

Institution: University of Dundee
Unit of Assessment: UoA5 Biological Sciences
1. Unit context and structure, research and impact strategy

The School of Life Sciences (SLS) at the University of Dundee makes fundamental discoveries on the molecular and cellular mechanisms underlying health and disease in humans, animals, plants, parasites and bacteria and translates that knowledge to address global challenges. All of our UoA5-related research occurs in SLS. With 700 staff from over 50 countries, SLS provides a dynamic, multi-national, collegiate and diverse environment within which to train the next generation of scientists and innovators. We have extensive productive interactions and collaborations with industry and take effective interdisciplinary approaches to address complex biological questions. State-of-the-art laboratory and technology facilities, and extensive professional service support, underpin our ambitious research portfolio and world-changing impact successes.

Our outstanding international profile is verified by many external benchmarks including being; the only UK institution in top 50 (26th) for research impact on global innovation (Nature Index 2017 Innovation); the world's most influential research institution in pharmaceuticals (Clarivate Analytics 2017); in the world top 100 for research quality (Nature Index, 2019); 1st in Europe and 2nd globally for scientific impact in 'Biomedical and Health Science' (CWTS Leiden Ranking 2020 for number and proportion of publications in the 1% most cited 2014-2017, minimum 1000 publications, using fractional-counting).

Our people are central to our success. Our diversity enriches our environment and how we approach our work. SLS has 78 Principal Investigators (PIs) leading research groups totalling 345 postdocs, 132 PhD students and 76 technicians/research assistants. We are loosely organised into **8 Research Divisions**, and some smaller groupings. Many PIs (22%) are affiliated with more than one Division or have additional affiliations to other Schools or institutions, facilitating interdisciplinary work at a variety of organisational levels. Each Division is supported by embedded Laboratory Management teams (16) and clerical staff (19). Core technology platforms (45 technologists) support all Divisions as do 24 wash-up/media-preparation/stores staff, 28 professional service staff (Finance, HR, Research & Innovation Services), and 3 business development managers. All but one Division are in a single interlinked complex. Plant Sciences is located at the nearby James Hutton Institute (JHI), with whom we have had a key strategic partnership since 2002, providing access to world-class crop research facilities.

Leadership and Management: We are led by the Interim Dean, *Prof Inke Nathke* (appointed May 2020). *Prof Nathke* is supported by a School Manager and five Associate Deans (ADs) for Research, Learning & Teaching, Internationalisation, Quality Assurance, and Professional Culture. The Associate Dean for Research is *Prof Claire Halpin* FRSE. Leadership and strategy development within the School also benefits from the experience of former Deans and Heads of School/Units including Regius Prof Sir Mike Ferguson FRS, Prof Doreen Cantrell FRS, Prof Dario Alessi FRS, Prof Sir Philip Cohen FRS and Prof Julian Blow FRSE FMedSci and from input from the Heads of our research Divisions. *Prof Nathke* contributes to the University Dean's group which feeds directly into the University Executive Group responsible for strategic planning and management of the University's activities. The School thus directly influences University strategy and resource allocation and holds authority and responsibility for policy implementation at School level.

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Major research groupings:

Division of Biological Chemistry and Drug Discovery, BCDD, aims to discover chemical solutions to biological problems, focusing on drug targets for neglected tropical diseases and innovative targets for cancer, Parkinson's and other disease treatments. **The Drug Discovery Unit**, the **Wellcome Centre for Anti-infective Research** and the **National Phenotypic Screening Centre** sit within BCDD but have many collaborative projects with other Divisions and institutions world-wide, including pharmaceutical companies.

Division of Cell and Developmental Biology, CDB, investigates the mechanisms of differentiation in developing organisms, stem cells and adult tissues. Their research combines embryology, genetic approaches, super-resolution cell and tissue imaging, genome-wide analyses, and mathematical modelling.

Division of Cell Signalling and Immunology, CSI, researches the mechanisms by which cells process antigens and sense and transmit external signals, particularly those detected by immune system receptors and those causing changes in cellular metabolism, autophagy or energy status.

Division of Computational Biology, CB, brings together computational, mathematical and biophysical scientists to tackle biological and medical questions. It has long-standing expertise in machine learning and artificial intelligence.

Division of Molecular Microbiology, MMB, investigates the processes that govern microbe interactions with the environment and other microbes. They benefit from large dedicated containment level 2 space which is used by researchers across SLS. The **Geomicrobiology Group** studies the transformations of metals and minerals by microorganisms.

Division of Gene Regulation and Expression, GRE, studies gene expression and chromosome biology using forefront technologies including live cell imaging, RNA/DNA sequencing and quantitative proteomics. The Division supports the **OME: Open Microscopy Environment** co-founded in Dundee. **The CRUK Nucleic Acid Structure Research Group** studies the structural and chemical properties of nucleic acids and their interactions with proteins.

MRC Protein Phosphorylation and Ubiquitylation Unit, MRC-PPU, investigates the mechanisms of protein phosphorylation and ubiquitylation in cell regulation and physiology, thus facilitating the development of drugs to treat related diseases. The Unit is an international centre for Parkinson's Disease research and hosts the **Division of Signal Transduction Therapy** (funded by Boehringer Ingelheim, GlaxoSmithKline and Merck).

Division of Plant Sciences, PS, explores the mechanisms by which plants grow and develop in response to their environment and to pathogens, as well as providing solutions for crop improvement. We have a close strategic partnership with the JHI where labs of our 10 plant science PIs are based for close interaction with JHI researchers and to access world-class greenhouse and field facilities.

We invest in world-class technologies to underpin discovery in all 8 Divisions through our **Centre for Advanced Scientific Technologies (CAST)** which includes: Advanced Quantitative Proteomics, the Dundee Imaging Facility, Flow Cytometry, Human Pluripotent Stem Cell Facility, Dundee CryoEM Feeder facility, X-ray crystallography, DNA/RNA sequencing, High-performance

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computing, Animal Facility and the Data Analysis Group. Our Facilities also support research for external customers/universities and deliver advanced specialist training to staff and students.

Strategic research plans from REF2014, reviewed below, have been fulfilled and exceeded:

Aim1: To double drug discovery capacity and deliver strategic collaborations in drug discovery with UK academic institutes and industry

The opening of the 4,700sqm '**Discovery Centre**' for **Translational and Interdisciplinary Research** in 2014 was central to achieving this aim. We recruited 8 new group leaders in Infectious Diseases and Drug Discovery and established the Wellcome Centre for Anti-Infectives Research (WCAIR) underpinned by a £13.6M Centre award. These initiatives and investments enabled many new strategic collaborations developing therapeutics for various disease areas such as with Bukwang Pharmaceutical Company and Oxford University (£4.2M, 2019, Parkinson's Disease); Takeda Pharmaceutical Company and Cambridge University (£4M, 2019, neurodegenerative disorders); not-for-profit Drugs for Neglected Diseases initiative and GlaxoSmithKline (£1.1M, 2018, leishmaniasis and Chagas disease); GlaxoSmithKline-Wellcome (£7.9M, 2017, neglected tropical diseases); Bayer, University of Cape Town and Bill & Melinda Gates Foundation (£6.5M, 2016, tuberculosis); and Innovative Targets Portfolio partnerships in multiple therapeutic areas (9 programmes with industry; projects with over 40 scientists from 18 institutions in 7 countries). Increasing the Drug Discovery Unit capacity (now 110 FTE) has achieved impacts including: licensing of ubiquitin-specific protease USP15 assets to Corbin Therapeutics (2019); bringing a windfall £5M to the University when SME partner IoMET, collaborating on cancer immunotherapies, was acquired by Merck Sharp & Dohme (2016); and two **Impact Case Studies** - one on a single dose cure for malaria, and a second on the delivery of therapeutics for visceral leishmaniasis.

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

A key part of our mission is to support local, and national, job and wealth creation. Increasing our footprint through our Discovery Centre allowed us to pre-incubate and nurture several companies, now successfully spun-out including drug discovery company Amphista Therapeutics Ltd (backed by Advent Life Sciences LLP and the Scottish National Investment Bank); informatics software company Platinum Informatics Ltd; dermatological medicines spin-out In4Derm (Scottish Enterprise High Growth Spin Out Programme); dermatological screening company Ten Bio (Sept 2019); and protein degrader company Outrun Therapeutics (Nov 2019). These originated from three research Divisions; GRE, BCDD, and MRC-PPU. The spinning-out of Amphista features in our **Impact Case Study** on PROTACs (PROteolysis TArgeting Chimeras) as revolutionary new tools to attack previously undruggable targets. Based on our excellent track record with spin-outs, we have secured City Deal support to create a next-phase Innovation hub to anchor inward investment in high-growth spinouts and start-ups (see **New Aim 2** below). Similarly, our Plant Science Division is a partner in the successful JHI City Deal bid to build an International Barley Hub and Advanced Plant Growth Centre, with spin-out opportunities (see **New Aim 4**).

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

Opening the Discovery Centre facilitated creation of the Division of Computational Biology (CB), which brings physicists and theoreticians from the School of Science & Engineering together with our bioinformaticists and quantitative biologists, to pursue biologically-aligned research. Recruitment into CB has brought additional expertise in artificial intelligence and machine learning. The value of our facilitation of interdisciplinary working is evidenced in our **Impact Case Study** on spin-out Exscientia Ltd which enables breakthrough productivity gains in drug discovery by

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deploying artificial intelligence approaches. Our *Photonics in Life Sciences and Medicine* initiative, supported through our PHOQUS (EU) PhD programme, successfully trained 10 students at the physics/biomedicine interface across three research Divisions: CDB, GRE, and BCDD, in collaboration with the Schools of Medicine and Science & Engineering. The acquisition of a triple-view lightsheet microscope in 2019 further enhanced capability in this domain. To facilitate better cross-School administration, we realigned our Dundee Imaging Facility under Professional Services management with academic steering group oversight.

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

We successfully used business intelligence, computing and data warehousing to pioneer the development of a unique customised Laboratory Information Management System (LIMS). This enabled our proteomics facility to manage sample collection and user communication, supporting diverse projects from research Divisions and external customers. In 2016, the LIMS software was deployed at the University of Manchester's Stoller Centre for Clinical Proteomics, (with £600,000 income to us), forging collaboration between the two leading UK proteomics facilities. Based on these successes, and the expertise of *Prof Angus Lamond* FRS (Founder and CSO), a spin-out company, Platinum Informatics, was incorporated in 2018 offering state-of-the-art software solutions for the management, visualisation and analysis of large complex data, as well as end-to-end mass spectrometry-based proteomics services. Our world-class expertise in proteomics continues to attract commercial collaborators and customers and underpinned **two Impact Case Studies** on the development of diagnostics for human African trypanosomiasis, and therapeutics targeting Parkinson's. Pioneering work led by *Prof. Jason Swedlow* (with the OME Consortium and European Bioinformatics Institute) developed the Image Data Resource, a unique public repository of image datasets allowing scientists worldwide to mine and integrate data in ways not previously possible.

Aim 5: To sustain ambitious goals for academic research

Over the assessment period we secured £302M research income (average £43M/annum) despite an increasingly competitive environment. This underpinned an annual average of 548 high-quality research publications. Our proactive recruitment strategy is central to sustaining our ambitious research goals and we have recruited 20 new PIs since 2014. We expanded research spanning the chemical-biology interface (>£2.5M recent School investment). An £8M award from the Scottish Funding Council catalysed establishment of the interdisciplinary National Phenotypic Screening Centre in 2015, offering sophisticated high-throughput phenotypic screening for human, animal and plant health research. We renewed our strategic partnership with the JHI in 2014 including 2 new joint appointments. We co-invested >£1M (with University of Aberdeen and JHI) in the Scottish Food Security Alliance (Crop) initiative to train 10 PhD students in cutting-edge crop, soil, and environmental science. Our MRC-PPU underwent a rigorous quinquennial review and successfully renewed MRC core funding (£25.6M 2018-2023). The diversity of our publications and discoveries since 2014 is exemplified by the composition of our output submission.

Future strategic aims and goals for research: Our strategic research goals for the next 5 years aim to enhance our progress and strengths, and nurture innovation:

New Aim 1: To found a Centre for Targeted Protein Degradation and expand our leading position in Drug Discovery

We are developing a world-leading position in the emerging area of Targeted Protein Degradation, which is fundamentally revolutionising academic chemical-biology and the drug discovery industry. Our vision is a Centre that produces novel tools, probes and approaches to investigate unexplored biology and target hitherto undruggable disease-causing proteins for degradation and therapy,

building on the work of *Ciulli*, *Sapkota* and *Virdee* and existing relationships with pharmaceutical companies.

New Aim 2: To develop a commercialisation pipeline that drives life sciences innovation and local economic growth

Our ambition is to catalyse a sustainable step change in innovation-led growth, leveraging inward investment to deliver inclusive economic benefit for the local region. We will use our £25M competitively-awarded City Deal funding to establish a new Innovation Hub (opening 2023) to anchor and support growth of life sciences/biomedical spin-out companies in Dundee, providing high quality jobs and skills opportunities for school-leavers and graduates. Over 15 years we intend this to attract £150M venture capital investment and support the creation of 10 life sciences companies.

New Aim 3: To integrate interdisciplinary activity in Quantitative Medicine & Biology

Dundee has a track record of developing analytical methods and data-driven technologies to support the study and treatment of disease. We generate large datasets through cell and tissue multi-dimensional imaging, advanced quantitative proteomics and metabolomics, GWAS, and chemical library screening for drug discovery. Along with the Schools of Medicine, and Science & Engineering, our vision is to advance these technologies while deploying the full potential of novel AI methods to exploit our rich datasets and uncover new insights to further biomedical research.

New Aim 4: To expand plant sciences capability and excellence through new initiatives with our strategic partner The James Hutton Institute

We are partnering JHI to establish the International Barley Hub (IBH) and an Advanced Plant Growth Centre (APGC) in Dundee using £62M City Deal support. The IBH will translate research into tangible impacts for all barley-related industries (breeding, farming, brewing/distilling, feed, food and health sectors). The APGC will provide state-of-the-art controlled-environment plant growing facilities. Our Plant Sciences Division will fully exploit these opportunities for recruitment and growth of excellent plant sciences research and innovation for economic, societal and environmental benefits.

New Aim 5: To grow our international research profile with new areas of excellence

Through ongoing recruitment in new areas and support/development of our PIs we will enhance our reputation and position ourselves for major industrial and UK Government funding by further aligning to priority areas such as ageing-related disease and artificial intelligence (Industrial Strategy) or expanding our work on infectious diseases (Wellcome).

Facilitating Impact from SLS Research

We recruit and invest in areas where we can achieve high quality research with impact, for example our substantial recruitment and investment into the Drug Discovery Unit. Indeed, each of our 6 **Impact Case Studies** is associated with one or more of our 5 post-2014 strategic aims above, demonstrating how each element of our strategy has been effective in facilitating impact. Through the University promotions procedures, we ensure that impact is recognised. We encourage and support our staff in commercialisation agreements and the development of spin-out companies, providing School funds for pre-commercialisation activity.

To ensure a coordinated strategy, we established a **Translation and Commercialisation Support Group** (TransComm, 2018) with 10 core members and expertise spanning commercialisation, technology-transfer, innovation funding, entrepreneurship and life sciences/biotech. The group has a fund to progress concepts and makes recommendations for further core investment/support

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where required to maximise impact. For example, spin-out In4Derm (incorporated 2019; winners 2019 Converge Challenge), focussed on topical drug treatment for skin disorders, was provided >£400,000 by SLS during Phase 1 and 2 development, complementing the £550,000 awarded from the Scottish Enterprise High Growth Spinout Programme. The TransComm group coordinates Venture Capital Funder visits, linking interests of funders with projects requiring investment. The **Dundee Accelerator Programme**, operated from the Dundee Centre for Entrepreneurship, provides assistance for early-stage businesses to improve their business offering, growth and investment potential. External funding, such as our MRC Confidence in Concept award, accelerates the impact of our research by supporting preliminary work or feasibility studies to establish the viability of a business idea.

Exemplar indicators validating the success of our approach include: i) Recognition of the global impact of our research in International Impact rankings (e.g. CWTS Leiden Ranking 2020); ii) Recipients of nationally-awarded prizes – *Hopkins* was BBSRC Commercial Innovator of the Year 2015; iii) Creation of successful spin-out companies (e.g. Amphista Therapeutics); and, iv) unprecedentedly, twice winning “Project of the Year” (2014/2018) from Medicines for Malaria Venture reflecting our step-change work on malaria drug treatments. Several of our Impact Case Studies reflect School/University investment leveraging subsequent impact in the DDU, in PROTAC research (~£1M bespoke space for commercially-sensitive work), and in enabling *Hopkins* to relocate to Harwell to develop company, ExScientia, while an SLS PI.

Supporting Interdisciplinary Research

A core ethos of the School is to promote interdisciplinary research. Our Divisions are housed in a single complex (except Plant Sciences) facilitating integrated approaches to address complex biological questions. Several PIs from other academic Schools are based in our complex and 22% of our PIs are affiliated with more than one Division. In the last 5 years, 10% of our publications involved at least 2 of our research groups. Our Mode of Action Group (established 2015) acts as a paradigm for our multi- and inter-disciplinary approach; they integrate high-throughput genetics, cell biology/biochemistry and chemical proteomics to undertake transformative drug target deconvolution studies and were awarded GlaxoSmithKline’s STOP prize in 2017. Events such as our Annual Research Symposium and Philosophy & the Life Sciences Seminar Series encourage cross-discipline working and collaborations. Researchers actively participate in the Dundee Interdisciplinary and Innovation Forum focusing on major societal challenges. We embed interdisciplinary working at early career stages e.g. through our MRC PhD programme “Quantitative and Interdisciplinary approaches to Biomedical Science” (commenced 2016).

We nurture interdisciplinary (life sciences/medicine/engineering/physics) collaborations with an institutional pump-priming fund of £200,000/annum (two schemes: the Inter-Institutional Interdisciplinary Partnership Fund and the Interdisciplinary Research Fund). Our LifeSpace, a Science Art Research Gallery (co-directed by School of Art & Design), provides a platform for interdisciplinary art/science interactions and a location for curatorial exchange between staff/students and the general public. During the assessment period, we supported 18 exhibitions spanning diverse themes. We actively invest in areas that support and enhance our interdisciplinary capabilities. Recent £2.5M investment at the chemical/biology interface (in addition to Discovery Centre investment) further increased our chemistry capacity to validate targets to treat fungal infections (*van Aalten*) and leveraged an Eisai partnership to develop oncology therapeutics (*Ciulli*).

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Open Research Environment

Funding to support Open Access publications is managed centrally for equitable distribution. Our Library and Learning Centre hosts an annual “Open Access” events week explaining the benefits of open access, while emphasising the importance of measuring research impact through non-journal-based metrics. SLS has been a signatory of the San Francisco Declaration on Research Assessment (DORA) since 2013 and actively encourages use of pre-print publications. We clearly stipulate on PI recruitment adverts that, in assessing applicants, we consider the scientific quality of their outputs not the Impact Factor of the journal where they are published. SLS PIs have been pioneers in Open Data and in the release or upgrade of innovative Open Platforms, Software and Tools that promote the analysis, sharing and management of research data including:

- Swedlow’s BioImage Archive (2019, <https://www.ebi.ac.uk/bioimage-archive/>) allowing storage, sharing and analysis of biological images.
- Barton’s Jalview (<https://www.jalview.org/>), for multiple sequence alignment, editing, visualisation and analysis, supporting >60,000 users and 2.1 million accesses since 2014 with 19 upgrades and 36 YouTube training videos.
- Lamond’s EPD: Encyclopedia of Proteome Dynamics (<https://www.peptracker.com/accounts/login/epd>) for sharing, analysing and visualising proteomics and other large-scale datasets. It aims to establish a “gold standard” for sharing large-scale data as usefully as possible.
- Barton’s upgraded protein secondary structure prediction server JPred that completed >1.5 million user-submitted jobs (<http://www.compbio.dundee.ac.uk/jpred4/index.html>).
- Swedlow’s OME: The Open Microscopy Environment (<http://www.openmicroscopy.org/>) that led Euro-BioImaging (EuBI) in building public resources for imaging data (2016-to date).

Positive Culture of Research Integrity

Research integrity and good research practice are Institutional strategic priorities. SLS’s *Prof Alan Fairlamb* CBE FRSE FMedSci chairs the University Research Governance & Policy Sub-Committee. *Prof Nathke*, our **Associate Dean for Professional Culture (ADPC)** over the REF period, has responsibility for oversight of Research Integrity within the School (with additional roles to promote an inclusive culture and staff development). All new staff and PhD students complete the University’s bespoke commissioned course ‘Responsible and Ethical Practice in Research and Publication’ (<https://www.dundee.ac.uk/research/governance-policy/researchintegritytraining/>) that has been adopted by a number of other HEIs across the UK. Our PhD students participate in annual research integrity workshops to ensure continued awareness. Tools to demonstrate provenance of data are an integral part of research integrity. Two SLS Divisions are currently trialling the use of electronic laboratory notebooks/management systems with the aim of adopting throughout the School. The MRC-PPU successfully trialled a policy (initiated 2018) ensuring primary data is securely stored in a locked read-only format in a centrally-managed repository at first submission of a research output. We aim to implement this policy School-wide. We have developed guidelines outlining best practice, including independent repeats of key experiments by a second researcher and deposition of large datasets in open access databases such as PDB, PRIDE, MIAME. Several of our outputs directly address data reproducibility and valid interpretation, e.g. Brenes et al (2019; *Mol Cell Proteomics*), the highly cited Schurch et al ‘How many biological replicates are needed in an RNA-seq experiment’ (2016, *RNA*; cited 199 times), and our RoSA (Removal of Spurious Antisense) open source software (<https://github.com/bartongroup>; Maura et al 2019 *F1000*). Other outputs highlighted anomalous results in the literature (e.g. Barakate et al., 2014 *Plant Cell*) or resulted in paper/patent retractions by other groups (e.g. Hogley et al., 2014 *Cell*; see retractionwatch.com).

Creation of the ADPC role was transformative for SLS, putting us in the forefront of UK Universities in how we deal with allegations of scientific misconduct. Our ADPC leads our Professional Behaviour and Research Integrity Group (established 2016) which is responsible for promoting an SLS culture of adherence to the highest standards of research integrity. The group has developed clear procedures for reporting and investigating potential research misconduct. It performs initial assessment on allegations before reporting to the Dean for further action. Since 2016, it has overseen 14 preliminary enquiries, 5 informal investigations and instigated 1 formal proceeding (upheld, and disciplinary action taken). We subscribe to *PubPeer* automated alerts so that issues raised by the wider community can be swiftly investigated and acted upon appropriately. We have held open forums on research integrity to foster increased awareness and develop an open culture where the nature and drivers of misconduct are discussed. These SLS initiatives prompted similar developments across the University. Each academic School now has a lead for research integrity who feeds into a University committee chaired by our ADPC who is also leading the establishment of a Scotland-wide Research Integrity Network.

2. People

The excellence and diversity of our staff underpins our success. Our ethos is fundamentally supportive, inclusive, and collaborative. Flexibility is a cornerstone of our approach, enabling staff at all career stages to exploit opportunities and fulfil their potential. We facilitate the success of our world-class researchers and research-support teams through effective and responsive managerial structures, the provision of advanced technology platforms run by skilled technologists, and a multitude of training and career development opportunities offered by the School and the University's Organisational and Professional Development team.

Principal Investigators: We aim to recruit and support the most talented international researchers and maintain a healthy sustainable demographic. On 31st July 2020, our PIs fell into the following age bands: 30-39 (10%), 40-49 (40%), 50-59 (24%), >60 (26%); gender: female (27%), male (73%); ethnicity: white (79%), BME (12%), other (9%). Our tenure-track PIs, representing 17% of our category A staff, are typically on 7-year contracts with a commitment to review for tenure within 5 years. We have 3 PIs on pre-tenure-**track** 3-year salary underwrite while they prepare fellowship applications – these automatically progress to a new 7-year tenure-track contract once they secure a fellowship. The gender balance in the tenure-track and pre-tenure-track group is almost 50:50 (7 females; 8 males) with only 2 being UK-born, illustrating our commitment to equality and diversity and to investing for the future. We achieve this using transparent and well-understood recruitment, mentoring and tenure processes. The remaining 83% PIs are tenured.

Recruitment. Our recruitment strategy is informed by the needs of our forward research plans and responds to recommendations from Divisional Quinquennial Reviews and our International Scientific Advisory Boards. Our Search & Recruitment Committee and Round Table appointment committees have diverse representation and gender balance. Appointments are made after lengthy consideration, usually involving two visits to Dundee including many short meetings with individual PIs, a presentation on candidates' current research and future plans, and a round table interview. Successful applicants are offered tenured (for senior appointments), tenure-track or pre-tenure-track positions. Over the period of assessment, SLS recruited 16 tenure-track/pre-tenure-track PIs, one acting PI (due to unexpected retirement) and 3 tenured PIs at Senior Lecturer/Professorial level. This includes an individual whose progression we supported from a technical role through to a tenure-track position. These appointments are in strategic areas: molecular parasitology and drug discovery (*Pawlowic, Wyllie*), molecular microbiology (*Dorfmueller, Bergkessel*), cell and

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developmental biology (*Murray, McGurk*), immunomodulation (*McSorley, Sollberger*), crop science (*Hein, Bulgarelli*), MRC-PPU (*Rousseau, Swamy*), DNA replication and epigenetics (*Alabert, Pelisch, Rasmussen*) and the application of machine learning (*Schweikert*). All but the 2 most recent pre-tenure-track appointments have won prestigious research fellowships illustrating the effectiveness of our procedures for identifying and supporting promising early-career researchers.

Start-up packages and mentoring. Pre- and tenure-track PIs receive a lab start-up package (>£30,000), plus re-location expenses (including immigration lawyer if required) and 50% matching funding for major equipment claimed on research grants. They are provided with excellent facilities and outstanding technology platforms to support research and benefit from targeted allocation of PhD studentships. Pre- and tenure-track PIs receive guidance from their Head of Division and Associate Deans for Research and Professional Culture, and are paired at the outset with a senior PI mentor who advises on how to run a group and on the preparation of manuscripts and grant applications. New starts are encouraged to participate in the cross-institutional Teaching, Research & Academic Mentoring Scheme run in partnership with the University of St Andrews, Abertay University, Glasgow School of Art and the JHI. We sponsor all new PIs to attend the well-regarded EMBO lab management course to further support them in lab leadership. We support PI recruits who identify as female to attend the Advance HE Aurora Leadership programme which aims to address the under-representation of women in leadership positions in Higher Education. Tenure-track PIs have limited teaching commitments although we encourage them to complete the Associate Module element of the Postgraduate Certificate in Academic Practice (PGCAPHE). This not only informs their teaching, but helps improve supervision of PhD students and develops other skills relevant to research. We support personal development and leadership training of senior and Professorial staff, for example by offering sessions with a personal coach.

Appraisals and Tenure Reviews. Every PI in SLS is appraised annually by their Head of Division in a discussion about performance over the past year and objectives for the next. Heads of Division have an annual appraisal with the Dean. Tenure-track PIs will additionally have a 'mid-term' review in their 3rd year to support and inform their case for tenure. Final tenure review typically occurs no later than the end of a PI's 5th year, but we underwrite their salaries for a minimum of 7 years, enabling the submission of grant applications for almost all of the tenure-track period. Special consideration is given to PIs whose research has been affected by personal circumstances including parental leave (maternity, paternity, adoption, etc.) or other carer duties; part-time work; disability including temporary incapacity; absence due to ill health. In the case of parental leave, SLS delays tenure review and extends salary underwrite by an appropriate time (e.g. by 12 months for each maternity). All tenure-track appointments have had their underwritten period extended to recognise the impact COVID-19 has had on establishment of their careers.

At tenure review, candidates submit a dossier of publications, funding, research achievements, wider contributions, and future plans. At least 5 expert external referees will comment in writing on whether the candidate is on a trajectory to become an international leader in their field. The dossier is evaluated by the Assessing Committee (chaired by the Dean or AD Research, with 2 distinguished External Assessors - directors of scientific institutes/departments – and 5-6 other senior academics). The PI presents a seminar and discusses future plans with the Assessing Committee who make a recommendation that is communicated to the PI immediately by the Dean. Over the REF period, 13 of 17 PIs who underwent review were awarded tenure including 100% of female PIs.

Postdoctoral Researchers and Other Research Staff: Our research assistant community is diverse – 47% female, 53% male; 22% BME, 7% other and 71% white ethnicity from > 50 different

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nationalities; with >10 individuals with declared disabilities (3.5%). The SLS Research Staff Association (SLSRSA; <http://rsa.lifesci.dundee.ac.uk/> established 2005) was one of the first such organisations in the UK. Initiated by postdocs for postdocs, it has since expanded to recognise all research staff. SLSRSA acts as a conduit to School management and has a seat on the School Research Committee; it assists in research staff career development; fosters a culture of debate and communication between research staff through events and activities; and helps new staff with local orientation. SLS provides SLSRSA with an annual budget (£7,000) to organise a seminar programme, including talks on careers beyond research. All research staff have an annual career development appraisal with their group leader and are encouraged to acquire transferrable skills through a broad spectrum of courses. We actively support the development of our research staff. Several research assistants without postgraduate research qualifications have been supported to study for a PhD (2 part-time PhDs, and 3 PhDs by publications since 2014). We funded fees for these staff and encouraged participation in training/development activities associated with our PhD DTP programmes. We strive to support postdoctoral researchers who are focused on an independent research career. Since 2014, 19 SLS postdoctoral researchers/technologists have been mentored by their PI/Head of Division to apply for very early career Fellowships or substantive grants. Of these, 7 were successful and 5 sought and were offered PI positions in SLS (*Swamy, Pelisch, Hickerson, Wyllie, van den Akker*). We actively support our postdocs to apply for small research grants (<£50,000), under the sponsorship of a PI, to enhance their experience and support career development for those aspiring to an independent position.

Implementation of the Concordat to Support Career Development: SLS fully supports the Concordat as does the University which retains its 'HR Excellence in Research' award from the European Commission. SLS fulfils the signatory responsibilities of championing the Concordat at all levels within the University. We seek to provide security for research staff through open-ended permanent contracts (after 4 years) and provide bridging funds from our Wellcome Trust Institutional Strategic Support Fund. Our ADPC regularly surveys views of researchers on our approaches to career support and development.

Flexible leave of absence: The University has flexible leave of absence policies for Periodic Leave/Sabbaticals, Special Leave-with-pay and Special Leave-without-pay. Requests are signed off by the Dean. It is SLS policy to support staff who need research, training or impact leave or contract changes. Requests are considered sympathetically and equally for staff of all career stages. No reasonable request is refused. During the review period, we granted e.g.:

- leave or contract adjustments for postdoctoral researchers to pursue research, training or impact activities elsewhere (2 formal requests)
- PI flexible working time abroad for research, teaching or impact activities (7 formal requests)
- contract adjustment enabling senior academic (*Hopkins*) to be CEO of spin-out, Ex-Scientia
- funding and time for senior and mid-career academics to develop spin-outs, Platinum Informatics (*Lamond*; Chief Scientific Officer) and Amphista (*Ciulli*; Director)
- salary support for two senior Research Assistants involved in early-stage commercialisation

Exchanges between academia and other stakeholders: We promote and enable knowledge and personnel exchange with other stakeholders (businesses, industry, public bodies) as essential to maintaining our international research vitality and relevance. Driving innovation and collaboration with industry is a key strategic priority. For example, our Division of Signal Transduction Therapy (DSTT) is one of the largest and longest international collaborations between the pharmaceutical industry and an academic research institution. We host visiting

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researchers from Industry (8 over REF period), often waiving the costs as an investment in the research base. These visits have led to formal research collaborations or contracts. PIs can be allocated time within our workload model for engagement in external activities, e.g. *Ferguson* as the Deputy Chair of Wellcome's Board of Governors; *Cantrell* as an MRC Council member. Our Wellcome Centre for Anti-infective Research has an extensive portfolio of training activities including providing placements in the DDU, and prioritising (with full scholarships) those working in countries endemic for neglected tropical diseases (18 placements to date from 9 countries in Africa, Asia and South America). Embedded procedures support the incoming individuals irrespective of career-stage. The programme also deploys trainers to external institutions wishing to develop skills in Drug Discovery, with training adjusted to suit needs. Through our Industrial CASE studentships, we partner with industry (SMEs and non-SMEs) on collaborative research projects, providing students with research experience in a non-academic environment (20 iCASE studentships over the assessment period).

Reward and Recognition of Research and Impact: Benchmarked metrics for both research achievement and a variety of research impacts are included in our promotions criteria. Our annual PI progress reports capture both research and impact contributions and assist in identifying candidates for promotion. We actively celebrate notable achievements in research outputs, grants won, honours awarded, and impact activities through our web-based 'news' displayed on screens throughout the complex and through the monthly "Dean's Message". We fund a number of annual prizes to recognise high-quality research and impact-related activities including: **Innovator of the Year** (two categories - best innovation and best early-stage new business idea); The **Howard Elder Prize** to recognise the PhD student/postdoc who published the most significant paper related to cancer; the **Molecular and Cellular Biology Prize** for excellence in basic research. Winners of **Innovator of the Year** get a place on the three-month Elevator accelerator programme designed to assist early-stage business owners/ideas to improve their business offering and investment potential. Our Translation and Commercialisation Group supports staff in achieving impact and makes recommendations for investment, including time provision in individuals' workload models.

Postgraduate Research Students: Training of the next generation of scientists is a top priority for SLS. Over the assessment period we invested £6.2M into our PhD programmes. All SLS PhDs are run by a centralised system headed by our Head of Postgraduate Studies (*Mackintosh*) supported by an administrative team of four. Each Doctoral Training Programme (DTP) has a Programme Lead (reporting to the Head of Postgraduate Studies) and a Programme Management Committee with diverse academic representation.

Student recruitment. We manage PhD recruitment using a bespoke online application system where we capture equality, diversity and inclusion data. We carry out equality impact assessments after each recruitment cycle which can be acted on accordingly. We run PhD advertisements and project descriptions through 'Gender Bias Decoder' to ensure no unconscious biases. Advertisements highlight availability of part-time study and support for those with caring responsibilities or disabilities. Scoring of applications ensures equal consideration of non-traditional routes and backgrounds, and shortlisting and interviewing is carried out by the Programme Management Committee to ensure consistency. All staff involved in recruitment must complete unconscious bias and equality, diversity and inclusion training.

Doctoral Training Programmes. We offer studentships as part of DTPs or on an individual studentship basis. Programmes include: BBSRC EASTBIO partnership between the Universities of Edinburgh, Aberdeen, St Andrews, Stirling and other organisations to provide high-level bioscience training (~7 students annually to Dundee); the Dundee MRC DTP in Quantitative & Interdisciplinary

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Approaches to Biomedical Science (9 students annually including 2 iCASE studentships); MRC-PPU Prize Studentships (~ 3 students annually) in the areas of signal transduction and DNA repair; Wellcome 4-year PhD programme in Integrated Molecular, Cellular and Translational Biology (5 students annually); and our international partnership programmes with the China Scholarship Council, CAPES (Brazil) and Marshall Aid (USA). Students on our MRC DTP and Wellcome programmes carry out rotation projects during their first year before making their final project choice. All students participate in a comprehensive Induction Programme and undertake 10 days of student-led generic skills training a year. All our programmes train students to be data literate, achieve basic coding competence, and acquire skills in quantitative aspects of biological research.

Monitoring and Support Mechanisms. Students are supported in their academic progress and career development throughout their studies. Each of the two academic supervisors meets their students regularly and is responsible for assessing academic progress. Template contracts are provided to foster successful student-supervisor relationships. Each student is assigned a 'Thesis Monitoring Committee' (TMC) of two additional academic advisors who monitor progress, personal career developmental plans, and well-being. Our mentorship arrangements draw on the expertise of diverse groups to provide the best advice possible. Peer-peer support is a critical component and students benefit from high postdoc-student ratios. Recognising and understanding stress in research students is a high priority and we strive to support positive attitudes and mental health. Innovative programmes such as 'Mind Matters' raise awareness of, and provide support for, those with mental health issues. Other activities such as 'Therapets' sessions are run as de-stressors. Students can seek pastoral support from the Head of Postgraduate Studies and their academic mentor. The SLS postgraduate office team have undergone mental health first-aid training and frequently act as the frontline. We are committed to equally supporting all our students impacted by the COVID-19 pandemic and have awarded funded extensions to all that required one. Over the assessment period, only three students did not pass their ordinance transfer (MSc to PhD transition) but submitted successful MSc theses. In UoA5, 283 FTE successfully completed their PhD and no students went over time, evidencing the effectiveness of our monitoring and support mechanisms.

Skills, career development and integrated research student culture. PhD students are fully integrated into the running and activities of the School, with representation on Divisional, Research and School Boards. All PhD students present their work at regular lab meetings, and in Divisional seminar series. Our students participate in a bespoke coaching programme led by an external consultant that enhances their resilience and builds capacity to manage relationships at all levels.

The School has an active PhD-led society (PiCLS) that facilitates networking through academic and social events. PiCLS organise their own annual Research Symposium where they invite external speakers and raise sponsorship (underwritten by the School). SLS works with PiCLS to facilitate student outreach and public engagement projects. All PhD students are required to attend at least one relevant scientific conference (UK or abroad). Our training programmes are closely aligned to the VITAE framework, which promotes professional skills development. Students are strongly encouraged to participate in career development opportunities such as the Biotechnology YES competition and the Max Perutz writing competition. Many students participate in placements or internships during their PhDs. The use of flexible and strategic funding allows us to support students after thesis submission which enables key publications to be completed and the acquisition of new skills, enhancing their ability to secure prestigious postdoctoral fellowships and support career transitions. To widen participation in postgraduate research, we target scholarships for our annual International Summer School (30-40 competitively-selected undergraduates) to students from universities whose mission statements and core aims are to help students from a

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variety of backgrounds (e.g. Universities of Westminster, and Highlands & Islands). Recognising the value of these experiences, we hosted 20 virtual research projects during Summer 2020 when laboratory access was restricted due to COVID-19.

Evidence of how the submitting unit supports equality and diversity: We are proud of our environment and culture that has allowed our community to perform to the highest level. We formalised our support of diversity, career development and research integrity by appointing an Associate Dean for Professional Culture. We are fully committed to the principles of the Athena Swan charter and have an Athena Swan Silver award (2018). The University is a Race Equality Charter (REC) member and *Prof Hari Hundal* from SLS is leading the University application for a REC Bronze award. We aim for parity across gender, race, age, physical and mental disabilities in all of our activities. Completion of online Equality, Diversity and Inclusion modules is mandatory for staff and students. We deliver unconscious bias training for new students and annually for staff. Our annual 'Peoples Award' recognises individuals/teams who have made positive contributions to our culture. The inaugural prize (2018) was awarded to two staff who developed our LGBT+ network. Students and staff also contribute to other networks (e.g. BAME, disabled) through which they can connect, find peer support and contribute to the University's policies. The University's former 'Women in Science Festival' now has a formal partnership with Dundee's Women Festival where we celebrate outstanding women in society (e.g. Christina McKelvie MSP; Helen Keen, the radio 4 comedian; Margaret Fairlie, the first woman professor in Scotland). The gender balance of speakers in our prestigious annual "Named Lectures" increased from 17% female (up to 2013) to 47% female (2014 – 2020). SLS has many women in key leadership roles - 4 out of 7 of the School's Executive Group are women.

We have well-established flexible working policies to support work-life balance (flexible working hours, semester time working, remote working, job-sharing); all recent requests (2017-2020) from Academic/Research staff have been approved. We instigated positive changes to postdocs' contracts at University level - individuals on fixed funding that ends during maternity leave have their contract extended to cover the whole leave period so that they receive full benefits, and maternity pay is not paid back if they do not return to work. Our shared parental leave policy allows *both* primary care providers to benefit from paid leave.

All PIs have time within our workload model for preparation of grant applications and associated professional service support is accessible to all. For individuals undertaking substantial leadership roles (Dean, Associate Dean, Head of Division) dedicated administrative and research support is provided to ensure that research continues unhindered. Leadership training is provided. We have a rotating co-opted member position on our School Executive Group to support succession planning and expanded career opportunities. Declaration of any mitigating circumstances is part of the academic promotions process.

Innovative use of strategic funding has underpinned our Flexible Dependent Care Grant scheme since 2015. This supports the professional development of researchers with primary care responsibilities e.g. by covering dependent care expenses when attending workshops, or professional development opportunities, or providing research assistant support to academics on parental leave (<https://www.dundee.ac.uk/research/issf/schemes/flexible-dependent-care-grants/>). Funds are available to all career stages, including undergraduates on our Summer School programme. Over the last 3 years of the assessment period, 15 individuals (8 female, 7 male) benefited from this support. PhD students with caring responsibilities receive enhanced stipends. During the assessment period, we funded two re-training "Return to Work Fellowships" for

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individuals returning to research after a career break. We award bridging funds to cover short-term funding gaps in researchers' portfolios with priority for applicants with extenuating circumstances.

We proactively support the well-being of our staff and students. We have a number of individuals with declared disabilities and adjustments are made to enable unhindered research activities e.g. we have provided adjustable height/size lab and office benching or chairs, and a signer is used in seminars for a deaf Masters student. Buddy systems are set up where required. Dedicated office space is provided where specialist needs are identified. SLS has 4 trained mental health first aiders as direct points of contact, and 3 bullying and harassment advisors, as well as first responders for gender-based violence. We have gender neutral toilets in support of an inclusive environment. Our School Outreach Officer (*Hardee*) is one of nine nationally selected members joining the British Science Association's Inclusive Science Engagement Network, a 2-year scheme to investigate how to make science engagement workplaces and activities more inclusive.

Construction of REF submission: Outputs have been selected and attributed to individual staff by our UoA Planning Group in a way that aims to maximise the overall quality profile for the submission. We have not flagged our interdisciplinary outputs as the membership of sub-panel 5 (Biological Sciences) is sufficiently diverse to be able to assess them. All REF returnable staff were invited to suggest potential impact cases studies and those chosen reflect the strongest impacts arising over the REF period as deemed by the UoA5 Planning Group. Of our 181 outputs submitted, 77% are from male PIs and 23% from females, similar to our overall UoA5 gender balance. Other comparisons based on protected characteristics suggest no bias in output selection. Prior to output selection, all Planning Group members completed training in: (a) unconscious bias awareness; (b) equality, diversity and inclusion; (c) information security. Our institutional Code of Practice was adhered to at all times.

3. Income, infrastructure and facilities

Research income: All PIs are responsible for obtaining funding for their research groups and are aware of our expectation that they should have continuous research income of at least £150,000/annum. Any PI not reaching this target for several years is offered additional support over and above the normal peer review processes and alternative options are sensitively discussed if appropriate. Tenure-track PIs are provided with significant support to win external fellowships and they benefit enormously from the prestige this brings to their careers. All PIs have access to our excellent technological facilities and are expected to ensure their sustainability by costing usage into grant applications. Grant opportunities are widely publicised, and the Associate Dean of Research will coordinate for demand-managed calls or where input from several PIs is needed (for example multi-user equipment grants). PIs with personal experience of grant and fellowship panels share non-confidential advice. These strategies have been very successful and, over the reporting period, our PIs have been awarded, collectively, £83M from Wellcome, £55M from the MRC, £25M from the BBSRC, £43M from CRUK and other charities (e.g. £4M from Michael J Fox Foundation for Parkinson's Research), £17M from the EU and ERC, £39M from industry, £14M from UK Government bodies, and £6.5M from other sources. Particularly notable awards include:

- £25.6M MRC Quinquennial renewal
- £13.6M Wellcome Centre award for Anti-Infectives Research
- £8M from SFC to establish the NPSC
- £8M portfolio award from Wellcome to develop drugs for leishmaniasis and Chagas' disease

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- £7.5M from Boehringer Ingelheim, GlaxoSmithKline and Merck for DSTT renewal
- £4.9M from Wellcome for the DDU Mode of Action group
- £3.6M from Bill & Melinda Gates for lead optimisation for neglected diseases/tuberculosis
- £2M from the BBSRC to study the architecture of biofilms

PIs with personal fellowships are listed in section 4. All but our 2 newest early career PIs have been successful in obtaining personal fellowships. These successes reflect both our robust recruitment strategy and comprehensive support/mentoring mechanisms. Our grant success rates for male versus female PIs are equivalent at ~35%. Research income is, on average, >£500,000 per PI per annum. This level of funding underpins high quality outputs and impact detailed in other sections.

Nature and quality of the research infrastructure: We use £1.5M of our annual School budget for infrastructure as matching funding for carefully chosen equipment grant and strategic award applications. For example, we are providing £2.1M as matched-funding for the MRC Quinquennial renewal award, £1.65M to the Wellcome Centre for Anti-Infectives and, on average, an additional ~£1M/annum to support studentship programmes. We are agile in coordinating and responding to wider infrastructure funding opportunities. Thus, over the assessment period, we invested >£10M in proteomics, compound screening and profiling and 'drug metabolism and pharmacokinetics' (DMPK), chemical-biology, fluorescence-activated cell sorting Next-Generation Sequencing, single-cell sequencing, high-resolution microscopy, multi-photon and light-sheet microscopy and high-performance computing. Over the next 5 years, our technology platforms will require >£5M investment, with the majority of this funding already in place.

Mechanisms for promoting research, sustaining and developing a vital research culture and delivering impact: A critical component of our research and impact success is the quality of our infrastructure and in-house support. All our laboratories were either built or refurbished within the last 25 years and are carefully maintained by our Laboratory Management team liaising with a responsive University Estates and Buildings team. The entire SLS 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 core staff and available for all to use; this arrangement significantly extends the range of equipment easily available to any individual research group. Our Stores provide same-day delivery to the bench and Central Technical Services provide media, wash-up and tip-racking.

A variety of communal activities (below) regularly bring specific groups, Divisions or the entire School together to celebrate and share our love of science. In 2020, all seminar/lecture/symposia activities continued, but moved online to times compatible with home-schooling.

Research Boards. Each Division operates a research board (monthly/bimonthly) that, via Division Heads, reports into a bimonthly School Research Committee, providing lively fora for discussing research and impact strategy, postgraduate/postdoctoral training, public outreach, and EDI. All boards have representation from technical support staff and from the postdoctoral and PhD associations.

Seminar Programmes. Each Division has a budget for a seminar programme where prominent external scientists give lectures and meet with our PIs, postdocs and PhD students. These 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 School hosts several high-profile Named Lectures throughout the year, delivered by distinguished scientists including Nobel laureates, and attracting high attendance (>200). They are aimed at a broad audience and bring all Divisions together in celebration of excellent science (<https://www.lifesci.dundee.ac.uk/research/events/named-lecture-archive>).

Annual Symposia. A key event in our calendar is the Annual School Research Symposium. This 3-day event of presentations, short-talks and posters takes place at a hotel in the Highlands and promotes academic and social interactions, leading to many fruitful scientific collaborations.

Divisional Symposia/Retreats. 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.

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 undergoes rigorous quinquennial review, organised by the AD Research and Head of Division, which informs strategic planning for the Division and School. Feedback is generally outstanding but we are not complacent and strive for continuous improvement.

Access to specialist research facilities. A core ethos is to have accessible scientific facilities that enable all staff/students to harness cutting-edge technology for discovery and translation while maximising effective and efficient use. Early-stage spin-out companies also benefit from access to accelerate their development. To best manage our core facilities, many of our major technology platforms have been incorporated into a *Centre for Advanced Scientific Technologies* (CAST; <http://www.lifesci.dundee.ac.uk/technologies>). CAST is run by 22 dedicated staff who ensure equipment is properly specified, operated and maintained. They contribute to experimental design and coordinate PhD student/postdoc training. Our scientific facilities are subject to external reviews allowing critical evaluation that assists in sustaining excellence.

CAST provides the following services:

- The **Proteomics Facility** operates 18 high-end state-of-the-art mass spectrometers, offering a range of services for analysing whole proteomes, proteins, peptides, oligonucleotides, oligosaccharides and small molecules. They have particular expertise in SILAC, TMT and Label-Free quantitative proteomics and the identification of post-translational modifications.
- Our state-of-the-art **Dundee Imaging Facility** operates cross-school (SLS, Medicine, and Science & Engineering) with a range of light microscopes, including 7 DeltaVision Deconvolution systems, 3 confocal microscopes, 2 electron microscopes, the latest state-of-the-art Zeiss 880 Airyscan for high-speed confocal imaging with super-resolution and the Zeiss spinning disk Axio Observer Z1 offering high-resolution data capture in living cells. The service provides technical expertise in localising proteins in fixed and live cells, and on tissue imaging.
- Our **Animal Facility** provides a transgenic service that re-derives in-coming mouse lines to a high barrier status, cryopreserves mouse lines and produces transgenic and gene-targeted mice. Current occupancy is about 5,500 mice, with smaller numbers of rats and frogs. Most mice are housed in individually-ventilated cages. There are facilities for category 2 and category 3 containment, small animal surgery, telemetry and activity monitoring.
- The **Flow Cytometry Facility** with 3 analysers and 2 cell sorters includes; a high specification five-laser, fifteen colour LSR Fortessa, eight-colour FACS Canto II, thirteen-colour Novocyte, an eleven-colour Beckton Dickinson Influx Sorter and a six-colour Sony SH800 sorter housed

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within a class 2 biosafety cabinet, in addition to a MUSE cell counter. The facility provides cell analysis and sorting services and advice.

- The **X-Ray Crystallography Facility** provides high-throughput robotics for crystallisation, sample mounting, X-ray screening and data collection.
- The **Human Pluripotent Stem Cell Facility** provides researchers across the University with verified hESCs and hiPSCs and differentiation systems, training in working with HPSCs and expertise in the development of cell-based assays.
- Our new **CryoEM facility**, equipped with a 200kV JEOL JEM-2200FS, is capable of high-resolution image data capture.
- **The Data Analysis Group** 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 (<https://daq.compbio.dundee.ac.uk/>).

Other significant facilities available within SLS include:

- Our **Drug Discovery Unit** has the full repertoire of professional, industry-standard expertise and infrastructure for early stage drug discovery. Multiple disciplines (biology, chemistry, pharmacology, bioinformatics, computational drug design) work together in an integrated management structure focusing on key areas, including diseases of the less-developed world and anti-microbial resistance (<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 School, plus many external customers (<http://www.kinase-screen.mrc.ac.uk/>).
- A **10xGenomics machine** is a cross-School resource, enabling researchers in SLS and in Medicine to perform single cell transcriptomics, feeding library preparations into the *Next Generation Sequencing* operated in the School of Medicine, equipped with the latest platforms including the NovoQ.
- Our **High-Performance Computing Service** enables safe and efficient storage, archiving and analysis of our ever-increasing quantities of data, from drug discovery, proteomics, microscopy and DNA sequencing, using >2 petabytes of high-speed parallel storage systems and a parallel computer cluster with over 3,500 CPU cores.

Evidence of cross-HEI shared or collaborative use of infrastructure: Through the Scottish Universities Life Sciences Alliance (SULSA; <https://www.sulsa.ac.uk/>), we provided 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 (Edinburgh). Our Proteomics facility has an excellent reputation for delivery and performed services for colleagues from many UK Universities over the reporting period. As a member of the Scottish Consortium for Macromolecular Imaging, we act as a feeder facility (for Dundee and St Andrews researchers) for the top-end JEOL 300 ARM cryo-EM in Glasgow. The National Phenotypic Screening Centre (NPSC) is built on a core partnership between the members of SULSA and the University of Oxford. State-of-the-art robotics, instrumentation and computation are located in the SLS Hub, and in Oxford, with link-up to an additional assay development team in Edinburgh. Screening and assay development have been delivered across the UK and beyond. The MRC Reagents and Services operates for academics worldwide, and our Drug Discovery Unit collaborates with a large number of universities (as of 31st July 2020, 19 active collaborations and membership of large consortia such as TB Drug Accelerator, MalDA malaria Drug Accelerator, and COVID-19 IMI2 CARE).

Major Benefits in-kind: In addition to synchrotron and EM allocations (valued at £2.73M over the assessment period), we benefit from other in-kind contributions such as: i) >£2.5M in-kind contribution from GlaxoSmithKline as part of our 2016-2021 Wellcome partnership to develop anti-parasite drugs, and £10M commitment by GlaxoSmithKline to move our pre-clinical candidates to the clinic; ii) a range of compound libraries (lead-like compounds, chemical diversity library, annotated libraries and clinically approved compound libraries), valued in excess of £10M, that have been gifted to the NPSC.

4. Collaboration and contribution to the research base, economy and society

Effective collaboration at the national and international level

Our culture is fundamentally open and collaborative. Of our total awards granted over the assessment period 19% involved at least 1 named external partner (industrial, HEI or other 3rd party) with joint funding. Of these joint grants, 20% were local collaborations within Scotland, 32% within UK, and 48% were international projects. We support development of fruitful relationships through several mechanisms such as funding external seminar programmes and use of strategic funding (our “Inter-Institutional Interdisciplinary Partnership Fund” and GCRF fund) to pump-prime national and international collaborations with a particular focus on global challenges.

Our training of overseas PhD students and postdocs has proved an effective long-term mechanism of developing international collaboration when students/postdocs return home to academic appointments (e.g. *Birch* - Huazhong Agricultural University; *Lilley* – Nankai and Xiamen Universities).

SLS PIs are involved in numerous large consortia tackling research problems too big for any one institution to address. For example, *Waugh* led on the successful global effort to sequence the genome of barley (*Nature* 544, 2017) and contributed to genome sequencing of the world’s most important cereal, wheat (*Science* 345, 2014). *Swedlow*, and The Open Microscopy Environment based in SLS, are contributing to the global effort across 1,000 institutions in 64 countries to develop the **Human Cell Atlas**, and map every type of cell in the body as a basis for understanding health and disease (funded by Chan Zuckerberg Initiative). *Alessi* is leading a \$9M project for ‘Aligning Science Across Parkinson’s (ASAP)’ with partners in the USA aimed at fostering collaboration/resources to better understand the underlying causes of Parkinson’s disease. *Ferguson* leads our partnership in UK SPINE, building a national knowledge-exchange network around therapeutics for age-related co-morbidities.

Many smaller grants (under £1M) also attest to international collaborations with partners across the world, for example *Halpin*’s collaborations with Vietnam and the Philippines on rice straw uses, *Simpson*’s work with the African Orphan Crops Consortium, WCAIR (*Read/Wyllie/Gilbert*) collaboration with colleagues at the University São Paulo, Brazil to investigate Amazonian bacteria and natural products for new drug development, and our 2018/19 Universities UK International (UUKi) *Rutherford Fund Strategic Partner Grant* that enabled 8 promising Australian ECRs to spend up to a year in Dundee for continuing collaborative research. Our Open Research platforms mentioned earlier also connect us daily with researchers worldwide.

Our strategic relationships with other UK institutions and details of inter-HEI resource sharing were 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

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developmental biology, stem cells, immunology, infectious diseases and bioinformatics through research 'clubs' (Scottish DNA Replication Network; Scottish Neuroscience Group; Scottish Fly Meeting; Scottish Microscopy Society; Infectious Disease Research in Scotland), and many others that SLS researchers contribute to. We support such networking both in principle and financially, and many inter- and multi-institute research collaborations emerge from such events. We have a long-standing strategic partnership with The James Hutton Institute where our Plant Sciences Division is co-located and supported them in their successful City Deal bid that secured £62M to build an International Barley Hub and Advanced Plant Growth Centre in Dundee. We are founding partners of SULSA (Scottish Universities Life Sciences Alliance), a strategic alliance between 11 Scottish Universities, and contributed to its Directorship (*Hopkins*, 2011-2016) and Executive (*Ferguson*; *Owen-Hughes*).

Collaboration with Industry

SLS has exemplary partnerships with industry with examples described in all of our *Impact Case Studies*. Our **Division of Signal Transduction Therapy (DSTT)** is one of the largest and longest international collaborations between the pharmaceutical industry and an academic research institution. Running for 22 years and attracting over £65M of investment, the DSTT was renewed in 2020 for a further 4 years with £7.5M from Boehringer, GlaxoSmithKline and Merck. DSTT researchers from MRC-PPU, CSI, and other Divisions deliver ideas from basic research on drug target identification and validation for cancer, arthritis, lupus, hypertension and Parkinson's Disease for rapid uptake by partner companies. The DSTT has helped to expedite the development of drugs for clinical use, bringing benefits to patients and accelerating the impact of our research. DSTT is widely regarded as a model for how academia should interact with industry. Boehringer also consider their partnership with *Ciulli* (BCDD) on the use of **PROTACs as therapeutics** to be a role model collaboration. One indicator of this partnership success is that Boehringer made *Ciulli's* PROTAC MZ1 the first external compound offered open-access to other researchers through its opnMe.com portal. **Direct industry collaborations** have been developed in most Divisions during the review period, for example plant sciences with crop breeders Syngenta, KWS, Secobra and RAGT (*Waugh*), biotech companies Chain Biotech and Corbion (*Halpin*), agribusinesses Simplot and Syngenta (*Birch*); MMB with Beauty-Hsiao Biotechnology Inc (*Stanley-Wall*) and AstraZeneca (*Van Aalten*); CSI, MRC-PPU and BCDD with Ono Pharmaceuticals (*Cohen*, *Arthur*, *Cantrell*, *Ciulli*); BCDD with Takeda (*Gray*); DDU with Pfizer, Bukwang and others already mentioned (*Wyatt*); CB and GRE with many clients of spinout Glencoe Software (*Swedlow*); the National Phenotypic Screening Centre's Phenomics Discovery Initiative partnered with Janssen, and many other examples.

Developing relationships with key research users to generate impact

We engage with many stakeholders, particularly pharmaceutical companies, in the drug discovery pipeline. *Hopkins* led SULSA's successful bid to establish the NPSC in partnership with the University of Oxford, and we offer a range of services and collaborative opportunities to the scientific community through the Phenomics Discovery Initiative (PDi). PDi is a public-private partnership between pharmaceutical companies and NPSC that seeks to identify, develop, and validate innovative phenotypic assays relevant to human disease. We have several productive partnerships with global non-profit Product Development Partnerships (PDPs) such as Medicines for Malaria Venture (MMV), Drugs for Neglected Diseases Initiative (DNDi) and the Foundation for Innovative New Diagnostics (FIND), described in **three Impact Case Studies**. Our WCAIR has further formal partnership agreements with GlaxoSmithKline (to discover new pre-clinical candidates for leishmaniasis and Chagas disease), Bill & Melinda Gates Foundation and the Foundation for the National Institutes of Health (tuberculosis drug discovery). WCAIR has a mission to develop capacity for research in drug discovery, and partners to train scientists from

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countries most affected by neglected tropical diseases (Ghana, Malawi) through placements in Dundee, short courses, expert visits and online resources. SLS (*Ciulli*, 2019) has a partnership with Eisai for cancer drug discovery using targeted protein degradation PROTACs (see **Impact Case Study**) and partners with Boehringer Ingelheim on the development of PROTACs as therapeutics.

Wider contributions to the economy and society

SLS is committed to exploiting the wider economic, policy and societal impacts of its research at all levels. For every pound of Scottish government funding, we generate £7 for the Scottish economy (Fraser of Allander Institute, 2016) and biomedical-related activity accounts for 16% of Dundee's total economy. Our productive interactions with industry are described earlier and in our **Impact Case Studies**. We host work-placements for school pupils and contribute to Breakthrough Dundee where our staff mentor local young people from care-experienced backgrounds. We are very active in public engagement with diverse audiences from schools, local community, industry, strategic bodies, local professional groups (see public engagement section below). We build creative partnerships to deliver high-quality, innovative engagement programmes. We regularly host patient research interest groups (e.g. Parkinson's disease) to inform our research. We are key contributors in responding to the global COVID-19 pandemic. SLS staff contributed to the establishment of the Lighthouse Lab in Glasgow using knowledge of high-throughput platforms (*Gray*), sat on SAGE (*Ferguson*), donated Kingfisher robots to the Lighthouse Lab Milton Keynes (*Lamond*), provided the research community with recombinant versions of all 29 SARS-CoV-2 proteins, along with clones and antibodies, established the Coronavirus Toolkit website and the COVID-19 protein portal (<https://mrcppu-covid.bio/>; <https://covid19proteinportal.org/>; *MRC-PPU Reagents and Services*) and carried out COVID-19-related research (e.g. *Wyatt, Gray, Cantrell, Kulathu, Virdee, Lamond*).

Public Engagement

The School is strongly committed to public engagement and outreach activities to inform the public about science and our research. Our excellent and innovative practices were recognised by being the 1st faculty in the UK to be awarded a Gold Engage Watermark from the National Co-ordinating Centre for Public Engagement (2017). Each Division has a public engagement (PE) champion. In 2016, we appointed a school-wide academic lead for PE (*Stanley-Wall*) who has responsibility for oversight of all PE activities and for developing and implementing our PE strategy (<https://www.lifesci.dundee.ac.uk/impact/public-engagement>). This is developed in consultation with staff and students across the School and aims to embed models for engagement that enable researchers to enhance the impact of their research. To this end, the School deploys a significant budget (>£120,000/annum) employing two Public Engagement Officers and a Schools Outreach Officer who provide administrative and logistic support for academic staff, postdocs, PhD students and support staff to participate in public engagement activities. A 0.5 FTE administrative post supports the PE team and academic lead in their activities. We benefit from the input and expertise of independently-employed PE practitioners (e.g. CRUK Research Engagement Manager) with whom we maintain close working relationships.

In addition to School-wide PE activities/support, most Divisions/Units additionally run engagement activities specific to their research. For example, WCAIR has a PE co-ordinator and manages, in collaboration with colleagues in the University's Duncan of Jordanstone College or Art & Design, the programme for LifeSpace, the exhibition space previously mentioned. WCAIR recently installed 'Para-Site-Seeing: Departure Lounge', an interactive installation that lets you be the deadly Leishmania parasite, and engaged with local Girl Guiding groups to launch a Medicine Maker badge. Their illustrated children's book describing the DDU's work through the eyes of a young

Unit-level environment template (REF5b)

schoolgirl was translated into Spanish for GlaxoSmithKline who ordered 1,000 copies (<https://wcair.dundee.ac.uk/public-engagement/projects/>). The Computational Biology Jalview team are active in outreach visits and activities for Schools and produced a range of resources for their website (<http://www.jalview.org/school-resources>). Plant Sciences runs an annual Plant Power day at the University's Botanic Gardens that attracts up to 1,000 people.

Contributions to the sustainability of the discipline and encouraging best practice

In addition to numerous research activities already mentioned that help to build and sustain the discipline, SLS researchers have developed several platforms and initiatives that connect and support researchers worldwide. As well as the Open research platforms mentioned earlier, some with dedicated training resources that specifically encourage best practice in the storage and analysis of data include:

- Jalview (*Barton*) a free program for multiple sequence alignment editing, visualisation and analysis supports 60K+ users globally. Its YouTube training videos have had 70K hits, and SLS has run training courses in Edinburgh, Liverpool, St Andrews, Glasgow, Cambridge, London, Oxford and Australia.
- OMERO (*Swedlow*) is a client-server software for managing, visualising, analysing and sharing microscopy images and associated metadata. It is used in hundreds of institutions world-wide.
- 3D-RNAseq (*Brown*) an easy-to-use open source App for three-way differential analysis of RNA-seq data, designed to be run by biologists with minimal bioinformatics experience with training video and workshops run across the UK.

Indicators of wider influence on the discipline

SLS PIs positively influence, support and contribute to the wider research community in many different ways. Some notable exemplars are provided below.

Governorships and senior office bearers: Chair REF2021 UoA5 Biological Sciences Sub-Panel (*Cantrell*), Deputy Chair Wellcome Board of Governors (*Ferguson*), Sir Henry Dale Fellowship Interview Committee (*Cantrell*), Royal Society Newton Fellowships Committee in Biology (*Alessi*), MRC-Wellcome Human Developmental Biology Resource Joint Steering Committee (*Storey*), EMBO Young Investigator Committee (*Labib*), and formerly (but within the assessment period) on Babraham Institute Board (*Cantrell*), Council of the MRC (*Cantrell*), The Francis Crick Institute Trustee Board (*Cantrell*).

International and national advisory board membership: Board of Directors of the Medicines for Malaria Venture (*Ferguson*), Scientific Advisory Board of the Crick Institute (*Ferguson* until 2019), Scientific Advisory Board of the London School of Hygiene and Tropical Medicine (*Ferguson* until 2019), Wellcome Trust Science Strategy Advisory Group (*Cantrell*), Scientific Advisory Board of ICR/Imperial Cancer Research Centre of Excellence (*Cantrell*), Governing Board of Tres Cantos Open Lab Foundation (*Fairlamb*), IBiolC Governing Board (*Halpin*), Scottish Industrial Biotechnology Development Group (*Halpin*), Scottish Universities Life Science Alliance Executive Committee (*Owen-Hughes*), Royal Society of Edinburgh Sectional Committees (*Halpin*, *Birch*, *Waugh*, *Cowling*, *Swedlow*).

Membership of major grant and fellowship awarding bodies: Royal Society University Research Fellowship Panel (*Halpin*), MRC BMC: Major Awards Committee (*Ferguson*), Wellcome Sir Henry Dale Fellowship Committee (*Labib*, *Cantrell*), EPSRC Panel of Experts (*Nathke*), UKRI

Unit-level environment template (REF5b)

FLF panels (*Alessi, Owen-Hughes, Halpin*), MRC Molecular & Cellular Medicine Board (*Rouse*), BBSRC Research Committees (*Simpson, Stanley-Wall*), ERC panel (*Blow*), Wellcome ERG (*Horn, Coulthurst, Field*).

Honours, fellowships and other awards: Our School includes 8 FRS, 30 FRSE, 12 EMBO members, 3 CBE and 2 Knighthoods. During the REF period, a multitude of honours and awards were conferred on UoA5 staff (<https://uod.ac.uk/3k4m4aN>) with particularly notable examples including: Knight Bachelor of the British Empire (*Ferguson*), CBE - Commander of the Order of the British Empire (*Cantrell*), 2 Fellowships of the Royal Society (*Palmer, McLean*), 11 Fellowships of the Royal Society of Edinburgh (*Muqit, Cowling, Barton, Stanley-Wall, Horn, Rouse, Labib, Hopkins, Birch, Halpin, Gilbert*), 4 Royal Society Wolfson Research Merit Awards (*Storey, Halpin, Birch, Cowling*), Fellowship of the Academy of Medical Sciences (*Lamond*), Membership of EMBO (*Palmer, Storey*), Royal Society of Edinburgh Patrick Neill Medal (*Coulthurst*), and Royal Society of Chemistry Khorana Prize (*Lilley*).

Research Fellowship awards: Of the 78 PIs in SLS, 20 held or won personal fellowships in the assessment period: 4 Wellcome Principal Research Fellowships (*Cantrell, Fairlamb, Lamond, Tanaka*); 2 Wellcome Senior Fellowship Renewal (*Owen-Hughes, Coulthurst*), 1 Cancer Research UK Career Development Fellowship (*Rasmussen*), 2 UKRI Future Leader fellowships (*Schweikert, Bergkessel*), 7 Wellcome Sir Henry Dale Fellowships (*Findlay, Murray, Januschke, Swamy, Dorfmueller, Pawlowic, Moraga*), 1 Wellcome Senior Fellowship in Clinical Science (*Muqit*), 1 Wellcome Senior Fellowship in Basic Biomedical Sciences (*Coulthurst*), 1 MRC Senior Non-Clinical Fellowship (*Cowling*), 2 Career Development Fellowships (*Hickerson, Pelisch*). Other significant research awards to current or former PIs in the period include: 8 Wellcome Senior Investigator Awards (*Field, Hardie, Crocker, Weijer, Cohen, Hay, Horn, Cowling, Tanaka*), 3 ERC Advanced Awards (*Waugh, Birch, Schaap*), 1 ERC Consolidator Award (*Cowling*).

Participation in the peer-review process: Our PIs contribute routinely and extensively to peer review of publications and grants, and many perform editorial roles on journals. Given the fluid nature of these commitments it is impossible to cite accurate figures over the review period, but all PIs contribute in one or several ways.

Responsiveness to national and international priorities and initiatives

We engage with funder opportunities and frequently host strategic visits from key funders such as UKRI, Wellcome, industry and government bodies. A national priority for research, clearly expressed by Government through the Department for 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 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 JHI. Much of this is detailed elsewhere in this document. We have been key contributors in responding to the global COVID-19 pandemic as explained previously.