Institution: University of Dundee

Unit of Assessment: UoA5 Biological Sciences

a. Overview

All Biological Sciences research returned in UoA5 for The University of Dundee occurs in the College of Life Sciences. With research and research-related awards to the College in excess of £284 million over the assessment period, and with the highest citations per paper of any European University in Life Sciences and Medicine (QS University Rankings 2013), The University of Dundee enjoys an international reputation as a centre of excellence for Biological Sciences research. The College of Life Sciences contains 81 research-active Principal Investigators (PIs). In October 2013, their associated research groups totalled 319 postdocs, 191 PhD students and 98 technicians/graduate research assistants. These research groups are organized into 11 Research Divisions that are supported by embedded personnel in the form of 15 Laboratory Managers and 30 clerical staff. The Divisions are supported collectively by 60 technologists, operating our core technology platforms, and by 26 wash-up, media preparation and stores staff. School of Research management and operations are supported by 28 dedicated College administrators including Finance, Human Resources, Research & Innovations services, and 3 business development managers embedded in the School of Research. Ten of our eleven research divisions are included in UoA5 (see section b) with one, Molecular Medicine, returned in UoA1. With the exception of Plant Sciences, located at the nearby James Hutton Institute to provide access to specialized crop research facilities, all our labs are in a single interlinked complex.

Some of the distinguishing features of College of Life Sciences include:

- *Advanced Quantitative Proteomics*
- *Advanced Light Microscopy*
- *Full Drug Discovery capability*
- *Enterprise-level High-Performance Computing*
- *Extensive interactions with industry*

The College Head, Prof. Doreen Cantrell FRS, is a Vice-Principal of the University and a member of the University Senior Management Team, responsible for strategic planning and management of all aspects of the University's academic activities. This ensures that the College directly influences University strategy and resource allocation and holds the authority and responsibility for policy implementation at College level. The College delivers its mission through its two schools, the School of Learning and Teaching and the School of Research, each headed by a Dean. The Dean of Research during the period under review has been Prof. Mike Ferguson CBE FRS.

b. Research strategy

Our aim is to maintain and develop our reputation as a world-class academic institution through the quality of our research and provision of an exemplary teaching environment. Over the last 5 years the high-level strategic objectives for our School of Research have been:

- *To promote the translation of basic research in life sciences towards clinical use and environmental impact.*
- *To build and develop new areas of interdisciplinary academic activity.*
- *To invest in high-quality facilities, services and physical infrastructure.*
- *To maintain the highest standards in the recruitment and development of all categories of staff.*
- *To maintain international collaborations with leaders in their fields of activity.*
- *To develop mutually beneficial partnerships with key funding agencies, industry and academic institutes in the UK and internationally.*
- *To underpin our ambitious academic goals and aspirations through sound financial planning.*

Significant changes over the assessment period: Over the assessment period, we have identified new research opportunities and exploited these by attracting new research leaders and by the strategic expansion of specific research groupings. This has resulted in the formation of 4 new research divisions: the MRC Protein Phosphorylation and Ubiquitylation Unit and the Divisions of Molecular Microbiology, Computational Biology and Cell Signalling and Immunology.

The MRC Protein Phosphorylation and Ubiquitylation Unit, headed by Prof. Dario Alessi FRS, was established in 2013 to exploit synergies between protein phosphorylation research in the MRC Protein Phosphorylation Unit (previously led by Sir Philip Cohen FRS) and protein ubiquitylation research in the Scottish Institute for Cell Signalling (created in 2008 with a £10 million investment from the Scottish Government). The combined laboratories became a University MRC Unit in 2013

with an award of £24 million (2013-2018). The recent (2012) renewal of the Division of Signal Transduction Therapy, which represents a collaboration between the MRC Unit and six major pharmaceutical companies, was predicated on combining expertise in these inter-related and drug-target rich areas. The Division of Molecular Microbiology was created in 2009 to develop research in bacterial growth, physiology, genetics, biochemistry and structural biology. The division now comprises 8 Principal Investigators with substantial funding from BBSRC, MRC and The Wellcome Trust and has a significant drug discovery agenda. The Division of Cell Signalling and Immunology was created in 2011 to bring together groups working on intracellular signalling pathways involved in immune and metabolic responses, areas of rapidly converging science. The Division of Computational Biology was created in 2013 to apply interdisciplinary approaches involving computational, mathematical and biophysical techniques, to biomedical problems. Four new appointments (joint with our School of Engineering Physics and Mathematics) have been made to date. In addition to these 4 new divisions, the Division of Plant Sciences, which forms a strategic partnership with crop sciences James Hutton Institute, has expanded considerably over the review period with 6 new PI appointments, some joint with the Institute. The Plant Sciences division works on fundamental and applied plant science, relevant to food security and bioenergy, that translates all the way through to plant breeding programs through the strategic partnership.

Future strategic aims and goals for research: The strategic research goals for the College of Life Sciences over the next 5 years will be catalysed and supported by the new 4,700 m^2 (£25 million) *Centre for Translational and Interdisciplinary Research* (CTIR), which will open in February 2014. The Centre is a new building, physically linked at all levels to the existing Life Sciences research complex, that will house 180 research staff and will be equipped with >£9 million of specialist capital equipment. This will help drive 5 strategic aims:

Aim 1*: *To double drug discovery capacity and deliver strategic collaborations in drug discovery with UK academic institutes and industry.

The translation of basic research into local, national and global therapeutic benefits is central to the College's strategic vision and the University's mission. The Drug Discovery Unit, part of the Division of Biological Chemistry and Drug Discovery, has created a successful paradigm for translating basic, innovative life sciences research into therapeutic opportunities. The Drug Discovery Unit contains the full range of disciplines (compound management and screening, medicinal and computational chemistry, structural biology, pharmacokinetics and *in vitro* and *in vivo* disease model efficacy) required to produce novel drug leads and pre-clinical drug candidates across a wide range of therapeutic areas under strong industry-experienced leadership. The Unit has grown over the 2008-2013 review period from 20 to 75 FTEs and raised over £30 million of research awards from The Wellcome Trust, The Bill & Melinda Gates Foundation, MRC, Medicines for Malaria Venture (MMV), Drugs for Neglected Diseases initiative (DNDi), the TB Alliance and industrial partners. The *Centre for Translational and Interdisciplinary Research* will double our drug discovery capacity, and bring drug discovery scientists into juxtaposition with computational biologists to further drive innovation. This, in turn, will expand our capacity to translate basic research into "validated target and lead compound" packages that can be spun-out, partnered or licensed to SMEs, large pharmaceutical companies or public/private product development partnerships. Moreover, the unit's professionalism and reputation enables participation in national, European and international consortia to develop drugs for neglected diseases and other unmet medical needs. An example (2013) was the UK's ability to secure a significant (£16.5 million) component of the Innovative Medicines Initiative (IMI) *European Lead Factory*, which is housed at the former Merck Newhouse (Glasgow) site but managed and administered through Dundee.

We will also continue to develop the Division of Signal Transduction Therapy consortium, which is allied to the MRC Protein Phosphorylation and Ubiquitylation Unit. Created in 1998, the consortium is one of the largest and longest collaborations between the pharmaceutical industry and an academic research institute worldwide. It currently includes six of the world's leading pharmaceutical companies - AstraZeneca, Boehringer Ingelheim, GlaxoSmithKline, Janssen Pharmaceutica NV, Merck-Serono and Pfizer – which have awarded core support of £14.4 million for the period 2012 to 2016. The consortium scientists deliver ideas and expertise in drug target identification and validation in multiple areas, including cancer, arthritis, lupus, hypertension and Parkinson's disease. The collaboration has had, and will continue to have, a massive impact on protein and lipid kinase drug discovery campaigns by multiple Pharma companies; we anticipate

this impact will extend to protein ubiquitylation, driven by expansion of our research in this area.

Aim 2: To establish a 'pre-incubator' that will provide early spin-outs and spin-ins access to specialised equipment, services and expertise.

An important part of our mission is to support local and national job and wealth creation. To achieve this, we believe it is imperative to provide a nurturing environment for fledgling biotechnology companies. We therefore strive to make laboratory space and facilities available to companies, such as Dundee Cell Products, Ubiquigent, Kinetic Discovery, GlycoBioChem and ExScientia, until they reach an appropriate size and scale of operation to physically and successfully spin-out. The proximity to expertise, technical facilities and academic research has allowed these companies to punch above their weight and they provide excellent examples of how companies can be successfully 'pre-incubated' within a University environment. A key objective of the new *Centre for Translational & Interdisciplinary Research* project is to provide an expanded, bespoke, environment for new companies to start up and to thrive. This objective will also benefit from the University of Dundee Venture Fund LP, an equity fund available to assist the formation of spin-outs from the University which runs alongside an existing Relationship Agreement we have with Frontier IP Group plc to accelerate access to capital and commercial expertise.

Aim 3: To dismantle barriers between the physical, computational and biological sciences

Artificial barriers between the physical and biological sciences must be removed to maximise scientific discovery. We have been successful at aligning chemistry with biology in our Division of Biological Chemistry and Drug Discovery and its associated Drug Discovery Unit. We now wish to grow our productive collaborations with Mathematics, Physics and Engineering by:

- Developing our new Division of Computational Biology, which brings bioinformaticians, mathematicians, physicists and software developers together and into juxtaposition with experimental biologists.
- Investing in our recently launched Photonics in Life Sciences and Medicine initiative. An early success for this has been the 2013 award of a €3.2 million grant for an interdisciplinary EU FP7 Initial Training Network PhD program, lead by Prof Kees Weijer FRSE, called PHOQUS (**pho**tonic tools for **q**uantitative imaging in tiss**u**e**s**). To support this initiative, we are creating an experimental lab for laser physicists, engineers and life scientists to work together on innovative approaches to imaging and its applications. Another component of this initiative is the establishment of a Centre for Tissue Imaging, led by Prof Kate Storey FRSE and supported by a 2013 Wellcome Trust equipment grant (with College co-investment) of £1 million.
- Developing a strategy to grow our BioEngineering footprint, with appropriate recruitment, as a joint initiative with our School of Engineering, Physics and Mathematics.
- Exploring opportunities in data visualisation by bringing together big data generators and users (medical and life sciences researchers) with data processing and visualisation experts (computer scientists, bioinformaticians and artists and designers), including the team led by Prof. Jason Swedlow FRSE that develops the Open Microscopy Environment software.
- Using the new Centre for Translational and Interdisciplinary Research atrium, coffee shop and art gallery as a central meeting place to catalyse collaborations between researchers from different disciplines.

Aim 4: To develop our expertise in quantitative proteomics, data warehousing and analytics

As sophisticated proteomics methodologies are increasingly embraced by Life Sciences academics and industry, growth in this area is set to explode. Building on our strong position in this area, through the expertise of Prof Angus Lamond FRS, we will combine quantitative proteomics with industrial and in-house experience in business intelligence (BI) computing and data warehousing to expand the functional annotation and exploitation of the human genome. New space (900 m^2) within the *Centre for Translational and Interdisciplinary Research* and substantial funds for capital equipment for this initiative (part of our £12 million award by the UK Research Partnership Infrastructure Fund) will allow a massive expansion of this initiative.

Aim 5: To sustain ambitious goals for academic research

Our pursuit of a strategy for ambitious scientific development depends on astute financial management, forward planning and responsiveness to new opportunities. Our flat management structure, transparent finances and constructive dialogue with the University Senior Management and Finance teams, allows us to invest for sustainable growth in an ever-changing financial and

technological landscape. Growth in the College of Life Sciences School of Research personnel over the last five years, with annual grant awards growing from £52 million to £87 million, illustrates our track record. It is also essential that we maintain strong relationships with key funding agencies to create mutually beneficial partnerships addressing innovation, and unmet medical and environmental needs. Maintaining a position at the forefront of research is also absolutely dependent on the recruitment, retention and development of outstanding staff at all levels (discussed in section c).

Research groupings

Our UoA5 submission can be organised into 10 groups reflecting our Research Divisions:

Division of Biological Chemistry and Drug Discovery, head Prof Ian Gilbert FRSC, has 12 PIs, 74 Postdocs, 22 PhD students and 22 Technicians. Their aim is the discovery of chemical solutions to biological problems using chemical and structural biology, *in vitro* and *in vivo* pharmacology, screening technologies and medicinal and synthetic organic chemistry. They focus on drug targets in neglected diseases and on innovative targets in other areas of unmet medical need. The division is currently supported by several strategic awards including three from the Wellcome Trust (totaling £12.7 million), the Bill & Melinda Gates Foundation (£3.3 million), and the Medicines for Malaria Venture (£1.1 million). Key achievements include: i) 2010: Validation of protein N-myristoyltransferase as a drug target, and delivery of a pre-clinical drug candidate, for human African trypanosomiasis (*Nature* 464, 728-732); ii) 2012: The discovery of fexinidazole metabolites as anti-leishmanial agents, leading to DNDi taking fexinidazole into Phase II clinical trials (*Science Translational Medicine* 4: 119re1); iii) 2013: Delivery of a pre-clinical drug candidate for malaria, to be developed in collaboration with the Medicines for Malaria Venture.

Division of Cell and Developmental Biology, head Prof Kate Storey FRSE, has 10 PIs, 20 Postdocs, 20 PhD students and 12 Technicians investigating the mechanisms of differentiation in developing organisms, stem cells and adult tissues. Their research combines embryology, genetic approaches, super-resolution & long term cell and tissue imaging, genome-wide analyses and mathematical modelling. Key achievements include: i) 2010: Demonstration that loss of asymmetric division in gut epithelial stem cells contributes to the oncogenic effect of mutations in the APC gene (*Cell Stem Cell.* 6, 175-181); ii) 2012: Identification of the long sought-for stalk inducing morphogen of *Dictyostelium* and first demonstration of a role for cyclic-di-GMP in eukaryotes (*Nature* 488, 680-683).

Division of Cell Signalling and Immunology, head Prof Colin Watts FRS, has 7 PIs, 28 Postdocs, 12 PhD students and 6 Technicians researching the mechanisms by which cells process antigens and sense and transmit external signals, particularly those detected by receptors in the immune system and signals that indicate changes in cellular metabolism or energy status. Key achievements include: i) 2008 & 2013: Demonstration that T cell metabolism impacts T cell fate, highlighting the importance of metabolic regulation in immune function (*Nat Immunol*. 9, 513-521 & *Nat Immunol* 14, 500-508); ii) 2012: Demonstration that the natural product salicylate affects metabolism *in vivo* by directly activating AMP-activated protein kinase (*Science* 336, 918-922).

Division of Computational Biology, head Prof Geoff Barton, currently has 5 PIs (3 returned in UoA15), 9 Postdocs and 3 PhD students. It was created in 2013 to bring together computational, mathematical and biophysical scientists to tackle biological and medical questions. A key achievement has been the development of *Jalview*, installed on over 55,000 computers worldwide and the *de-facto* standard software for multiple sequence alignment and analysis.

Centre for Anatomy and Human Identification, head Prof Sue Black OBE FRSE, has 2 PIs, 3 Postdocs, 11 PhD students and 2 Technicians. Their research covers the analysis of adult and juvenile remains and 3D facial reconstruction. Key achievements include i) 2008: The development of a novel approach to identify perpetrators of child sexual abuse. ii) 2011: Introduction of Thiel embalming to the UK, significantly improving surgical research; iii) 2013: Reconstruction of the faces of King Richard III, Mary Queen of Scots and the bard Robert Burns.

Division of Molecular Microbiology, head Prof Tracy Palmer FRSE, has 8 PIs, 14 Postdocs, 35 PhD students and 3 Technicians investigating the processes that govern microbe interactions with hosts, the environment and other microbes. Much of their research is multidisciplinary, with expertise in microbial growth, physiology, genetics, biochemistry, structural biology, bioinformatics, drug discovery and biophysics. Key achievements include i) 2013: Discovery of hydrophobin, a key component of bacterial biofilms (*PNAS* 110, 13600-13605); ii) 2013: Discovery that bacterial phytopathogenesis is regulated by cyclic-GMP signaling (*EMBO. J*. 32, 2779-2781).

Centre for Gene Regulation and Expression, head Prof Julian Blow FRSE FMedSci, comprises 11 PIs, 75 Postdocs, 27 PhD students and 11 Technicians studying the cell biology of gene expression and chromosome biology using techniques including live cell imaging and quantitative proteomics. The Centre has been awarded two Wellcome Trust strategic awards (2008 - £5.2 million and 2013 - £5.4 million) and an additional Wellcome Trust Strategic Award for the development of Open Microscopy Environment (OME) software (£4.2 million). Key achievements include i) 2011: Demonstration that Snf2-related enzymes are required genome-wide to organize nucleosomes relative to transcription start sites (*Science* 333, 1758-1760); ii) 2012: Elucidation of the molecular basis by which RING E3 ubiquitin ligases promote the transfer of ubiquitin to substrates (*Nature* 489, 115-120); iii) 2013: Demonstration that PHD1 can hydroxylate a critical centrosome protein to facilitate mitotic progression, linking oxygen sensing with cell-cycle control for the first time (*Dev. Cell* 26, 381-392).

MRC Protein Phosphorylation and Ubiquitylation Unit, head Prof Dario Alessi FRS, comprises 17 PIs, 72 Postdocs, 29 PhD students and 37 Technicians investigating the mechanisms of protein phosphorylation and ubiquitylation in cell regulation and human disease, thus facilitating the development of drugs to treat diseases caused by abnormalities in these processes. The Unit is supported (2013-2018) by a £24 million award from the Medical Research Council and also hosts the Division of Signal Transduction Therapy (funded for 2012-2016 by £14.4 million from six leading pharmaceutical companies). Key achievements include i) 2010: Discovery that the DNA repair endonuclease FAN1 is recruited to sites of DNA damage by interaction with the monoubiquitylated form of FANCD2 (*Cell* 142, 65-76); ii) 2010: Demonstration that WNK protein kinases regulate blood pressure by activating SPAK and OSR1 (*EMBO Mol Med* 2, 63-75); iii) 2012: Demonstration that mitochondrial depolarization activates the Parkinson's disease protein PINK1 and identification of the first physiological substrate for this enzyme (*Open Biol* 2, 20080).

Division of Plant Sciences, head Prof John Brown, comprises 10 PIs, 16 Postdocs, 31 PhD students and 5 Technicians exploring the mechanisms by which plants grow and develop in response to their environment and to pathogens, as well as providing solutions for crop improvement, biofuel development and the assessment of biodiversity. Key achievements include i) 2010: First demonstration of the mode-of-action of an effector from any filamentous plant pathogen inside a plant cell (*PNAS* 107, 9909-9914); ii) 2012: Release of the barley "gene-ome" sequence assembly (*Nature* 491, 711–716); iii) 2013: Identification of caffeoyl shikimate esterase in lignin biosynthesis and its manipulation to facilitate biomass use (*Science,* 341 1103-1106).

CRUK Nucleic Acid Structure Research Group, head Prof David Lilley FRS, has 2 PIs, 8 Postdocs and 1 PhD student studying the structural and chemical properties of nucleic acids and their interactions with proteins. Key achievements include 2008: Demonstrating and applying the orientation-dependence of FRET between fluorophores attached to DNA (*PNAS*, 105, 11176-81).

Mechanisms for promoting research, sustaining and developing a vital research culture:

Administrative and technical support. The College of Life Sciences provides comprehensive support for research: Divisional Lab Managers provide technical support, maintain equipment, run the purchasing system, deliver staff training and implement health & safety policies; our stores provide same-day delivery to the bench; Divisional secretaries co-ordinate the administrative functions that underpin research activities; and senior administrators assist with the implementation of College Strategy. The College has devolved staff from University Human Resources, Research & Innovation Services and Finance, which ensures their support is focused on our research needs.

School and Divisional Research Boards. Each Research Division operates a bimonthly research board that, via Division Heads, reports into a bimonthly School of Research Board. These Boards provide a lively forum for discussions on research strategy, postgraduate and postdoctoral training, and public outreach. All boards have representation from the postdoctoral and PhD associations and from administration (Human Resources, Research & Innovation Services and Finance).

Seminar Programmes. Each Division, with a budget from the College, operates a seminar programme in which prominent scientists give lectures and meet with our PIs, postdocs and PhD students. These seminars enrich PhD and post-doctoral scientist experience and are interspersed with seminars by the postdocs and PhD students themselves, providing them with further training.

Named Lectures. The College hosts several high-profile Named Lectures throughout the year. These lectures are given by distinguished scientists including Nobel laureates and are aimed at a very broad audience, enriching the academic environment (http://tinyurl.com/qf9k5st).

Annual Symposia. A key event in our calendar is the Annual College of Life Sciences Research

Symposium. This 3-day event of presentations and posters takes place at a hotel in the Highlands and promotes academic and social interactions, leading to many fruitful scientific collaborations.
Divisional Symposia. Divisions hold one or more symposia each year to review current research and develop future plans. These events take various forms, including scientific talks, brainstorming sessions, poster presentations and networking activities and external invitees and/or members of other Divisions and Colleges generally attend.
International Scientific Advisory Boards (ISABs) and Quinquennial Reviews. Divisions benefit from the input of ISABs that provide invaluable advice regarding the overall research portfolios and strategies. Each Division also undergoes rigorous quinquennial review, organised by the Dean of Research and Head of Division, which informs strategic planning for the Division and the College.
Open Access. The College has a robust open access policy and provides administrative support to ensure that open access publication guidelines set by granting organisations are met in full.
Public Engagement. The College is strongly committed to public engagement and outreach activities to inform the public about science and our research. To this end, the College deploys a significant budget (>£50,000 per year) and employs a Public Engagement Officer and a Schools Liaison Officer who provide administrative and logistic support for academic staff, postdocs, PhD students and support staff to participate in public engagement activities. We have recently boosted our schools outreach work, targeting the most disadvantaged schools in Dundee.

Evidence of multi- and/or inter-disciplinary developments: The College strongly encourages collaborations between research groups, and 13% of our publications in the last 5 years involved at least 2 of our research groups. We are investing heavily in the future of interdisciplinary research through our new *Centre for Disciplinary and Translational Research*. This will strengthen research across the chemistry/biology interface, with significant expansion in chemical biology and drug discovery, and across the physics/biology interface through our newly formed Division of Computational Biology. Further, our *Photonics in Life Sciences and Medicine* initiative with its the PHOQUS PhD programme will train students at the laser physics/biomedicine interface. We are also nurturing cross-discipline (life sciences / medicine / physics / engineering) collaborations with an institutional pump-priming fund (£360,000 per year) for interdisciplinary translational medical research and our Wellcome Trust Clinical PhD Programme focuses on training clinicians in basic life sciences laboratories. We have actively fostered collaboration with clinical colleagues in our College of Medicine Dentistry and Nursing by creating cross-disciplinary research initiatives, such as: ***The Centre for Dermatology and Genetic Medicine*** (part of the Division of Molecular Medicine and supported by a £6 million Wellcome Trust strategic award) which translates basic discoveries in genetic skin disease into clinical application, utilising expertise in biology, physics, drug discovery, bioinformatics and medicine. ***The Dundee Diabetes Research Centre***, a joint venture between Life Sciences and Medicine, hosts over 20 research teams that supports diabetes research from the laboratory to the clinic. ***The Dundee Cancer Centre***, established in 2010 and funded by Cancer Research UK, facilitates collaboration and communication between cancer researchers across the University and NHS-Tayside. ***The Centre for Forensic and Medical Art***, a collaboration between the Colleges of Life Sciences and Art and Design that performs facial reconstructions, archaeological investigations, human identification, medical illustration and creates museum & media exhibits. Interactions with the ***College of Art and Design*** will continue to develop with the co-direction of the *Centre for Translational and Interdisciplinary Research* art gallery and our joint Data Visualisation initiative.

c. People, including:

i. Staffing strategy and staff development

Principal Investigators: We aim to recruit and support the most talented researchers and maintain a healthy and sustainable demographic: in October 2013 our PIs fell into the following age bands: 28-40 (37%), 40-50 (23%), 50-60 (32%), >60 (8%). We achieve this using transparent and well-understood recruitment, mentoring and tenure processes:
Recruitment. Taking into account the views of The School of Research Board, recommendations from our International Scientific Advisory Boards and the conclusions of quinquennial reviews, the Dean of Research makes strategic decisions about when to recruit new PIs into specific Divisions and/or research areas. Appropriate Search Committees are then convened and shortlisted candidates give a formal seminar to the College followed by a 'round-table' with the Search Committee to discuss their research and how they might fit into the College. Search Committees

comprise the Dean, the Head of the relevant Division, the Head of another Division, 2 or 3 other PIs with relevant expertise and generally a senior academic from another College or leading research organisation. All PIs recruited by Search Committee are either tenured (for senior appointments) or placed on tenure-track with a 7-year appointment. Over the period of assessment we have recruited 20 tenure track PIs and 8 PIs at the tenured Reader or Professorial level.

Start-up packages and mentoring. We provide new PIs with excellent facilities and outstanding technology platforms to support their research. They also benefit from targeted allocation of College PhD studentships and all receive a start-up package (typically >£30,000) for items of general equipment, as well as substantial (typically 20-50%) matching funding for major items of equipment on research grants. Tenure-track PIs receive mentoring by their Head of Division, senior PIs and the Dean of Research, who provide advice on how to run a group and on the preparation of manuscripts and grant applications. Our tenure-track PIs are not required to teach in the first 3 years of appointment, while they focus on establishing their laboratories, and they have limited teaching commitments thereafter (typically up to 10 lectures a year) until tenure review.

Tenure Review. Tenure review is coordinated by the Head of College. We perform 'mid-term' reviews early in the 3rd year of appointment to provide timely feedback and help improve the case for formal tenure evaluation. A 'tenure-track PI club' was established in 2011, which organises quarterly meetings where items of interest are discussed. This group has a seat on the School of Research Board and is thus empowered to bring their comments and suggestions forward to College management. Tenure review occurs no later than the end of a tenure-track PI's 5th year, but we underwrite all their salaries for a minimum of 7 years (regardless of the length of external fellowships), allowing tenure-track PIs to carry on submitting grant applications and hiring staff for almost all of the tenure-track period. At tenure review, candidates submit a list of publications, funding applications and an overview of their research achievements, contributions to public engagement and a summary of their future plans. At least 5 external referees of high international standing are asked to comment on whether they think the candidate has, or will, become a leader in their field and whether they would be competitive for tenure in their own institutions. The same documentation and the comments of the referees are then provided to an Assessing Committee, chaired by the Head of College and comprising the Dean of Research, two distinguished External Assessors (who are generally directors of scientific institutes or departments) a Vice Principal or Dean of The University of Dundee outwith Life Sciences, the Head of the Candidate's Research Division and the Head of another Research Division. The PI then presents a seminar followed by a discussion with the Assessing Committee about future plans. The Assessing Committee then makes a recommendation that is delivered to the PI as soon as possible by the Head of College. Over the period of assessment, we have performed 13 tenure reviews, 9 of which were successful.

On-going Review. Every PI, tenured and tenure-track, is appraised annually by their Head of Division to discuss performance in the past year and objectives in the next. All Heads of Division and tenure-tack PIs also have a formal annual appraisal with the Dean of Research.

Postdoctoral Researchers: The College of Life Sciences Postdoc Association (CLSPA; http://postdoc.lifesci.dundee.ac.uk) was established in 2005 and was one of the first such organisations in the UK. It is run by postdocs for postdocs to be their voice in interactions with College management, assist in postdoc career development, catalyse interactions between them, foster a culture of debate and communication and help new postdocs with local orientation through events and activities. With an £8,000 annual budget provided by the College, the association organises a seminar programme, including seminars on careers beyond life sciences research. The Postdoc Association also convenes a working party, which includes PIs and Human Resources staff, to assist postdocs achieve their full potential. The scheme, implemented in 2008, includes an annual formal review to: i) improve and develop working relationships and the working environment; and ii) provide structure and focus for career development. The review looks at eight aspects of the researcher's role: research achievement and goals; research skills and techniques; research environment; communication skills; teaching skills; networking and conferences; research management (including writing and reviewing manuscripts); and career management. In addition, postdocs are encouraged to acquire transferrable skills from courses run by the University's Organisational and Professional Development team, which develops its programmes in close collaboration with the College of Life Sciences. The quality of our environment is reflected by the

College being voted amongst the top-10 “Best Places to Work” (outside the US) by our postdocs in polls conducted by *The Scientist* magazine in 2009, 2010 and 2011.

Implementation of the concordat to support Career development: The College of Life Sciences plays a major role in the University’s Concordat Working Group (http://tinyurl.com/o85v345). Dundee University has been recognised by the European Commission for its 'HR Excellence in Research' and the College takes an active part in an Early Career Academic Mentoring Scheme (joint with St Andrew’s University) that ensures that researchers (post-docs and early career academics), are supported in developing their careers through a variety of possible career paths.

Evidence of how the submitting unit supports equality and diversity: The College of Life Sciences is committed to Equality and Diversity. Over the assessment period, the College has implemented new procedures that take equality and diversity issues into account. For example, the Assessing Committees for evaluating PIs for tenure make allowance for those whose research output may have been limited or affected by personal circumstances. This allowance can be in the form of extending the individual’s tenure track contract (by 9 months for each period of maternity leave, for example) and/or by expecting a lower volume of outputs. The College has also taken steps to promote an inclusive working environment by, for example, scheduling all meetings and seminars to be compatible with family commitments. We are fully committed to the principles of the Athena Swan charter and in this regard for the last 5 years, the University has had an annual ‘Women in Science Festival’ to celebrate and support women in science, technology, engineering and mathematics. The College has a number of outstanding women scientists in key leadership roles and Prof Cantrell, Head of the College, is chair of the University Athena Swan Steering Group and has led an application in 2013 for a Bronze Award.

ii. Research students

The training and supervision of postgraduate research students: The College of Life Sciences considers the training of the next generation of researchers to be a top priority. The aims of our PhD Programme are: i) To train students in research by performing well-supervised, high-quality research projects at the forefront of international science in well-equipped laboratories. ii) To make students aware of the theory, practice, capabilities and limitations of modern techniques in life science research. iii) To train students in generic research skills: experimental design, data analysis, literature survey, communication skills, teamwork and computer skills. iv) To assist students to obtain employment upon completion of their studies. v) To provide an intellectually exciting and supportive work environment.

The College PhD programme offers studentships from the MRC, BBSRC (including 6 CASE awards with industry over the assessment period), CRUK, the Wellcome Trust, A-Star (in which students spend two years in Dundee and two in Singapore), CAPES (for Brazilian students), The China Scholarship Council, PHOQUS (for EU students training at the physics/biomedical interface), and from the University itself, as well as a Clinical PhD programme, run jointly with our Medical School, where clinicians are trained in basic research. The PhD programme is overseen by an academic director (Dr Arno Muller), with an administrative support team of three who manage the implementation of the programme. The majority of our students carry out rotation projects in diverse laboratories during their first year before they make their final project choice. All students participate in an Induction Programme that covers a series of laboratory-based training sessions, including core skills in molecular and cell biology. In addition, the first year students undertake advanced course work in informatics and data analysis and participate in ‘Super Seminars’ - biweekly seminars given by PIs with associated journal clubs lead by one of the students. This format stimulates pro-active learning in diverse areas. In addition, all students undertake 10 full days of generic skills training a year from a wide portfolio of courses which have been developed between the College of Life Sciences and the University Organisational and Professional Development team.

It is important to provide talented undergraduates (the PhD students of tomorrow) with research experience. We achieve this by running an International Summer School for 33 competitively-selected undergraduate students each year and by supporting a team of interdisciplinary undergraduates to compete in the annual iGEM synthetic biology competition, under the direction of Prof Frank Sargent FRSE. We are proud to report that the Dundee team won a gold medal at the iGEM European finals in 2013.

Evidence of a strong and integrated research student culture: PhD students are fully integrated into the running of the College, with representation on Divisional, School of Research and College Boards. PhD students take part in all Divisional and College activities, e.g Divisional seminar series, symposia and the Annual College Symposium. All PhD students present their work at regular lab meetings led by their research supervisor. Each student is also allocated a thesis committee. Thesis committees consist of 2 experienced PIs who meet with the student formally twice a year in documented meetings. They discuss research progress and look after the academic welfare of the student. The College also provides financial (£8,000 pa) and administrative support for the College of Life Sciences' PhD Association (PiCLS; http://picls.lifesci.dundee.ac.uk/). A key role of PiCLS is to facilitate networking between PhD students through a combination of academic and social events. PiCLS also organises their own annual Research Symposium where they are responsible for inviting the external speakers and raising sponsorship (underwritten by the College). The students also give talks and present posters at this event. The College also works with PiCLS to facilitate student outreach and public engagement projects, as well as enhancing student communication skills through generic skills training. All PhD students are required to attend at least one relevant scientific meeting (UK or abroad). The College also supports the VITAE Programme, which promotes professional skills development, and students are strongly encouraged to attend a VITAE-sponsored course during their studies.

d. Income, infrastructure and facilities

All PIs are responsible for obtaining funding for postdocs and technicians in their own research groups. Many PIs obtain personal fellowship support (see list in section e). Over the reporting period, our PIs have been awarded, collectively, £54 million from the MRC, £24 million from the BBSRC, £84 million from the Wellcome Trust, £17 million from CRUK and other charities, £26 million from the EU and ERC, £29 million from industry, £38 million from UK Government bodies, £8 million from Product Development Partnerships and £5 million from other sources. Research spend for the PIs submitted in this return is, on average, >£400,000 per person per annum. This level of research activity is only possible with excellent infrastructure and facilities. All our laboratories were either built or refurbished within the last 16 years and are carefully maintained by our system of Laboratory Managers liaising with a responsive University Estates and Buildings team. The entire College complex is in open-plan format, stimulating collaboration between groups and facilitating technology transfer. Each Division has one or more centrally-located large equipment rooms, containing equipment owned by individual labs that is maintained by Divisional Laboratory Managers and that is available for all to use; this arrangement significantly extends the range of equipment easily available to any individual research group.

Nature and quality of the research infrastructure: We use the majority of our annual £1 million College budget for infrastructure (generated from grant overheads and Research Excellence Grant) as matching funding for carefully chosen equipment grant and strategic award applications (several of which have been mentioned in section b). In addition, we are agile in coordinating and responding to wider infrastructure funding opportunities. Thus, over the assessment period, we have invested >£12 million in proteomics, compound screening and profiling and 'drug metabolism and pharmacokinetics' (DMPK), FACS, Next Generation Sequencing, super resolution OMX microscopy, multi-photon and light-sheet microscopy and high-performance computing. Investment in our technology platforms over the next 5 years is projected to exceed £17 million, with the majority of this funding already in place.

To best manage our core facilities, several of our major technology platforms - proteomics, microscopy, animal facilities, oligonucleotide synthesis, flow-cytometry and X-ray crystallography - have been incorporated into a *Centre for Advanced Scientific Technologies* (CAST; http://www.lifesci.dundee.ac.uk/cast/). CAST is run by dedicated experienced staff who ensure equipment is properly specified, operated and maintained. They also contribute to experimental design and coordinate PhD student and postdoc training. This ensures that our specialized and expensive technology is available to all research groups. CAST provides the following services. ***The Proteomics Facility*** operates 8 mass spectrometers, including 4 Thermo Orbitrap systems, with 6 support staff. They offer a range of mass spectrometry and proteomics services for the analysis of whole proteomes, proteins, peptides, oligonucleotides, oligosaccharides and small molecules. They have particular expertise in SILAC quantitative proteomics and the identification of protein modifications. Our state-of-the-art ***Light Microscopy Facility*** operates a range of light

microscopes, including 7 DeltaVision Deconvolution systems, 3 confocal microscopes, 4 electron microscopes and a super-resolution OMX Blaze Structured Illumination system. The service also provides technical expertise in localizing proteins of interest in fixed and live cells, and also on the imaging of tissues. Our ***Animal Facility*** provides *a* transgenic service that produces transgenic and gene-targeted mice and undertakes cryopreservation of mouse lines, and can also isolate cell lines from gene-targeted mice. Current occupancy is about 10,000 mice, most of which are housed in individually ventilated cages, with other small rodents and amphibians on a smaller scale. There are facilities for category 3 containment, small animal surgery, telemetry and activity monitoring. The ***Flow Cytometry Facility*** includes a high specification five laser, fifteen colour LSR Fortessa, six colour FACS Canto II, and two FACS Calibur analysers, in addition to a DIVA cell sorter. The facility provides cell analysis and sorting services and advice to all. The ***Oligonucleotide Synthesis Facility*** delivers high quality oligonucleotides, from primers to long DNA for gene synthesis, and makes modified DNA and RNA. The ***X-Ray Crystallography Facility*** provides high-throughput robotic for crystallisation, sample mounting, X-ray screening and data collection.

Other significant facilities available within the College of Life Sciences include the following. Our ***Drug Discovery Unit*** contains the full range of disciplines required to produce drug leads and drug candidates across multiple therapeutic areas. Its compound screening technology includes a full range of robotic handlers and readers (http://www.drugdiscovery.dundee.ac.uk/). ***The International Centre for Kinase Profiling*** analyses the selectivity of protein kinase inhibitors, a technique pioneered in Dundee. It is heavily used by the Drug Discovery Unit, other members of the College, plus many external customers (http://www.kinase-screen.mrc.ac.uk/). Our ***Next Generation Sequencing Service*** delivers rapid, inexpensive and accurate genomic data and includes Illumina HiSeq2000 and MiSeq platforms. Geared towards whole genome and RNA sequence analysis, these provide a new approach to elucidating genomic structure and function and gene expression. Our ***High-Performance Computing Service*** addresses the needs arising from developments in drug discovery, proteomics, microscopy and DNA sequencing that lead to the generation of ever larger quantities of data. It provides the ability to safely and efficiently store, archive and analyse data using >1 petabyte of high-speed parallel storage systems and a 1000 core parallel compute cluster. ***The Life Sciences Data Analysis Group***, run jointly by the Division of Computational Biology and the Centre for Gene Regulation & Expression, advises on programming, statistics and biological data analysis. Interacting extensively with PhD students and postdocs, they run training courses, help analyse datasets (from microarray, NGS, proteomics, imaging) and develop software and databases (http://www.compbio.dundee.ac.uk/dag/).

Evidence of cross-HEI shared or collaborative use of infrastructure: Through the Scottish Universities Life Sciences Alliance (SULSA), we provide access to OMX super-resolution microscopy and compound screening and pharmacokinetics for all Scottish HEIs. Similarly, we benefit from access to, for example, metabolomics (Glasgow) and 800 MHz NMR and cryo-electron microscopy (Edinburgh). We are also co-developing facilities in advanced Electron Paramagnetic Resonance (EPR) with St Andrews University and have an arrangement with Aberdeen University for reciprocal access to small molecule (Dundee) and biologics (Aberdeen) facilities and expertise for drug discovery. Our Proteomics facility has a very good reputation for delivery and, over the reporting period, it has performed services for colleagues from the Universities of Aberdeen, Bath, Bristol, Cambridge, Cardiff, Durham, Edinburgh, Glasgow, Leeds, Leicester, Liverpool, London, Oxford, Sheffield, Stirling, Sussex and Surrey.

Major Benefits in-kind: In addition to synchrotron allocations (valued at £2.3 million over the assessment period), we benefit from other significant in-kind contributions such as: i) Our 2011-2016 Wellcome Trust (peer-reviewed and legally binding) partnership with GlaxoSmithKline contains >£2.5 million of in-kind contributions from the company to develop anti-parasite drugs. ii) Prof Lamond's collaboration to develop proteomics software with Teradata (2011-2013) has involved the loan of >£300,000 of computing hardware and donation of >£100,000 of software developer time. Most recently (2013), we entered into a Technology Alliance Partnership with Thermo Fisher Scientific Inc., a leading provider of mass spectrometers, giving us access to new technology and instrumentation before it is commercially available.

Policy and practice in relation to research governance: The University Research Governance & Policy Committee is chaired by Prof Alan Fairlamb CBE FRSE FMedSci from the College of Life Sciences. It ensures our governance and policies for research conduct are appropriate, current

and transparent. The committee has established an easy-to-use 'policy roadmap' to guide Principal Investigators and research staff to the correct policies that govern particular research activities, including policy on the appropriate commercialisation of Intellectual Property.

e. Collaboration or contribution to the discipline or research base

Indicators of wider influence and contributions to the research base: Prof Doreen Cantrell is Chair of the MRC Infections and Immunity Board and sits on the MRC Strategy Board. Prof Mike Ferguson is on the Board of Governors for the Wellcome Trust and the Board of Directors of the Medicines for Malaria Venture. Prof Alan Fairlamb has advised WHO (2003-2012), the Drugs for Neglected Disease initiative (2003-2010), was a council member for the Academy of Medical Sciences (2010-2013) and is on the Governing Board of The GlaxoSmithKline Tres Cantos Open Lab Foundation. Prof Angus Lamond was Chair of the Wellcome Trust Expert Review Group on the Molecular Basis of Cell Function (2011-2013). Sir Philip Cohen is a member of the Board of Trustees for MRC Technology. Prof Andrew Hopkins is Director of the Scottish Universities Life Sciences Alliance (SULSA) and member of the Scottish Life Sciences Advisory Board. Prof Sue Black is a permanent member of the Home Office Disaster Victim Identification Committee.

Participation in the peer-review process: Our PIs are frequent paper and grant reviewers and sit on over 30 journal editorial boards, 20 National and 10 International Grant committees and between 2008-2013 have participated in more than 10 site visit assessments of other Institutions and are members of 35 different advisory panels (http://tinyurl.com/o7lhuna).

Fellowships and relevant awards: Of the 81 PIs in the College of Life Sciences, 19 currently (2013) hold personal fellowships. The following fellowships were awarded in the assessment period: • 4 Wellcome Trust Principal Research Fellowships • 1 Cancer Research UK Senior Research Fellowship • 5 Wellcome Trust Senior Research Fellowships • 6 Royal Society of Edinburgh Personal Research Fellowships • 1 Royal Society of Edinburgh Enterprise Fellowship • 1 Royal Society University Research Fellowships • 1 MRC Senior Non-Clinical Fellowship • 1 Wellcome Trust Senior Fellowship in Clinical Science • 1 Wellcome Trust Intermediate Clinical Fellowship • 1 Wellcome Trust Early Postdoctoral Training Fellowship for Clinician Scientists • 2 Wellcome Trust Career Development Fellowships • 1 Wellcome Trust Sir Henry Dale Fellowship • 2 MRC Career Development Fellowships • 1 BBSRC David Phillips Fellowship • 5 Wellcome Trust Sir Henry Wellcome Postdoctoral Fellowships. Members of the College also received a range of other prizes and awards, including 7 Wellcome Trust Senior Investigator Awards and 3 European Research Council Starting Grants (http://www.lifesci.dundee.ac.uk/awards).

Over the assessment period, the College of Life Sciences was recognised by: • Award of a Regius Professorship in Life Sciences (Ferguson) • Award of CBE (Fairlamb and Ferguson). • Colworth Medal of the Biochemical Society (Rouse) • Tenovus Medal (Rouse) • Lister Research Prize (Cowling) • Royal Medal of the Royal Society (Cohen) • Royal Medal of The Royal Society of Edinburgh (Ferguson) • Novartis Medal & Prize of the Biochemical Society (Hardie, Hay, Lamond) • BBSRC Innovator of the Year 2011 (Swedlow) • Colworth Medal of the Society for General Microbiology (Gadd) • EMBO YIP (Cowling) • 11 other national and international prizes. Also over the assessment period PIs have been elected: • Foreign Associate of the US National Academy of Sciences (Cohen) • Fellow of the Royal Society (Alessi, Cantrell, Hay, Lamond) • Fellow of the Academy of Medical Sciences (Hunter, McLean, Watts, Alessi, Blow) • Fellow of the Royal Society of Edinburgh (Owen-Hughes, Palmer, Sargent, Storey, Swedlow, Tanaka, van Aalten, Wyatt, Schaap, Waugh) • Fellow of the Royal Society of Chemistry (Gilbert) • Fellow of the Royal Society of Arts (Storey) • Membership of EMBO (Hay, Tanaka). Finally, a Queen's Anniversary Prize for Higher Education was announced in Nov 2013 to our Centre for Anatomy and Human Identification

Extent of collaborations with external bodies and industry: Our substantial collaborations with ***industry*** and our important Plant Sciences research partnership with the ***James Hutton Institute*** have been described earlier. Other notable collaborations are with The ***Wellcome Trust Sanger Institute***, where our Centre for Gene Regulation and Expression and Division of Biological Chemistry and Drug Discovery are collaborating experimentally and strategically on, for example, human induced pluripotent stem cells, mutational profiles in response to known and suspected genotoxic agents, gene expression across the cell cycle at the mRNA and protein level, and anti-parasite drug mode of action. We are also exploring collaborative opportunities and synergies in drug discovery with the ***Oxford Target Discovery Institute***. Researchers in our Centre for

Anatomy and Human Identification work closely with the ***UK police force*** and ***Interpol***.

Responsiveness to national and international priorities and initiatives: A national priority for research, clearly expressed by Government thorough the Department of Business Innovation & Skills and the UK Research Councils and by the major medical charities, is to demonstrate knowledge-transfer and societal impact through the translation of basic research. We feel that we have responded well to this challenge through our extensive collaborations with pharmaceutical company partners, our investment in in-house drug discovery capability, our nurturing of (and continued support for) local Biotech companies and the strategic partnering of our Plant Sciences research with The James Hutton Institute. Much of this is detailed elsewhere in this document. Validation of our reputation for impact and translation includes our winning the (peer-reviewed) national BBSRC *Excellence with Impact* competition in 2011 for "The Greatest Delivery of Impact", using data collected from 2008 to the end of 2010. To quote: *"This department was felt by the judges to have achieved an extraordinary range of significant impacts from their research. The department's research had led to wide ranging and tangible achievements of both social and economic benefit. It had an impressive number of staff engaged in enterprise activities, and had clearly understood how to incentivise, recognise and reward staff for their impact activities."*

Other specific examples of how we have responded to national initiatives include: i) In 2009, we responded to a call by Lowlands and Uplands Scotland European Regional Development Fund (ERDF) 2007-2013 for projects to encourage growth of the Scottish economy. We were awarded £2.1 million for capital equipment to support a number of translational programmes and early spin-out companies, such as GlycoBiochem, Kinetic Discovery and Ubiquigent. ii) In 2012, the UK Research Partnership Investment Fund (UKRPIF) was launched by the UK Government to "enhance the research facilities of higher education institutions undertaking world-leading research and to strengthen the contribution of the research base to economic growth". To access the fund, universities had to demonstrate scientific excellence, innovation, translation and the ability to match the UKRPIF support with twice the co-investment from private companies or charities. The College of Life Sciences successfully won £12 million to complete the development of the *Centre for Translational and Interdisciplinary Research* in this competition. iii) The College has been involved in two Knowledge Transfer Partnerships with biotech companies, funded by the TSB.

With respect to international priorities and initiatives, we have successfully responded to calls by The Medicines for Malaria Venture to perform screens, hit-to-lead and lead-optimisation chemistry to yield a pre-clinical drug candidate for malaria. We have responded to calls by the Drugs for Neglected Diseases initiative and GALVmed to do the same for kinetoplastid diseases, delivering thus far a pre-clinical drug candidate for human sleeping sickness, compounds in field trials for animal trypanosmiasis and compounds in late lead-optimisation for leishmaniasis. We have similarly responded to a request by the Bill & Melinda Gates Foundation and the TB Alliance to establish a lead-optimisation centre of excellence for the delivery of new tuberculosis drugs.

Effective mechanisms to promote collaboration at the national and international level: Our view is that collaborations work best 'bottom-up', *i.e.*, through the shared interests of individuals and groups of scientists. However, collaborations can be also catalysed by providing scientists with the opportunity to meet each other through establishing meaningful strategic partnerships with other organisations. For example, the training of overseas PhD students (and postdocs) is one of the most effective long-term mechanisms of developing international collaboration and we have formal PhD training partnerships with ***A-Star Singapore***, ***CAPES Brazil***, ***The China Scholarship Council***, ***ICETEX Colombia*** and the ***USA Marshall Programme***. Another mechanism is to arrange visits for groups of scientists to and from selected institutions. In this regard, we are exploring and participating in collaborations in imaging and cell and chemical biology with the ***National Centre for Biological Science, Bangalore***, in drug discovery and parasitology with ***The University of Sao Paulo*** and in chemical biology with ***Xiamen University, China***. Our strategic relationships with other UK institutions and details of inter-HEI resource sharing have been described earlier. These represent important mechanisms to stimulate national collaboration, as does active participation in 'cluster' events and initiatives. The 'Scottish HEI cluster', which extends to the North of England, is very active in promoting research activity in areas such as cell and developmental biology, stem cells, immunology, infectious diseases and bioinformatics. We support such networking both in principle and financially, and many inter- and multi-institute research collaborations emerge from such events.