Institution: Nottingham Trent University (NTU)

Unit of Assessment: A03 – Allied Health Professions, Dentistry, Nursing and Pharmacy

1. Unit context and structure, research and impact strategy

Overview of the Unit's strategic vision and key achievements

Since 2014, Nottingham Trent University's A03 Unit of Assessment (UoA) has grown significantly and is characterised by excellent, impactful and multidisciplinary research, building on the pedigree established in previous submissions:

- Continuing development and strategic recruitment of high calibre academics has created cross-disciplinary teams, with 34.0 FTE in scope in the UoA, up from 23.8 FTE in REF2014 and 14.0 FTE in RAE 2008.
- PhD completions have increased to 85, up from 40 in REF2014.
- In addition to the UoA's £3.68M of research income in REF2021 (REF4b), a further £3.77M was received for our cancer research via an NTU trust giving a total of £7.45m (§3.1).
- Strong economic and societal impact, recognised by a Queen's Anniversary Prize in 2015, has expanded further with Intelligent OMICS Ltd. generating revenues with pharma and biotech companies and through international drug trials and new spin-out Pharm2Farm Ltd. being acquired via a £2.37M share issue and having a market valuation of £40M by end 2020.

1.1 Unit Structure – Centre for Health, Ageing and Understanding Disease (CHAUD)

Research in the UoA is organised within an over-arching structure, the **Centre for Health, Ageing and Understanding Disease (CHAUD)**, which has amalgamated two previous Research Centres (van Geest Cancer Research Centre, and Biomedical, Life and Health Sciences). CHAUD's vision is to 'deliver world-leading research to tackle current and emerging global health challenges', dovetailing with the University's Health and Wellbeing Research Priority's ambition to 'improve peoples' lives through understanding disease, health promotion and illness prevention, addressing the social determinants of health, and developing interventions'.

To deliver this vision, CHAUD's research seeks to understand, detect, and treat both chronic health conditions and cancers with poor outcomes whilst also improving significantly lifelong wellbeing in an increasing older adult population. CHAUD's biomedical scientists, clinicians, biologists, chemists, mathematicians, bioinformaticians and computational modellers work collaboratively with a wide range of national and international partners and stakeholders to bring interdisciplinary approaches to bear on tackling major societal health challenges. Underpinning this endeavour is our expertise in the interrogation of the molecular and biological basis of disease by comparative analysis of the transcriptome, proteome, immunome, epigenome and microbiome in health and disease, using integrated high throughput 'omics' platforms and advanced statistical and computational modelling.

Research professor and clinician Rutella is the Director of CHAUD, responsible for the Centre's overall strategy and management, supported by a Deputy Director, Verderio, who is also the A03 Research Coordinator. An Advisory Group includes Heads of Department (Bioscience, Maths and Chemistry, within the School of Science and Technology), CHAUD Research Theme Leads (see below), the School Associate Dean for Research (ADR), and postdoctoral research fellows. The creation of an ADR in every academic school has been a major investment in research leadership during this REF period and connects CHAUD directly with the University Research Committee and University Leadership Team.

The CHAUD Advisory Group steers strategic investment, underpinning multidisciplinary working and dissemination activities, and fosters an inclusive research culture including running weekly

seminar series and supporting early career researchers (ECRs) and postgraduate researchers (PGRs). The ADR, supported by the School Research Committee, has oversight of CHAUD strategy and activities. This ensures complementary support for, and cross-disciplinary working with, the School's three other Research Centres. CHAUD has expanded on the UoA's two platforms in REF2014 (Health and Disease; Enabling and Cross-cutting Technologies) and is now organised into 4 Research Themes that coalesce expertise (§2.1.1) and activity into groupings of externally credible critical mass.

Cancer Biology, Immunology and Therapeutics Research Theme (CBIT) (from within Health and Disease platform in REF2014).

Lead: Pockley.

Research: fundamental and translational research into prostate and breast cancers, haematological malignancies, pancreatic cancer and glioblastoma multiforme, focusing on patients with low median survival rate.

Aim: improve patient diagnosis and treatment, enable patient stratification through investigating molecular targeted epigenetic therapies.

Diabetes, Chronic Diseases and Ageing Research Theme (DCDA) (from within Health and Disease platform in REF2014).

Lead: Christian.

Research: pathophysiology of type 2 diabetes, inflammatory-based chronic diseases (kidney, respiratory, cardiovascular, gastrointestinal), and neurological diseases of ageing (Alzheimer's, Parkinson's), relevant to obesity and associated metabolic diseases.

Aim: understand molecular mechanisms of cell dysfunction leading to disease and identify potential new targets for therapeutic intervention.

Antimicrobial Resistance, Omics and Microbiota Research Theme (AROM) (from within Health and Disease platform in REF2014).

Lead: Hoyles.

Research: applies classical microbiology (aerobic, microaerophilic, anaerobic), molecular biology, systems biology, and bioinformatics to study host–microbe interactions, phage biology, pathogen evolution, population genomics and epidemiology, antimicrobial resistance, development of novel antimicrobials and the human microbiome in health and disease.

Aim: to define the contribution of the microbiome and its metabolites to obesity, diabetes, and neurological disorders.

Underpinning Technologies Research Theme (UTec) (Enabling and Cross-cutting Technologies platform in REF2014).

Lead: Ball.

Research: computationally intensive simulation of multicellular systems using cellular automata models, modelling of complex biological systems e.g. applied to neuronal signalling within intricated network structures, modelling of biomolecule functionality.

Aim: mathematical statistical, computational, and synthetic chemistry approaches applied to biological challenges, to provide new enabling tools for biomedical applications and increase the multidisciplinarity of our research.

1.2 Research and Impact strategy

1.2.1 Achievement of REF2014 Research strategy

In REF2014 (REF5) we aimed to promote excellence in our UoA's research through: (i) major investment in staff including targeted recruitment of staff of a range of seniorities, nurturing the potential of ECRs, and supporting grant capture in niche areas; (ii) transformative investment in

infrastructure; (iii) deployment of investment in our cancer research to focus on linking biomarker discovery and immunotherapy, supported by patient group involvement and clinical links; and (iv) delivery of advances in niche research areas, via collaborative working and multidisciplinary working, including with the Anthony Nolan facility and with industry. These aims have been achieved and significant outcomes have been delivered, as follows:

(i) The research capability of the UoA has been strengthened in the period with 23 new external appointments of international standing across all of the CHAUD Research Themes, including two 'tenure-track' 5-year independent research fellows (§2.1).

An indicator of this success is the UoA's accelerating externally funded research profile, with £1.2M of the external research grant income secured by A03 investigators in the final year of the REF2021 period (AY2019-20) with major grants extending beyond the REF2021 period (§3.1). The UoA has grown the diversity of funding sources across CHAUD's Research Themes, encompassing UKRI, UK charities, international non-profit organisations, trans-national funders, and industry (§4.2.3). The UoA has 10 funded projects with NHS Trust or international hospitals, e.g. the NIHR Phase II 8-center ASTIClite clinical trial (§3.1; §4.2.1).

(ii) Investment in new buildings included the Interdisciplinary Science and Technology Centre (ISTeC, £11m, 2018), and the Medical Technologies and Innovation Facility (MTIF, £23m, 2020) (§1.2.2, §3.2). £1.7M equipment capital investment has ensured that our pre-existing Interdisciplinary Natural Sciences Research and John van Geest Cancer Research Facilities remain at the cutting edge (§3.2).

(iii) Our cancer research activities, funding, and stakeholder engagements have grown and broadened in scope, supported by investment in facilities (§3.2) and strengthened by appointments across the range of seniorities (professor, associate professor, two lecturers, senior independent research fellow) (§2.1) embracing technological developments in the molecular biology and translational spaces. Research includes projects on: understanding and diagnosis of aggressive prostate cancer pathways (Pockley and Rees) supported by The Roger Counter Foundation and Healthcare and Bioscience iNet (*Oncogene*, 2016; *eLIFE*, 2020); epigenetic therapies (Hatziapostolou) supported by Pancreatic Cancer UK (*Gut, 2019; PNAS, 2020*); cancer imaging and diagnostics supported by Deutsche Forschungs-gemeinschaft (Germany); cancer immunoprofiling (Rutella) supported by U.S. based biopharmaceutical companies; and identification and clinical validation of molecular drivers of proliferation and response to chemotherapy in breast cancer (Ball) (*Lancet Oncology*, 2016). CHAUD and our spin-off Intelligent OMICS provided collaborative PhD training on the EU 'Training Network for the Immunotherapy of Cancer' and will host PhD exchanges on the T-OP ITN (Rees, Pockley, Ball) (§2.2.1).

(iv) Work with the Anthony Nolan facility has included Rutella and Pockley's project on 'Correlating the cellular content of umbilical cord blood transplants with clinical outcomes', and joint publications, e.g. Rees (*Vox Sanguinis*, 2015).

The UoA's international research collaborations with government organisations (Scopus/SciVal) incorporate: CNRS, Institut national de la santé et de la recherche médicale, National Research Institute for Agriculture, Food and Environment, and Institut de recherche pour le dévelopement in France (19 joint papers); German Research Center for Environmental Health and Cancer Research Center (9); National Institute of Health, USA (8); Chinese Academy of Medical Sciences, Chinese Academy of Sciences, Jiangsu Academy of Agricultural Sciences, and Ministry of Ecology and Environment (7); and Agency for Science, Technology and Research, Singapore (2). Our 24 joint papers with industry labs range from ones with Novozymes A/S in Denmark, Razi Vaccine and Serum Research Institute in Iran and Sony in Japan, F. Hoffmann-La Roche AG in Switzerland to Eli Lilly in the U.S. Exemplars of our collaborative work are given in (§4).

1.2.2 Achievement of REF2014 Impact strategy, and Enabling and Facilitating Impact

In REF2014 (REF3a) we aimed to deliver research impact through: (i) promoting and supporting end-user engagement; (ii) capitalising on links with the BioCity Nottingham incubator,

and working with external NHS and industrial representatives; and providing staff with excellent (iii) peer and expert support and time, and, (iv) resources. These aims have been achieved by the following activities that have enabled and facilitated our impact:

(i) Our impact case studies showcase our extensive end-user engagement and major beneficial impact. Ball and spin-out company Intelligent OMICS (formerly CompanDX) are exploiting NTU-s AI-based algorithms, bringing better healthcare to the military (with U.K. and U.S. Defence Labs, DSTL and DTRA), and working with Wuhan Pulmonary Hospital (China) on phase 2A clinical trials that enable patients with latent tuberculosis to receive treatment. Cave and spin-out company Pharm2Farm have worked with suppliers and agrochemical manufacturers, and with end users, including South Korean farmers and an Indian co-operative, improving their plant and crop yields. Rutella's clinical trial contributions include identifying patients with a chemotherapy-refractory form of acute myeloid leukaemia unlikely to benefit from cytotoxic chemotherapy, so avoiding debilitating overtreatment.

(ii) We have secured £9.7m competitive D2N2 Local Enterprise Partnership (LEP) Local Growth Fund co-funding for the £23m Medical Technologies and Innovation Facility (MTIF, opened 2020), including a research centre at the University and a technology and prototyping centre on the Boots Enterprise Zone (§3.2). The overall bid was led by Barnett (former A03 professor) and conceived with NTU's strategic partners: MediCity Nottingham (part of the BioCity family); Medilink East Midlands; Cheata Clinical Trials; Derby Teaching Hospitals NHS Foundation Trust; Nottingham University Hospitals NHS Trust; and Boots plc. Market insight was provided by 25 CEOs/MDs responsible for business growth and new product development of D2N2-based healthcare companies. The UoA's wider extensive work with NHS Trusts, international and national hospitals and medical centres, industry and industrial networks is detailed in (§3.1; §4).

(iii) Support for UoA researchers at all career stages has facilitated impact. School-based initiatives with PhD researchers (§2.2) and staff including research fellows (e.g. Fast Track Impact workshop by Prof Mark Reed) have contributed to researchers' ability to identify and communicate research impacts. The expanded University Knowledge Exchange team provided online and in person training on IP/exploitation. An 'impact sabbatical' (§2.1.2) was provided for Impact Case Study lead, Cave, who was then released at 0.2 FTE to spin-out company Pharm2Farm. We have held industry showcase events at our PhD and ECR focused Science and Technology Annual Research Conference and held regional networking events supported by NTU's Enabling Innovation Programme (ERDF funded). NTU's Knowledge Exchange support service has also enabled licence agreements with spin-out company Pham2Farm Ltd, with Agrimin (supporting an Innovate UK project) and with 2B Scientific Ltd, as well as facilitating new collaboration agreements (UCB Pharma UK; Ultimovacs AS, Norway; Altevax SAS, France), joint PhDs with industry (UCB Pharma; NanoString Technologies Inc., USA) and agreements for sample analysis and access to specialist instrumentation and know-how (Scancell Holtings Ltd.; Crown Bioscience).

(iv) NTU support of some £366k for the development of the impact showcased in our Impact Case Studies has included patent filing and maintenance costs (£113k), engagement of external technology transfer consultancy advice (£105k), researcher support and travel (£28k), and PhD studentships (3 in REF2021 period, £120k stipend plus tuition fee).

1.2.3 Future Strategic Research and Impact Objectives

Our strategy for the next REF period will capitalise on our interdisciplinary approach and significant investment in this cycle into state-of-the-art enabling technologies and outstanding staff. Rather than having separate strategies, our research and impact are approached synergistically.

(i) Focus on pre-clinical, translational and clinical research, prioritising challenging-to-treat diseases and chronic health conditions in our core research areas. We will continue to realise our aim of improving people's lives nationally and globally, building from the work showcased in our Impact Case Studies (§1.2.2). Ball's in silico methods will underpin the development of SPAG5 as a biomarker of proliferation in breast cancer, enable latent tuberculosis biomarker IP to be exploited in China, and provide validated biological drug targets that will be exploited

by top 10 pharmaceutical companies. Cave's nanoparticle fabrication and functionalisation technologies will be developed for anti-viral facemasks, inks, disinfectants, and lateral flow devices, and to improve global food security via enhanced bioavailable ruminant feeds and in fungal protection treatments for crops. Rutella will pursue investigational therapies that exploit genetically engineered T cells for leukaemia and for advanced haematological malignancies, with major UK and US Cancer Centres. We will develop biomarker stratification by examining urinary extracellular vesicles to aim to predict the progression of Chronic kidney disease with UCB BioPharma Ltd.

(ii) Support our best basic science with programmes conducive to discovery that can be applied to patient care. For example, basic research into stem cell metabolism and adipocyte regulation in the areas of metabolic reprogramming and obesity continues to be supported by BBSRC. Links between host health and the gut microbiota (host–microbiota co-metabolism) will be explored with funding in place from GutsUK, Diabetes UK and EU Horizon 2020 ATHLETE in the next REF cycle (§3.1).

(iii) Ensure sustainability of our research, expanding our capacity and engagement with relevant national and international organisations, aligning applications with UKRI strategic priorities, the NIHR translational programme, and Horizon Europe 2021-27, including through the UoA's strong links with the NHS and Healthcare suppliers. Our recently awarded DTP with the University of Nottingham and the National Biofilms Innovation Centre (BBSRC funding of £15M, DTP3 2020-2024, §2.2.1) will provide significant collaborative opportunities.

(iv) Grow capabilities in data science and develop and sustain our culture of data sharing and openness in clinical trial and biomarker data. We will recruit further high calibre staff to strengthen our existing interdisciplinary computational team and expand data-driven research, including through our participation in a responsible data sharing in immuno-oncology initiative (Society for Immunotherapy of Cancer SITC; U.S.A.). We will accelerate work to further generate and share health-related research data, engaging with research council strategies.

(v) Support impact generation of our budding basic and translational research programmes, continuing to bring together scientists from different specialities to find creative solutions to global health challenges. MTIF (§1.3; §3.2) will support early-stage innovation to translate discoveries for medical use, engaging regularly with NHS and national/international industrial representatives. The UoA will support and promote applications to schemes such as Royal Society International Exchanges, US-UK Fulbright Award, Newton Fund and BBSRC International Travel Grants to assist with building partnerships.

1.3 Approach to Interdisciplinary Research

The UoA's interdisciplinary and multidisciplinary research has been supported by investment and facilitated by NTU's School of Science and Technology, in which CHAUD is one of 4 Centres:

- A03's intra-Theme collaborations include: McArdle (CHAUD's CBIT Research Theme) and Hoyles (AROM) on the role of microbiome-associated metabolites on the blood-brain barrier supported by HeadCase Trust; Al-Ahmady (Early Career Researcher in DCDA) and Cave's (UTec) work on Alzheimer's disease supported by The Marmont Trust; and Verderio (DCDA) and Ball's (in both UTec and CBIT) work on enabling kidney fibrosis interactomes with funds from Kidney Research UK.
- A03's work with the C24 UoA (Sport) includes: the effects of the histidine containing dipeptide carnosine on the metabolism of cancer cells (McArdle and Turner in A03; Sale in C24) underpinned by seedcorn funding from the University's over-arching Health and Wellbeing Research Priority; and examining a potential role for carnosine in cardiac function (Turner in A03; Doig, Sale and Elliott-Sale in C24) through a PhD project supported by Natural Alternatives International (U.S.A.) by the match-funding scheme from NTU's Doctoral School.
- The EU Horizon 2020 sustainable beekeeping project B-GOOD brings together experts in apiculture, bee physiology and pathology, assay development, ecology, agricultural science, socio-economics, engineering, modelling and data mining, from the public and private sector,

and from 5 SMEs and non-profit organisations. The NTU contribution uses smart electronics technologies (Newton in B12 Engineering UoA) to monitor honeybee hives (Bencsik in C14 Geography and Environmental Studies UoA) and extract complex sequences (Chuzhanova, A03 UoA).

1.4 Strategy for an open research environment

Our arrangements here are designed to promote effective sharing of research and data. All the UoA's full text outputs are deposited in the Institutional Repository (IRep) and deposition of manuscripts as preprints, when allowed, is encouraged. The UoA and the University have funded Open Access (£130k), for example including for U.S. journals that would otherwise only provide restricted public access (e.g. *Journal of the American Society of Nephrology*; *Gastroenterology*). Full research data have been routinely uploaded to public open archives: PRIDE for proteomics; NCBI's GEO for large datasets; GitHub repository for Java codes; and ArrayExpress for transcriptomic data.

Research data and GDPR management training is provided at University level. The UoA's PhD students each produce a data management plan and are trained in the culture of open access and securing data in accessible locations.

To enable research reproducibility, NTU seedcorn internal funding to Pockley (£25K) has strategically supported the establishment of good clinical laboratory practice in the UoA, which is a requirement for NIHR-funded projects. To qualify the UoA for clinically aligned projects in the REF period, Quality Management Systems (QMS) have been implemented according to the practices of 'Quality in Non-Regulated Scientific Research'.

1.5 Supporting a culture of research integrity

We are committed to the highest standards of research integrity and the relevant professional frameworks including the Concordat to Support Research Integrity. Matters relating to research integrity, including research ethics, Code of Practice for Research, and a Responsible Metrics Statement are overseen centrally (see REF5a) and managed locally. Robust scrutiny of projects requiring ethical approval undertaken by staff and PhD candidates within the UoA is overseen by specific School of Science and Technology-wide Research Ethics Committees (invasive human, non-invasive, animal, GMO work). This approach ensures projects are scrutinised from different disciplinary perspectives. Researchers who work with human samples must undertake training on the Human Tissue Act and its related codes of practice. For animal work, our scientists employ NC3R-developed experimental design tools (§3.3).

University-wide training resources are available to all staff and students through online modules which cover more general aspects of research integrity. This central resource complements training arrangements at local level, which are designed to meet the needs of specific committees. Our library Research Data Management Officer provides advice and support on GDPR and safe and secure data archiving. Training on good research practice is promoted as part of ongoing professional development. The UoA's 'Statistical Taskforce' (led by Chuzhanova, with Crofts, Ball and Hoyles) has provided support for researchers on statistical analysis, power calculations and advice on 'big data' management. Cross-UoA training initiatives included *R* statistical package courses, jointly with the Computing UoA, and a hands-on MinION sequencing workshop (delivered by Dickins and Thomas). Aspects of ethics and integrity are also addressed in the GDPR, equality and diversity, and unconscious bias training that is required for all staff members.

2. People

2.1 Staffing and Staff Development

2.1.1 Recruitment and staffing strategy

Our staffing and recruitment strategy has been to appoint and develop excellent research active staff and PhD students to create sustainable teams in our priority areas. We have proactively

enabled their success through infrastructure investment (§3.2) and strategic research development funding; £2.88M of University internal investment has been disbursed within the UoA since 2014. Of the 23 new external appointments in the REF2021 period, twelve are ECRs, including two 5-year independent research fellows (IRFs) with a well-defined and supported progression route to academic posts.

There is balanced representation across seniority levels within the UoA, with 5 professors, 4 associate professors, 23 lecturers/lecturer lecturers, and 2 independent research fellows. All Category A staff are permanently employed. Senior staff (professors and associate professors) provide leadership of CHAUD and its Research Themes (§1.1) along with high-quality mentoring support across the UoA.

Research capability has been strengthened in the period with strategic external appointments of international standing across all four CHAUD Research Themes.

- CHAUD's Cancer Biology, Immunology and Therapeutics Theme has focused on linking biomarker discovery and immunotherapy with the support of clinical links. The professorial appointment of Rutella (previously Executive Director of Clinical Research, Sidra Medical and Research Center, Qatar), a clinician with >25 years expertise in immunogenomics, strengthened personalised cancer research established by Pockley and Ball. We have invested in epigenetic research with the strategic appointment of Polytarchou (UCLA) to associate professor, bringing expertise in inflammatory bowel disease and cancer, and Hatziapostolou (University of Southampton) as senior independent research fellow. New lecturer/ECR appointments Coutts and Ahmed (both University of Oxford) have reinforced translational research.

- CHAUD's Diabetes, Chronic Diseases and Ageing Theme has been formed by increasing our expertise in metabolic diseases and complications with two professorial appointments McTernan and Christian (both University of Warwick), and lecturer/ECR recruitments Antonysunil (University of Warwick) and Hulse (University of Nottingham) , in order to complement and expand on the existing expertise of Turner, Verderio, Hargreaves, and Dickenson. Aging research, including neurodegeneration and inflammation, was bolstered by the lecturer/ECR appointments of Brookes (University of Nottingham), Al-Ahmady (University of Manchester) and El-Sherbiny (University of Leeds) and independent research fellow Ugun-Klusek (internal staff development, §2.1.3).

- CHAUD's Antimicrobial Resistance, Omics and Microbiota Theme continues to focus on genomic epidemiology. The scope and strength of the Theme has been significantly expanded by the appointment of Hoyles (MRC intermediate research fellow, Imperial College London) to associate professor (subsequently promoted to professor) bringing expertise in microbiomics and metabolomics, McLean (University of Nottingham), bringing new expertise on antimicrobial efficacy of metals, and the appointment of 3 lecturers/ECRs, Leo, Negus, and McVicker and 2 lecturers, Winter (University of Nottingham) and Thomas (University of Bolton) bringing additional complementary expertise.

- CHAUD's Underpinning Technologies Theme has been strengthened by the appointment of lecturer/ECR Cross (University of Leicester), who brings expertise in innovative chemical synthesis, complementing Cave's work in nanochemistry. The appointment of Campeotto (Wellcome Trust ISSF Fellow, University of Leicester) builds computational science expertise, complementing the work of Crofts, Ball, and Dickins.

2.1.2 Staff development strategy

Staff development is coordinated by the CHAUD Director (§1.1). In line with the UK Concordat to Support the Career Development of Researchers, a range of opportunities are offered, tailored to career stage. Our mentorship programmes provide all staff below professorial level with a senior research mentor (professors or associate professors), to complement support through the Department-run annual appraisal system including Individual Research Plans to identify short-term goals and longer-term career objectives. Developing funding applications through individual peer-review and sandpits aids colleagues to transform new ideas into stronger project proposals. Internal funding (§2.1.1) provides for short-term pump-prime studies to strengthen proposals.

Sabbatical leave has been provided across all CHAUD Research Themes to allow concentration on research, impact and building collaborations. Six-month sabbaticals were awarded to: Turner, who wrote grant applications on sabbatical leading to funding awards from Diabetes UK and the British Council for PhD studentships; Dickins, who developed machine learning techniques to dissect very large RNA Seq datasets; and Cross, who expanded research activities in peptide-drug conjugates chemistry (*Organic Letters*, 2019). Ten-month sabbaticals were awarded to: Cave, enabling impact development (§1.2.2); and Polytarchou, who developed US research collaborations (§4.2).

The UoA has also provided conference travel/fees support (circa £20k/year, 2014-2020) to UoA staff and PhD research students. The institutional workload planning model is designed to ensure sufficient time for research activities; in addition, the Biosciences Department achieved a 16% reduction in overall teaching time and 28% reduction in assessment time during 2018-2019.

Examples of senior progression include: Professor McTernan to School Associate Dean for Research (2020); Professor Rutella to Director of CHAUD (2019); Associate Professor Verderio to UoA Research Coordinator (2018); and Associate Professor Hoyles to a professorship in 2020. The University operates a performance reward scheme, including financial bonuses, through the annual appraisal process with an equality assessment exercise undertaken via moderation. The University also celebrates research success with Ball and Rutella being awarded Vice Chancellor's Outstanding Researcher Awards in 2018 and 2019, respectively.

2.1.3 Ensuring a vibrant and inclusive research culture

The UoA benefits from a vibrant community of research assistants and research fellows from around the world (35 in the REF period). Postdoctoral staff are actively supported in their transition to academic or non-academic posts by the School's Staff Development Programme and via the University's appraisal framework, involving regular career development meetings with senior academics. Staff undertake a bespoke programme, offered through NTU's Researcher Development Gateway, to assist career planning and grant writing. There are also opportunities to gain teaching experience and qualifications. Typically, our postdoctoral fellows progress to industry or academia. An example beneficiary of this support is Ugun-Klusek, who obtained an MSc and PhD at NTU, and was awarded a 5-year Independent Research Fellowship in 2014.

Nurturing Early Career Researchers (ECR) through support is key to our long-term development strategy; ECRs constitute 35% of the UoA composition. ECRs have access to, and have benefitted from, internal funding schemes, including capital equipment, consumables budgets, and short pump-prime project funding. Around half of the UoA's ECRs have been provided with University funded PhD students as Director of Study in the REF period, with senior academics in mentoring roles as second supervisors. ECRs have received start-up packages to facilitate the transition of their research at NTU, for example tissue culture laboratory facilities, bench refurbishments, and new equipment. They have also benefitted from reduced teaching and administrative loads for ECRs (typically, in the Department of Biosciences, a reduction of 60% in Year 1, 30% in Year 2 and 10% in Year 3 from initial appointment). Project proposal development sandpits have benefitted ECRs (2015-2018), as evidenced by ECR successes with starting grants (§3.1). Springboard Champion, Christian, is supporting ECRs in their applications to the Academy of Medical Sciences Springboard Scheme (awards up to £100,000 over two years).

2.2 Research Students

2.2.1 PhD funding and recruitment

The expansion and support of the UoA's postgraduate student community is core to the success of our research environment. The University has provided internal funding for at least 7 PhD Scholarships per year in the UoA, plus a CARA studentship for refugees in the UK. The UoA provided consumables funding to enable work of the highest quality. A further 3 part-time PhD students study as academic associates with a concurrent 0.5FTE 5-year Lectureship, promoting career development (see also IRF, §2.1.1).

Collaborative PhD research has been promoted via joint funding. Our University-Industry Scheme has match-funded PhD projects with UCB Pharma Ltd and Nanostring Technologies Ltd. NTU provided strategic leadership of University Alliance's DTA Applied Biosciences for Health, UA-DTA, with subsequent successful capture of EU Horizon 2020 Marie Skłodowska-Curie Action co-funding (£600k).

Full external PhD research project funding involves BBSRC CASE, European Foundation for the Study of Diabetes, and the British Council. PhD studentships in A03 and in spin-off Intelligent OMICS have been externally funded via our participation in the EU H2020 IMMUTRAIN ('Training Network for the Immunotherapy of Cancer', €273k to A03, 2016-2019) partnership of 9 academic institutions and 5 industrial partners across 7 countries. We will host PhD researcher exchanges on the new EU Marie Curie ITN T-OP ('Training Network for Optimizing Adoptive T cell Therapy of Cancer', 2021-2025).

The new Nottingham BBSRC funded Doctoral Training Partnership (£15M, DTP3 2020-2024) is a collaboration between University of Nottingham (UoN), NTU and the National Biofilms Innovation Centre. This DTP builds from strong NTU/UoN collaborations, including joint PhD supervisions, an NTU/UoN Microbiology Forum, and both joint papers and grants (e.g. NIHR and MRC). A03's expertise and infrastructure underpin the DTP's training foci in Biotechnology and Biosciences for Health, building from our UA-DTA leadership (described above).

Fair and consistent admission is ensured by the School of Science and Technology level Postgraduate Research Tutors who chair PhD interviews. PhD applicants are required to have an MSc degree (with Merit) or a first-class or 2:1 BSc Honours degree. EDI data on enrolled PhD students is available at School of Science and Technology level; our gender balance is the same as the Sector (HESA) whilst our PhD population is considerably more ethnically diverse than the Sector (HESA).

2.2.2 PhD development, support, and training

The NTU Doctoral School provides admissions, enrolment, progression, and viva administration support, whilst the School Postgraduate Research Tutor provides coordination of, and support for, the PhD community. PhD students are represented on the School's and University's Research Committees. Supervisory teams include at least two NTU staff, with at least one having supervised to successful completion. All supervisors receive School and University level training to support their role and are invited to meetings of the School's Supervisors Best Practice Forum. External co-supervisors or advisors are encouraged for match-funded PhDs. PhD students typically meet with their supervisors weekly in the UoA. Progress monitoring support at 6-monthly intervals, includes Month 6 Project Approval and Month 18 Transfer from MPhil to PhD events. An experienced Independent Assessor is appointed to assure annual monitoring, project approval and MPhil/PhD transfer processes.

PhD students receive induction and training in research methods, management and knowledge transfer through courses provided by the UoA, School and/or NTU Doctoral School. They are invited to participate in a rolling programme of professional development, the NTU Doctorate*Plus* Programme, directly mapped to the Vitae Researcher Development Framework. The 'Teacher Training for PGRs' programme launched in 2019 has guided four PGRs to attain Associate Fellow of the Higher Education Academy. Since 2018, the UoA's PhD students have benefited from an informal weekly PhD community event led by the Head of Department of Biosciences, which has supported the development of a cohesive cohort, exchanges of methodologies, and promoted

access to facilities, collaborative student work, and mental health awareness. Our PhD students participate and present in School of Science and Technology research seminars. Our annual 2-day School Research Conference includes PhD students and postdoctoral research fellows on the organising committee and chairing sessions, mentored by the Associate Dean for Research. ECRs and PhD students actively contribute to the NTU/UoN Microbiology Forum (§2.2.1). The UoA's PhD students have won best paper awards, including Furini 'Best abstract' (young authors) at 52nd ERA-EDTA 2015 Congress of the European Renal Association and Hanafy 'Best Poster presentation' at Royal Society of Biology 2019 PG symposium. External PhD travel awards have been received from IBRO (International Brain Research Organization, £5K), Newton-Bhabha Fund for one student mobility (~£10K), FEBS Young Scientist's forum, and Gordon Research Seminars (£1500).

Positive indicators (measured at School of Science and Technology level) of the success of our recruitment, development and support policies and structures include high overall satisfaction amongst PhD students: 84% in the 2019 Postgraduate Research Experience Survey, 3% higher than the Sector. The UoA has a high completion rate in 4 years: 78% in 2019/20. Overall, the UoA's PhD completions during the REF2021 period have increased to 85, up from 40 in REF2014.

2.3 Strategies and support for, and promotion of equality, diversity, and inclusivity

Across all academic and research staff in our School, 32% identify as women (28% in 2014), 16% identify as Black Asian and Minority Ethnic (BAME) (13% in 2014), and 4% declared a disability in 2019 (4%in 2014). 35% of the UoA's research staff are from BAME communities. 50% of the PhD students, postdoctoral researchers and technical support staff recruited in the period post 2014 are international.

We recognise that diverse teams encourage more creative and innovative solutions to research challenges. EDI support for the UoA is provided at the School of Science and Technology level. Our School Athena Swan Champion coordinates activities including nominations to the Advance HE Aurora programme (two from A03 in this REF cycle), events for International Women's week, Black History month, LGBT History month, the installation of an on-campus nursing room for nursing mothers, and maintenance of an EDI intranet with links to staff networks, policies and resources. Recruitment processes across the School have transitioned through gender decoding of recruitment materials and mixed-gender interview panels, to attract a more diverse staff pool. Staff training improves knowledge and understanding of equality and diversity within the workplace. We have introduced essential unconscious bias training for all staff.

The UoA supports NTU's institutional target to increase the representation of women within the professoriate to 35% by 2022. A03 is making progress with 20% female professors and associate professors. We encourage a flexible and inclusive approach for staff working from home or remotely. The University Support of Academic Returners scheme funds up to £5K following a period of caring-related leave to support career pathway development. The UoA has prioritised several internal funding requests related to flexible working arrangements or parental leave (e.g. £5k contract extensions or variations).

Staff perception of EDI issues is very positive. The 2018 staff survey (run by independent company Capita) collected responses at departmental level. In the Department of Biosciences, of which a significant proportion of UoA staff are members, there was an aggregate average 95% positive response to EDI questions on equality of opportunity, including EDI awareness and the University's approaches to respect and equality of opportunity. 100% of colleagues who responded said that the workplace is free from harassment and bullying. The University was awarded the bronze Athena Swan charter mark in April 2019 (see REF5a) and targets a silver submission in 2023. Departments that manage staff who are within A03 are developing action plans towards departmental Athena Swan submissions from 2022.

Our UoA REF submission and output portfolio were developed in accord with our institutional Code of Practice. Category A staff were advised by email about the window for the voluntary declaration of Individual Staff Circumstances, and the University's Head of Equality, Diversity, Inclusion and Wellbeing provided a Q&A session and debrief for our Research Centre, explaining what the process is, how it works, how reductions work, and emphasizing that the process is voluntary.

3. Income, infrastructure and facilities

3.1 Income

The UoA attracts a diverse stream of research income, reflecting its multidisciplinary and international strengths. The UoA has grown the diversity of funding sources across the UoA's CHAUD Research Themes, encompassing: UK Government funding organisations (BBSRC, National Biofilms Innovation Centre via BBSRC/STFC/Innovate UK, National Institute for Health Research); UK charities (e.g. Rosetrees Trust, Guts UK, Tropical Health and Education Trust); International non-profit organisations (e.g. Crohn's and Colitis Foundation, U.S.A.); trans-national funders (EU Horizon 2020); and industry. Specific examples of the latter include: diabetes and kidney disease research grants totalling £204k including to McTernan from UK Charity Novo Nordisk Research Foundation, to Verderio from UK company UCB Pharma Ltd and to Hulse from European Foundation for the Study of Diabetes (ongoing); Rutella's cancer research which has received £216k International funding from Macrogenics, Kura Oncology Inc., NanoString Technologies (U.S.A.) and Sidra Medical and Research Centre (Qatar National Research Fund); and Pockley and Polytarchou's work with St Bartholomew's Hospital on the National Institute for Health Research ASTIClite project (£518k to NTU, 2018-2022) (§4.2).

As a result of the UoA's underpinning focus on translational research, and greater engagement with international and industrial stakeholders (§4.2), we have attracted research income totalling £3.68M in REF2021 (£3.51M in REF2014). In addition, a further £3.77M was received in the current period for our cancer research via the John van Geest Cancer Research Trust, established with a major donation from the Van Geest Foundation. Our drawdown from the Trust has supported research facilities, salaries of seven research fellows and assistants, and two research officers.

There is an ascending trajectory of external investment in the UoA's research, with £1.2M external research grant income secured in the final year of the REF2021 and major grants extending beyond the REF2021 period awarded to: Christian (BBSRC grant BB/P005209/2, 10/2019-08/2021, £161k); Pockley (UKRI Covid-19 response project 73437, 10/2020-03/2022, £104k to NTU, £2.4M total budget); Cave (Marmont Trust, 01/2020-12/2022, £118k); and Hoyles (Diabetes UK, 09/2020-08/2024, £83k, EU H2020 ATHLETE, 01/2020-12/2024, £377k to NTU, 21 partners and €12.0M total budget).

Three of our ECR staff have attracted funding for pilot studies, including Coutts (Wellcome Trust Seeding Award for the study of autophagy in cancer), Brookes (Alzheimer's Disease UK) pump-priming grant, and Hulse (European Federation for the Study of Diabetes grant).

Benefits-in-kind received include £350k from ABSciex towards Pockley's proteomics research, £18k of cloud compute credits from Oracle Corporation to support its collaboration with Dickins and Ball on Machine Learning over transcriptome data, and Campeotto has received free time on the Diamond Synchrotron Light Source (Didcot, Oxford), SOLEIL synchrotron (St. Aubin, Paris), and ALICE High-Performance Computing (HPC) (Leicester LISCB).

3.2 Facilities

The UoA has benefitted from significant investment in infrastructure and facilities, including £34M in new buildings and research labs that house CHAUD research and impact activities, targeted specifically to support our Research and Impact Strategies (§1.2). Two new buildings have increased research capacity in biomedical research and enhanced interdisciplinary collaboration with other disciplines.

The Interdisciplinary Science and Technology Centre (ISTeC, £11M including £5M from HEFCE/Research England, 800 m^2 research wing; completed 2017) brings STEM subjects together to support collaboration between different subject areas, outreach activities, and industry engagement. This provides the UoA with metabolic and epigenetic laboratories, incorporating new

resources such as Seahorse XF24 (£120k) to measure ATP real time production rate and an Oroboros platform to monitor Oxidative Phosphorylation OXPHOS (£90k).

The Medical Technologies and Innovation Facility (MTIF, £23M including £9.7m from D2N2 Local Growth Fund, 3318 m^2 on two sites; completed 2020) supports early stage research and development in medical technology and medical devices. The Boots Enterprise Zone building features a state-of-the-art manufacturing facility, focussing on industrial pilot projects. The Clifton campus building supports early-stage innovation and impact generation activities from our researchers. It houses microbiology and tissue culture labs and an Imaging Suite, featuring: atomic force microscope (Dimension ICON AFM, purchased 2016, £185k); scanning electron microscope (Jeol FEG SEM JSM-7100F + EDX, purchased 2015, £250k); transmission electron microscope (Jeol JEM 2010 TEM, replaced 2019, £640k). This Imaging Suite is centrally financed and supported by technical support staff, including regular training sessions.

Our pre-existing Interdisciplinary Natural Sciences Research Facility contains microbiology containment level 2 facilities and has expanded capacity to include next generation Illumina MiSeq sequencing. The UoA's John van Geest Cancer Research Centre possesses state-of-the-art laser capture micro-dissection and cell analysis facilities, and houses transcriptomics and proteomics instrumentations. During the REF2021 period there has been a significant investment of £1.7M upgrading these facilities. New NanoString nCounter™ FLEX and GeoMx platforms (£430k) for multiplex amplification-free gene expression and spatial profiling have boosted the impact of our work on treatment-resistant cancers. A circa £1M investment in upgrading Proteomics capabilities includes ESI MS/MS sequencing and quantitative data-independent acquisition mass proteomics instrumentation (Bruker UltrafleXtreme and SCIEX TripleTOF™ 5600 and 6600 systems). New epigenetic resources include 256-well QPCR, Ultrasonicator, and TapeStation system (£110k). The pre-clinical Animal Unit incorporates a new PerkinElmer IVIS Lumina Series III fluorescent and luminescent in vivo imager (£150k). Multiplex ELISA (£50k) acquired since 2014, has boosted multidisciplinary projects (with C24 and B12) in partnership with the Anthony Nolan Cord Blood Development Centre. Other relevant new facilities in the School of Science and Technology include an IncuCyte (£135k) for real time cell evaluations, which allows mimicking of cell stress/tumour microenvironment, and a Zetaview™ Nanoparticle Tracking Analyser (£51k).

New communal facilities hosted by the School include a Linux HPC cluster (installed 2017-18, currently 44 nodes of 16-20 cores each, up to 128 GB RAM / node and 30 TB storage) which supports the UoA's bio-mathematicians. CHAUD researchers have access to synthetic and analytical chemistry facilities (e.g. NMR spectrometer £270k; Waters Xevo-G2XS-QTOF MS £400k; Biotage SP Wave microwave and semi-automated peptide synthesiser £30k).

3.3 Organisational and operational infrastructure supporting research and impact

Technical support for research in the School of Science and Technology is provided by a diverse team of (on average) twenty technical support staff, including a School Technical Manager and three building-specific technical leads. The University is a signatory of the Science Council's Technician Commitment, which aims to support career development and sustainability for technical support staff in research. Technical support staff ensure a high standard of maintenance and operation of equipment, training provision, and safety. Animal facilities are staffed by five additional animal experimenters with significant animal surgery and pre-clinical modelling experience, who can deliver and report reproducible studies to the highest of standards, and in alignment with the NC3Rs ARRIVE (Animal Research: Reporting of In Vivo Experiments). The quality of the work undertaken in this UoA is exemplified by a significant level of use under contract by a commercial company. The School supports the majority of the costs of facility maintenance, and the close proximity of all facilities (§3.2) on NTU's Clifton campus 'Science Quarter' have facilitated cross-discipline collaborations (§1.2). Access to our facilities has attracted UK and overseas researchers, for example our advanced Mass Spectrometry resources underpinned research contracts with the CNR Institute in Milan (Institute of Neuroscience), and VU Medical School Amsterdam. In turn, we access facilities in other institutions free of charge, an example of this is work by Al-Ahmady which has used the surgical suite and behavioural facility at the University of Manchester (Stuart Allan's group) (*ACS Nano* 2019).

Support to impact is enabled by a IP and Commercialisation Manager (Condliffe) to: (i) establish licence agreements; (ii) support identifying, protecting and exploiting Intellectual Property (IP) and patent applications; (iii) liaise with venture Capital investors and facilitate joint PhD agreements with industry. A business development specialist (Wilby) supports the commercialisation of research capabilities, costing research collaborations and agreements for sample analysis, and access of specialist instrumentation and know-how. A knowledge exchange and impact specialist (Matini) provided training/workshops and enabled impact opportunities (2014-2018). The University's Research Operations team supports grant application processes, facilitated by our 'Worktribe' research management platform, and the Research and Strategic Partnership Development team supports research grant and external partnership development, including Innovate UK and EU funding (§3.1, and see REF5a).

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

4.1 Research collaborations, networks, and partnerships

Global engagement has been central to the UoA raising its profile and reputation, and supporting its impact strategy (§1.2.2). The composition of the UoA, which includes a number of international scientists, naturally encourages strong international partnerships and networking. This has been further strategically fostered through internal support for conferences, visits, and exchanges at all career levels. The majority, 58%, of submitted researchers' publications (outputs with NTU affiliations, Scopus/SciVal, in 2014-2020) in the REF review period have at least one international co-author, increased from 52% in REF2014. Our international standing is also evidenced by increased external income from international organisations (§3) which constitutes about one third of research income in REF2021 (REF 4b).

In the REF period we have pursued a number of initiatives that have expanded our international networks, some supported by sabbaticals for developing strategic partnerships with international universities and companies (§2.1.2). UoA members have established links with Makerere University of Public Health and Pharmacy with the support of the Tropical Health and Education Trust. This work, alongside our colleagues in the C20 Social Work and Social Policy UoA, has tackled antibiotic resistance via antimicrobial stewardship initiatives. National and international exchanges have included Hoyles' Hamied Foundation UK–India Antimicrobial Resistance Visiting Professorship (2019–2020) and a visiting professorship at The Department of Surgery and Cancer, Imperial College London. Campeotto and Al-Ahmady held honorary fellowships at the University of Leicester and University of Manchester, respectively. Bilateral research exchanges and joint PhD projects have taken place with the Indian Institute of Technology, Bombay, and are under development with the University of Bologna, Italy. PhD researcher mobility projects have included exchange schemes (§2.2.2). Ball received Indian Government funding, under the Global Initiative for Academic Networks initiative, to deliver a course on 'Genome Informatics' at Panjab University (Course 1425/176004H07, 2018).

Our visiting scholar programme has supported 29 visitors during the REF2021 period. At senior level, this included several NHS consultant clinicians as honorary professors (§4.2), international academics such as Eric Tartour, Professor in Immunology and Head of the Biological Immunology Department at the European Hospital Georges-Pompidou-APHP and Professor at University of Paris (visiting period 2013-2016); and Wei Chen, Professor in Nano-Bio Physics, the University of Texas at Arlington (2018-2021), who contributed to the UoA's nanoparticle research. A further 16 visiting scholars and visiting research fellows, of which 13 were international, have enriched the UoA's research.

4.2 Collaborative generation of research impact

An indication of the effectiveness of our strategy is the intense network of interdisciplinary and cross-sectional projects across academia, industry, and hospitals/clinical centres worldwide. In the REF period new partnerships have been established with a broad range of stakeholders involving all CHAUD Research Themes generating wider impact.

4.2.1 Collaborative generation of research impact with NHS Trust Hospitals

Translational medical research and transition to patient benefit has been undertaken in close collaboration with NHS Trust hospitals. Pockley worked with University Hospitals of Leicester NHS Trust (M Khan) to develop a simple blood test for detecting and identifying the clinical risk of prostate cancer in asymptomatic men (*eLife,* 2019). Pockley and Polytarchou's work with St Bartholomew's Hospital (J Lindsay) on NIHR ASTIClite project (§3.1) is testing whether autologous Haematopoietic Stem Cell Transplant is an effective treatment for Crohn's disease, with A03 researchers using our state-of-the-art genomics, proteomics, immunology and bioinformatics platforms to identify the mechanism behind therapeutic responses in this trial. Polytarchou worked on a National Institute for Health Research project with the Nottingham Digestive Diseases Centre (T Monaghan) on faecal microbiota transplantation in *Clostridium Difficile* infection (*Gastroenterology*, 2019). McTernan worked with University Hospitals of Coventry and Warwickshire NHS Trust (S Kumar) on the impact of gut hormone in bariatric surgery (McTernan, *BMC Med*, 2017). Hoyles worked with Norfolk and Norwich University Hospitals NHS Foundation Trust (P Clarke) on Klebsiella populations in preterm infants and antimicrobial resistance (*Microbial Genomics*, 2020; *Nature Microbiology,* 2020). As described in an Impact Case Study, Ball has worked with Nottingham University Hospitals NHS Trust (S Chan), as part of an NIHR-funded i4i project which is developing a new approach for predicting the response of women with breast cancer to chemotherapy (Ball, *Lancet Oncology*, 2016). Overall UoA members have collaborated with at least 20 different NHS Trusts and over 30 departments.

4.2.2 Collaborative generation of research impact with International and National Hospitals and Medical Centres

Staff in the UoA have also forged new strong partnerships with international university hospitals and centres of excellence which have enriched the environment and developed wider contributions to society. Examples include: Pockley has worked with the 'TranslaTUM' (Central Institute for Translational Cancer Research at the University Hospital rechts der Isar, Technische Universität München), one of Germany's Excellence Centres, on a new approach for isolating circulating cancer cells from patients and the successful conclusion of a randomised Phase II clinical trial in patients with non-small cell lung cancer (*Clinical Cancer Research,* 2020); Polytarchou has worked with the Ohio State University Comprehensive Cancer Research Center (Columbus, USA), UCLA School of Medicine (Los Angeles, USA) and Harvard Medical School (Boston, USA) on non-coding RNA-based therapeutics for intestinal inflammation and cancer (*Gut,* 2019; *American Journal of Pathology*, 2019); Hatziapostolou has worked with The Cedars-Sinai (Los Angeles, USA) and Stanford Medical School (Stanford, USA) on epigenetic networks in pancreatic cancer (*Gastroenterology*, 2015; *PNAS* 2020); Christian has worked with The Chinese Academy of Sciences (Institute of Biophysics, P Liu) on lipid droplets in stem cell biology and early embryo development, in a collaboration with V Azuara, Imperial College London and with A Vidal-Puig (Wellcome-MRC Institute of Metabolic Science, Cambridge) on Rgs7, a regulator of G protein activity, in adipose tissue (BBSRC-funded projects) (*EMBO Molecular Medicine*, 2018); Verderio has worked with the University of Patras (Greece) (D Goumenos) and the University of Sheffield (T Johnson) on urinary exosomes biomarkers in CKD (, *J Amer Soc Nephr,* 2018); Ugun-Klusek has worked with the University of Tübingen, Germany on neuronal-specific functions of PINK1 in Parkinson's disease (*iScienc*e, 2020); Hoyles has worked with the Hospital of Girona 'Dr Josep Trueta' (Spain) and seven other international partners in collaboration with E Dumas (Imperial College London), on the links between the gut microbiome and the host phenome to hepatic steatosis/non-alcoholic fatty liver disease (*Nature Medicine,* 2018); Hoyles has worked with the University of Mississippi Medical Center, Mississippi State University (USA) (Thomas, *Scientific Reports*, 2015) on microbial sequencing projects; and Dickins has worked with the Pennsylvania State University (PA, USA) on evolutionary dynamics of the mitochondrial genome (*PNAS*, 2014). In addition, international collaborative working, showcased in the Impact Case Studies includes Ball's work with The Wuhan Pulmonary Hospital (China) on application of Ball's ANN algorithm in disease diagnosis, and Rutella's work with the Princess Margaret Cancer Centre (Toronto, Canada) and the Children's Hospital of Philadelphia (Philadelphia, USA) on predictors of therapeutic response in AML (Rutella, *Science Translational Medicine*, 2019), and with the

University of Regensburg, Technische Universität Dresden and Martin Luther University (Germany), University of Bologna (Italy), and 20 others international institutes on a salvage Immunotherapy for refractory AML (Rutella, *Blood*, 2020).

Work with national centres of excellence includes Hoyles' work with the Quadram Institute Bioscience and Blizard Institute on gut-brain axis, Coutt's work with the University of Oxford's Department of Oncology, Machesky's work with the Cancer Research UK Beatson Institute on the role of the role of actin nucleation and Al-Ahmady's work with the University of Manchester on nanomedicine based platforms for drug delivery.

4.2.3 Collaborative generation of research impact with industrial networks

The UoA's industrial networks (national and international) have flourished in the REF period as a result of engagement with stakeholders in the research process and working with industry with support of professional service colleagues (§3). As part of an Innovate UK-funded project in collaboration with the University of Nottingham, Pockley has delivered essential pre-clinical studies relating to the development of a new vaccine for SARS-CoV-2 by Scancell Ltd (ongoing funding obtained, §3.1). Dickens and Ball have worked with the Oracle Corporation on machine learning of AML transcriptome data for the production of scalable workflows for computational-intense bioinformatic tasks. Verderio's work with UCB BioPharma has led to a CKD progression biomarker fingerprint for clinical use/identify patients going to clinical trial (CAI001; NCT04335578). Pockley also has a collaboration with Royal Free Hospital/University College London on the translational potential of natural killer (NK) cell priming (Pockley, *PLoS ONE*, 2019). This significantly supported submissions for public listing in the USA and regulatory approval for Phase I clinical trial in the UK for a US/UK company (INmune Bio International Ltd). Rutella's work funded by NanoString Technologies (Seattle, WA, USA) and by MacroGenics (Rockville, MD, USA) has led to improved laboratory protocols to successfully profile bone marrow samples. This resulted in the demonstration of improved clinical outcomes after flotetuzumab immunotherapy, opening up new perspectives in the oncology sector, as showcased in an Impact Case Study.

4.3 Economic, societal, and public engagement

The UoA's staff have engaged with multiple cancer and diabetes patient initiatives. Members of our Cancer Biology, Immunology and Therapeutics CHAUD Research Theme have supported help groups such as 'Tackle Prostate Cancer', 'PROSTaid' and the 'Friends and Bredrin' cancer support and self-help group, which is primarily focussed on prostate cancer in African men, as well as other ethnic minorities, with talks at sport clubs (Prostaid Golf Days), hospitals, community centres and charities. They have organised patient and carer visits to our John van Geest Cancer Centre. They have also contributed to a new interactive App, 'Check Tings Out', developed in collaboration with the African Caribbean community and aimed to address the inequality in prostate cancer diagnosis, treatment, and survival in this community. Pockley has supported the publication of 'Hear Me Now! One Year on!' and was invited to its launch at the BME Against Cancer ('B'Me') event at House of Lords, London. Verderio has engaged with CKD patients at a Kidney Research and Innovation event at Royal Derby Hospital, and McTernan and Hulse have carried out research with groups seen to be at risk of prejudice because of obesity/diabetes, resulting in publications from the perspective of BAME or poorer communities.

Members of the UoA have engaged with the general public via a range of dialogue and outreach activities. McArdle has participated in annual Health and Well-Being Days and McVicker and Winter in World Antibiotic Awareness Week events, involving staff, students, and the general public. Hoyles and Winter contributed to a Microbiology Society funded summer school which provided online, real-time training in assembly and annotation of whole-genome sequence data to over 100 Ugandan students. Outreach activities that have involved our staff include Brookes promoting Alzheimer's Research UK on 'Pint of Science' (2019); Winter presenting at Nottingham Festival of Science and Curiosity events and making secondary school visits; Al Ahamady contributing 'Soapbox Women in Science' events; McLean undertaking public engagement activities for the National Biofilms Innovation Centre; Winter offering training to students in low income countries as part of People's Open Education Initiatives; and Verderio engaging with

Japanese Women in STEM at Nagoya University (host, Kiyotaka Hitomi). UoA members have been highly active on media on a broad range of topics, including Cave on the BBC Horizon Science Programme 'The Contraceptive Pill is it Safe' on how oestrogen affects weight gain, McTernan on CBBC 'Operation Ouch' presenting the role of adipose tissue in the body, Ball and Turner on 'The Conversation' news site on personalised medicine and causes of diabetes, respectively, and Verderio's 'World Kidney Day' activities have included speaking for Kidney Research UK on BBC East Midlands Today.

4.4 Contribution to the research base

Members of the UoA have received awards and honours, including Forsythe and Billett who were cited in the Queen's Anniversary Prize to the University in 2015 for their contribution in food security, Pockley who is Senior Fellow (elected) of Cell Stress Society International since 2015, and Ball who is Fellow of the Royal Society of Medicine.

The UoA members' service on national and international committees includes: Pockley, who is on the scientific advisory boards of Prostate Cancer UK, Breast Cancer NOW and Northwest Cancer Research; Ball who is a member of the Breast Cancer Now tissue bank; and Hoyles is research committee member for the Healthcare Infection Society and sits on the International Life Sciences Institute Europe Expert Group.

Membership of national and international peer review panels include: Rutella who has served on the Selection Committee of Deutsche Forschungsgemeinschaft (Germany); Verderio who has been external review panel member for French National Research Agency; McTernan who has served for The Fundação para a Ciência e a Tecnologia, I.P. (Portugal); and Cross who has been an EPSRC Peer Review College member. UoA members have also performed grant reviewing for UK research councils and charities such as BBSRC, UKRI (Future Leaders Fellowship grant), MRC, Wellcome Trust, Kidney Research UK, Diabetes UK, British Lung Foundation, and International funders such as Telethon, The Netherlands Organisation for Scientific Research, and The Netherlands Organisation for Health Research and Development.

Staff within the UoA have editorial responsibilities for over 20 different journals, for example: Rutella is Section Editor-In-Chief (Haematology) of *Journal of Clinical Medicine*. Associate Editorships include Hargreaves for *Environmental Toxicology and Pharmacology*, Brookes for *Journal of Alzheimer's Disease*, and Hoyles for *BMC Microbiology*. Editorial board memberships include Turner for *Biochimica Biophysica Acta* (Molecular Cell Research), Leo, Campeotto and Ahmed for *Scientific Reports*, and Verderio for *Cells*.

The UoA's staff have been involved with organisation of a variety of scientific meetings. For example, since 2007 the UoA has organised the East Midlands Proteomics Workshop in collaboration with local Midlands universities. Croft has co-organised a mini-symposium at the European Conference in Mathematical and Theoretical Biology (ECMTB) (2016), Hoyles has been an organiser of the Royal Society of Chemistry meeting on Tackling Antimicrobial Resistance (2018), and Verderio proposed and co-organised a symposium on Transglutaminase (Life Sciences 2019: Post-translational modification and cell signalling) with the Biochemical Society, Pharmacological Society and Physiological Society.