Institution: University of Dundee
Unit of Assessment: UoA1 Clinical Medicine
1. Unit context and structure, research and impact strategy

The University of Dundee's **UoA1** research occurs in the **School of Medicine (SM)**, co-located with Ninewells Hospital, one of the largest Teaching Hospitals in the UK. Opened in 1974, Ninewells Hospital was specifically designed to physically embed the medical school within it; with shared spaces and functions radiating from a central concourse. This design facilitates integration of our **Research Divisions with NHS Clinicians and Services**, creating an environment that drives synergistic translational research and clinical innovation. **Our goal is to deliver world-leading globally impactful research, simultaneously training the next generation of clinical and non-clinical researchers in a fully interdisciplinary environment**. UoA1 researchers work in partnership with the NHS and our local and global community. Co-location of basic and clinical science also ensures strong interconnectivity between laboratory science, translational research and clinical research. All activities are underpinned by a substantial investment in basic and clinical research infrastructure.

The **University of Dundee enjoys an international reputation as a centre for excellence in basic and applied biomedical research**. We were most recently rated 1st in the UK for Medicine and for Medical Technology (Complete University Guide, 2021); were recognised as the most influential scientific research institution world-wide in pharmaceuticals (Clarivate Analytics, 2017) and 5th in the world for field-weighted citations (CWTS Leiden Rankings, 2019). Our **commitment to impact was recognised as world leading (100% 4*)** in REF2014, and we have built on these achievements throughout the current assessment period. In terms of academic achievement, we have secured more than £130M in research awards and featured in the Reuters/Clarivate Highly Cited Researchers List.

UoA1 has **five Research Divisions** and 66 clinical and non-clinical Principal Investigators (PIs) leading research teams comprising: 57 postdoctoral research assistants (PDRAs), 11 Clinical Research Fellows, 10 Clinical Lecturers (SCREDS), 8 Graduate Research Assistants (GRAs), 18 Project Managers, 12 Clinical Trial Managers, 19 Research Nurses, 8 Statisticians/Data Scientists and 40 Technician staff. Postgraduate researchers (PGR) are also vital to our research culture, with 139 PhD and MD completions since 2014. Our research community is supported by a core team of Service Facility and Professional Services Managers who have collective responsibility for operations, academic and research support staff.

Leadership and Management

UoA1 is led by **Palmer**, the Associate Dean for Research (ADR). The ADR is a member of the Medical School Executive Group (SEG) chaired by **McCrimmon** (Dean of Medicine), along with four Associate Deans (Research-led Teaching, Learning & Teaching, Internationalisation, Quality Assurance & Academic Standards) and the School Manager. The SEG has overall responsibility for strategic planning and management of all aspects of the School's academic activities including sustainability. **McCrimmon** is a member of the Deans Group, with representation from each of the 10 academic Schools, operating under the aegis of the University Executive Group.

The UoA's five Research Divisions are each managed by a Head of Division (HOD) and Deputy. The Research Management Group (**RMG**) meets monthly to coordinate across these with a focus on research strategy and planning. RMG is chaired by **Palmer** and has broad representation from

HODs, the AD Research-led teaching, leads for ED&I, Research Integrity, Public Engagement, Doctoral Studies and the ***Director of NHS R&D***.

Research Structure

The UoA's **Research Divisions** are **Cellular Medicine, Systems Medicine, Molecular & Clinical Medicine, Population Health & Genomics** and **Imaging Science & Technology**. They are complimentary and porous by design, linked by cross-cutting themes, facilitating collaboration within the UoA and beyond (Figure 1). Conceived around methodological approaches and associated facilities, the Research Divisions collectively aim to deliver bench-to-bedside patient and wider societal health outcomes. Staff belong to Divisions for administrative purposes, but PIs are not restricted to single disease-based research groupings, rather they are encouraged to collaborate freely across the School and with colleagues across the University consistent with the **One Dundee** approach. This approach was signposted in REF2014 and delivered early in the current REF cycle, boosting our world leading interdisciplinarity and challenge-led contributions to: ***Precision Medicine***, ***Cellular Stress & Metabolism***, ***Health & Bioinformatics***, ***Infection & Antimicrobial Resistance***, ***Translational Neuroscience and Cancer***. Success in promoting a collaborative interdisciplinary research culture is also evidenced by 11 researchers from the School being returned to other units: Psychiatry & Neuroscience (UoA4), Medical Engineering (UoA12) and Medical Education (UoA23). The wider strategy context is explained in REF5a.

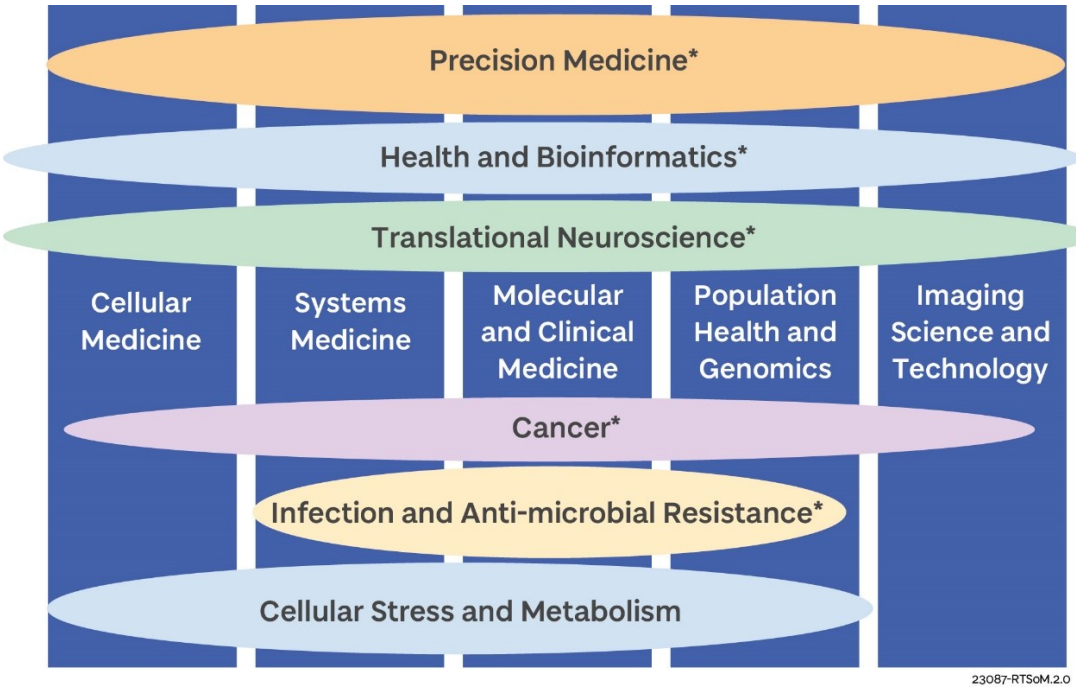

Figure 1: UoA1's Research Divisions and cross-cutting themes

Cellular Medicine: Works at the interface of Cellular/Molecular Biology and Medicine focusing on understanding the molecular mechanisms of cellular responses to stress, including DNA damage and metabolic stress, and the consequences for human carcinogenesis, metabolic disease and neurodegeneration. Research teams are interdisciplinary, employ a wide variety of state-of-the-art experimental systems/techniques (gene editing, single cell fluorescence microscopy imaging, transgenic mouse models) and have access to the clinical samples, crucial for our translational studies. Our goals are to obtain detailed mechanistic understanding and discover novel biomarkers of disease processes, to reveal novel therapeutic targets and disease-specific vulnerabilities, and to contribute to the development of new therapies. The influence of the Division in the development

of therapeutics is reflected by numerous research collaborations locally, nationally and internationally, including industrial collaborations/ consultancies with GlaxoSmithKline, AstraZeneca, Tesaro, Reata Pharmaceuticals, Aclipse, Vividion, and vTv Therapeutics.

Systems Medicine: Utilises *in vivo* systems (human volunteers and experimental rodent models) to develop deeper understanding of health and disease. Areas of strength include: **reproductive biology**: improvement of human fertility, development of novel contraceptive agents and investigation of pre-eclampsia; **cardiovascular**: laser Doppler imaging in human and animal models to study vascular function, with extensive expertise in telemetry technology; **neuroscience:** study of pain (part of UOA4), anti-depressant action and neurological conditions (Huntington's, Alzheimer's, Parkinson's MND) and behavioural programmes involving cognition and memory; **metabolic disorders**: mouse metabolic phenotyping centre offering state-of-the-art metabolic phenotyping (CLAMS, ECHO-MRI, stereotaxic surgery), investigating links between obesity, diabetes and Alzheimer's disease, and the study of the interactions between hormones and metabolism; **pharmacology & toxicology**: established expertise in transgenic models including an extensively humanised mouse line to improve the drug development process and reporter mice to investigate the role of oxidative stress in neurodegenerative disease and other conditions related to environmental pollution. The **Biomarker & Drug Analysis** core facility provides academic expertise, equipment and analytical resources for clinical research and drug development. Extensive use is made of health informatics data to better understand the impact of genetic variation and define pathways determining individual sensitivity to drugs and environmental chemicals, a cornerstone in the development of stratified/personalised treatment of diseases.

Molecular & Clinical Medicine: Combines clinical and experimental medicine research to "translate" our understanding of the cellular and molecular processes underlying disease into improved clinical treatments and patient care. The priority research themes include **cardiovascular**: pursuing cardiovascular risk reduction; respiratory infections; airway inflammatory disease; and **metabolic**: atopic eczema; skin cancers; endocrine disorders; hepatitis and liver disorders; Parkinson's disease; and gastroesophageal cancers. The **Medicines Monitoring Unit** (MEMO) is a dedicated clinical research unit embedded within the Division, providing innovative solutions that meet the needs of industrial, regulatory and academic partners. MEMO design and deliver streamlined studies, which capitalise on technological advances to engage participants, randomise populations at scale, and monitor outcomes using routinely collected health datasets. MEMO has over 40,000 patients currently randomized in these innovative clinical trials. Major achievements include: Expertscape 'first in the world' for Bronchiectasis; development and deployment of **Intelligent Liver Function** testing (iLFT) into NHS (Royal College of Physicians Innovation Award Winner 2019, and American College for Clinical Chemistry UNIVANTs Healthcare Excellent Global Winner 2019); delivery of the first Phase III RCT in chemotherapy resistant oesophageal cancer in a western population.

Population Health & Genomics: Has electronic medical records and population health at its core. It combines established expertise in epidemiology, genomics, clinical medicine, health screening and lifestyle interventions to improve health at the population level. The research component of the **Health Informatics Centre** (HIC) is embedded here, and the Division's distinctive informatics contribution arises from the use of health data, pioneering the linkage of genomic data to electronic medical records (e.g. Tayside Bioresource and Tayside Centre for Genomic Analysis). We are part of the Scottish substantive **Health Data Research UK** site. Areas of strength are: **Precision Medicine**: diabetes, cardiovascular disease, renal medicine, epidemiology, pharmacoepidemiology and genomics, transcriptomics, pharmacovigilance and clinical trials, patient apps and clinical decision support; **antimicrobial stewardship and resistance**: infection epidemiology and

genomics; **chronic pain**: novel therapies, epidemiology and genetic epidemiology; **Preventative Medicine & Improving Healthcare Safety**: health screening especially bowel screening, disease risk reduction, public health and lifestyle intervention; **Global Health***:* including the NIHR Global Health Unit, which is tackling health outcomes in diabetes.

Imaging Science & Technology: Performs clinical research at the interface between the physical and medical sciences, particularly oncology, cardiovascular disease and clinical neuroscience. Unique features are surgical technology collaborations with industry, generating >50 patents, an industrial research programme based on **soft-embalmed Thiel cadavers** (a unique resource in the UK) and a **focused ultrasound** (FUS) facility for research and treatment of tremor disorders including Parkinson's Disease. We were first in the UK to **have ISO Certification for technology development including robotics**. The **Clinical Research Imaging Facility** (CRIF) is a joint University/NHS Tayside core enterprise housed in purpose-built clinical research imaging suites within the Clinical Research Centre. It has a research-dedicated Siemens 3T MRI scanner with fMRI equipment and a GE PET-CT scanner in a custom-built facility for interventional radiology research. **Acquisition of NICE-approved MRI guided equipment** (2nd site in the UK) has allowed extension of our Focused Ultrasound capability to neurosurgery for surgical trials and translational neuroscience studies of brain function. In collaboration with PH&G, we are utilising the national PACS dataset (routine clinical radiology for Scotland) to develop **novel machine-learning clinical prediction methods** for analysing routinely acquired imaging data. Imaging methods employed by the Division include multiparametric MRI, shear wave ultrasonography, optical coherence elastography, endomicroscopy, structural and functional neuroimaging, PET and SPECT scanning. Significant collaborations exist with the School of Science & Engineering (SSE) for combined research and teaching (including a new international joint educational programme with China).

Review of strategic research plans described in REF2014
We have fulfilled all four of our research objectives, which were:

Aim 1. Exploit Informatics/Genomics revolutions for improved medicine and healthcare
Our world-class reputation as a centre for **Health Informatics** continues to grow. Building on excellence in diabetes, our health informatics teams have been extraordinarily successful, making the University of Dundee the **third most funded institution in the UK within the EU Innovative Medicines Initiative** (IMI). The Scottish Care Information-Diabetes Collaboration formed the basis for the Scottish Diabetes Research Network (**McCrimmon**) and in 2018, Dundee became a substantive partner in HDR-UK (**Jefferson**) led by former Dean Morris (departed 2014). SM has taken leadership roles in cross-university interdisciplinary collaboration (Computing and Engineering) in the informatics of routinely collected medical images (MRC/EPSRC £3.8M) and Global Precision Diabetes Medicine (NIHR Unit, £7M).

Aligned with our eHealth ability, we have developed **world-leading Biorepositories** (GoDARTS, Generation Scotland), with blood samples (gathered since 1997) pre-consented for genetic analysis, providing a platform for new research in cancer, cardiovascular disease and diabetes, asthma, skin disorders, and other diseases. We have scaled these bioresources at population level, establishing the **Scottish Health Research Register** (SHARE), where consent for interception, storage and research on "spare blood" has been obtained for 300,000 individuals across Scotland (led by **Palmer**). We are coupling our strengths in informatics and genomics with molecular, cellular and organismal analysis of the mechanisms of diseases and secured our capability in these areas with appointment of a cohort of Early Career Researchers (ECRs) and Clinical Senior Lecturers (CSLs).

Aim 2: Develop multi-disciplinary research themes across disease boundaries

A key objective was to build cross-disciplinary research to exploit developing fields and to focus on common clinical or scientific questions. We achieved this by **reorganising** our Research Divisions (Figure 1) to embrace challenge-led themes through initial investment from our Medical School **Development Fund** (£40K pa) between 2013 and 2015, thereafter drawing on the **Wellcome Institutional Strategic Support Fund (ISSF)**, matched-funded from the University (£360K pa) to pump-prime new interdisciplinary and translational research. Our clinicians are working with colleagues in the physical sciences, engineering and mathematics, ensuring impact in clinical medicine through a pathway for the application of scientific discoveries to *in vivo* models and patients. We are leading several initiatives in precision medicine in cancer, asthma, cardiovascular disease and diabetes. As a major partner (with Aberdeen, Glasgow and Edinburgh Universities) in the Scottish Funding Council-funded **Precision Medicine Innovation Centre**, we are key partners of strategic projects with industry including Astra Zeneca in ovarian cancer, chronic obstructive pulmonary disease and non-alcoholic liver disease.

Aim 3: Develop translational research between the laboratory and the clinic

We have extended the traditional “translational model” by actively supporting “bench-to-bedside" and “bedside-to-bench" research, using shared expertise to clarify the biological mechanisms, underlying the role of candidate susceptibility genes, with major progress in our understanding of the mechanisms of drug response and allergic disease being driven from our translational genomics research (**Pearson**, **Palmer**, **Brown** A, **Rena** and **Sutherland**). Our translational research is supported by the **Tayside Academic Health Sciences Partnership** (AHSP), the Tayside Biorepository and core research facilities for biomarker development. The Drug Discovery Unit in the School of Life Sciences (SLS) offers facilities for pre-clinical drug discovery following target identification, and many of our PIs exploit this resource. Funding from the Gates Foundation (£780K) has supported screening work to identify potential male contraceptives (**Barratt**). We have strengthened capacity in this theme through the targeted recruitment of translationally-minded research staff, including **Martins DaSilva** (Reproductive Medicine), **Cantley** (Diabetes Research), **Banerjee**, **Masson** (Precision Cancer Medicine) and **Henstridge** (Neurodegeneration).

Aim 4: Engage with the NHS and industry to deliver improvements in Healthcare

Strategic alignment with AHSP allows synergistic interaction with key NHS partners to support development of clinical trials and translational research. During the period of assessment, we have worked with other Scottish Medical Schools and their NHS partners (as part of the **Chief Scientist Office Stakeholder Board**) to extend the AHSP model to other regions. The appointment of nine early career NHS consultant research fellows with protected research time, has built further clinical research capacity. Significant success was also realised through £25M awarded to the UK/Scottish Government supported Cities Deal ***Growing the Tay Cities Biomedical Cluster***, inclusive of £5M for a unique clinical R&D facility within the **Tayside Innovation MedTech Ecosystem** (TIME). We have secured strategic partnership agreements with Medtronic, Canon and Storz and have been successful in developing Knowledge Transfer Partnerships with SMEs (Onorach, Oxstem-beta, Moor Instruments). Strategic alliances are in place with major Pharmaceutical companies, including Astra Zeneca and GSK.

Anderson and **Steele** (Independent Chair of UK National Screening Committee) lead the **Cancer Screening and Prevention Research Group**, engaging closely with the NHS through the Scottish Bowel Screening Programme and the Scottish Cancer Taskforce. This has facilitated rapid implementation of research findings into the Scottish Bowel Screening Programme and significant investment from the Scottish Government (£978K) in studies linking lifestyle interventions with bowel and breast screening. The recruitment of **Grunwald**, one of the UK’s most prominent stroke

thrombectomy interventional neuroradiologists, was a strategic appointment, augmenting our imaging expertise and enriching our critical mass tackling neurological diseases. We have also invested in a novel focussed ultrasound modality for treatment of tremor and with the potential to treat Parkinson's disease and brain tumours.

Future strategic aims and Five-Year plan

We aim to deliver on the University's mission to ***transform lives, locally and globally*** through active engagement in its four interdisciplinary themes: ***Health and Wellbeing***, ***Social Justice***, ***Innovating Technology*** and ***Creativity and Design***. We will do this through cross-School and wider institutional initiatives and through partnership with stakeholders engaged with medical research, innovation and healthcare outcomes worldwide.

UoA1's strategic aims centre around building capacity in precision medicine, especially where we can use established expertise in data analytics, including health data, imaging and bioinformatics. Considerable effort and significant investment have been made developing a Precision Medicine focus that unites public and global health, genomics, translational medicine and computing.

New Aim 1: To exploit the Big Data universe to deliver Precision Medicine

We will play a leading role in shaping the emerging paradigm shift to data-driven precision medicine, using advanced analytics from Artificial Intelligence (AI), development of novel 'omics'-based technologies, our unique national bioresources and novel data sources, such as "Retinomics" (prognostic features derived by AI from routine eye scans). Multi- and interdisciplinary capacity is vital to build on the major successes already gained from collaboration with our Schools of SLS (quantitative biology, bioinformatics) and SSE (computing, image analysis, AI).

To deliver on improvements in healthcare, we will further engage with the NHS through a full programme of NHS innovation and Health Care Improvement, and the development of SHARE as a platform for a P4ME (Predictive, Preventive, Personalised, and Participatory) learning healthcare system will be pivotal. Major priorities will be to:

- Deliver robust pipelines of electronic clinical decision making supported by the growing availability of whole genome data on patients coming to clinic;
- Improve early diagnostics to interpret routinely collected data (exemplified by our £2.9M MRC funded PiCTURES programme), to analyse routine images (e.g. brain scans) for early detection of neurodegenerative disease, intelligent Liver Function Testing and next generation Bowel Cancer screening;
- Use routinely collected health care data to optimise both quality and efficiency of care pathways;
- Deliver interventional neurology, including pre-hospital intervention for stroke, thrombectomy for stroke and development of neurological implementation of focussed ultrasound.

We shall also build on our expertise in leading precision medicine clinical trials and implementing these findings into clinical care in cardiovascular and metabolic disease, cancer, diabetes, and respiratory disease. We are well placed to be innovative in partnering with potential sponsors for patient centred trials including remotely delivered protocols.

New Aim 2: Enhanced engagement and leadership of the University's research themes
With already strong interdisciplinary collaborations in the area of ***Health and Wellbeing*** we see opportunities to develop new partnerships in Realistic Medicine that examine inequality as a driver of poor health outcomes; aligned to the theme of ***Social Justice***. We aim to extend our collaborations with Duncan of Jordanstone College of Art and Design (DJCAD, ***Creativity and Design***) in the design of health care processes and in Citizen Science. We will continue to work closely with Engineering and Computing to innovate in surgical robotics and Big Data analytics (***Innovative Technology***). This wider engagement with interdisciplinary themes will be underpinned through the recruitment of new ECRs into UoA1 and will be aligned with new, jointly developed, taught postgraduate (TPG) courses offered by SM. The Executive Groups of SM, SSE and SLS conduct regular joint meetings to support these interactions; a recent success being the Joint Educational Programme with Northeastern University China.

New Aim 3: Collaborating across disease boundaries to accelerate translation to the clinic
The introduction of our research themes has promoted interdisciplinary research and together with a cohort of new appointments, has provided a robust and sustainable translational research platform, that will accelerate clinical implementation. We will develop translational opportunities in the areas of cellular and metabolic stress, inflammation and neutrophil biology, clinical and pre-clinical pharmacology, and biomedical engineering together with disease specific clinical excellence. Collaborations with SLS, Engineering and Computing will deliver field advancing experimental medicine studies and early and late phase clinical trials with major translational components in respiratory diseases (including bronchiectasis), gastrointestinal cancers, neurodegenerative, metabolic, cardiovascular and liver diseases and in reproductive medicine.

New Aim 4: To transform lives globally
We will build on our track record in changing the practice of medicine at the international level, particularly in clinical pharmacology, drug safety, cancer screening and surgical technology. Expansion of our research into low-and-middle income countries (LMIC), e.g., our NIHR Global Health Unit for diabetes outcomes research (**Palmer**) is delivering a global precision medicine platform in diabetes and other non-communicable diseases. This has been extended to Malaysia (December 2020) with joint UK-MRC and Malaysian Government (Newton-Ungku) funding and emerging collaborations with the School of Social Sciences to investigate social and environmental determinants of health in Uganda and Bangladesh. We are also looking at novel approaches for cost-effective disease screening and management in low resource, rural environments in India, sub-Saharan Africa and Afghanistan, using global accessible internet and mobile technologies (such as hand-held retinal scanners).

Enabling and facilitating IMPACT
Achieving impact is central to the University's mission of transforming lives locally and globally. Impact activities are part of the achievements assessed, and this forms an integral part of the annual appraisal process for all academic staff. Our success was highlighted by our achievement in being ranked joint first for Impact in REF2014, and for REF2021, we have SM staff contributing to impact cases in UOA4, UOA12 and UOA23. These demonstrate our commitment to conducting research that is interdisciplinary, innovative and impactful.

We facilitated impact activity with the following: In May 2014, the first Academic Health Sciences Partnership (AHSP) in Scotland was established in Tayside, jointly supported by the Scottish Government, University of Dundee and NHS Tayside. The University funded the appointment of an Associate Director, Business Projects Lead and academic cluster leads in Quality Improvement, Biomedical Research, Informatics, and Design and Innovation. Tayside AHSP collaborates with

Scottish Health Innovations Limited (SHIL) to support those delivering and receiving care across the health and social care domains in becoming 'innovation active' and promulgating ideas. UOA1 researchers with NHS colleagues have developed the **intelligent liver function test** (iLFT) which allows additional automatic and specific testing of blood from patients suspected of having a liver disorder, or who have unexplained abnormal results. Trials reveal a 44% increase in diagnosis of liver disease, giving patients earlier access to treatment. iLFT is now standard practice across NHS Tayside and is expanding across Scotland. iLFT has received prestigious awards, including: Innovation award at Royal College of Physicians' Excellence in Patient Care Awards, 2019; UNIVANTS of Healthcare Excellence Award, 2019.

In line with the 'Realistic Medicine' agenda of Scotland's Chief Medical Officer, Dundee V&A Museum and Tayside AHSP are developing a leadership programme in Health Care Design that places citizens at the heart of identifying and tackling systemic health and care issues. Employing innovative design techniques, medical students from SM and design students from DJCAD worked with patients and staff in the Ninewells Emergency Department to improve the patient experience. Students mapped out and designed infographics about patient journeys that gave key indicators on how the department functioned and the healthcare professionals encountered; consequently, new signage was created to help patients find their way easily to different parts of the department. SM and DJCAD are currently developing a joint TPG in Health Care Design.

Tayside AHSP was instrumental in building an innovative relationship between SM, other Schools, Tayside Health Board and Medtronic, one of the world's largest medical technology companies, and bringing them together under a strategic partnership agreement. Tayside AHSP is also looking at pathways of care in stroke and thrombectomy patients and using interventional radiology to speed early diagnosis. Strategic alliances are in place with other major pharmaceutical and MedTech companies, including Canon (using AI to analyse routinely collected pathology (in collaboration with iCAIRD) and radiological images (PiCTURES)), GE (early diagnostics), Astra Zeneca (precision medicine) and Abbot (iLFT).

The SM Commercialisation Group (SMCG) is supporting researchers at all career stages on how to best exploit the outputs of their research, offering advice on commercialisation agreements and where appropriate, the development of spin-out companies. SMCG membership is drawn from academia, commercialisation, technology-transfer, innovation funding and entrepreneurship and thus offers complimentary expertise. The **Dundee Accelerator Programme**, operated from the Dundee Centre for Entrepreneurship, assists early-stage business owners and teams to grow and attract investment. Exemplar indicators demonstrating the success and validation of our approach include: i) Recognition internationally of the global impact of our research – rated fifth in the world in the 2019 CWTS Leiden Ranking for Biomedical and Health Sciences; ii) Creation of a successful and commercially viable spin-out companies (My Way Digital Health, Vascular Flow Technologies); iii) Developing KTPs with local small-medium enterprises in MedTech (**Murdoch**, **Cantley**) and clinical research (Zhelev).

Supporting interdisciplinary research

Interdisciplinarity is embedded in our research and teaching activity to address challenges and enhance impactful research. The introduction of themes within SM (Figure 1) has increased our flexibility for interdisciplinary interactions. Examples include:

Translational Neuroscience (Parkinson's Disease): **Sammler**, a CSL co-located with Alessi in MRC-PPU, has developed assays for LRRK2 mutations and is conducting clinical trials of LRRK2

kinase inhibitors in SM, and we have invested in novel focussed ultrasound for movement disorders in Parkinson's (Gilbertson).

Infection and Antimicrobial Resistance: **Chalmers**, **Davey**, **Marwick** and **Palmer** form an integral part of the pan-institutional *Centre for Antimicrobial Resistance* delivering innovation in antimicrobial research and clinical practice. PIs from other Schools participate in our seminar programme, and we participate actively in the Dundee Interdisciplinary and Innovation Forum (DIIF), a platform to engage across the University on major funding opportunities. Over the census period, 32% of our publications involve members from at least two disciplines and our relationship with Tayside AHSP provides a catalyst for innovative multi-disciplinary working with the NHS. We have close links with the SSE through our shared interest in biomedical engineering enabling industry engagement (Medtronic, Storz, GE).

Our MRC Doctoral Training programme "Quantitative and Interdisciplinary approaches to Biomedical Science" (first cohort 2016, managed by SM/SLS) provides a strong collaborative interface for interdisciplinary research and training. Similar platforms operate for our Wellcome Trust (clinical and non-clinical PhDs) and BBSRC EASTBIO PhD programmes. As mentioned previously, the Wellcome ISSF award provides bridge funding and pump priming for activities across SM/SLS in key strategic interdisciplinary areas (infection and anti-microbial resistance; cellular stress and metabolism; cancer) and flexible funding to stimulate, develop and enhance the strongest life and health sciences-related research in Medicine and the STEM subjects. 'Big Data' and AI has fostered collaboration between SM and Computing (Programme awards in PICTURES and NIHR Global Health Unit) and the creation of a research-led TPG course in Data Science and Applied Precision Medicine. Other recently created postgraduate programmes enabling future interdisciplinary research are Quantitative Medicine and Biology (SLS, SSE and SM) and Health Care Design for Well Being (SM, DJCAD and School of Health Sciences).

Promoting an open research environment

Open Access is supported centrally by our Library and Learning Centre and ensures open access publication via Discovery (PURE). The Health Informatics Centre (HIC) provides a unique platform for safe access for research on routinely collected health records. SM is a leader in providing online access to tissue for research, with the Tayside Biorepository software system (delivered by HIC and funded by the Chief Scientists Office), being rolled out to manage tissue holdings throughout Scotland. Tayside based cohorts are open for access to researchers for blood- and genetic-based studies with GoDARTS contributing to many pivotal global GWAS studies. Data from these studies is available on application and from repositories such as the European Genome-Phenome Archive (EMBL_EBI). Novel federated access to GoDARTS genetic association results are publicly available on the Accelerated Medicine Partnership Type2 diabetes knowledge portal. Both activities are part of the EBI-ELIXIR programme. Building on this, SM has established the national Scottish Health Research Register (SHARE), aiming to obtain consent from 1 million Scots for the use of their medical records and genetics for research using "spare blood". This is a highly sophisticated platform, managing consent, and access for researchers to population scale data. SHARE has supported pioneering "recruit by genotype" clinical trials in both academically and commercially led clinical studies. The University is the highest ranked university and non-commercial organisation in Europe on the EU trials tracker for compliance for clinical trials reporting and transparency, supported by Tayside Medical Sciences Centre (TASC), which has been commended nationally by the UK Parliament Science & Technology Committee and UK Research Integrity Office (UKRIO).

Supporting a culture of Research Integrity

The SM Research Integrity Group (RIG) supports and adheres to the five commitments for good research conduct and governance, as defined by the *Concordat to Support Research Integrity*. RIG ensures all staff and postgraduate students engaging in research get appropriate training and understand the policies and ethical procedures relevant to undertaking a research project. The University promotes researcher awareness and engagement with research integrity issues via a mandatory online training course "Responsible and Ethical Practice in Research and Publication". The course covers: ethical approval and practice; plagiarism and recycling of text and research outputs; authorship; collaborative research and data management; peer review and publication ethics; general issues such as research misconduct and questionable research practice. The course is mandatory for all postgraduate research students registered since August 2016. Research involving animals or human participants (including use of their tissue or data) requires approval by the appropriate Research Ethics Committee. RIG membership comprises the RI Lead (**Dinkova-Kostova**), a clinical and non-clinical senior academic researcher, SM ED&I Lead and the Senior Research Governance Manager from TASC). Members of RIG provide education, training, and impartial advice on the responsible conduct of research, and any member can act as a confidential first point of contact for staff and students with specific concerns. RIG ensures that information can be disclosed independently of an individual's line management, treating all disclosures sensitively and confidentially.

2. People

Staffing Strategy and Staff Development

UoA's1 staffing strategy is to create a vibrant and sustainable research community in support of our research ambitions, building on our strengths across our divisions and themes and enhancing our impact and interdisciplinary approach. Our 2017/18 HESA return indicated that our academic demographic was top heavy with 61% Professors, 6% readers, 11% Senior Lecturers, 9% Lecturers and 5% ECRs. We are addressing this imbalance through an ongoing reinvestment programme of core resource and recruiting new academic mid-career T&R staff and ECRs in our strategic research areas. This is rebalancing our demographic and remains a strategic focus. New appointments have been made based on four criteria: potential/proven research and knowledge exchange excellence; potential/proven collaborative and interdisciplinary working; commitment to the development of colleagues; commitment to societal impact. On census day, we had 48% Professor (29% clinical and 19% non-clinical), 6% Reader (1% clinical and 5% non-clinical), 21% Senior Lecturer (9% clinical and 12% non-clinical), 8% Lecturer (0% clinical and 8% non-clinical) and 17% ECRs (3% clinical senior lecturers/lecturers and 14% non-clinical tenure track PIs). This healthier and more sustainable demographic is reflected in our age bands: under 39 (15%); 40 to 49 (42%); 50 –59 (24%); 60 or over (19%). For this submission, 30% of our Cat A staff occupying the above positions are female and 19% are members of BAME groups.

Recruitment: The School Executive Group, including the ADR and Divisional Research Leads, make strategic decisions about when to recruit new PIs into specific Research Divisions according to strategic fit within the cross-cutting themes. Principal Investigators are recruited by the Research Management Group (in line with the University's ED&I policy and with representation from another School). Short-listed candidates, having sent a research plan as part of the application process, give a formal seminar followed by a "round table" discussion allowing them to highlight their current and future research plans. Academic clinical appointments are at Senior Lecturer level or above and carry full tenure; clinical capability is appropriately assessed in respect of consultant opportunities available within NHS Tayside. HODs/PIs are expected to promote the careers of

postdoctoral researchers and facilitate access for clinical colleagues with an interest in research into the Divisional research environment.

Over the period of assessment, we have recruited 12 PIs: **Newey** (Clinical Senior Lecturer, 2014), **Petty** (Clinical Professor Oncology, 2015), **Doney** (Clinical Senior Lecturer, 2016), **Murdoch** (Senior Lecturer, 2018), **Colvin** (Chair of Pain Medicine 2018 returned in UoA4), **Kang** (Lecturer, 2019), **Martin** (Lecturer, 2019), **Cantley** (Senior Lecturer, 2019), **Jefferson** (Chair of Data Science, 2019), **Cunningham** (Senior Lecturer, 2019), **McLean** (Clinical Senior Lecturer, 2020) and **Grunwald** (Chair of Interventional Stroke Medicine, 2020). We have continued our policy of actively nurturing ECRs towards obtaining their own externally funded research fellowships and subsequent independent academic careers. From an extension of our **Discovery Fellow programme**, appointments made under the University's recent **Baxter Fellowship** programme and the Ninewells Cancer Campaign, we have recruited 10 non-Clinical Lecturers/Research PIs: **McNeilly** (2018), **Shoemark**, **Brown** A, **Henstridge**, **Huang** (all 2019) and **Masson**, **Banerjee**, **Dicker**, **Siddiqui** and **Dawed** (all 2020); and the following clinical ECRs: **Mordi** (Clinical Lecturer, 2016) and **Bell**, **Martins da Silva**, **Mowat** and **Sammler** (all Senior Clinical Lecturers, 2019).

Start-up packages and mentoring: All academic recruits are given a start-up package appropriate to their circumstances, varying from funds to recruit a PDRA (typically up to 3 years), an initial consumable allowance (up to 10K pa) and match-funding for major items of equipment secured on research awards. New ECRs receive a targeted doctoral student package (£90K over 3 years), laboratory space and resource (as appropriate) for items of general equipment. UoA1 staff have access to funding from the Tenovus (Tayside), a resource that has provided small to medium-sized grants (£20K to £100K) to many new PIs over the past few decades.

Tenure and review: Tenure period is 4 to 5 years and tenure and pre-tenure PIs are supported by the ADR, their HOD and paired with an experienced researcher to act as their mentor. Moreover, they participate in the cross-institutional Teaching, Research & Academic Mentoring Scheme. Staff are sponsored for engagement with the **Advance HE Aurora Leadership programme**. Tenure review is coordinated by the Dean and evaluations are undertaken annually to provide feedback and support to facilitate successful appointments at the end of their tenure period. Personal circumstances which may have impacted on performance during the tenure period are considered (carer duties, disability due to incapacity, ill health). Staff who have taken parental leave have their tenure period and salary extended for 12 months.

Ongoing review of research staff: PIs are appraised annually by their HOD, and the HODs by the ADR. These appraisals are monitored centrally using an Annual Research Review process, and summarised for consistent oversight by the University Research and Knowledge Exchange Committee, chaired by the Vice Principal (Research). This process is used for performance management and for the quality assurance of the research data management systems including the web-based Discovery portal.

All staff including PDRAs and other research support staff have an annual Objective Setting and Review with their line manager (usually group PI). This focuses on positive achievements in the year and reflections on individual experiences in the post and specifies individual training and development plans.

Postgraduate research (PGR): A total of 139 FTE PhD and MD students successfully completed during the current REF assessment period. All UoA1 PGRs benefit from the School's mission, training the next generation of clinical and non-clinical researchers (and the equity and quality of

experience gained) as a top priority. We appointed a new Director of Doctoral Studies (**Rena**) in 2019, who is a member of the University's **Doctoral Academy** Board, with the remit to provide institutional leadership and promote best practice on all matters relating to research degrees and research students. PhD and MD student recruitment is integrated across our research activities and coordinated with our School Internationalisation team.

PhD and MD students are recruited based on their academic attainment via open competition. The selection process is managed through the UCAS online application system, and we advertise PhD opportunities on *FindaPhD.com* and the School website. Most of our MDs are funded from clinical trial awards, a crucial means of enabling junior doctors in the NHS to pursue academic research training across several speciality areas. Shortlisting and interviewing are carried out by academic staff cognate with the research area. The Research Postgraduate Committee also vet all applications before a formal offer is issued. All staff involved in recruitment must complete unconscious bias and equality, diversity and inclusion training.

Doctoral Training Programmes: We offer funded PhD studentships within Doctoral Training Programmes (DTPs): Dundee MRC DTP (offering iCase opportunities), BBSRC EASTBIO, Wellcome Trust; or on an individual studentship basis. The MRC DTP "Quantitative and Interdisciplinary approaches to Biomedical Science" is managed jointly by SM and SLS. The INSPIRED DTP (part of our NIHR Global Diabetes Unit, led by **Palmer**) is training 10 Indian PGRs in Dundee and three at the University of Madras in genomics, big data analytics and health informatics; the Alzheimer's Society DTP across four Scottish Universities (current cohort is nine students, two based in Dundee); we hold a European Network Doctoral Training Award (€3.9M iPlacenta PhD training programme, led by **Murdoch**) encompassing innovative modelling of the placenta for Maternal and Foetal health. From 2021, the Ninewells Cancer Campaign (NCC) will fund nine non-clinical and clinical PhDs as part of a novel doctoral training programme in Precision Cancer Medicine.

Monitoring and Support Mechanisms: PGRs are supported in their academic progress and career development throughout their studies, having a minimum of two supervisors (main supervisor must be accredited – see below). Students are assigned to a Thesis Monitoring Committee (TMC), which meet at least twice pa, comprise three academics and are chaired by an experienced supervisor. Students are expected to provide written reports, or other documentation (literature reviews, progress reports, thesis plans) before TMC meetings. Students and supervisors complete a questionnaire assessing progress and the TMCs provide written feedback to student and supervisor. TMCs provide an independent assessment of student progress and the quality of their research supervision, an ongoing point of contact for the student, independent of their supervisor(s) and offer pastoral support to maximise student wellbeing. For 1st year students, TMCs input to the Upgrade Review, which is the process for formalising candidacy to a named degree. To pass the Upgrade Review, students must complete the University's Research Integrity Modules and prepare a research proposal, which is reviewed by an Upgrade Committee. Additionally, students give oral presentation of their research, followed by an interview with the Upgrade Committee. Feedback is provided to the student and supervisor(s). Potential supervisors must gain accreditation and can access the University's structured training programme (encompassing good practice in supervision, roles and responsibilities, governance issues, case studies) and incorporating reflective and group discussion exercises.

Skills, career development and integrated student research culture: Our PGRs have access to a comprehensive Occupational and Professional Development (OPD) programme mapped to Vitae's Researcher Development Framework, in line with the **revised Concordat to Support the**

Career Development of Researchers, which helps them become more effective, efficient and confident in the key competencies required for professional career development. Students are integrated into all activities in the School, have representation at Divisional and School level and present their work at lab meetings and across our School seminar programmes. All research students have access to the University's Career Service, which can assist with all aspects of career planning. Access to School and cross-School training programmes is supported centrally by the University's Doctoral Academy. SM has programmes that demonstrate a strong and integrated research student culture, including student outreach and public engagement. SM is committed to building a cohort of research-trained clinical academics, as evidenced by our recruitment of four clinical senior lecturers during 2019. SM has recently revitalised its Research Staff Association (RSA) bringing together all our research community (PhD students, technical staff, postdocs and PIs) to provide guidance on career development that aligns with the principles of the Concordat. RSA also provides a less formal "social" platform and will help ensure that all research staff in the SM are encouraged to be proactive in their career development, know their rights and responsibilities as research staff and engage with the support available.

Evidence of how the submitting unit supports Equality, Diversity and Inclusion

SM is fully committed to advancing equality, diversity and inclusion for all staff and students informed and supported by the University Equality Outcomes Plan. A dedicated ED&I Lead (**Harvey**) chairs the SM ED&I committee with representation from all divisions in the school and student body. The ED&I Lead reports directly to the Dean and SEG and has responsibility for progressing the equality agenda within the School; an equality impact assessment planning tool is employed to ensure equitable and fair decision making for all staff, and measures are in place to ensure protected groups are not inadvertently disadvantaged. We are committed to the principles of the Athena SWAN Charter and hold a bronze award; recruitment panels are gender-balanced, and we promote an inclusive family-friendly working environment (scheduling of meetings and seminars are flexible with broader family commitments). New recruits are assigned individual mentors, not necessarily in a cognate research discipline, but who can provide advice and direction on a path of personal development that help staff take control of their own careers. We have several outstanding women scientists in key leadership roles, including **Belch** OBE (Outstanding Women of Scotland - Saltire Award), **Dinkova-Kostova** (top 1% cited researcher), **Anderson** (President UKSBN, Stephen Fry Public Engagement Award 2019) and **Martins da Silva** (BBC 100 Women). The School is committed to rewarding staff fairly and equitably and continues to work towards reducing our gender pay gap.

Integration of clinical academics and NHS-employed active researchers

The integration of our Research Divisions with NHS-based research and service work has had significant impact on clinical and translational research, capacity building, research training and service delivery. Tayside AHSP provides infrastructure and governance support for clinical trials to UoA1 by enabling a significant portfolio of academically-led commercial and non-commercial research projects. Petty is the lead recruiter for gastroeosophageal cancer clinical trials in Scotland, identifying Tayside as the only region in Scotland meeting government targets for recruitment in this disease. NHS staff undertaking non-commercial clinical trials include Leese, Burton (ageing with Witham), Conway, Kismet and Gilbertson, Mannick (ENT), Irving (Cardiology), Connelly (Dementia), Ghaffar (Dermatology), MacAskill, Bhat (Rheumatology), Baines (Vascular Medicine), Morrison (Neurology), Spielmann (ENT) and Ferguson (Cancer).

TASC has an annual budget of £7M, investing £4.9M in academic staff and £800K in facilities support (Clinical Research Imaging Facility, Biorepository, ECHO services, HIC – detail below). TASC invests in SM clinical staff (currently 27 academic sessions) and also guaranteed research

sessions via NHS Research Scotland Fellowships (0.2 FTE for 3 years awarded to Ibrahim, Baldie, Connell, Gilbertson, Parcell, Hernandez-Santiago) and local AHSP Fellowships (0.2 FTE for 2 years awarded to Pitsinis, Sandler (working with VAMPIRE/Trucco)), allowing clinicians and healthcare professionals to work collaboratively with University researchers.

Tayside Clinical Trials Unit (TCTU) is a UKCRN accredited CTU providing pre-award design and methodology support for clinical trials and bespoke activity, relating to data management systems, drug management and statistical analysis. This ensures research teams can deliver studies to timelines and on budget. TCTU works on an international platform, recruiting participants for trials from across the UK and Europe and working with other Universities. Recently, TCTU successfully delivered the 12,000 patient ECLS (Early Detection in Lung Cancer) study.

Many of our clinical academics lead NHS Research Scotland platforms and networks, thereby supporting the set up and delivery of clinical and epidemiological research across Scotland: CSO R&D Director, East of Scotland (**George**), Primary Care (**Guthrie**, now **Morales**); Cancer East (**Nabi**); Diabetes (**McCrimmon**); Genetics (**Berg**); Hepatology (**Dillon**); Infectious Diseases (**Marwick**); Metabolic & Endocrine (**Leese**); Dementia & Neurodegenerative (**Connelly**). The Scottish Centre for Respiratory Research (**Lipworth**) has attracted £1.3M in Pharma funding over the period of assessment and **Foerster** (£368K) for clinical trials in psoriasis and other skin conditions.

UOA1 PIs and NHS colleagues responded quickly to the COVID-19 crisis with more than 30 active COVID-19 related projects including: 5 clinical trials, which include STOP-COVID (**Chalmers** & **George**) the only Scottish-led COVID trial funded by NIHR (UPH badged), STAR-COVID-19 (**Chalmers** & **Dinkova-Kostova**) and PHOSPH-COVID (**Chalmers**), a national study on the long-term consequences of COVID-19, that could inform personalised treatment strategies (MRC-NIHR, 25 partners, £8.4M). NHS Tayside has another 24 active COVID-19-related studies ongoing, which range from patient samples, data and questionnaires. Dundee is also the Scottish lead site for the EMSEMBLE-2 COVID-19 vaccine trial (Janssen/J&J) and recruited the first patient globally to this international trial.

Construction of Unit Submission

Consistent with the University's published Code of Practice, the UoA Planning Group operated inclusively and in a fully transparent manner. At least one output was attributed to each member of the unit, thereafter outputs were selected to maximise the overall quality profile. Of 161 outputs submitted 73% are from males and 27% from females, comparable with the UoA's gender balance. Other comparisons based on protected characteristics indicate no bias in output selection. The Planning Group invited all REF eligible staff to suggest potential impact case studies and those chosen, demonstrate the strongest impacts arising over the REF period. All members of our Planning Group completed training on ED&I, unconscious bias, and information security awareness training prior to output selection.

3. Income, infrastructure and facilities

Research income: The Unit had research income of £141.6M during the reporting period, including nearly £13M from UKRI and £23M from UK Health Research Funding Bodies. UoA1 has secured significant new research awards during the current period from major funding bodies, including: £18.5M from UKRI, £20.5M from UK Government Sources, £21M from UK Charities (competitive calls ARUK, BHF, DUK, CRUK), £4M from other Charitable sources, £8.2M* from EU Government Funding H2020, IMI (*UoA1 participant allocations only) and £19.3M from UK Health

Research Funding Bodies (NIHR, CSO). Total Industry/Commercial funding exceeded £27M; including industry funding (UK, EU and International) for academic-led clinical trials (supported by TCTU), pharmaceutical sponsored clinical trials led by UoA clinical PIs and other commercially funded non-clinical projects within the UoA. This continuing success provides the foundation for the sustainability of our research into the future.

Nature and quality of research infrastructure: The UoA research benefits from an extensive range of state-of-the-art facilities, shared with SLS, SSE and the NHS to support the interdisciplinary and translational nature of our research. Large-scale investment in Big Data computing (provided by capital and programmatic awards from MRC and NIHR), and the purchase of Illumina NovoSeq and Oxford Nanopore Promethion sequencers provide our genomics core facility with the latest and most powerful technology; further enhanced by the co-development of single cell sequencing capabilities in collaboration with SLS. In 2016, our immunoassay core service purchased the Simoa HD-1, a cutting-edge ultrasensitive immunoassay platform that enables development of novel ELISAs. Local fundraising and School match-funding has enabled the purchase of a novel MR-guided focussed ultrasound platform for non-invasive neurological intervention research (creating the 2nd such facility in the UK). This facility has the potential to support ground-breaking research in the area of treatment of Tremor, Parkinson's disease and brain cancer. Research infrastructure is currently being upgraded as part of the Tay Cities Deal allowing us to take our MedTech platform forward into the 2020s.

Management, Administration & Technical Support
Our Core Facilities Management Team comprises an Academic lead for each Facility with support from Finance and Operations. The Operations Manager leads a team of laboratory managers who maintain equipment, run purchasing, staff training and Health & Safety. Central stores and autoclave, glass washing facilities are coordinated within Operations, as is liaison with NHS Estates ensuring upkeep of the laboratory and office space.

A variety of communal activities (below) bring different groupings together and many are promoted amongst our NHS colleagues. In 2020, most of these activities continued on-line in timelines compatible with home schooling and other care responsibilities.

Divisional Research Meetings
These are chaired by the HOD, meet regularly during the year and bring together within their respective administrative areas, PIs, UG/ PG teaching staff and representatives from the PDRA/doctoral community and attendance from operations, research support and HR. These meetings provide a lively forum for discussions on research and impact strategy, postgraduate and postdoctoral training and public engagement. HODs report to the monthly Research Management Group, chaired by the ADR.

Seminar Programmes
Each Division runs an open seminar programme for external investigators to present their research to all staff across our research community – including other Schools and colleagues in the NHS. These seminars enrich PhD, MD and post-doctoral scientist experience and PIs and supervisors actively encourage the attendance of more junior staff. In addition, Divisions hold weekly "Research in Progress" talks giving the opportunity for doctoral students and PDRAs to present their work. A weekly "Grand Rounds" is held for the medical staff and students focussing on clinical subjects.

Named Lectures
DCAT (Dundee Clinical Academic Track) Lecture, awarded annually to an outstanding clinician scientist (over the last 5 years to Professors David Adams, Moira Whyte, Sarah Tabrizi, Rebecca Fitzgerald and David Newby); the Margaret Fairlie Lecture, awarded annually to an outstanding female academic (most recently Professor Dames Anna Dominiczak and Sally Davis); Newton Jung biannual Lecture in Diabetes (Professors Nick Wareham, Helen Colhoun and Andrew Hattersley); the annual Mackenzie Lecture in honour of Sir James Mackenzie, (pioneer in general practice research/ safe use of medicine), Professors Liam Smeeth, George Davey-Smith and Mark Caulfield): Jacqui Wood and Rees Memorial Lectures, established in 2016 and 2018 respectively for clinical and pre-clinical cancer research (Professors Adrian Hayday, Karen Vousden and Chris Wild).

Access to specialist Research Facilities
To best manage our core facilities, the major technology platforms have been incorporated into the **Centre for Advanced Scientific Technology (CAST)** housed in SLS but available to all UoA1. CAST provides the following services: Proteomics/Fingerprints; FACS analysis and sorting; X Ray Crystallography; Imaging and microscopy Electron Microscopy (transmission and scanning). These facilities are run by dedicated, qualified and experienced service managers. Comprehensive training is available across the facilities particularly for PGRs, PDRAs and ECRs.

Over the assessment period, we have invested over £6M in facilities for UoA1 staff in SM. These facilities are available to researchers across the University and to external clients, They operate on the basis of a sustainable fee-for-use business model, delivering quality service (operated to Industry standard), fast response to user demands and affordable prices for a “state-of-the-art” environment appropriate for our interdisciplinary research needs.

Biomarker & Drug Analysis/Mass Spec Facility: Provides analytical services for quantitative and qualitative analyses of soluble clinical biomarkers (potentially pathogenic material), drug compounds and metabolites (pharmacokinetics) with ultramodern LC-MS/MS instruments. Available to Dundee researchers, external academics (Universities of Nottingham, UCL, Cambridge, Edinburgh, Aarhus, Sarajevo) and commercial clients (GlaxoSmithKline, Mereo Biopharma, PH Biopharma). It has been Good Clinical Laboratory compliant since 2016.

Immunoassay & Biomarker Facility: Processes and analyses samples for biomarkers using various immunoassay techniques (includes ELISA, high sensitivity single molecule bead-based assay (Quanterix SIMOA HD-1) multiplex assays (Luminex Bio-plex 200 and MSD Quickplex SQ120), RIA and FACS (cell counting). Services are provided to Dundee researchers, external academics (Universities of Exeter, Birmingham and Edinburgh) and commercial clients (Pfizer, Polyphor, VHSquared). The facility is GCP certificated.

Behavioural Neuroscience Facility: Offers a range of rodent behavioural phenotyping, cognitive and social testing services and training for researchers wishing to conduct their own experiments within the facility. In 2018, metabolic profiling of cells and mitochondria to interrogate cellular bioenergetics (mitochondrial respiration and glycolysis) using the Seahorse XF24 analyser was added. External clients include Concept Life Sciences.

Tayside Centre for Genomics (TACG): Provides services, including next generation sequencing, microarray genotyping, Real Time PCR, and whole genome sequencing (WGS). TACG continues to grow and has recently benefited by investment from large external research awards, such as the £2.4M NIHR-Anti Microbial Resistance Capital award (**Marwick**). The facility has an Illumina

NovaSeq 6000 next generation sequencing system, an Oxford Nanopore GridION 3rd generation sequencing system. Recent investment in an 10X genomics platform supports a growing cross-School interest in looking at expression levels in single cells.

By incorporating innovative areas of research, we have created the opportunity to enter an expanding market for genome-wide microarray genotyping and WGS. This allows researchers to align genomic data with phenotypic data held in several study datasets (GO-SHARE, GO-DARTS, GO-TARDIS) through the Tayside Bioresource and with the prescribing data held within data safe havens of the Health Informatics Centre (HIC). These approaches have the potential to increase the effectiveness of medical treatments in precision medicine. Importantly, NGS technology is increasingly used for many biological readouts including RNA expression, splicing, epigenetics and nuclear chromatin architecture, and the facility provides a one-stop solution to run these. Clients include NHS Tayside, James Hutton Institute, Abertay and Glasgow Universities.

Image Guided Therapy Research Centre (IGTRF): Has received significant investment in research imaging, establishing unique MRI/CT/Fbeam interventions suites in the Clinical Research Imaging Facility and Wilson House to deliver research and training through translational initiatives between the SM and CAHID (Centre for Anatomy and Human Identification). By exploiting the unique physical properties of Thiel cadavers in image-guided therapy research, “functional” Thiel embalmed cadaveric models combined with medical imaging have been developed for advanced simulation training in image-guided procedures and medical device testing. IGTRF has formed strategic partnerships with Medtronic, Vascular Flow technologies and Animal-Free Research and has a growing commercial client base (MedAlliance, LimFlow, Cook Medical, Pathfinder Medical, Tricares and Perfuze). We have recently invested an additional £1.4M establishing an image-guided focussed ultrasound facility (led by Gilbertson) to investigate the use of focussed ultrasound in treatment of a wide range of neurological conditions, including tremor, Parkinson’s Disease and, potentially, cancer. This makes Dundee the second such facility in the UK, and we expect immediate and direct benefits to patients in the north of the UK.

Health Informatics Centre (HIC): Has the dual mission to safely and effectively support researchers to deliver world-leading research and to conduct its own world-leading research (led by **Jefferson**). HIC are embedded in the HDR-UK alliance, established to develop and apply cutting edge data science to address the most pressing health research challenges facing the public. HIC is an ISO207001 credited research environment (SAFE HAVEN), consolidating patient contact and recruitment, governance approval, software development, data linkage and data entry. In the last five years, HIC has supported a portfolio of over 600 separate research projects, generating £5.5M in income for services (total value of serviced research projects being £156M). In this period, HIC has provided 2,000 separate linked anonymised data extracts for research, developed bespoke software for 50 research projects and supported many recruitment projects involving 10-100s of thousands of participants (Mammoth, Drink Wise Age Well, STRADL, DOLORisk, SHARE).

HIC’s electronic medical data coverage encompasses Tayside and Fife (20% of the Scottish population) between 1972 and the present day, and national level data is held for the SHARE cohort. Using CHI numbers, patient cohort data can be aligned to Specialist Biobanks (GoDARTS, Generation Scotland, GoSHARE), eHEALTH records, public records, specialist data types and research databases (TASC FORCE, POPADAD, Trace RA). Impactful research, empowered by HIC, includes repurposing of metformin (**Lang**) and bronchiectasis and air pollution (**Chalmers**). Funded by the Chief Scientist Office, HIC has developed management software for Biorepository requests (portal for access to human tissue banks across Scotland), which is now being extended

through funding from HDR-UK. The development of "Trust" (Tayside Randomisation System) has over 700 users, mostly UK-based but with increasing reach into the rest of Europe. HIC also supports CRIP, EMBARC (**Chalmers**) and texting apps (TRAM, BRIGHT, SKIPIT, GAME OF STONES, MACRO) and developed websites (SHARE, GoSHARE, ChildSmile). The Scottish Medical Imaging Project (scale is 1.7 Petabytes), involving all 14 Scottish Health Boards, has access to 30 million image sets (CT, MRI, Ultrasound, Nuclear Medicine, X-ray). HIC is involved in collaborations that seek to develop clinical tests and associated AI algorithms to stratify patients with various conditions.

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

Effective collaboration at National and International level

UoA1 staff have collaborations across Scotland with several national NHS Research Networks continuing to be led from the Ninewells site, including those for Primary Care, Diabetes, Dementia and the establishment of SHARE. Collectively, these bring over £2M annually in infrastructure support to SM and have helped secure over £100M in external research awards from national funding bodies. SHARE underpins MRC Pathfinder grants in mental health research in both Edinburgh and Glasgow and is a key resource for the phase 2 of Generation Scotland (2020-2024), funded by the Wellcome Trust. The SHARE platform has also been licensed to Imperial Health Partners to deliver their patient register "Discover". To date, SHARE has 300,000 individuals signed up, ready to take part in medical research, and over 100,000 residual "spare blood" samples, stored for research instead of going into the clinical waste. This goes hand in hand with the fact that SHARE/HIC/Tayside Biorepository are developing the national governance and informatics platform for the NHS Biorepositories throughout Scotland.

Since 2015, UoA1 PIs have secured participant funding from EU H2020/IMI programmes in excess of £8.2M within research consortia worth £108M. Notable studies within this portfolio, led by UoA1 PIs are: Bronchiectasis (iABC consortium, **Chalmers**); biomarkers in diabetic kidney disease (BEAT-DKD, **Palmer**); biomarkers in atopic dermatitis (BIOMAP, **Brown** S); Hypo-RESOLVE study into hypoglycaemia (**McCrimmon**); Cardiomyopathy in T2D (CARDIATEAM, **Lang**); assessing risk and progression in T2D (RHAPSODY) and INTEGROMED (both **Pearson**); Omics-based strategies in endocrine hypertension (ENSAT-HT, **Jefferson**); and Trials@Home: Centre of Excellence (**Mackenzie**, **Macdonald**). These programmes currently rank us in the top 6 in Europe and 3rd in the UK for IMI funding and bring industrial collaborations, which lead to follow-on research (e.g. NovoNordisk PhD Studentship, **McCrimmon**).

The flagship of the University's Global Challenges Research is the £7M NIHR Global Health Research Unit on Diabetes Outcomes Research (**Palmer**), a collaboration with the world-renowned Madras Diabetes Research Foundation in Chennai (Dr V Mohan, Director). This research programme is comparing the characteristics of over 600,000 individuals with Type-2 Diabetes to deliver precision medicine for the condition in LMIC countries and, at the same time, capacity building with doctoral training of 11 students from India in health informatics, genomics and Big Data science. The programme has adopted 30 rural villages in Tamil Nadu, offering free diabetes screening and care; and, in collaboration with the Norgrove Foundation, sponsors the training of female medical students at the Moraa Educational Complex, Kabul (the first female only University in Afghanistan). We have also installed solar PV cells on the roof of the research centre in Chennai, supplying free power for the biorepository freezers.

Key collaborations across the University include the use of AI to analyse retinal images. This funding has leveraged two internal projects, one taking the precision diabetes theme to Nigeria and

Ethiopia, the other extending our impact case study on the use of brain natriuretic peptide levels as a cardiovascular risk predictor into the South Asian setting (**Lang**). The Indian collaboration has resulted in the MRC awarding a global challenges research fund project to assess High Intensity Bollywood dancing as an effective metabolic intervention in teenage Indian girls (THANDAV study). In March 2020, The NIHR Unit global platform for precision diabetes research was extended to Malaysia with a joint Malaysia-UK/Newton MRC award (PRIME, £337K). A large contribution to the respiratory health of India has also been seen with the development of the bronchiectasis register in India (**Chalmers**).

The **Male Reproductive Health Initiative** (**Barratt**) is a newly established and rapidly growing global consortium of key opinion leaders in research, medicine, funding and policy agencies, industry and patient support groups, who are progressing the significant task of accomplishing the goals of the strategic roadmap. Within this consortium of scientists and other specialists, we are addressing the global crisis in male reproductive health (declining sperm counts, increasing male reproductive system abnormalities, effects of advanced paternal age and paternal lifestyle) and the associated significant health conditions (diabetes, metabolic disorders and cardiovascular disease).

Interdisciplinary working of the UoA with other disciplines has been widely translated into impact as evidenced by speciality clinicians and biochemists “leaning in” to deliver novel paradigms in diagnosis and screening, including the iLFT (**Dillon**, **Dow**), the national FIT colorectal cancer programme (**Steele**, **Fraser**) and clinical management of bronchiectasis (**Chalmers**). Some of our academics’ research has changed guideline recommendations for prescribing with demonstrable impact on clinical care, in other words, lives have been saved by transitioning research into day-to-day practice. This includes cardiovascular-focused clinical pharmacologists (**Lang**, **MacDonald**, **Mackenzie** & **George**) and academic General Practitioners delivering significant impact on population health (**Guthrie**, **Morales**). Overall, our links to health informatics has been pivotal to all the submitted impact case studies.

The UoA has made substantial contributions to COVID-19 research, notably **Chalmers**’ involvement in the steering groups for a wide range of national and international COVID-19 research projects, including PHOSP and Atomic 2, as well as being the primary investigator on twoCOVID-19 specific clinical trials. **Chalmers** is also the Chair of the joint European and Chinese Respiratory Societies Task Force for COVID-19 and one of two UK representatives on the International COVID-19 Task Force.

Our core facilities contribute to the national research base providing services to national and international, academic and commercial entities, including the Tayside Clinical Trial Unit, the Health Informatics Centre, the Tayside Centre for Genetic Analysis and the mass spectrometry unit, which all provide services to academic researchers from other UK universities and research institutes and to commercial entities.

Public Engagement

UoA1 participates and leads important public engagement (PE) activities, supported by the School’s PE Working Group and through membership of the University’s Public Engagement Forum. The Group conducts outreach activities to develop relationships with Primary and Secondary Schools (including “in school” workshops for S5/6 pupils) across Tayside. ‘Doors Open’ events have run since 2016, consistently attracting between 100 to 200 visitors, who are able to gain a better understanding of all aspects of the School, including research, teaching, clinical trials and surgical skills.

SM staff take part in other outreach activities, including ‘Skype a Scientist’; ‘Soapbox Science’; Dundee Women’s Festival; Dundee Science Festival; University of Dundee Festival of the Future; MRC Festival. With funding from the Wellcome Trust, the Medical Imaging and Technology Group (part of IS&T) produced a "Medical Marvels” showcase in Medical Technology at the Dundee Science Centre. We work closely with PE managers from other organisations, including CRUK and ARUK, participating in lab tours and evening meetings in the School. SM staff work with Medical Research Scotland (‘Meet the Researcher Showcase’); Brain Awareness Week (‘Meet the Expert’); Perth Breast Cancer Support Group; Diabetes support groups; British Heart Foundation Supporters Group; Alzheimer’s Society; Maggie’s Centre and have been invited to speak at events in the Scottish Parliament.

In 2018, **Steele** & **Anderson** won the University’s **Stephen Fry Public Engagement award** for their contribution to setting up the *Centre for Research into Cancer Prevention & Screening*. The Centre works with the public to increase awareness of cancer risk, improve understanding of cancer-related health behaviour, and highlight the importance of screening and early detection initiatives through the activities of the Scottish Cancer Prevention Network. **Martins Da Silva** was chosen to participate in the BBC’s 2019 ‘100 Women’, showcasing the stories of inspirational women to a global audience of 426 million people a week (via TV, digital and radio platforms across the English-speaking world) and presented in 42 other languages. **Colvin** was nominated in the 2019 ‘Women of the Year’ awards, selected for their achievements and contribution to society. UoA1 staff (**Henderson**) also played a leading role in the preparation of the successful submission for the **Gold Engage Watermark** from the National Coordinating Centre for Public Engagement (NCCPE), where Dundee was the first University in Scotland and third in the UK to receive this distinction.

SHARE has been developed to inform the public on their potential role in medical research and has been consulted by NHS England for the development of a UK-wide COVID-19 Vaccine Trial volunteer database. As part of Medic Insight events (organised by senior medical students), SM PIs and staff are involved in introducing our research programmes to the next generation of medical and biomedical sciences students. The Medic Insight team partnered with the Dundee Widening Access to Medical School Society to organise an Exploring Careers in Healthcare event in May 2019, when more than 150 Year 1-3 Secondary School pupils and parents were introduced to opportunities to study medicine, dentistry, nursing and biomedical sciences in Dundee. During 2019, approximately 100 5th year pupils have attended one of 3 week-long Medic Insight programmes, where research-based sessions were led by our PIs and PhD students.

Indicators of wider influence, support and contribution to the wider research community

Honours and Fellowships: During the REF period, honours to UoA1 staff include: Order of the British Empire (**Belch**) and Commander of the British Empire (**Steele**); Fellowships of the Royal Society of Edinburgh (**Anderson**, **McCrimmon**, **Steele**, **Palmer**); Fellowship of the Academy of Medical Sciences (**Steele**); Fellowship of the European Respiratory Society (**Lipworth)**; Global Highly Cited Researchers List (**Palmer** 2010-2018, **Dinkova-Kostova** 2019).

Medals and Awards: Professor Sir Bob Edwards Memorial Lecture (**Barratt** 2014); Finalist in Best UK Research Paper (**Mackenzie** 2014); Scottish Crucible Leadership Development Programme Award Grant (**Morales** 2014); International Society of Pharmacoepidemiology Scholarship (**Morales** 2014); International Epidemiology Association Scholarship (**Morales** 2014); RD Lawrence Award from Diabetes UK (**McCrimmon** 2015); Diploma of Special Recognition, World

Cultural Council (**Brown** S 2015); Finalist in UK Research paper of the year BMJ awards (**Mackenzie** 2016); Circulation Research Best Manuscript Award (**Rena & Lang** 2016); National Expert European Medicines Agency (**Morales** 2016); Roger Harman Travelling Fellowship African Awards (**Brown** A 2017); EASD Minkowski Award (**Pearson** 2017); Winner of EACPT Scientific Award (**Mackenzie** 2017); Patrick Neill Medal from Royal Society of Edinburgh (Chalmers 2017); Scottish Crucible attendee (**Henstridge** 2018); Scottish Crucible Award (**Mordi** 2018); Grahame Smith Prize for Clinical Pharmacology (**Mackenzie** 2018); Independent Scientific Expert European Medicines Agency (**Morales** 2018); "Outstanding Contribution in Reviewing" JACI (**Brown** S 2017); Winner Innovation Award Excellence in Patient Care from Royal College of Physicians (**Dillon** 2019); European Society of Vascular Medicine Lifelong Achievement Award (**Belch** 2019); Winner UNIVANTS of Healthcare Excellence Award (**Dillon** 2019); Dorothy Hodgkin Lecture (**Pearson** 2020).

Visiting Professorships and Fellows (ongoing): Pharmacoepidemiology Aarhus University, (**MacDonald** 2014); University of Edinburgh (**Pearson** 2016) and University of Chinese Academy of Science (**Pearson** 2019); Visiting Fellow with the Cancer Council WA, Australia (**Anderson** 2015).

Research Fellowships and Programmes: Marie Curie Fellow (**Kang** 2014–2016); EU FP7 Marie Curie Incoming International Fellow (**Murdoch** 2014-2016); Wellcome Investigator Award (**Pearson** 2014-2021); Wellcome Senior Research Fellowship (**Brown** S 2015-2021); CRUK Programme Award (**Dinkova-Kostova** 2015–2021): CRUK Programme Foundation Award (**Saurin** 2016–2022); CRUK Career Development Award (**de la Vega** 2017–2023); Wellcome Clinical Research Career Development Fellowship (**Morales** 2019–2022); Scottish Government Chief Scientist Office (CSO) Clinical Research Fellowship (**Mordi** 2017–20); CSO Senior Clinical Academic Fellowships (SCATS): **Newey** (2016–2021), **Chalmers** (2018–2022), **Sammler** (2019–2024).

Participation in peer review: CSO Translational Clinical Studies Research Committee (**Chalmers** & **Petty**); CSO Clinical Academic Fellow Review & Interview Panel (**Petty**); Chair of CSO Population Research Committee (**Steele**); CSO Health Improvement, Protection and Services Research Committee (**Anderson** and **Marwick** (Vice-Chair)); Clinical Lead for Infection Intelligence Platform (**Marwick** 2014 – 2017); Wellcome Clinical Interview Committee Chair (**Pearson** 2020); MRC-Populations and Systems Medicine Board (**McCrimmon** 2018 onwards and **Palmer** 2019 onwards); Wellcome ERG Genetics & Genomics (**Brown** A, Chair). United Arab Emirates Government nominated expert for the review of the United Arab Emirates Healthy Futures programme 2018 (**Palmer**); Speciality Advisor in Medical Oncology to CMO (Scotland) (**Petty** 2010 onwards); External Reviewer University of Edinburgh Clinical Trials and R&D (**George** 2020), Expert Advisors to Government of Malaysia on Early Phase Clinical Trials (**Lang** and **George**, 2019).