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Delivering Science for Wales 2014-15

Annual Report on our Strategy for Science in Wales

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Foreword

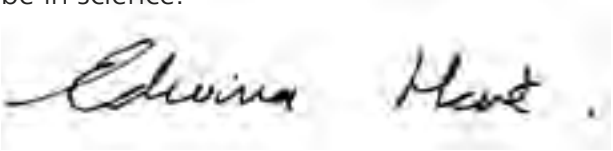
Mrs Edwina Hart MBE CStJ AM
Minister for Economy, Science and Transport

I am pleased to see another year of developments that are helping to deliver our ambitions for science, set out in March 2012 in *Science for Wales*.

The Sêr Cymru programme is now fully underway and I look for it to produce some excellent outcomes in future years. I was impressed and encouraged by wonderful Research Excellence Framework results won by academic research teams across our universities and announced just before Christmas 2014. Our universities have amply demonstrated the very real quality of much of their research and the equally pleasing impact that we have seen from a wide range of departments – helping our economy and public services in so many ways.

In this report, you will see that we have put in place much of what was called for but there is more to come. Further plans to build on and complement Sêr Cymru are being made. We have just heard from the European Commission the good news that our application to its COFUND scheme, to provide research fellowships in our universities, can proceed to the next stage. Building research teams that are excellent and which can be sustained at that level takes time and effort. While we should not look to see overnight results from this strategy, there is progress and each year we are learning more about the causes for our historic difficulty in securing our share of competitive research funding. We need to see more science researchers in post at all levels. The Welsh Government is playing its part in making this a reality, with Universities Wales, the Higher Education Funding Council for Wales (HEFCW) and our university partners throughout Wales. I am particularly pleased to welcome Professor Diana Huffaker to Wales after the good news, received only recently, that she has accepted a Sêr Cymru research chair at Cardiff University.

Securing the new generation of scientists, technologist, engineers and mathematicians was another key aspect of *Science for Wales*. This past year has given us significant new proposals to consider for education through the Great Debate in science and more generally. Alongside these developments in formal education, complementary science engagement activities have continued through the year, many supported by our National Science Academy. These both enthuse our pupils and educate their parents or guardians about the benefits, personal and economic, which can come from following a scientific or technical career, as well as showing the fun and interest there can be in science.



Introduction by the Chief Scientific Adviser for Wales

Professor Julie Williams CBE

A key aspect of my role as Chief Scientific Adviser is overseeing the delivery of the Welsh Government's science strategy, so it is good to report continued progress through the year and the development of further plans to boost our universities' capacity to do excellent research and increase their capture of competitive research income. The most significant event in the science field over this past year has been the delivery of the long-awaited Research Excellence Framework (REF) results. These have proved to be very good and encouraging news for Wales.

Achieving our expected share by population size of competitively-awarded research and especially that from the UK Research Councils was and is a really ambitious target. Getting to 4.9 per cent of such funding is a long-term ambition. We now understand better the reasons for our present levels of funding, through the findings of the Elsevier report, highlighted last year. This showed that research in Wales is efficient, highly cited, highly collaborative and generally of high quality but we simply do not have enough of the excellent researchers we need to win more funding than we do. Although I see that the percentage won from the Research Councils has dropped back, on the latest available figures, to 3 per cent, this is countered by a rise in the competitively-awarded funding won from all sources, which has now grown to 3.8 per cent. Only very recently, new analysis by Professor Peter Halligan and Dr Louise Bright, featured in this report, has refined our understanding of the lack of scientific research staff numbers and placed the shortfall at around 600.

This annual report sets out just some of the highlights achieved in the REF results – both those demonstrating the highest level of research excellence and also higher levels of research impact. Impact is a new measure, not used in the previous exercise in 2008. It is defined as 'an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia'. I pointed out last year the major contribution our scientists, in the broadest sense, make to our knowledge economy. This is powerfully evidenced in a number of the REF impact case studies. The economic effect from research outcomes is over and above the role universities have as economic actors in their own localities, as employer; as consumer of local goods and services; as entrepreneur and as focus for much community activity. I think it is important that we celebrate their very real successes in the REF. Beyond the good examples here, there were many more we could not include and I would encourage you to look on our university websites at further, equally impressive, research impacts.

Sêr Cymru was set up to help Wales' universities increase their research quality and research capacity. Just as this report was being completed, we had the excellent news that Professor Diana Huffaker, a talented electrical engineer and entrepreneur from UCLA in California had agreed to take up what is our fourth Sêr Cymru research chair, working at Cardiff University. Wales is very fortunate to have secured such an able academic, who will also, I'm sure, prove to be a strong role model for women in or aspiring to scientific careers.

We have worked up a second element, now known as Sêr Cymru II, which will aim to complement the existing and new research chairs and national research networks, by bringing on promising young researchers and those in mid-career, as well as helping to bring back some talented people who have left research careers. Again, this is a contribution by the Welsh Government to helping to increase research capacity significantly. From this increase we hope to see a rise in the research funding won for Wales.

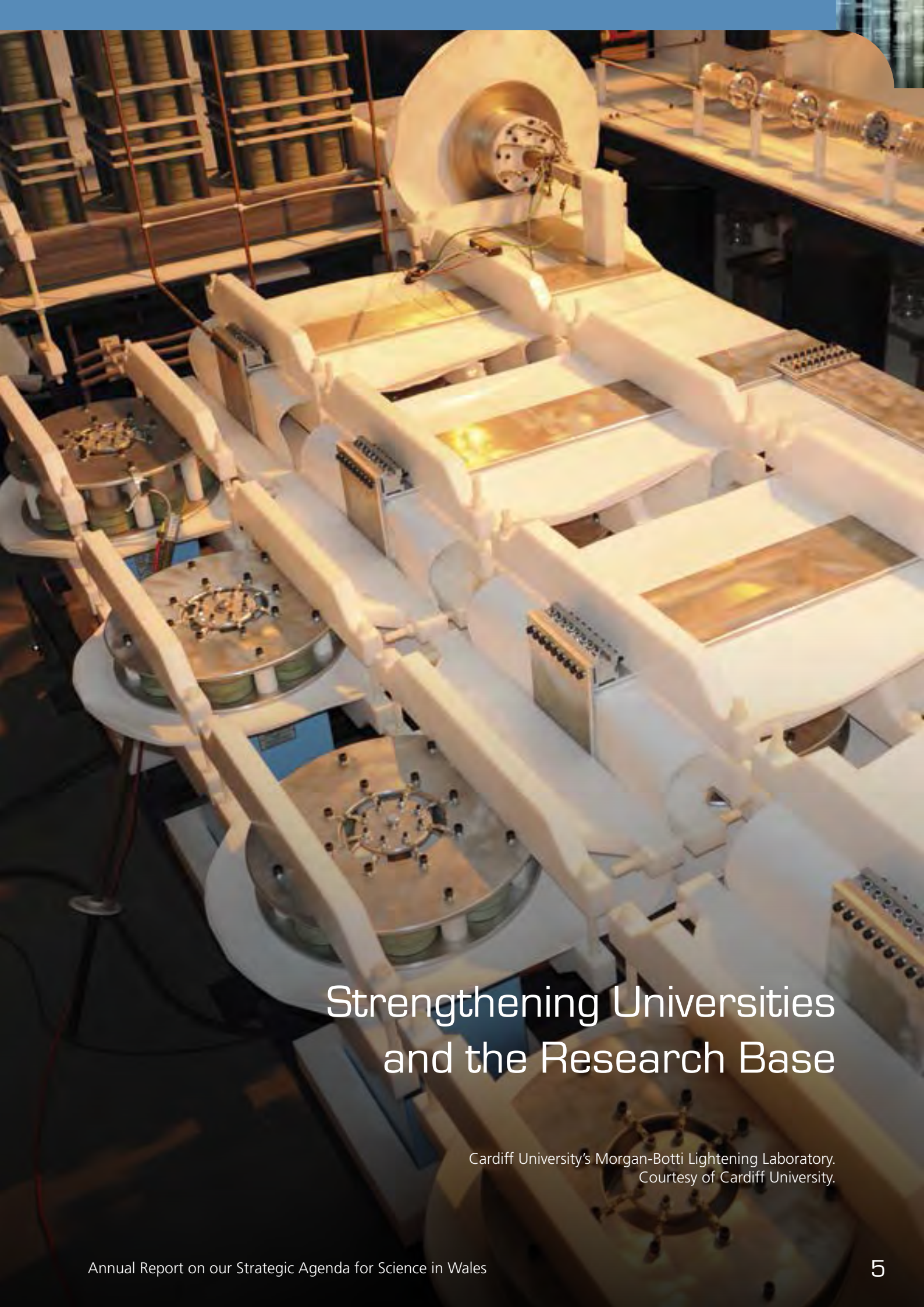
Closer to home we have also just heard that an application to the European Commission's COFUND scheme has had the green light to go forward to the grant agreement stage. This stands to bring very significant funding to allow us to bring yet more talented researchers to work in Wales. Again, this is a very pleasing development and it is discussed further in the main text of this report.

Another significant area of activity has been in the world of education, where Professor Graham Donaldson's review has reported and a national conversation, called the 'Great Debate on Welsh Education' has started, to go through his proposals in detail. I was pleased to see that the proposed new curriculum would feature, from the earliest years to GCSE, both maths and numeracy and science and technology as two of six 'areas of learning and experience' and that both numeracy and digital literacy could be built in as cross-cutting responsibilities for all teachers. We need many more young people pursuing careers in science and technology and all our young people to be more comfortable with scientific concepts which materially affect their daily lives. The Royal Society estimated last year that the UK will need one million new scientists, engineers, technicians and mathematicians by 2020. Given that these will be high quality jobs, I am keen that many of them are developed in Wales.

An excellent campaign to explain the importance of science as a subject and how it can benefit the future careers for many of our young people in Wales began in the autumn of 2014. It includes engaging new materials for the classroom, sign-posts events and seeks to provide information to parents or guardians about the real importance of being scientifically literate in the technologically advanced world we inhabit. Parents are so often key influences on their children's choice of career and we need them to give science a

fair hearing and consider it as a choice for their children. I commend the 'Qualified for life: focus on science' campaign.

The National Science Academy or NSA has recently completed its latest round of funding, allocated in 2013, for a wide range of science engagement activities. They are now considering future funding arrangements. Some highlights of the activities they funded are reported here but the strategic review of its activities coupled with our future strategy document for the NSA, published soon, will feature more detail.



Strengthening Universities and the Research Base

Cardiff University's Morgan-Botti Lightening Laboratory.
Courtesy of Cardiff University.

This is the third year since ***Science for Wales*** set out the Welsh Government's agenda for science in Wales. When it was published, while we knew we could point to some areas of excellence, we know also that there was too little recent, robust evidence about the quality and quantity of research and, especially, scientific and engineering research in Wales.

What was clearly known was that Wales' higher education institutions (HEIs) were not securing their population-equivalent share (4.9 per cent but often rounded to 5 per cent) in competitively-awarded research funding. This has been a concern for some years. Professor Robin Williams' 2013 report 'Recognising the Quality of Research at Universities in Wales' argued that the quality of our research base was good, but the lack of sufficient researchers within Wales in the high-spending areas of medicine, engineering and the physical sciences prevented greater grant capture. He set the deficit at about 200 academics. The percentage of research funding that Wales wins, particularly from the UK Research Councils, fluctuates annually but it has been steadily around 3.0 to 3.5 per cent over some years.

In last years' Annual Report we were able to highlight the findings from a jointly commissioned study by Elsevier, which gave us hopeful and positive news on the efficiency, collaborative nature and reputation of research in Wales. Again it showed that while we had excellence we did not have enough of it to boost competitive grant capture.

Now, the recently-published Leadership Foundation for Higher Education report 'The Case for Growing STEMM Research Capacity in Wales' by Professor Peter Halligan and Dr Louise Bright, adds to our understanding of this area. Their work shows that, for many years, universities in Wales have won a smaller proportion of UK research funding than Wales' share of the population would suggest. Since the 1990s, successive attempts to strengthen research have been made, but the overall share of research grants has remained stubbornly low. This is particularly so in the science, technology, engineering, mathematics and medicine (STEMM) disciplines. This goal of securing 'population share' of UK research income has proved elusive, mostly due to Wales' historic shortfall in STEMM research capacity.

Analysing data from the Higher Education Statistics Agency (HESA), they established that Welsh universities have 4.1 per cent of total UK academic staff in the STEMM disciplines, compared to Wales' 4.8 per cent share of the UK population. 646 more researchers would be needed to give Wales a 'population equivalent' share of UK STEMM researchers. They contrast this with Scotland's 12.3 per cent of total UK academic staff in the STEMM disciplines, against their only 8.3 per cent of UK population. The largest staff deficits in Wales' HEIs were noted in clinical medicine; biosciences; physics; electrical and

computer engineering; mechanical, aero and production engineering, and maths (see the table below for more detail). These disciplines are all those covered by the highest-spending UK research councils – the MRC and EPSRC.

While the report is very positive in welcoming our Sêr Cymru I investment into Wales' research capacity, it notes that more is needed to generate critical mass, hence our continuation of support through Sêr Cymru II. Halligan and Bright suggest that addressing this deficit, which in Wales is made up of 96 per cent (621 Full-time equivalents) STEMM-related researchers, should see Wales competitively-awarded grant capture rising significantly. This is especially so given the known effectiveness and productivity of Wales-based researchers.

The authors do go on to argue that over-emphasising our universities not capturing a notional 5 per cent of UK research funding gives a misleading picture of Wales' true research performance. It many respects it is very strong.

Table 1: Capacity shortfall in Welsh HEIs related to research council performance, 2012/13

Bold text below indicates the large STEMM resourced councils.

Right: Table from Halligan & Bright: 'The Case for Growing STEMM Research Capacity in Wales' (Leadership Foundation for Higher Education) page 35

UK research council	Subject disciplines	Wales % of UK RC income	2012/13 Wales staff deficit (FTEs)	BIS 2012/13 Total UK % funding allocation (Dec 2010)
AHRC		4.3%		3.6%
BBSRC	Biosciences	4.9%	-0.59 (62)	13.9%
EPSRC	Electric and computer engineering Mechanical engineering Maths	2.6%	-1.9 (65) -2.2 (78) -2.4 (75)	**29.1%**
ESRC		3.6%		5.9%
MRC	Medical	2.0%	-1.29 (242)	**21.2%**
NERC		4.9%		11.5%
STFC (Core and Cross facility)	Physics	2.7%	-2.1 (84)	**9.7%**

In December 2014, the results of the long-awaited Research Excellence Framework or REF were published. They represent the first comprehensive independent overview of research in universities across the United Kingdom, since the 2008 Research Assessment Exercise (RAE).

Left: A researcher with a Petri dish. Courtesy of Swansea University.

The REF was undertaken on the basis of submissions from universities to subject-based assessment panels. In the 2014 REF, there were 36 assessment panels, each responsible for a separate group of subjects, called a Unit of Assessment (UoA). Submissions were assessed against three elements:

- Research outputs – primarily publications such as academic journal articles, books and chapters in books, but also other forms of outputs, such as design, performances and exhibitions.
- Impact – any effect on or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life beyond academia.
- Research Environment – including research strategy, collaborations, physical infrastructure and facilities.

The results were assessed using a five-point quality scale:

4★– world-leading quality

3★– internationally excellent

2★– internationally recognised

1★– nationally recognised

Unclassified – below the standard of nationally recognised.

The REF panels assessed separately each of the three elements of the submissions – outputs, impact and environment – and created sub-profiles for each, showing the proportion of work judged to reach each the different quality levels. These sub-profiles were then combined into an overall quality profile for each institutional submission.

The results for Wales' universities were excellent, backing up the positive outcomes from the Elsevier study and adding to our stock of the robust evidence we needed. The proportion of world-leading quality research (4★) in Wales more than doubled since RAE in 2008 and the proportion of 3★ also increased considerably.

Table 2: REF (2014) and RAE (2008) quality profiles, Wales and UK comparison

	4★	3★	2★	1★	Unclassified
Wales 2014	30%	47%	20%	3%	0%
UK 2014	30%	46%	20%	3%	1%
Wales 2008	14%	35%	36%	14%	1%
UK 2008	17%	37%	33%	11%	1%

Wales' universities performed particularly well in the impact element of the REF (See the 'Promoting business innovation and the exploitation of science' chapter below, for a selection of excellent case studies). Almost half of the case studies they submitted to demonstrate impact were judged to be at the very highest quality level (4★) and 86 per cent was judged to be in the top two quality levels (4★ and 3★ combined). These figures confirm the very significant contribution that research in Welsh universities makes to our economy, society and culture.

Table 3: REF (2014) Sub-profiles for outputs, impact and research environment

	4★	3★	2★	1★	Unclassified
Overall quality profile	30%	47%	20%	3%	0%
Research outputs	22%	51%	23%	3%	1%
Impact	49%	37%	10%	3%	1%
Environment	42%	40%	16%	2%	0%

Departments in various universities in Wales recorded strong performances over a range of subjects, with world-class achievements at more than one institution in these units of assessment, including several in the science and engineering field:

- Psychology/Psychiatry/Neuroscience
- Allied Health Professions
- General Engineering
- Geography/Environmental Studies/Archaeology
- Sport and Exercise Sciences/Leisure and Tourism
- Sociology.

There were also strong performances by individual institutions, for instance, Cardiff University in Architecture and the Built Environment; Business and Management; Sociology, Education and Aberystwyth University in Politics and International Studies.

The table below shows units of assessment where Welsh universities performed especially successfully in research outputs in scientific fields. Ranking the institutions according to the grade point average (GPA) of their quality profiles, Cardiff University came sixth and Swansea University 26th in the UK. Welsh institutions recorded 'top ten' rankings in numerous Units of Assessment (see table below). The GPA rankings cited here are based on those produced by the Times Higher Educational Supplement. Other GPA calculations using slightly different methods are also published.

Table 4: UK GPA ranking in REF research outputs by unit of assessment

UK Ranking	Unit of Assessment	University
1	Civil & construction engineering	Cardiff
2	Allied health professions, dentistry, nursing & pharmacy	Swansea
2	Psychology, psychiatry and neuroscience	Cardiff
3	Sociology	Cardiff
=4	Allied health professions, dentistry, nursing & pharmacy	Cardiff
=5	Education	Cardiff
6	Physics	Cardiff
=7	General engineering	Cardiff
=7	Sports & exercise sciences, leisure & tourism	Cardiff Met. & Bangor
8	Clinical medicine	Cardiff
8	Earth systems and environmental sciences	Swansea
9	Chemistry	Cardiff

Some highlights for the Research Excellence Framework

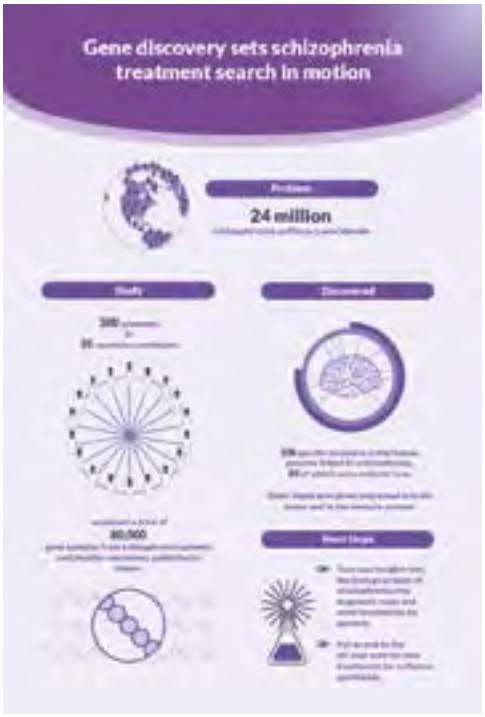
What follows is a selection of that work which achieved some of the highest scores in overall REF research quality calculations. The top 10 in the UK rankings cited are on the basis of the oft-used GPA or grade point average.

Cardiff University's Civil and Construction Engineering researchers achieved first place across the entire UK for research quality. Over the REF period, 110 new research awards with a total value of £16.5 million were secured and more than 800 papers were published. Civil engineers from the School of Engineering are working to meet industrial and societal needs, providing news ways

of constructing and managing national infrastructure as well as understanding, protecting and exploiting the environment. Much of the work is multidisciplinary in nature. Among the aims are reducing environmental impact and increasing sustainable practices in a wide range of areas including construction, fuel, energy, waste disposal, water quality and flood protection. Through this work of the highest quality they are clearly achieving these aims, since their research impact score (discussed below) was equally stellar.

Psychology, Psychiatry and Neuroscience at **Cardiff University** was rated second in the UK for research quality, confirming Cardiff's position as a world-leading centre of excellence for all these areas of study. Two Professorial appointments in Clinical Neuroscience and Behavioural Genetics have enhanced the collaboration between the School of Psychology and the Medical Research Council (MRC) Centre. Over £9m of joint grants were awarded in the period between 2008 and 2013. The MRC Centre for Neuropsychiatric, Genetics and Genomics and the School of Psychology are major partners in the Neuroscience and Mental Health Research Institute. Research has also been enhanced by establishing the Cardiff University Brain Research Imaging Centre (CUBRIC) and the Wales Autism Research Centre, led by the UK's first Chair in Autism Research, Professor Susan Leekam.

One example of their work is the worldwide molecular genetic study, led by Professor Michael O'Donovan from the University's MRC Centre for Neuropsychiatric Genetics and Genomics, which last year found 108 specific locations in the human genome linked to schizophrenia, 83 of which were entirely new, These provide important new evidence about the causes of this widespread, debilitating condition and point to new biological mechanisms and pathways. As expected many genes were active in the brain but a surprising number were active through the immune system. The study was undertaken through the examination of 80,000 samples from schizophrenia patients and healthy volunteers and published in 'Nature'.



Left: Professor Michael O'Donovan and a poster setting out the study he led on genes influential in schizophrenia. Courtesy of Cardiff University.

Swansea University's College of Medicine achieved second place across the whole UK in the **Allied Health Professions** element of their unit on research quality. They had 54 per cent of research judged as 4★ and 41 per cent 3★. They won significant sums over the REF period, such as approaching £7.5 million from the UK Research Councils and similar funding bodies and just under £3 million from competitively awarded charity research funding. Research is focused in the Institute of Life Science (ILS), which has had over £100 million invested in research infrastructure. Its interdisciplinary research facilities support specialist centres such as the EPSRC National Mass Spectrometry Facility; the Centre for NanoHealth (working also with Swansea's Colleges of Engineering and Science) and a UK Centre of Excellence in eHealth and Informatics (CIPHER), part of the new UK Farr Institute for Health Informatics. Pioneering work on informatics has been further recognised by a new award of £8 million to host the Centre for Administrative Data Research and Evaluation (CADRE), part of the ESRC Big Data Network (one of only 4 major UK centres).

Physics at **Cardiff University** achieved 6th place overall on quality. Physics and Astronomy at Cardiff University is at pains to support fundamental science (although an impressive 63 per cent of research was found to be outstanding for its impact). They came top among Physics departments for the proportion of overall submissions deemed 'world leading' 4★ and 'internationally excellent' 3★. All four elements of their work (Condensed Matter and Photonics; Gravitational Physics; Astronomy, and Astronomy Instrumentation) aim to achieve this world-class performance, evidenced by outputs in major, high-impact journals, strong and diverse research income and collaboration with major international centres of excellence.

EPSRC grants have increased from £1.8 million to £4.8 million since the RAE. Significant other funding, much from European sources, amounts to £23.3 million over the period. Substantial investment in research infrastructure, such as a state-of-the-art low energy electron microscopy suite and facilities to grow and characterise diamond, including nanodiamonds, will help to ensure this performance can be maintained. Many international collaborations are underway, including the Cardiff-led SPIRE instrument consortium for the Herschel satellite. This saw eighteen units from nine countries, led by Astronomy instrumentation at Cardiff, designing one of the three measuring instruments on the satellite complementing the telescope, on the four-year mission 2009-13. This has garnered a wealth of imaging and spectroscopy data about our universe in the 60 – 700 μm (or microns) wavelength range – data which would be blocked by the atmosphere on earth.

Another element of engineering at **Cardiff University – General Engineering** was equal seventh (with Dundee University). Their research outcomes span three of the School of Engineering's research themes – Energy; Mechanics, Materials and Advanced Manufacturing; Health, Security and the Digital World. Much of the work is multidisciplinary and by its nature involves long-standing international links with industry (e.g. Rolls Royce, EADS and Tata Steel). As with much of the excellent research featured here, it too is impactful (at 80 per cent at 4★ – very near the top in the UK) with discoveries applied in the areas of offshore wind, surgical simulation and power amplifiers for future wireless systems. Research grant success came from a wide range of sources and included £10.1 million from the UK Research Councils. In the same period, industrial and public collaborations saw 92 new awards with a value of £6.2 million. Facilities and equipment of the highest quality include the £1.4 million Morgan-Botti Lightning Laboratory (used to investigate the effects of lightning strikes on aircraft) and a multi-million pound Gas Turbine Centre, crucial to research into safe, low-carbon power and emission reduction.

Cardiff Metropolitan University put in a joint submission with **Bangor University**, in Sport and Exercise Sciences, Leisure and Tourism, based on a 20-year collaboration between these two institutions, now strengthened in the Institute for Research Excellence in Sport and Exercise. It brought these two HEIs a joint seventh place for highly-rated research articles in their field. Many of these achieved a high impact score, for their influence in sports medicine and sport and exercise practices, boosting the overall quality rating. Such studies helped Cardiff Metropolitan to perform very strongly, as a post-1992 university, where the volume of research activity is generally lower. It placed at 41st, helped by its high impact scores – the highest post-1992 HEI in the UK on overall quality.

Left: Nuclear Magnetic Resonance spectrometer. Courtesy of Cardiff University.

Clinical Medicine at **Cardiff University** was ranked eighth in the UK on overall research quality, achieving a GPA of 3.25 (maximum possible 4.0). 80 per cent of their work was graded as outstanding on impact and this is examined below. The research covers a wide range of topics, such as molecular and cellular biology; clinical trials; the evaluation of innovations in practice and linking with pharmaceutical and diagnostic sectors in preclinical research and clinical trials. Research successes include the discovery of a new bacteria resistant to antibiotics; new treatments for leukemia, breast and prostate cancers being devised; and kidney dialysis treatment made better. The aim is to make best use of basic research strengths to support translational research, improve outcomes for patients and create value for the economy of Wales and the wider UK. During the REF period, the Clinical medicine researchers won £83.7 million in grant and infrastructure funding. They published more than 2100 articles in peer reviewed journals including ***Cell, Nature, Science*** and the ***New England Journal of Medicine***. 105 PhD and 46 MD students were supervised to completion. Researchers led and took part in numerous multi-centred clinical trials and pharmacogenetic work which have contributed to novel cancer treatments and begun attempts to target inherited cancers with individualised therapies.

Left: A Design Drawing of the new CUBRIC Building at Cardiff University. Courtesy of Cardiff University.

For the **Earth systems and environmental sciences** unit of assessment at **Swansea University**, researchers in the Department of Biosciences gained eighth place across the UK. 93.8 per cent of research outputs were regarded as world-leading (4★) or internationally excellent (3★) and Swansea Biosciences had the highest percentage of publications judged 'world-leading' in this sector. Eighteen PhDs were awarded in the period. Funding of £1.1 million from the UK Research Councils and similar bodies was accompanied by £5.75 million won from EU Governmental sources. An impressive 80% of this work was also impactful at the highest levels and an example is given below.

Chemistry at **Cardiff University** gained a UK ranking of 9th with 95 per cent of research outputs deemed 'world-leading' (4★) or 'internationally excellent' (3★). The research strategy has been to encourage fundamental science across all branches of Chemistry and its interfaces with other scientific disciplines. They still gained an impact assessment showing half of their work to be outstanding, though. This is bred of international collaborations and strategic partnerships (research links to over 40 companies and 120 universities and research institutes) and excellent facilities. Over £20 million has been invested directly in recent years, with much more from Research councils and collaborating businesses, helping them move to this successful position. During the REF period research awards were won totaling £29.8 million from 152 grants. This is up 290 per cent on their average annual income under the RAE. The Cardiff Catalysis Institute (CCI) is one example of the strong investment in excellent facilities. It brings together researchers from different areas of chemistry, focused on both fundamental understanding of catalysis and its application in industry. Catalysis is at the core of the UK economy, contributing over £50 billion annually. It is central to the wellbeing of society and is involved in some way in 80 per cent of all manufactured goods. Catalysis is the change in the rate of a chemical reaction due to the help of a catalyst. Unlike other chemicals which take part in the reaction, a catalyst is not itself consumed by the reaction. A good example is the use of molecules of gold either to aid the process of water purification or the production of plastics, instead of harmful mercury.

Aberystwyth University and **Bangor University** entered a joint submission in the **Agriculture, Veterinary and Food** and **Earth systems and environmental sciences** units of assessment and achieved an overall quality rating at equal 17th and equal 16th respectively. This joint submission reflects the strategic partnership of these HEIs, with a Biosciences, Environment and Agriculture alliance founded in 2007. In general terms, Aberystwyth focuses more on Agriculture and Bangor on research on the Environment. This alliance, in practical terms, means research staff from the Institute of

Biological, Environmental and Rural Sciences (IBERS), chiefly based at Aberystwyth and the College of Natural Sciences at Bangor University were the researchers submitted for these units. In Agriculture 57 PhDs were awarded in the period and just over £31.75 million was awarded by UK Research Councils and other funders.

Aberystwyth University hosts one of the world's most sophisticated new research greenhouses – the National Plant Phenomics Centre – and oat varieties developed through its award-winning breeding programme today account for 65 per cent of all oats used in the UK. The plant breeding team at IBERS, led by **Professor Athole Marshall**, recently secured BBSRC funding to apply the latest genetic tools and resources, including genomic selection, to improve key traits that will increase the production and utilisation of oats, enhancing grain yield, quality and composition.

Left: The National Plant Phenomics Centre at IBERS. Courtesy of IBERS.

In summary, the REF results confirm objectively and publicly that there are very significant research strengths in Wales – strengths in both the quality and impact of research. They provide further evidence, however, in support of the Chief Scientific Adviser for Wales' view, underpinned by the analyses of Williams, Elsevier and now by Halligan and Bright (see above), that Welsh universities need to grow their research capacity, particularly in the STEM disciplines.

As the Welsh Government's contribution to addressing this long-standing issue, the Sêr Cymru programme, which will soon be rolling out a second phase, is intended to increase Wales' research capacity in key areas of science. In due course, a growth in numbers working in good quality research teams should see Wales' HEIs start to increase the funding won from the research councils with the largest budgets, particularly, the Engineering and Physical Sciences Research Council (EPSRC) and the Medical Research Council (MRC).

The Chief Scientific Adviser for Wales is keen that Welsh universities should maximise their use of the major research facilities managed by the Science and Technology Facilities Council (STFC) on behalf of the

whole UK research community. The equipment that STFC operates, at sites such as Harwell in Oxfordshire and Daresbury in Cheshire, is large scale and of national and international importance, including lasers, accelerators and large high-performance computing facilities. Last year the Welsh Government responded to a consultation by the UK Government Department for Business, Innovation and Skills (BIS) on long-term capital investment in scientific research. Our response made the case for better access for Welsh researchers to UK national facilities and greater funding to cover the cost of repairing and upgrading existing research assets, especially equipment which is essential not only for cutting-edge science but also for innovation activities, in partnership with industry.

So it is important to encourage Welsh researchers to take every opportunity to use such 'big kit', just as, for example, Dr Rudi Winter and his colleagues in the Materials Physics research group at Aberystwyth University are making use of the very intense X-ray beams produced at the Diamond Light Source in Didcot, the UK's national synchrotron facility. This huge machine, half a kilometre in circumference, is designed to produce very intense beams of X-rays, infrared and ultraviolet light, and it provides Dr Winter's team with a unique probe to understand the properties of industrial materials, such as thermal coatings, and the processes they undergo during manufacture or use.

The equipment pictured below is at Engin-X an engineering science facility at ISIS. It is one of the first dedicated engineering neutron diffractometers, measuring internal and residual stresses deep within structural material and components. These stresses have a considerable effect on material properties and the lifespan of engineering components. Measurements on this equipment are typically carried out in collaborative experiments between universities, industry and ISIS to address a wide range of engineering problems, such as:

- structural integrity of welds for nuclear power plants;
- manufacturing challenges with magnesium alloys for the automotive industry;
- thermal deformation characteristics of nickel-base super alloys for aero engines.

Right: Professor Julie Williams with Engin-X at ISIS in Harwell, with Professor John Womersley, Chief Executive of the STFC and Professor Robert McGreevy. Courtesy of STFC.

Sêr Cymru

Professor Diana Huffaker at a welcome event in Cardiff.
Courtesy of Cardiff University.

Just after the end of this reporting year, we were delighted to be able to announce the fourth Sêr Cymru research chair. This summer, Professor Diana Huffaker comes to Cardiff University from UCLA, California. Professor Huffaker is a distinguished female electrical engineer. Her research develops unique materials, which in turn enable the production of new devices with new features and functions. She is best known for pioneering combinations of compound semiconductors and the development of innovative 'quantum dot' materials, used in optoelectronics and laser physics. Graduate students from Professor Huffaker's California lab. recently formed a spin-off company to commercialise the lab's research into high-sensitivity electronic receivers.

In Cardiff, as part of the Compound Semiconductor Research Foundation (a collaboration between Cardiff University and technology firm and semiconductor manufacturer IQE) Professor Huffaker will be establishing a world-class compound semiconductor lab. Her presence, in such an important and senior role, will also provide another strong role model for young women and girls in Wales considering careers in science and engineering.

Our three established research chair 'stars', Professors Barron and Durrant at Swansea University and Professor Barde at Cardiff University, continue building their teams and their research portfolio.

Professor Barde has managed his move from Basle, Switzerland to Cardiff, having to build and equip new laboratories and recruit the required staff, who are of excellent quality. Helpfully, he has recruited a highly-rated researcher from Switzerland, who has moved with him. Professor Barde has recruited other very capable academics too, so there is now strong potential in his team.

He is pursuing three lines of research: further exploration of his brain-derived neurotrophic factor, known as BDNF, discovery and its possible link to depression; understanding the modes of action of Fingolimod (a drug) in the context of Multiple Sclerosis and 'blue skies' research into other brain and central nervous system development disorders. The Professor is also actively collaborating with the researchers of the Life Science NRN. He has plans for the development of industrial links but this is only at an early stage at present.

Professor Durrant and a team of senior and middle-ranking research staff and support staff are all in place with Swansea University (Professor Durrant is shared equally with Imperial College, London). His particular research lies in polymer and organic photovoltaics. In collaboration with SPECIFIC, he has established new laboratory facilities in Baglan, which will work collaboratively with Imperial College and is now known as 'Sêr Solar'. There they are undertaking novel research work with some notable outputs already achieved,

such as the invention and development of an entirely new flexible electrode technology for solar cells, developed in collaboration with Oxford University.

Other collaborative effort includes projects with Bristol University and an application for research council funding for work with two other prestigious universities. Such joint activity with other significant UK universities is acting as a spur for further collaboration with other world-renowned universities in the PV field. It is fair to say that Professor Durrant's presence at Swansea University has raised the profile of the University's Sêr Solar and SPECIFIC innovation and knowledge centre activities to having world recognition. Professor Durrant and his team can point to a long list of collaborative grant applications and recent awards with many potential collaborations in the pipeline. There are early patent applications, resulting from the research work, with potential for commercial exploitation. He has successfully managed the establishment of Solar Press, an energy harvesting technology company in Wales and the spin-out of BIPV Ltd. The established relationship with Tata Steel continues to have huge industrial potential.

Professor Barron's phased move to Swansea University from Rice University in Texas is not yet complete. We are fortunate, however, that he has already brought existing research activity and significant funding from an industrial sponsor across into Wales. He has already appointed two new senior lecturers and five post-doctoral fellows to help him drive his research forward and is much engaged with seeking competitive research grants. It is to be welcomed that four of the five post-doctoral fellows are female. Professor Barron has been active in engaging collaboration partners in pursuit of potential EU Horizon 2020, UK Research Council and industrial funding applications. His research involves the application of nanotechnology to fundamental problems in energy research. Recent significant achievements include:

- winning a £1 million BP research award;
- working with a large number of industrial and academic partners;
- recruitment of a high proportion of women researchers to the team;
- research advances in the developing field of shale-gas exploration and extraction;
- research memoranda of understanding signed with multiple global partners;
- facilitation of the creation and growth of the Energy Safety Research Institute (ESRI) on Swansea University's new Science and Innovation Campus. This will concentrate elements of the university's energy research with a unique focus on safety.

The three **National Research Networks**: Life Sciences and Health Network led by Cardiff University; Advanced Engineering and Materials Network by Swansea University and Low Carbon, Energy and Environment Network by Bangor University (on behalf of the Aberystwyth-Bangor Universities Strategic Alliance) are all beginning to thrive. While it will always take an appreciable time to establish an effective network, generating significant numbers of academic outputs, they are all now generating the collaborative research activities sought and have 37 new PhDs and 11 new Post-Doctoral researchers in post.

The **Life Sciences Research Network** has made four calls for PhD students and Fellows and awarded a total of 43 projects. By the autumn of 2014, these projects had already leveraged in a further £1.1 million. The network put out a call for 'Endeavour' funding to back science projects and was able to award three – two to Aberystwyth researchers and one to Cardiff. Aberystwyth has since been able to win BBSRC match funding for its research projects.

As just one example of the quality of work being undertaken within the networks, research in the laboratory of Dr Richard Clarkson (Cardiff University School of Biosciences and European Cancer Stem Cell Research Institute) had established that a particular protein was specifically associated with metastatic progression (the process of spread to other organs) in breast cancer models. Collaborative work with drug discovery scientists Dr Andrea Brancale and Dr Andrew Westwell (Cardiff University School of Pharmacy and Pharmaceutical Sciences) has exploited this by seeking to design potential small molecule inhibitors for this protein. PhD student Jitka Soukupova worked on this idea from 2010-2013. The team used computational modelling methods and virtual screening to try to identify the best inhibitors in testing . One compound showed powerful activity against the protein's ill-effects, without killing off other cells and gave remarkable effects over control testing – almost complete suppression of metastases, with daily administration. After a provisional patent was filed, a commercial investor licensed the IP. This discovery and the IP was behind the launch of an AIM-listed company, Tiziana Life Sciences, launched in April 2014. Fundraising allowed the operations in Cardiff to expand and the project moved to pre-clinical development. Progress continues and further registration and the first studies in patients are expected in 2016-17.

Left: Drs. Clarkson, Westwell and Brancale working in a Cardiff University laboratory. Courtesy of Cardiff University.

With the Advanced Engineering and Materials Network, already the aim of encouraging collaborative research activity has been well met with joint network research between engineers at Swansea, Cardiff and Bangor Universities. Usefully, the independent TWI research organisation has been brought in as a partner by the three universities. From their two calls for PhD students no fewer than 10 of the 33 appointed involve more than one university working on a common research theme. A further PhD award was made to the University of South Wales and to TWI.

The **Low Carbon, Energy and Environment Network** has organised itself around eight research 'clusters'. All have now been awarded, through late 2014 into early 2015 and all with multiple universities and other research bodies involved.

Left: Publicity material for two of the National Research Networks. Image for Welsh Government.

The clusters are:

AQUAWALES: Minimising the impacts of intensive aquaculture in the face of climate change – Swansea University, Aberystwyth University and Cardiff University with Cardiff Harbour Authority, FishGen, Natural Aptitude, Natural Resources Wales, Pontus Aqua, Research Centre in Biodiversity and Genetic Resources, SkillFish and the Wye & Usk Foundation.

Plants and architecture: Looking at this relationship through biomimicry, a science that studies nature's best ideas and then imitates these designs and processes to solve human problems, understanding how buildings and plants interact with each other, and their environment, so that we can develop the cities and crops of tomorrow – Aberystwyth University, Bangor University and Cardiff University.

GEO-CARB-CYMRU: Assessing, characterising and enhancing geologic carbon storage and geothermal energy in Wales – Aberystwyth University with British Geological Survey Wales, Cardiff University, National Museum Wales and University of Leeds.

QUOTIENT: Quantification, optimisation and environmental impacts of marine renewable energy – Bangor University, Cardiff University and Swansea University.

RESILCOAST: Integrating ecosystem resilience into coastal planning for the persistence of natural flood protection and wetland ecosystem services – Bangor University, Cardiff University, the NERC's Centre for Ecology & Hydrology and Swansea University with Natural Resources Wales, Plymouth Marine Laboratory and the Royal Netherlands Institute for Sea Research.

Cleaner cows: Consequential life cycle assessment of environmental & economic effects of dairy and beef consolidation and intensification pathways – Bangor University, Aberystwyth University and Cardiff University, working with Farm Business Survey and DairyCo.

Climate-Smart Grass: A strategy for grassland to safeguard forage production against extreme weather events through resilience to multiple-stresses. Bangor University and Aberystwyth University with NERC's Centre for Ecology and Hydrology, Bangor

Enhancing agricultural productivity and ecosystem service resilience in multifunctional landscapes: – Bangor University and Aberystwyth University with the Centre for Ecology and Hydrology , Natural Resources Wales, Coed Cymru and Snowdonia National Park Authority.

Further details of all these clusters are available on this NRN's website. The process of recruiting staff to undertake research in these various clusters is underway but will not be completed until well into 2015.

The AQUAWALES cluster has already achieved success, with two wins in February 2015 of joint BBSRC and NERC funding, totalling £480,000 for research into the disease resistance and domestication of Atlantic salmon (jointly, on one of the calls, with the University of the Highlands and Islands).

Planning for further research capacity support – Sêr Cymru II, COFUND and other European Commission funding inputs

Professor Julie Williams, our Chief Scientific Adviser for Wales, has brought forward further programme elements to complement these star appointments and research networks, by helping support early and mid-career researchers (Fellows and Senior Fellows) and, additionally, to help those who may have had career breaks to resume research careers aspiring to the highest academic positions. This new phase is called Sêr Cymru II. Planning continues on the various elements proposed as the reporting year ends, including work with stakeholders who may provide assistance with the programme and work collaboratively with it, such as HEFCW and Health and Care Research Wales. Integral to this plan is collaborative working with the Wales European Funding Office (WEFO) to deploy European Commission funding to exploit its synergies with other support for science and research capacity in Wales.

Recently we learnt that the application which the Welsh Government had made to COFUND on behalf of its partners had succeeded in moving to the grant agreement stage and we expect to finalise it over the summer. COFUND is a scheme, within the European Union's Marie Skłodowska-Curie Actions programme, which aims to encourage researchers' movement across borders. It does this by offering additional funding to existing or new regional and national academic fellowship programmes.

The aim of the application is to support some 90, three-year fellowships, over a five year period, to help build research capacity in Wales. The total funding package is worth in the region of €20 million. €9.5 million would come from the Commission, with match funding coming from Welsh Government, HEFCW, universities, industry representatives, and third sector organizations. Work with WEFO is developing a parallel strand to COFUND, which will support Sêr Cymru II. We are recruiting a panel of distinguished experts from science, business or the charitable research funding sector, practiced in considering academic research proposals, to form an Independent Evaluation Panel. This will consider both the Capital funding call and all the fellowship applications, as well as helping to develop strategy for increasing research capacity in Wales.

WEFO is itself developing a portfolio of investments with other stakeholders, aiming to deliver an additional £230 million of research income into Wales, during the 2014-20 programme period, leading to a longer-term 10 per cent annual increase in competitive and private research funding. An example of such capacity building was the announcement of the £35 million (with £20 million ERDF) Aberystwyth Innovation and Enterprise Campus, in December 2014, which also secured £12 million from the Biotechnology and Biological Sciences Research Council (BBSRC). Discussions are also underway

about potential ERDF support for Fellows and Senior Fellows and the European Social Fund or ESF will continue to support the Higher Skills agenda.

WEFO is also working closely with research and innovation stakeholders on aligning EU Horizon 2020 support mechanisms along a 'stairway to excellence', to support more Welsh organisations to access Horizon 2020 funding. This will include the targeted use of structural funds where appropriate.

Women in science

In the summer of 2014 the Chief Scientific Adviser for Wales commissioned a task and finish group to undertake a review of the roles of 'women in science'. The group, co-chaired by Professor Hilary Lappin-Scott of Swansea University and Professor Karen Holford of Cardiff University, is looking into:

- Why girls and women remain underrepresented in many science, technology, engineering and maths (STEM) educational courses and occupations?
- What can be done to encourage and support girls and women to pursue opportunities in these areas?
- How different organisations in Wales can help to address the problem?

The review aims to draw up practical recommendations to achieve change. Their report is due to be delivered in October 2015.

Promoting business innovation and the exploitation of science

Postdoctoral Researcher speaking at Life Sciences National Research Network Event, Cardiff Bay. Courtesy of Life Sciences Research Network.

In *Delivering Science for Wales for 2013-14* we explained that the publication of *Innovation Wales*, with its supportive advisory mechanism, effectively completed the actions in the field of innovation, which *Science for Wales* itself had called for. As a result, further developments in the field of innovation will no longer be reported here.

UK REF research impact successes

What the Research Excellence Framework did, for the first time, was to solicit case studies from 154 higher education institutions across the UK, which were rated to give an impact score for their research institutions. Impact is here defined as 'an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia'. Wales' Universities impressively demonstrated both their strength and their breadth in this new element of assessment.

Table 5: UK ranking in REF research impact terms by unit of assessment.

Research Impact Ranking	Category	University/ies
1	Psychology, psychiatry & neuroscience	Swansea joint 1st
1	Civil & construction engineering	Cardiff 1st
1	General engineering	Cardiff joint 1st
1	Architecture, built environment & planning	Cardiff joint 1st
2	Allied health professions	Cardiff
2	Sociology	Cardiff
2	Modern languages and linguistics	Bangor
4	Chemistry	Cardiff joint 4th
5	Physics	Cardiff
5	Sport & exercise science, Leisure & tourism	Swansea
6	Psychology, psychiatry & neuroscience	Cardiff

Research Impact Ranking	Category	University/ies
6	Agriculture, veterinary & food science	Aber/Bangor joint submission
6	Sport & exercise sciences, leisure & tourism	Cardiff Met/ Bangor joint submission
7	Clinical medicine	Cardiff
7	General engineering	Swansea
8	Biological sciences	Cardiff
8	Geography, environmental studies & archaeology	Swansea
9	Biological sciences	Bangor joint 9th
9	Geography, environmental studies & archaeology	Aberystwyth
9	Education	Cardiff

What follows highlights just some of these impact studies. Many but not all of these are taken from categories in the table above, where Wales' researchers achieved top scores on impact across the UK. They show how research is exploited to find real-world solutions to a huge variety of problems. The REF website has all of the impact case studies detailed, by HEI (where Welsh Institutions are towards the bottom of the page) and by unit of assessment.

Swansea University's Psychology, Psychiatry and Neuroscience impact submission was rated joint top (with 3 other HEIs). In 1997 the Home Office commissioned a study of underage test purchasing of alcohol. The study, designed by researchers at Swansea University, led directly to legislation in England and Wales, and later in Scotland and Northern Ireland. This permitted underage test purchasing of alcohol under official supervision (previously young-looking adults had had to be used, with a lesser deterrent effect). Subsequent legislation now requires local authorities to use this approach to control the supply of alcohol to children. Used routinely by every UK police force and local authority trading standards department (and widely adopted overseas too), it has seen sales of alcohol to underage people fall by over 60 per cent. It is a good example of close-working with the 'end-users' of research. The Swansea Centre for Substance Abuse Research had a well-established research reputation which meant the Home Office approached them to undertake this study.

In the same unit of assessment, **Psychology, Psychiatry and Neuroscience** but from **Cardiff University**, placed 6th for impact in the UK, **Dr Stan Zammit** and colleagues examined the complex relationship between cannabis use and its long-term effects on

Above: Dr Stan Zammit, Cardiff University.

mental health, in particular its influence on the risk of schizophrenia. They found that individuals who used cannabis regularly had a substantially increased risk of schizophrenia compared to those who did not use this drug. The research has transformed international policy and framed the debate on cannabis use. It has influenced the UK's Advisory Council on the Misuse of Drugs classification review, and was used to support statements made by the White House Office of National Drug Control Policy (ONDCP) in the US.

Right: Rolling Cannabis cigarettes. Image: Thinkstock.

Above: Professor Andrew Smith, Cardiff University.

Another Cardiff University team, led by **Professor Andrew Smith**, studied the risks and consequences of maritime fatigue and found that reporting systems are inadequately designed to record factors relevant to fatigue. Excessive working hours are often hidden by falsified audit. Fatigue was consistently associated with poor quality sleep and long working hours. 50 per cent of the seafarers reported working weeks of 85 hours or more. This research has led to significant changes across industry and government, including improved safety training, new international legislation, and company policy aimed at reducing fatigue and improving health and safety at sea.

Right: View from bridge of large container ship. Courtesy of Cardiff University.

We have seen that **Clinical Medicine** at **Cardiff University** performed exceptionally well, in overall research quality terms. Much of their work was also highly impactful, with their case studies for the REF achieving a 4★ rating for 80 per cent and the remaining 20 per cent assessed as 3★.They used research from both the Institutes of Infection and Immunity and Cancer and Genetics, based on the University Hospital of Wales campus. Co-location here allows for easier clinical interactions with the NHS and patients across Wales. Work with commercial partners has led to development of novel biomarkers, new targets and new drugs. Clinical medicine researchers have links to business in Wales and internationally. This has achieved £1.78 million in licensing and spinout revenue over the REF period.

An example is work led by **Professor Malcolm Mason** found that treating locally advanced prostate cancer with a combination of radiotherapy and hormone therapy halved the risks of dying from the disease. It is now a standard of care, enshrined in European and North American guidelines, that all such patients who are fit enough to receive it, should be offered combined modality radiotherapy plus hormone therapy.

Left: Professor Malcolm Mason, Cardiff University.

A trio of post-1992 Universities (**Cardiff Metropolitan University**, **University of South Wales** and **University of Wales Trinity Saint David** achieved an 18th equal position for their research impact in the **Art and design, history practice and theory** unit of assessment. As part of this submission, Cardiff Metropolitan's Surgical & Prosthetic Design Group based at PDR (The National Centre for Product Design & Development Research), has undertaken research which has led to major improvements in reconstructive surgical procedures and reduced NHS surgical costs since only a quarter as many surgical procedures are required. Under the leadership of **Dr Dominic Eggbeer**, digital data from very accurate Computer

Above: Dr Dominic Eggbeer, Cardiff Metropolitan University.

Aided Design (CAD) techniques is used to plan surgery and develop prostheses. The result is improved quality of life for some 2,500 patients in 84 hospitals, with prostheses completed and fitted within six weeks, rather than up to one year.

Right: CAD-derived titanium prosthetis on model skull. Courtesy of PDR at Cardiff Metropolitan University.

Cardiff University's Civil and Construction Engineering researchers already achieved first place across the entire UK for research quality, as noted above. Equally remarkably, an outstanding 100 per cent of this unit of assessment was found to be world-leading 4★ work in research impact terms. They are at the forefront of finding solutions to some of the most pressing global challenges related to the built and natural environments. Through multidisciplinary research they play a vital role in reducing environmental impact and increasing sustainable practices in a wide range of areas including construction, fuel, energy, waste disposal, water quality and flood protection. Cardiff maintains strong industrial links, undertaking 30 research contracts with industrial sponsors in recent years, including seven knowledge transfer partnerships.

Above: Professor Hywel Thomas, Cardiff University.

Backed by the European Commission's EURATOM programme, **Professor Hywel Thomas** and a team of researchers in the School of Engineering's Geoenvironmental Research Centre developed a model to simulate the behaviour of a nuclear waste repository over time. This helped them to understand how barriers perform in nuclear waste disposal. The model's findings went on to influence the design and build of a number of new international nuclear waste storage facilities in places such as Sweden and Finland. The software has been utilised by International Nuclear Waste Disposal Authorities.

Right: Research in the School of Engineering. Courtesy of Cardiff University.

A second research impact case study from this unit of assessment saw researchers in the **Hydro-environmental Research Centre**, led by **Professor Roger Falconer**, recognising the need for more accurate models to predict flood risk and water quality levels for a range of extreme events. They integrated and refined existing models to give more accurate solutions for dam breaks and embankment breach flows. This model is now used by major organisations around the world on large-scale projects and, in particular, for mitigation planning against national and international risks associated with floods and water quality.

Above: Professor Roger Falconer, Cardiff University.

Left: Flooding in Aberystwyth. Courtesy of Natural Resources Wales.

For **Allied health professions, dentistry, nursing and pharmacy, Swansea University** achieved 66 per cent 4★ with the remainder at 3★. The **College of Medicine** put in a case study relating to research underway for some years into the science for more effective light therapy. This has contributed to considerable activity in the market for laser and intense pulsed light (IPL) products. Technological impact from this research has made treatments available for a number of troublesome skin conditions such as acne, atopic eczema and pigment disorders. **Professor Marc Clement's** work and subsequent computer-based predictive modelling, to predict the optimum wavelengths and energy levels, have established what is required to achieve the desired effect. Valuable intellectual property and local manufacturing of laser and IPL products with commercial partners have resulted.

Above: Professor Marc Clement, Swansea University.

Left: Therapeutic use of laser light. Courtesy of Swansea University.

Above: Professor Helen Snooks, Swansea University.

Another example, from the **Allied health professions, dentistry, nursing and pharmacy** unit of assessment, shows the considerable changes that **Professor Helen Snooks** of **Swansea University** and colleagues have brought about through their research. They collaborated with clinicians, policy makers and academics to identify ways of treating patients more cost-effectively than by routinely taking them to hospital emergency departments. Their work has been a major influence across the UK and internationally by showing that telephone advice, decision support and referring patients other than to Emergency Departments are safe and effective ways to resolve an emergency call. Costs have been saved, ambulance and casualty staff have been freed for other work and patient's safety, quality of care and experience of the health services has not been lessened.

Above: Professor Rory Wilson, Swansea University.

For the **Earth systems and environmental sciences** unit of assessment, researchers in the **Department of Biosciences** at **Swansea University** impact scored a little lower than their 8th overall, coming in at 12th across the UK. Research by **Professor Rory Wilson** aided public understanding of long-distance animal movements through the development of a 'Daily Diary' tagging device, which subsequently informed the National Geographic's popular ***Great Migrations*** series. His devices allowed, often for the first time, the tracking of movement, energy expenditure and the use of their environment by a wide variety of animals, from whales to birds migrating around the world. Sales of the devices and of the programme and associated materials have been considerable.

Right: A whale-shark tagged for long-distance animal movement research. Courtesy of Swansea University.

Above:Professor Tariq Butt, Swansea University.

Again, in this unit of assessment, **Professor Tariq Butt's** research in response to growing concerns about health and environmental risks posed by conventional chemical pesticides has resulted in environmentally-friendly alternatives to chemical pesticides being developed and brought to market.

Increasing the science and engineering talent pool

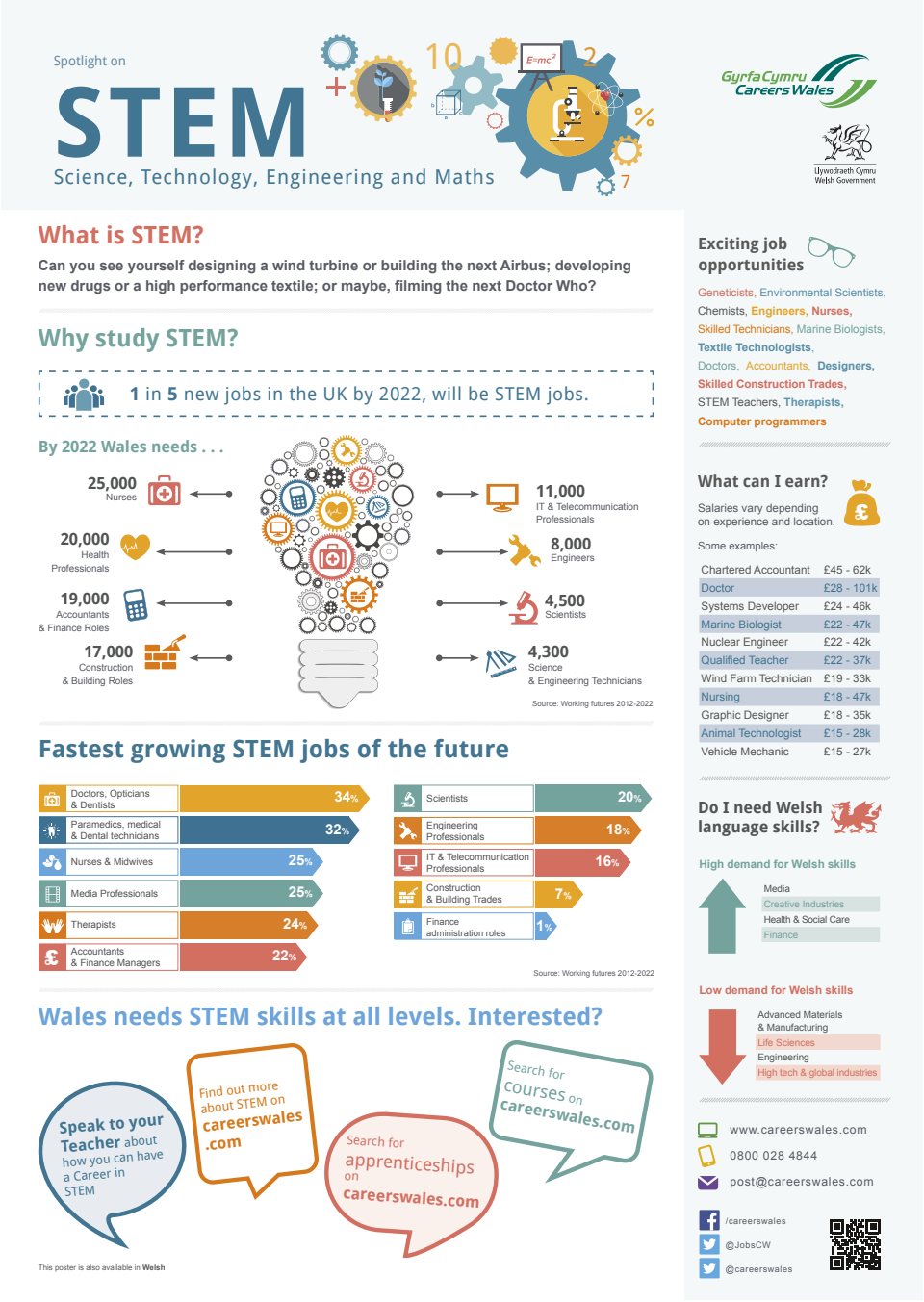
Pupil from Abertillery Comprehensive School at the Royal Institution's L'Oreal Young Scientist Centre, London. Courtesy of Abertillery Comprehensive School.

This year has seen Professor Graham Donaldson undertake his independent enquiry into Wales' curriculum and assessment arrangements in schools. His report, ***Successful Futures***, published in late February 2015, proposes a substantial set of changes to overhaul the whole spectrum of compulsory education. He proposes that the curriculum should be organised into six 'areas of learning and experience': expressive arts; health and wellbeing; humanities; languages, literacy and communication; maths and numeracy; and science and technology. These last two would place STEM subjects solidly into the curriculum across primary and secondary settings. A cross-curriculum responsibility for literacy, numeracy and digital learning is also advocated in the report. These are all crucial to success in the sciences.

The Great Debate on Welsh Education has now completed its first phase and there will be further phases of this debate, as the Government response to the proposals and the future of Wales' curriculum develops. It is most important that the changes made get it right for years to come. The Chief Scientific Adviser for Wales saw Professor Donaldson more than once during the enquiry. She lobbied strongly for the central place that STEM subjects should have in any modern curriculum – given their vital importance of scientific skills to the Welsh economy, as well as to being an effective citizen in the modern world, where science impacts so strongly on everyday life. The stated purposes of the proposed new curriculum are to 'develop ambitious, capable learners, ready to learn throughout their lives; enterprising creative contributors, ready to play a full part in life and work; ethical informed citizens of Wales and the world; and healthy, confident individuals ready to live fulfilling lives as valued members of society' – science impacts on much of this and it is pleasing to see it specifically referenced among Professor Donaldson's proposals.

'Qualified for Life: Focus on Science' and other educational developments

In October 2014, as part of a wider educational improvement plan – ***Qualified for Life*** the Welsh Government set out to provide a range of information and assistance for science teachers, for parents, guardians and for pupils studying science – badged as 'Focus on Science'. As part of this focus, new teaching materials have been made available, to help teachers and learners with their science studies. The aim is to develop an approach that would see all young people in Wales becoming more scientifically literate. Performance in the 2012 round of PISA (Programme for International Student Assessment) had dropped in science. To help to remedy this – especially because the tests do require a particular approach to understanding and answering the questions, a set of PISA Style science questions and guidance for teaching staff PISA Scientific Literacy: a short guide for Key Stage 4 teachers are both being provided. A Science Planner highlighting science and science



Left: A Spotlight on STEM poster for schools from 'Focus on Science'.

education related events coming up across Wales is also being made available to teachers each term.

A delivery plan for Wales covering Science, Technology, Engineering and Maths (STEM) Education and Training has been drafted for publication later in the year.

Qualifications

Revised AS / A Level qualifications in Biology, Chemistry and Physics, for teaching from September 2015, have been accredited by Welsh Government. For these subjects, only WJEC specifications will be approved for use in maintained schools and FEIs.

The Review of Qualifications found that GCSEs are widely understood and valued. If a 14 to 16 year old learner is capable of achieving

a level 2 qualification in Science, then the Welsh Government believes that this should be a GCSE. The Welsh Government is currently developing a new GCSE Science suite, for first teaching from September 2016. The qualifications within the new Science suite which, as set out in November 2014, will be the only ones that will count towards the 'two science' elements of the new capped points score for reporting from 2018, will consist of the following qualifications:

- GCSE Biology
- GCSE Chemistry
- GCSE Physics
- GCSE Science (Double Award)
- GCSE Applied Science (Double Award)*
- GCSE Applied Science (Single Award)*

* These will not offer suitable progression routes to AS or A level qualifications in the sciences.

The Minister for Education and Skills has recently agreed that the suite should include a GCSE Applied Science (Single Award). Welsh Government expectation remains that most learners will take at least two science GCSEs or the revised GCSE Science (Double Award), with only a minority of learners being entered for the Single Award qualification.

A revised, more rigorous Welsh Baccalaureate will be implemented from September 2015. The flexibility of the revised qualification means that there are opportunities within the Skills Challenge Certificate for learners to explore STEM subjects, through both the Challenges and the Individual project.

A levels and GCSEs in Wales will retain practical or controlled assessments, where they are assessing an important part of the subject, with these assessments contributing towards the final grade.

In December 2014, the Minister for Education and Skills introduced a Bill to the National Assembly for Wales to establish Qualifications Wales as an independent regulator of qualifications in Wales. It is hoped that the organisation will commence operation in the autumn of 2015.

In 2014, Dr Lyn Evans the celebrated Welsh scientist from **CERN**, now director of the new Linear Collider organization and formerly director in charge of CERN's existing Large Hadron Collider, had raised his concern about science teachers from Wales. He observed that they were not taking up the opportunities for professional learning, afforded by the subsidised outreach work which is offered at this unique scientific facility, built near Geneva. Thanks to facilitation

by the Welsh Government and support from the National Science Learning Centre, in February 2015 a party of 16 physics teachers from across Wales were able to go out to Geneva and experience this amazing scientific resource and the cutting-edge particle physics which takes place there. This approach links closely with that announced by the Minister for Education and Skills on 16 March through the New Deal for the Education Workforce, building a coherent approach to teacher career-long professional learning.

Left: Physics teachers from Wales visit CERN in Geneva. Image: for Welsh Government.

Earlier in 2014, the Chief Scientific Adviser for Wales visited the **Royal Institution** in London and had the chance to witness the impressive laboratory space that is their L'Oreal Young Scientist Centre. This allows young people and their teachers to experiment and explore science and technology beyond the classroom, at a largely subsidised rate. We were able to undertake a pilot programme running up to the end of the year, sending six parties from schools across Wales to experience this stimulating environment, which has so much potential to spark an interest in science as a future career.

Left: Pupil from Abertillery Comprehensive School discussing her experiment with Royal Institution Young Scientist Centre staff. Courtesy of Abertillery Comprehensive School.

Right: Pupils and staff from Holywell School at the Royal Institution's Young Scientist Centre, London. Courtesy of Holywell School.

The National Science Academy

The National Science Academy or NSA has continued to support the wide variety of science engagement projects, which had succeeded in securing its funding, in the competitive grant round run in 2013. Since 2012, they have deployed £2.2 million to deliver around 50 STEM enrichment projects by a variety of providers across Wales. The latest grant funding round in 2013 was for £1.33 million. Examples of the exciting and innovative STEM enrichment this supported include:

Bangor University – Revision School & app

NSA funding has enabled a Bangor University led innovative project to develop a bilingual Biology and Physics revision guides and the creation and launching of bilingual smartphone and tablet GCSE science revision apps. – 'Adolygu' is the first ever such app. It has received positive reviews.

Cardiff University – Robotic Telescope

An innovative feature of NSA grant awards is a Cardiff University project involving a Robotic Telescope specifically aimed at use by primary school students in Wales. The Robotic Telescope was secured via NSA match funding and is located at the Cerro Tololo Observatory in Chile. Use of the Robotic Telescope, together with linked activity kits, will be available to schools in Wales with the necessary internet access. Additional benefits will come from continuous professional development sessions for primary school teachers.

Left: The robotic telescope in Chile for use by primary schools. Courtesy of Cardiff University.

Institute of Physics – Lab in a Lorry

NSA has awarded funding to the Institute of Physics to run the 'Lab in a Lorry' on a pan-Wales basis. It has provided and maintained a mobile science laboratory delivering 'hands-on' physics experiments for secondary school pupils.

Prince's Trust

The NSA awarded grant funding to the Prince's Trust, forming part of the Fairbridge Programme. The project seeks to engage young people who are not in education, employment or training (NEETS). It encouraged over 30 young people via a programme of STEM related-activities to acquire and improve life skills and is considered complementary to the Welsh Government's 'Qualified for Life' campaign. The project has seen several of the cohort going on either to pursue further studies or to secure work experience, such as

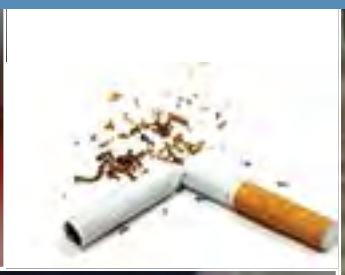
enrolling at a further education college to study Aircraft Engineering; Engineering or IT-related courses and gaining work experience within the voluntary sector.

British Science Association – Crest Awards

The NSA recognises the value of STEM enquiry-based projects. Consequently, it funded the British Science Association (BSA) to deliver the CREST Awards programme. This has resulted in a higher percentage of students in Wales achieving a CREST Award, when compared to the rest of the UK.

NSA has also undertaken, at the behest of the Chief Scientific Adviser for Wales, a strategic review of it operation and function. This review of performance in recent years, covering both the extent and the nature of its mission is about to be published, as part of the strategic document setting out the NSA's future funding strategy, priorities and intentions.


Courtesy of FERA




Courtesy of Natural Resources Wales


Courtesy of Natural Resources Wales


Image for Welsh Government


Courtesy of FERA


Courtesy of Forestry Commission

Improving delivery in government

The Chief Scientific Adviser for Wales' role of providing independent advice across Government has been supported by the Chief Scientific Adviser's Division. This small team of civil servants, with some secondees from academia, provide research, drafting and policy development assistance to the CSAW, as well as addressing government business matters focused on science and research. The National Science Academy is also run from within this Division.

The CSAW has had the benefit of advice and assistance from the distinguished Science Advisory Council for Wales or SACW. In December 2014, the initial Council membership had completed their four-year term. Professor Julie Williams is most grateful for their advice, experience and consideration of a wide range of issues for her and for Professor Harries before and would like to thank them publicly.

Science Advisory Council for Wales 2010-2014

- Professor Chris Pollock (Independent Co-Chair)
- Paul Allen
- Professor Huw Beynon
- Simon Bradley
- Kevin Bygate
- Professor Bridget Emmett
- Professor Sir Martin Evans
- Professor Chris Gaskell
- Professor Siân Hope
- Rebecca Villis
- Professor Tavi Murray
- Professor Ole Petersen
- Wendy Sadler
- Professor Sir John Meurig Thomas
- Professor Ken Walters
- Professor Robin Williams

The CSAW has taken the opportunity, before appointing new members, to review the terms of reference of the SACW and its make-up. The intention is to make SACW a somewhat smaller and more strategic body, still personally appointed by the CSAW to advise. They will, generally, be less concerned with operational issues.

A structure of academic and other advice, focused on specific topics of interest to the CSAW and her work is being put in place to compliment the SACW's new higher-level role. A series of subject-

specific expert groups will assist by studying a given range of current science-related issues. Examples would include novel semi-conductors, critical raw materials and energy systems.

There are already arrangements in place to give the CSAW rapid access to local and United Kingdom advice on scientific issues, for emergency and civil contingency situations.

A wide range of science-facing work goes on across the Welsh Government. All manner of areas including health practices; environmental concerns; transport planning; fisheries; forestry; support for hi-tech. industry require varying degrees of scientific, technical or engineering expertise and there are a number of qualified experts directly employed to advise Welsh Government Ministers and oversee scientific policy aspects. The CSAW chairs a Senior Science Strategy Group, which meets as required, to consider matters of interest and concern to the leaders in these various science-facing fields. A Science Co-ordination Group, again normally led by the CSAW and meeting quarterly, affords an opportunity for all the scientifically-qualified staff and those interested in or working on science and technology-related policy areas to come together.

Professor Williams has attended meetings convened by the UK Government Chief Scientific Adviser, Sir Mark Walport, for the CSAs of Whitehall Departments, key Government Agencies and the Devolved Administrations, to discuss matters of mutual interest.

Left: 'Japanese Larch Disease' (Phytophthora Ramorum) in a forest near Neath.

Sitting exams. Image: Lifestock.

Appendices

Appendix A: Research income of higher education institutions in Wales 2013/14

Institutions	Total Research Income	Recurrent Research Funding		Research Councils		UK-based charitable bodies		UK central government bodies		UK industry, commerce & public corporations		EU sources		Non-EU sources	
	£K	£K	%	£K	%	£K	%	£K	%	£K	%	£K	%	£K	%
WALES															
University of South Wales	8,968	3,043	34	483	5	136	2	1,565	17	788	9	2,830	32	0	0
Aberystwyth University	28,143	7,643	27	9,565	34	695	2	3,948	14	1,092	4	4,686	17	183	1
Bangor University	30,526	7,568	25	3,961	13	1,385	5	6,610	22	734	2	8,946	29	574	2
Cardiff University	136,565	43,015	31	22,723	17	19,424	14	28,800	21	4,977	4	12,003	9	4,783	4
UW Trinity St David	1,201	827	69	56	5	121	10	50	4	36	3	0	0	12	1
Swansea University	55,563	12,507	23	11,489	21	1,857	3	12,802	23	2,097	4	12,308	22	1,121	2
Cardiff Metropolitan University	4,133	1,247	30	109	3	22	1	1,628	39	373	9	751	18	0	0
Glyndŵr University	1,962	0	0	341	17	1	0	1,011	52	427	22	180	9	2	0
University of Wales Centre for Advd.Welsh & Celtic Studies	950	398	42	509	54	43	5	0	0	0	0	0	0	0	0

Institutions	Total Research Income	Recurrent Research Funding		Research Councils		UK-based charitable bodies		UK central government bodies		UK industry, commerce & public corporations		EU sources		Non-EU sources	
TOTALS															
WALES	268,011	76,248	28.45	49,236	18.37	23,684	8.84	56,414	21.05	10,524	3.93	41,704	15.56	6,675	2.49
Wales (% of UK)	3.8	3.9		3.0		2.4		6.4		3.4		5.3		1.8	
ENGLAND	5,680,915	1,557,530	27.42	1,339,539	23.58	826,091	14.54	688,892	12.13	257,491	4.53	642,100	11.30	332,298	5.85
England (% of UK)	80.7	79.5		80.4		83.0		77.7		82.3		81.4		88.1	
SCOTLAND	955,998	276,493	28.92	256,365	26.82	132,470	13.86	111,382	11.65	40,871	4.28	88,825	9.29	34,675	3.63
Scotland (% of UK)	13.6	14.1		15.4		13.3		12.6		13.1		11.3		9.2	
N. IRELAND	137,028	48,690	35.53	20,738	15.13	12,514	9.13	30,020	21.91	4,106	3.00	16,572	12.09	3,434	2.51
N. Ireland (% of UK)	1.9	2.5		1.2		1.3		3.4		1.3		2.1		0.9	
TOTAL UK	2	1,958,961	27.82	1,665,878	23.66	994,759	14.13	886,708	12.59	312,992	4.44	789,201	11.21	377,082	5.35

Sources: HESA Resources for Institutions of Higher Education 2013/14 (for all figures except recurrent research funding)
HEFCE, HEFCW and SFC Recurrent Grant Circulars, 2013/14 (for recurrent research funding only)

Note: Recurrent Research Funding consists of QR and PGR (or equivalent)

All figures subject to rounding

Appendix B: Number of graduates[1] in STEMM subjects from Welsh higher education institutions, by level of qualification and classification 2013/14

	Class of Degree	1st class Hons.	Upper 2nd class Hons.	Lower 2nd class Hons.	3rd class Hons./ Pass	Unclassified	Classification not applicable	Total
Medicine & dentistry	Doctorate	.	.	.	.	.	65	**65**
	Other higher degree	.	.	.	.	*	235	**235**
	Other postgraduate	.	.	.	.	*	500	**505**
	First degree	20	60	75	5	270	.	**435**
	HND/DipHE	.	.	.	.	.	10	**10**
	Total	20	60	75	5	280	805	**1,250**
Subjects allied to medicine	Doctorate	.	.	.	.	5	60	**65**
	Other higher degree	.	.	.	.	25	290	**320**
	Other postgraduate	.	.	.	.	25	530	**550**
	First degree	445	925	550	150	75	.	**2,145**
	Foundation degree	.	.	.	.	15	15	**35**
	HND/DipHE	.	.	.	.	10	165	**175**
	Other undergraduate	.	.	.	.	15	180	**195**
	Total	445	925	550	150	170	1,240	**3,480**
Biological sciences	Doctorate	.	.	.	.	5	155	**160**
	Other higher degree	.	.	.	.	130	530	**660**
	Other postgraduate	.	.	.	.	25	55	**80**
	First degree	555	1,520	760	115	35	.	**2,980**
	Foundation degree	.	.	.	.	.	65	**65**
	HND/DipHE	.	.	.	.	30	50	**80**
	Other undergraduate	.	.	.	.	35	165	**200**
	Total	555	1,520	760	115	255	1,025	**4,230**

1 Including Postgraduate and undergraduate students

	Class of Degree	1st class Hons.	Upper 2nd class Hons.	Lower 2nd class Hons.	3rd class Hons./ Pass	Unclassified	Classification not applicable	Total
Agriculture & related subjects	Doctorate	.	.	.	.	.	10	**10**
	Other higher degree	.	.	.	.	10	50	**55**
	Other postgraduate	.	.	.	.	.	5	**5**
	First degree	15	80	85	15	*	.	**200**
	Foundation degree	.	.	.	.	10	90	**100**
	HND/DipHE	.	.	.	.	*	15	**20**
	Other undergraduate	.	.	.	.	*	15	**15**
	Total	15	80	85	15	25	190	**405**
Physical sciences	Doctorate	.	.	.	.	.	95	**95**
	Other higher degree	.	.	.	.	10	240	**250**
	Other postgraduate	.	.	.	.	*	20	**20**
	First degree	250	560	305	55	*	.	**1,175**
	Foundation degree	.	.	.	.	.	*	*
	HND/DipHE	.	.	.	.	.	40	**40**
	Other undergraduate	.	.	.	.	*	75	**80**
	Total	250	560	305	55	20	475	**1,665**
Mathematical sciences	Doctorate	.	.	.	.	.	10	**10**
	Other higher degree	.	.	.	.	*	45	**45**
	Other postgraduate	.	.	.	.	*	*	*
	First degree	125	110	85	25	.	.	**345**
	HND/DipHE	.	.	.	.	.	5	**5**
	Other undergraduate	.	.	.	.	*	20	**20**
	Total	125	110	85	25	5	80	**430**
Computer science	Doctorate	.	.	.	.	.	35	**35**
	Other higher degree	.	.	.	.	75	185	**260**
	Other postgraduate	.	.	.	.	5	40	**45**
	First degree	215	310	220	85	30	.	**855**
	Foundation degree	.	.	.	.	5	50	**55**
	HND/DipHE	.	.	.	.	10	95	**105**
	Other undergraduate	.	.	.	.	5	105	**115**
	Total	215	310	220	85	130	510	**1,470**

	Class of Degree	1st class Hons.	Upper 2nd class Hons.	Lower 2nd class Hons.	3rd class Hons./ Pass	Unclassified	Classification not applicable	Total
Engineering & technology	Doctorate	.	.	.	.	.	110	**110**
	Other higher degree	.	.	.	.	35	420	**455**
	Other postgraduate	.	.	.	.	*	65	**65**
	First degree	410	535	410	90	55	.	**1,505**
	Foundation degree	.	.	.	.	*	100	**105**
	HND/DipHE	.	.	.	.	*	150	**150**
	Other undergraduate	.	.	.	.	5	420	**425**
	Total	410	535	410	90	105	1,270	**2,820**
Architecture, building & planning	Doctorate	.	.	.	.	*	15	**15**
	Other higher degree	.	.	.	.	.	145	**145**
	Other postgraduate	.	.	.	.	.	25	**25**
	First degree	55	155	90	25	75	.	**395**
	Foundation degree	.	.	.	.	15	40	**55**
	HND/DipHE	.	.	.	.	15	25	**40**
	Other undergraduate	.	.	.	.	25	85	**110**
	Total	55	155	90	25	130	335	**785**
Grand Total	Doctorate	.	.	.	.	15	555	**565**
	Other higher degree	.	.	.	.	290	2,140	**2,430**
	Other postgraduate	.	.	.	.	65	1,240	**1,305**
	First degree	2,095	4,255	2,580	560	545	.	**10,035**
	Foundation degree	.	.	.	.	50	365	**420**
	HND/DipHE	.	.	.	.	60	555	**620**
	Other undergraduate	.	.	.	.	95	1,065	**1,160**
	Grand Total	2,095	4,255	2,580	560	1,120	5,920	**16,530**

Source: HESA

Appendix C: Wales level Key Stage 4 science data for 15 year olds 2009-2014

Only includes maintained mainstream secondary schools – excludes independent schools; pupil referral units; special schools and NEWBES (Pupils not from an English or Welsh based education system).

	2009	2010	2011	2012	2013	2014
Total number of schools	222	222	221	220	219	215
Total number of pupils aged 15	35,936	35,348	34,316	33,684	34,874	33,417
Number of pupils achieving equivalent of A*-C in Science	22,482	22,782	23,008	24,351	26,856	28,389
Percentage of pupils achieving equivalent of A*-C in Science	62.6	64.5	67.0	72.3	77.0	85.0
	Number of schools with pupils entering					
Single Science	205	198	201	205	207	199
Double Science	220	219	216	215	214	207
Triple Science	104	110	119	128	133	135
BTEC Science	9	21	45	96	158	186
	Percentage of schools with pupils entering					
Single Science	92.3	89.2	91.0	93.2	94.5	92.6
Double Science	99.1	98.6	97.7	97.7	97.7	96.3
Triple Science	46.8	49.5	53.8	58.2	60.7	62.8
BTEC Science	4.1	9.5	20.4	43.6	72.1	86.5
	Number of pupils entering					
Single Science	6,020	6,266	6,137	5,862	6,553	5,941
Double Science	23,706	22,725	20,693	18,597	14,965	12,508
Triple Science	3,553	3,690	4,179	4,855	5,071	5,472
BTEC Science	229	845	1,863	4,126	9,029	11,595
	Percentage of pupils entering					
Single Science	16.8	17.7	17.9	17.4	18.8	17.8
Double Science	66.0	64.3	60.3	55.2	42.9	37.4
Triple Science	9.9	10.4	12.2	14.4	14.5	16.4
BTEC Science	0.6	2.4	5.4	12.2	25.9	34.7

Appendix D: Number of pupils aged 17 studying science-related subjects at GCE Advanced level (a-d)

Group	Subject	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Science	Biology	2,000	1,887	1,822	1,832	1,785	1,862	1,916	1,849	1,789	1,761
	Biology: Human	21	15	23	22	16	32	0	0	0	0
	Chemistry	1,414	1,411	1,332	1,467	1,476	1,448	1,514	1,420	1,470	1,568
	Physics	956	972	942	889	982	1,013	974	919	946	966
	Science: Environmental	8	6	8	0	5	*	0	*	6	*
Design Technology	Science (Vocational Qual.)	13	7	22	41	32	85	130	132	200	222
	D&T Food Technology	33	47	40	50	44	7	52	44	39	40
	D&T Product Design	706	864	792	764	797	792	805	679	600	549
	D&T Systems Cont.	*	*	8	*	0	0	*	*	6	*
	D&T Textiles Technology	0	0	0	0	0	36	25	24	15	11
	Design and Technology	0	0	0	0	0	19	0	0	0	0
	Home Economics	51	56	46	48	32	0	0	0	0	0
	Home Economics: Food	0	0	0	0	0	16	24	19	16	15
Mathematics	Additional Mathematics	0	0	0	0	0	0	0	*	0	0
	Mathematics	1,724	1,690	1,826	1,967	2,058	2,171	2,130	2,133	2,243	2,216
	Mathematics (Further)	104	91	85	81	130	107	144	183	183	186

a) Pupils aged 17 on 31 August of that academic year. Only includes schools with pupils aged 17 on register.
b) Includes maintained mainstream secondary schools. Excludes FE colleges – data for this is collected separately.
c) Excludes discounted qualifications e.g. if a pupil has resat an exam, it will only count as 1 entry.
d) Excludes NEWBES (Pupils not from an English or Welsh based education system).
* data item has been suppressed as it is too low and may be disclosive.

Appendix E: List of acronyms

AHRC	Arts and Humanities Research Council
AIM	Alternative Investment Market
BBSRC	Biology and Biological Sciences Research Council
BDNF	brain-derived neurotrophic factor, generally known by its acronym.
BTEC	Business and Technology Education Council
CAD	Computer-Aided Design
CCI	Cardiff Catalysis Institute
CERN	European Organisation for Nuclear Research (from the former 'Conseil Européen pour la Recherche Nucléaire') – known only by its acronym
CSAW	Chief Scientific Adviser for Wales
CUBRIC	Cardiff University Brian Research Imaging Centre
DipHE*	Diploma in Higher Education
EngD	Doctor of Engineering – a postgraduate research degree
EPSRC	Engineering and Physical Sciences Research Council
ERDF	European Regional Development Fund (WEFO administered)
ESF	European Social Fund (WEFO Administered)
ESRC	Economic and Social Research Council
ESRI	Energy Safety Research Institute (at Swansea University)
FEIs	Further Education Institutions
GCSE	General Certificate of Secondary Education
GPA	Grade point average
HEFCE	Higher Education Funding Council for England
HEFCW	Higher Education Funding Council for Wales
HEI	Higher Education Institution
HESA	Higher Education Statistical Agency
HND*	Higher National Diploma – a further education qualification
IBERS	Institute of Biological, Environmental and Rural Sciences (Aberystwyth University)
ILS	Institute of Life Science (Swansea University)
IPL	Intense pulsed light
MD	(Latin – 'Medicinae Doctor') – in the UK, a higher level research degree in medicine
MoU	Memorandum of Understanding
MRC	Medical Research Council
NEETs	Young people 'not in education, employment or training'
NERC	Natural Environment Research Council

NEWBES*	(Pupils) Not from an English or Welsh based education system
NHS	National Health Service
NRN(s)	National Research Network(s)
NSA	National Science Academy
ONDCP	Office of National Drug Control Policy – a part of the US President's Executive Office
PGR*	Post Graduate Research
PhD	Doctor of Philosophy – a postgraduate research degree
PISA	Programme for International Student Assessment
PV	Photovoltaic
QR*	Quality Research
R&D	Research and development
RAE	Research Assessment Exercise (2008 and previously)
REF	Research Excellence Framework (2014)
SACW	Science Advisory Council for Wales
SFC*	Scottish Funding Council
STEM	Science, Technology, Engineering and Mathematics
STEMM	Science, Technology, Engineering, Mathematics and Medicine
STFC	Science and Technology Facilities Council
TWI	Formerly The Welding Institute but now known only by its Acronym
UCLA	University of California, Los Angeles (known widely by its acronym)
WEFO	Wales European Funding Office
WJEC	Welsh Joint Education Committee – a qualifications awarding organisation

* Only found in the Appendices