billion in income from higher student lifetime earnings and increased business output and £6.9 billion in added tax revenues. Additionally, the public purse and the rest of UK society will experience savings as better-educated students lead improved lifestyles. This leads to a present value of £823.9 million in wider societal savings related to health, crime, and income assistance.

**87%** of graduates included in this analysis work in a variety of occupations after leaving university.

OVER 70% of graduates are employed in occupations related to their degree six months after graduation. These graduates are in a range of exciting and fulfilling careers that put their education into practice. Graduates included in this analysis support a number of critical healthcare occupations; nearly one-third of identified graduates are employed as nurses.

Top occupations for graduates

Students included in this analysis work in a variety of occupations after leaving university.
Physiology of sports concussion: cells to systems

Physiological research conducted by members of the Neurovascular Research Laboratory at the University of South Wales led by Professor Damian Bailey focuses on the integrated molecular-haemodynamic mechanisms underpinning accelerated neurodegeneration (loss of brain function) caused by recurrent concussion in contact sports such as rugby.

Studies related to the project include a longitudinal observation of professional rugby union players across one season and a comparison of retired rugby union players with a non-concussed control group. The findings of the studies suggest that sports-related concussion serves as a model of accelerated brain ageing and may increase a person’s trajectory towards neurodegenerative disease in later life. Published findings from the studies have identified novel mechanisms and biomarkers of sports concussion that have helped better guide and inform clinical management of players. These biomarkers have translational relevance across the spectrum of health and neurodegenerative disease. Professor Bailey has contributed to a number of televised science documentaries highlighting that the benefits of physical activity for the brain can be reversed due to the underlying damage caused by recurrent sports concussion.

The research has raised public and player awareness of the long-term neurological complications caused by recurrent sports concussion. The project’s science has contributed to establishment of “Head for Change”, a charitable foundation pioneering positive change for brain health in sport focused specifically on supporting ex-players who are affected by neurodegenerative disease as a result of their professional sporting career in football or rugby.

Additionally, World Rugby has recently changed professional rugby union laws and guidance with a specific aim to reduce contact especially during training sessions prior to a game.

Professor Damian Bailey
University of South Wales, UK

Development of an accurate and sensitive antibody test against SARS-CoV-2 virus

Professor Delibegovic led the Scottish Government’s Chief Scientist Office (CSO) Rapid Response in COVID-19 (RARC-19) research programme to develop an accurate and sensitive antibody test against SARS-CoV-2, in collaboration with an SME, Vertebrate Antibodies Limited (VAL) and NHS Grampian.

In this project, they used an artificial intelligence (AI) application and bioengineered a novel antigen display platform for development of accurate COVID-19 antibody screening tests. The University of Aberdeen team worked with VAL, using VAL’s proprietary AI platform to identify the specific elements of the virus that trigger the body’s defence systems.

The approach was successfully used for the development of a combination of sensitive tests that could be used for mass screening of COVID-19 cases, identification of high-risk patients/carriers, providing data on the prevalence of COVID-19, surveillance of vaccination programs and evaluating the efficacy of vaccines against circulating SARS-CoV-2 strains.

The team developed a “game changing technology” with the tests successfully passing Phase 2 independent validation by the National Institute for Biological Standards and Control (Department of Health and Social Care). This led to international interest including from the Tony Blair Institute for Global Change, which believes these tests will be crucial in low- and middle-income countries where vaccines are scarce.

The platform has received worldwide media attention and is now available for research purposes through several international distributors. Two tests are in final rounds of independent verification at the National Institute for Biological Standards and Control: Universal EpitoGen test intended to identify cases with an antibody response to SARS-CoV-2 following infection or vaccination; Differential EpitoGen test intended for use to distinguish between vaccine-induced and infection-induced antibody response to aid ongoing vaccine and virus surveillance efforts.

Several international stakeholders are evaluating the platforms to roll out in their respective countries including the USA and South Africa.

Professor Mirela Delibegovic
University of Aberdeen, UK
Severe heat exposure and working practices

This body of work investigated the health and well-being of firefighters undergoing severe and repeated heat exposures in their everyday working practices. This is a particular issue for fire instructors who can be exposed to training-based fires up to 30 times per month.

We undertook a series of studies on firefighters working practices and surveyed firefighters around the UK about their current working activities. We measured the physiological and perceptual responses to firefighting activities, alongside the longer-term immunological and inflammatory markers at baseline and as a result of firefighting. We also investigated methods to improve pre, per and post-cooling to reduce the physiological consequence of heat exposure.

This work demonstrated that high exposure fire instructors (those doing more than 9 fires per month) were at greater risk of experiencing inflammation, immunosuppression and symptoms such as headaches, night sweats, fatigue and mood changes. We worked with the Fire Brigades Union Learning team to develop an educational package for firefighters on heat illness, preparing and recovering from the heat and managing heat exposure volumes. This package is now offered to all firefighters in the UK and has been taken on by many services around the world as part of firefighter training.

Dr Alan Richardson
University of Brighton, UK

Supporting secondary school students preparing for mainstream examinations to manage their stress

This project evaluated learning efficiency in the classroom by integrating physiological mechanisms that enhance attention, preparedness and readiness to learn. Through this workshop we explored autonomic nervous system regulation as an effective method of preparing an individual to counteract stress. The format involved edutainment and student preparing for formal examinations such as GCSE/A Level.

This project was a randomised crossover trial whereby students were academically evaluated during simulated stressful conditions mimicking official examination conditions. All students evaluated how stress impacted their physiology and underwent sensory integration activities (proprioception and vestibular). Students were academically retested under identical conditions and scores were compared.

As a result of the findings from the project, a permanent bespoke sensory integration space integrated within the school was established and staff and students were trained to incorporate this activity in the lead-up to examination period.

This activity was also disseminated at a national event called NI Sciencefest in February 2022 to an international audience.

Dr Cathal Breen
Ulster University, UK

Using physiology teaching to enhance the behavioural skills required of tomorrow’s doctors

The General Medical Council’s outcomes for graduates sets out behavioural skills such as “respect”, “empathy”, “compassion”, “interpersonal skills” and “active listening” required of newly qualified doctors. These skills are generally not taught alongside physiological knowledge.

We collaborated with the School of Drama at Queen’s University Belfast (QUB) to test whether physiology teaching can be used to provide training in these core skills. We blended science and art approaches to design and implement a non-classical physiology tutorial on the physiology of hypofertility by inviting final-year drama students to act as simulated patients.

Analysis of student surveys demonstrated that the experience was more engaging, authentic, and unpredictable than even general practice family attachments with genuine but “ideal” patients.

Realistic simulations of doctor-patient interactions emphasised the importance of physiology to patient care, while also embedding “human factors” skills, thus enhancing the educational experience for medical students. Simulations ensure that medical students use a safe environment to make mistakes before seeing real patients. This work was recognised by QUB Centre for Medical Education (“notable impact on education/practice”) for its potential to change teaching practices in the medical curriculum when introducing physiology concepts.

Dr Seán Roe and Dr Etain Tansey
Queen’s University Belfast, UK
Graduate impact

The education and training of graduates who studied courses with a core physiology component has a large impact on the UK economy. Students who have studied courses with a core physiology component are entering the workforce with greater knowledge and skills, including statistical analysis, and scientific evidence-based reasoning. All of these skills supplement the discipline-specific knowledge. After graduation, 97% of students included in this analysis stay in the UK and are more productive compared with those not attending university because of the quality education they received.1 Per standard economic practice analysing the labour market returns to higher education, the higher income and productivity is compared to not attending university. However, this analysis takes into account that some graduates may have realised similar earnings in a separate discipline and that employers may be able to import some labour had these graduates not graduated. These adjustments are referred to as counterfactual scenarios and detailed in the full report.

Over time, the skills of former students accumulate, steadily increasing the training level and experience of the UK’s workforce. As the skills embodied by graduates build up, higher earnings generate additional rounds of consumer spending, while new and enhanced skills and training translate into increased business output and higher property income, causing still more consumer purchases and additional spending. The sum of all these direct and multiplier indirect effects comprises the total impact of the students’ added skills in the UK economy.

As a result of their education, students who studied courses with a core physiology component receive higher earnings and increase the productivity of the businesses, public services and organisations that employ them. In AY 2018-19, these graduates generated £22.6 billion in added income for the UK economy. For context, this is equivalent to supporting over 777,200 average-wage jobs in the UK, or approximately 1.4% of the total gross domestic product (GDP) of the UK in AY 2018-19.

In AY 2018-19, students who completed courses with a core physiological component generated the most impact in careers related to health and social care – creating nearly £10.3 billion in added income, or 46% of the overall economic impact of these graduates.2 As shown in Figure 1, these graduates work in a number of roles, ranging from nurses to medical radiographers.

Table 1: Impact Created by graduates included in the analysis in AY 2018–19

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Impact (£ billion)</th>
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<tbody>
<tr>
<td>Midwives</td>
<td>4%</td>
</tr>
<tr>
<td>Paramedics</td>
<td>4%</td>
</tr>
<tr>
<td>Physiotherapists</td>
<td>5%</td>
</tr>
<tr>
<td>Medical radiographers</td>
<td>3%</td>
</tr>
<tr>
<td>Nurses</td>
<td>40%</td>
</tr>
<tr>
<td>All other (including non-health related occupations)</td>
<td>44%</td>
</tr>
</tbody>
</table>

These are impacts that would not have been generated without the presence of graduates who studied courses with a core physiology component in the UK workforce and economy.

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1. Estimates of the percentage of physiological sciences students remaining in the UK is based on HESA data provided by JISC.
2. For the full breakdown of industries, please see the main report.
Benefits to students
In AY 2018–19, approximately 245,810 students studied courses with a core physiology component in the UK. In order to attend universities or colleges, the students paid out-of-pocket expenses for tuition (except for home students in Scotland), fees, books, and supplies. Additionally, students did not earn money they would have otherwise earned had they been working instead of attending university. The total investment made by students who completed courses with a core physiological component in AY 2018–19 amounted to £4.2 billion, equal to £1.1 billion in out-of-pocket expenses and £3.1 billion in delayed earnings. In return for their investment, students who completed courses with a core physiological component will receive a stream of higher future earnings that will continue to grow throughout their working lives. For example, the average graduate included in the analysis from AY 2018–19 will gain employment with an annual salary of £25,600 six months after leaving with a relevant qualification. These earnings of a graduate who completed courses with a core physiological component are higher than if they had not received a relevant AY 2018–19 qualification. For example, a Level 6 graduate (equivalent to a bachelor’s degree) will earn £685,200 (not adjusted for inflation) more in earnings across their working life compared to if they had a Level 3 education (equivalent to A Level in England, Wales, and Northern Ireland and Highers/Advanced Highers in Scotland). Comparing the increase in earnings across all students who study courses of which physiology is a core component in AY 2018–19 yields £18.6 billion in higher future earnings over their working lives as a result of their education and training in a relevant subject.

Subtracting the £4.2 billion in costs from the £18.6 billion in benefits yields £14.4 billion in net benefits, also called net present value. The students’ benefit-cost ratio is 4.4. In other words, for every £1 students invest in courses of which physiology is a core component (in the form of out-of-pocket expenses and forgone time and money), they will receive a cumulative value of £4.40 in higher future earnings. The students’ investment in courses of which physiology is a core component has an average annual internal rate of return of 20.3%.

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Graduate Impact</th>
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<tr>
<td>Providing safe and effective care for pregnant women who have undergone female genital mutilation (FGM)</td>
<td>How one inspirational physiology lecturer lead me into a whole career as a respiratory physiologist</td>
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</tbody>
</table>

Physiological knowledge empowers students and midwives to understand their boundaries of their own sphere of practice and competencies and when to refer to other specialties and what they can contribute.

Dr Laura Ginesi
University of East Anglia, UK

Physiological knowledge empowers students and midwives to understand their boundaries of their own sphere of practice and competencies and when to refer to other specialties and what they can contribute. The knowledge of homeostasis and physiology enables midwives to promote normal mechanisms of pregnancy and labour; they can recognise and troubleshoot slight deviations, returning the situation to the normal spectrum.

For example, midwives’ understanding of physiology of genitalia and pelvis is vital, particularly when patients have undergone FGM. Understanding how such changes in the body create new physiological and anatomical states is vital to midwives’ role in saving lives globally.

The most difficult time for a woman to live with the consequences of FGM is around birth when the stretching of the perineal tissue is reduced and affects descent of the baby’s head. The scar tissue covering the vaginal opening and urethra needs to be cut open to work with the altered physiological state. If this is not completed the life of the mother and baby can be put at risk.

<table>
<thead>
<tr>
<th>Student Perspective</th>
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<tbody>
<tr>
<td>£685,200 Lifetime higher earnings, Level 6 graduate</td>
</tr>
<tr>
<td>£14.4 BILLION Net present value</td>
</tr>
<tr>
<td>£4.40 Students gain for every £1 invested</td>
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<tr>
<td>20.3% Rate of return</td>
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</tbody>
</table>

I was an undergraduate student in physiology & zoology at the University of Sheffield and took a specific module in exercise physiology taught by Dr Gwendoline Barer. Her beautifully constructed presentations unearthed the world of respiratory and cardiac physiology and their interactions within cardio-pulmonary exercise testing. This seemed to bring together all the respiratory physiology practical and theory and helped me understand the subtle interactions of human physiology and its control. It also spilled over into an understanding of metabolism and substrate utilisation and the balance of “fine” and “course” control of biological systems in biochemistry, physiology, endocrinology and many other aspects of human biology.

This understanding of physiology started an enthusiasm for clinical physiology that has remained with me throughout my career. As a clinical scientist I have always been fully aware of the difference between human biology and clinical medicine and often trusting the biology more than medical opinion in making clinical decisions.

I have enjoyed an amazing clinical career which has included both clinical and research work in aspects of human physiology and metabolism. I have taken great opportunities to be an international scientific leader at a phenomenal period of technology and development in the NHS.

Professor Brendan Cooper
University Hospital Birmingham NHSFT, UK
CASE STUDY | BENEFITS TO STUDENTS

Physiology curricula within pre-registration nursing education in Scotland

An expert group of physiologists and nurse educators developed and agreed a core curriculum of physiology outcomes which identified the physiology all nurses require to know on qualification for safe practice and patient care and also supporting the achievement of the Nursing and Midwifery Council (NMC) standards for future nurses.

The project, funded by The Physiological Society, provides those in nurse physiology education a structure and guide of learning outcomes divided into a systems approach to structure their physiology teaching across the nursing degree.

In the end, there were 177 outcomes agreed. These learning outcomes do not suggest how they should be delivered, but gives the basic level required for qualification as a nurse commensurate with the Nursing and Midwifery Council (NMC) standards for the “future nurse”.

In Scotland, the numbers for student nurses and midwives continue to increase. For 2022-23, the total has been set at 4,837 – a rise from 4,449 in 2021-22.

At Queen Margaret University (QMU), offering a four year programme for adult nursing registration, our target is 101 for 2022/23, having been 82 for 2021/22.

This means we have over 300 students actively engaging with physiology across their nursing programme.

At QMU, we are embedding these outcomes across our four year programme for adult nursing registration. The Master’s programme is based on the person-centred practice framework; therefore, physiology is incorporated throughout some of the module streams rather than being within one distinct module.

We are continuing to ensure our programme includes the required breadth and depth of physiology content within the new person-centred curriculum framework.

Physiology knowledge underpins clinical skills which are key in the nursing curriculum, e.g. cardiopulmonary resuscitation and venepuncture – the requirement to understand the physiological response for cardiac cycle and perfusion and clotting underpin being able to carry out these skills safely. The pre-registration outcomes provides a benchmark for considering what those who are post-registration require in further qualifications, e.g. advanced clinical practice roles.

Dr Alison Wood
Queen Margaret University
Edinburgh, UK

CASE STUDY | GRADUATE IMPACT

Physiology as a bridge to improve access to STEM for Gypsy, Traveller, Roma, Showmen and Boater Communities

The team designed, developed and delivered live an online version of “Science Travels” to a primary school in Wiltshire. In addition, Marie Bowers successfully developed and delivered a GTRSB cultural awareness session for University of Glasgow staff and students and presented the “Science Travels” project at the Royal Society of Biology Connects session “Thinking Outside the Box” a new approach to outreach.

There was overwhelmingly positive feedback from pupils and staff from the online event at the Wiltshire school and this interaction has forged a link between school and university and engaged and empowered the pupils, who aim to use the donated materials to show their peers the wonders of physiology as part of British Science week.

Staff and students at the University of Glasgow (UoG) and beyond are now aware of the GTRSB educational and health inequalities and can more effectively identify and challenge this form of racism and improve the education, health and STEM employment prospects of the communities.

Gypsy, Traveller, Roma, Showman and Boater (GTRSB) communities are very poorly represented in the world of science with only 4% accessing higher education. Students worked collaboratively to design activities to engage young people in STEM, and to provide support and role models in science for GTRSB communities without ostracising them. Physiology was used as the bridge to connect and support the journey of discovery into the fascinating world of living systems.

Marie Bowers and Dr Iain Rowe, University of Glasgow, UK
Higher earnings and increased tax receipts

As discussed under the ‘Benefits to Students’ section, students included in this analysis earn more because of the skills and qualifications they acquire while attending university. The output of businesses, organisations, and health systems is increased because the enhanced skills of the students boost wider productivity. This in turn raises profits and other business property income throughout the national economy. Together, increases in earnings and business output stimulate corresponding increases in value added to the UK economy, raising prosperity in the UK.

Furthermore, the tax base is expanded since, as graduates earn more, they make higher income tax payments and National Insurance contributions. The portion of the higher earnings that graduates spend also leads to higher value added tax (VAT) receipts. Likewise, as employers increase their output and make more purchases for supplies and services, they benefit the public purse through their higher corporation tax and VAT payments.

The higher earnings of graduates, businesses, and organisations, along with broader increases in income across the UK arising from these higher earnings, amounts to a present value of £27.8 billion. Due to these higher earnings, the public purse will see an additional present value of £6.9 billion in added tax revenues. Together, this means society and the public purse will see a total present value of £34.7 billion in higher earnings and increased tax revenues over the course of the working lives of students who studied courses with a core physiological component in AY 2018-19.

Aerospace medicine is a key enabler of military aviation and a fundamental support pillar to civil aerospace activities. It is a vital component of the management of safety and risk in all human aviation and spaceflight activities. Applied human physiology research activities are key components of the test and development of new operational capability (e.g. aircraft and associated life support or escape and protection systems). Underlying all of these activities are the teaching of aerospace physiology. At King’s College London, our previous aerospace and space physiology courses, along with our ongoing MSc in Human and Applied Physiology or BSc module in Extreme Physiology have inspired generations of scientists and doctors to enter the aerospace field. Our internationally recognised Diploma in Aerospace Medicine course is in its 55th year and has been delivered at KCL for over 20 years in partnership with the RAF, UK CAA, British Airways and many other organisations. This course has trained generations of UK and international doctors who work in the UK or internationally in both military and civil aerospace sectors. Their work is underpinned by our physiology teaching, which enables them to contribute to human safety and performance in aviation and space endeavours around the world.

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CASE STUDY | BENEFITS TO SOCIETY AND PUBLIC PURSE

Using physiology to develop physiological output data

ADInstruments was founded in 1986 and develops simple, flexible tools to help researchers and educators record and analyse physiological data quickly and efficiently. ADInstruments’ products are cited in more than 30,000 research papers in peer-reviewed journals and their equipment is the preferred choice for tens of thousands of scientists and educators around the world.

As one example of this, ADInstruments products are supporting the work of Professor Leith Meyer from the University of Pretoria, South Africa, who conducts research is into improving outcomes for rhinos that have to be anaesthetised as part of Kruger National Park’s programme to deter poachers. Once the rhino is immobilised, Professor Leith’s team uses ADInstruments monitoring system adapted from human exercise physiology studies to monitor the rhino’s ventilation, tidal volume, respiratory rates, and metabolism during anaesthesia. The findings allow the capture process to be fine-tuned for the rhino, to keep them as healthy as possible.

In addition to recruiting physiologists to support and maintain the development of products, ADInstruments also has physiologists in its marketing and communications departments.

One of our UK-based employees, a recent Biomedical Sciences graduate uses her physiology knowledge day to day in her marketing role to understand the research questions scientists have and how ADInstruments tools help them achieve their goals. For her, it is very rewarding to help tell the story of the scientists through marketing communications and share awareness of their research through various user stories.

In addition, sales staff at ADInstruments require a solid understanding of physiology principles so they can advise scientists what tools would be best suited for their research plans. Almost all of ADInstruments’ staff are educated to a degree level in science – it is an organisation where physiologists make tools for physiologists.
Social and public purse savings

The social value of graduate education also consists of the savings that accrue to society and the public purse through the improved lifestyles of former students. Higher levels of education are statistically correlated with a variety of life changes that generate social savings in three main categories: 1) health, 2) crime, and 3) unemployment. By combining data sets that relate learning to improved social behaviour, we can quantify how education contributes to the lowering of social and public purse costs and ultimately improves quality of life.

Health service savings include avoided costs for treatment and medical staff time associated with smoking, obesity, and mental ill-health. While the public purse primarily benefits from reduced NHS expenditures, the savings to the rest of society are multi-faceted. For example, some individuals will spend less time away from work, live healthier lives and see reduced private healthcare costs. Savings strictly to the public purse amount to a present value of £100.1 million, while savings to the rest of society are equal to a present value of £311.5 million. Together, the AY 2018-19 students included in this analysis from AY 2018-19 will save the public purse and the rest of society a present value of £311.5 million over their working lives from healthcare and health-related costs. A key aspect of the analysis is the amount of health-related research being undertaken within physiology and life science departments. Much of the research undertaken within physiology has health benefits for society as a whole and thereby reduces NHS costs in areas such as exercise for people receiving treatment for cancer and healthy ageing. As such, these graduates make a significant contribution in reducing the burden of healthcare and health-related costs.

Crime savings consist of reduced security expenditure and insurance administration, lower victim costs, and reduced criminal justice system expenditures. While the public purse will benefit from reduced costs on security expenditures, citizens across the UK will benefit from reduced costs of crime, such as damage or theft of property. Savings accruing to the public purse amount to a present value of £69.3 million while savings to the rest of society equal a present value of £286.2 million. Together, the AY 2018-19 students included in this analysis will save the public purse and the rest of society a present value of £355.5 million over their working lives from crime-related costs.

Unemployment savings comprise the reduced demand for unemployment benefits, which is a direct saving to the public purse. The public purse will realise savings of £58.8 million (present value) due to lower unemployment over the course of the working lives of students identified as part of this analysis from AY 2018-19. Altogether, the social and public purse savings of those included in the analysis from AY 2018-19, accumulated across their working lives, equal a present value of £825.9 million related to health, crime, and unemployment benefits in the UK. Figure 2 demonstrates the relationship between benefits to society and benefits to the public.

Figure 2: Present value benefits to society and the public purse

CASE STUDY | BENEFITS TO STUDENTS

Physiology as a core healthcare science

Physiology is an essential component of the core training for all healthcare professionals, including medical, dental, nursing, physiotherapy and pharmacy students. This is delivered by physiologists through lectures, practicals, demonstrations and small-group activities to deliver an understanding of the physiological basis of health and disease to enable the safe graduation of over 900 healthcare professionals a year from the University of Birmingham. Similar training is provided across the UK, by other higher education institutions, to provide around 45,000 healthcare students a year for the national workforce, with the majority working for the NHS. As such, physiology education has a direct and significant impact on the treatment and care of patients across the UK.

Additionally, the graduation of healthcare professionals with physiological knowledge enables them to begin their careers with a suitable scientific basis for the understanding of disease processes and the skills to facilitate their own lifelong learning and research ambitions as they progress to specialisation within different fields of medicine.

Professor Prem Kumar
University of Birmingham, UK
CONCLUSION

The results of this study demonstrate that the provision of higher education underpinned by physiology found within universities and colleges large and small creates significant value from multiple perspectives. Overall, the accumulation of graduates of courses of which physiology is a core component in the workforce provides an impact of £22.6 billion in added income to the UK economy every year. In addition, the class of AY 2018-19 will contribute a present value £35.6 billion to society over the course of their working lives, including £6.9 billion in added tax revenues and a reduction of £825.9 million in social savings across healthcare, unemployment benefits, and crime reduction. The courses that these students undertake are also economically beneficial to the individual student. Every £1 a student spends on their course with a core physiology component yields £4.40 in higher future wages, an annual rate of 20.3% compared with not having studied that course.

Students who study courses of which physiology is a core component are equipped with the required knowledge and transferable skills making them more likely to live and promote healthy lifestyles. This could in turn reduce the associated costs to the healthcare system. Furthermore, the knowledge delivered through such courses underpins the provision of healthcare through innovative approaches to societal problems such as informing preventive medicine, the design of PPE and the response to novel pandemics.

As a result of this independent economic assessment, it is concluded that courses of which physiology is a core component deliver significant value to students and society in terms of research, teaching, and knowledge exchange across a wide range of disciplines.

PARTNERS

The Physiological Society

As the largest network of physiologists in Europe, with academic journals of global reach, The Physiological Society continues a 140-year tradition of being at the forefront of the life sciences. We support the advancement of physiology by promoting collaboration between physiologists around the world and research that will contribute to a better understanding of the complex functions of living organisms. The Society is committed to ensuring that the full potential of courses with a core physiology component in the UK is realised and that departments have the opportunity to showcase their work.

For more information, see www.physoc.org or @ThePhySoc

The Academy for Healthcare Science

The AHCS was established as a joint initiative of the UK Health Departments and the professional bodies across Healthcare Science. The Academy’s specific role in the education and training system, through Registration and Equivalence has enabled the development and strengthening of relationships with key stakeholders across the Healthcare Science workforce and beyond.

The AHCS is the single overarching body for the entire UK Healthcare Science (HCS) workforce, working alongside the healthcare science professional bodies and also professionals from the Life Science Industry and Clinical Research Practitioners, helping to strengthen the visibility of the contribution of those workforces.

In subsequent years, the Academy has evolved and now maintains a Professional Standards Authority (PSA) Accredited Register with many parts, a non-Accredited Register and Directories, all of which sit within the regulatory framework, administrative functions and oversight of the Academy.

Emsi Burning Glass

Emsi Burning Glass is a leading provider of economic impact studies and labour market data to universities, workforce planners, and regional developers in the UK, US, and internationally. Since 2000, Emsi Burning Glass has completed over 2,000 economic impact studies for educational institutions in four countries. Visit www.economicmodelling.co.uk for more information about Emsi Burning Glass’s products and services.