Institution: Nottingham Trent University

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

a. Overview

During the assessment period biomedical research at Nottingham Trent University (NTU) has built on its success in order to achieve the objectives outlined in our RAE 2008 submission, aided by substantial development of the research environment. Of particular note was the establishment of a purpose-built John van Geest Cancer Research Centre (JvGCRC) in 2008 within the School of Science and Technology (SST) complex. This was followed by the establishment of The Biomedical, Life and Health Sciences Research Centre (BLHS, a virtual Centre) in 2010, to encapsulate other aspects of biomedical research. Finally, the bespoke Rosalind Franklin facility (opened October 2012) greatly enhances our research capability.

The Biomedical Sciences Unit includes staff from both BLHS and JvGCRC, with broad academic backgrounds (Biochemistry, Pharmacology, Immunology, Microbiology, Bioinformatics, Biomathematics and Analytical/Synthetic Medicinal Chemistry) within three academic Departments (Biosciences, Chemistry & Forensics, Physics & Mathematics), with extensive skill sets to support interdisciplinary activity. The Unit has a balanced profile of professorial (8) and non-professorial (15.8 FTE) staff. Biomedical research activities are identified under two platforms, (a) Health and Disease and (b) Enabling and Cross-cutting Technologies, which have benefited from planned new staff appointments resulting in a significant increase in research activity since 2008.

b. Research strategy

i. Overall research strategies and evidence of achievement of aims

In RAE 2008 20% of Biomedical Sciences (UoA12) research was rated 4*, and 30% 3* with 14 category A FTEs submitted. The Biomedical Sciences Unit has continued to benefit from SST's strategy to promote collaboration across Departments, and joint infrastructure investment, resulting in a significant increase in our interdisciplinary biomedical research activity since 2008:

- Significant increase (70%) in category A staff submitted from 14 FTE in RAE 2008 to 23.8 FTE
- Average annual research income increased from £854,885 to £1,661,684 (annual income/FTE increased from £61,063 to £69,819, above inflation for the period).

The forward looking strategy in our RAE 2008 submission stated that we would: build on the existing core interdisciplinary themes, notably those involving emerging pathogens, cancer immunology/immunotherapy and enabling technologies such as bioinformatics/biomathematics; exploit synergies with our General Engineering unit (UoA 25/RAE2008, 55% at 3*/4*), embed new appointments and establish the JvGCRC. Continuity of core themes is provided by 10 staff who were submitted in RAE 2008 while evidence presented in sections (bi-iii) and (dii) demonstrates that the other strategic aims have been achieved.

The objectives for biomedical sciences' research and their implementation are defined below:

a. To sustain and grow research activity and further develop research excellence

Support was partly provided by highly selective allocation of QR funds to support PhD studentships (includes 6 for ECRs), research fellows/assistants (2 FTEs/annum) and 6 month periods of sabbatical leave for high calibre staff (7 in period 2008-12, 5 in 2013-14). Sabbaticals have been used to conduct feasibility work, learn new skills and/or expand/re-enforce collaborations which support grant capture. Examples: BBSRC Case Studentship (Cave), Kidney Research UK grant (Verderio-Edwards), Royal Society UK-China International Exchange Scheme award (McNally). Other staff focused on collaborative outputs (De Girolamo, Dickenson, Forsythe, Hargreaves).

b. To strategically promote multi- and cross-disciplinary research of relevance to end-users

Research Centres provide workshops/research fora to discuss specific research themes, to both underpin alignment of research excellence and further promote cross-disciplinary collaborations. QR funds were used to support interdisciplinary research with impact. Co-funding/supervision of PhD projects with Directors of Study (DoS) in other UoAs was provided (3x B15 on bio-inspired materials and drug design; 3x C26 on genotype and physiological traits linked to sport performance and equine stress indicators), and DoS in A03 but co-supervisors in other UoAs (2x B15 on novel imaging methods; 2x B11 on biomedical mathematics). International collaborations have been promoted by providing funding for travel, as outlined in section (ei).

c. *To enhance research culture, infrastructure and dissemination of research*

BLHS and JvGCRC organise weekly research seminars and SST runs a two-day Annual Research Conference to train post graduate research (PGR) students and encourage cross-fertilisation of ideas, inspired by both internal and external keynote speakers. Staff and PGRs participate in international conferences. Staff are actively involved in Outreach activities (running master classes and Bioscience Research Conferences for post 16 year olds) and teach both MSc/MRes (ca. 80 students/annum) and undergraduate (ca. 1000/annum) levels.

ii. Specific research activities and integration of staff within the Unit

Themes identified under the two main platforms are as follows, with associated staff in each case. (Early Career Researchers, ECR, in italics; other staff appointed during the period underlined).

Health and Disease

• Tumour biology: Discovery and application of new cancer biomarkers for detecting cancer, monitoring disease progression, discovering molecular pathways and developing new approaches to treat patients using immunotherapy (Rees, *Montiel-Duarte*, Pockley and *Regad*).

• Cell biology, ageing and pathology: Molecular and cellular basis of cell death/survival and major life threatening diseases and conditions (neurodegenerative, cardiovascular, kidney diseases, diabetes); cell cycle control (Barnett, Billett, *Colombo,* Hargreaves, Turner, Verderio-Edwards).

• Neurobiology, toxicology and pharmacology: Mechanisms of memory formation; brain organisation; use of cellular models to study toxicity, cell signalling and cardioprotection (Billett, *De Girolamo*, Dickenson, Hargreaves, *Tinsley*).

• Pathogen research: Whole genome sequencing based approaches to understand the evolution of bacterial pathogens; molecular epidemiology; molecular basis of pathogenicity; development of rapid diagnostics (*Dickins,* Forsythe, Manning, McNally).

Enabling and Cross-cutting Technologies

• Bioinformatics and biomathematics: Development of mathematical, statistical and computational solutions to 'post-genomic' and other biological challenges (Ball, Chuzhanova, *Crofts, Richards).*

• Therapeutic chemistry, analysis and imaging: Use of state of the art analytical and synthetic techniques to develop methods and materials to investigate biological processes and structures; bio-inspired compounds for use as potential drugs (Allin, Cave, Hanley, *Richards*).

• Proteomics and genomics: Bio-marker and gene pattern profiling for disease and food authenticity; use of genomic analysis in pathogen typing (Ball, Billett, Forsythe, Hargreaves, McNally, Rees, Turner, Verderio-Edwards).

Targeted staff recruitment since RAE 2008 has refined our research themes to reflect research strengths. The platform 'Health and Disease' now includes 'Pathogen research', reflecting the broader aspects of our microbiological research activities, now that staff recruited prior to 2008 (Manning and McNally) are established and an ECR (Dickins, previously Center for Medical Genomics, Penn State University, polymorphism dynamics in viruses) appointed. The theme 'Tumour biology' was strengthened with the recruitment of Pockley (Chair, 2012, Head of Immunobiology Unit, Sheffield Medical School) with a primary interest in novel therapies for cancer based on heat shock proteins and ECRs Montiel-Duarte and Regad (2010, 2011, previously on short-term contracts at NTU) respectively working on leukaemia and the molecular mechanisms of tumour growth and progression. Similarly the theme 'Neurobiology, toxicity and pharmacology' was enhanced in 2010 by Tinsley (MRC Centre for Synaptic Plasticity, University of Bristol) and De Girolamo (NTU), ECRs with expertise in respectively topographical brain connections and *in vitro* models of neurodegeneration. The theme 'Cell biology, ageing and pathology' was strengthened by recruitment of a Reader in Biomedical Science (Turner, 2012, Centre for Diabetes, Queen Mary London), with established research on Type 2 diabetes, and an ECR (Colombo, 2013, Wolfson Institute for Biomedical Research, UCL) recognised for work on control of metabolism/cell cycle.

The platform 'Enabling and Cross-cutting Technologies' has replaced 'Biomolecular and Microbial Analysis' and includes 'Bioinformatics and biomathematics', an expansion of the bioinformatics theme following the strategic recruitment of three new staff. Chuzhanova, 2010, Chair of Biomedical Mathematics, develops novel computational methods/algorithms to study mutagenesis in pathology, and spent most of her previous academic career at Cardiff University. ECRs Crofts (2010, Mathematics and Statistics, University of Strathclyde) and Richards (2011, Biomolecular Medicine, Imperial College), work on different aspects of bio-mathematical modelling including,

respectively, modelling of brain function and complex biochemical data. 'Biosensors and imaging' now incorporates smart materials, following recruitment of Allin (Chair, 2012, with expertise in medicinal chemistry and drug design; previously at School of Physical and Geographical Sciences, Keele University) and Richards (synthesis of phase 2 xenobiotics), re-branded as 'Therapeutic chemistry, analysis and imaging'.

iii. Future research plans

Our future strategy is to build on the two platforms through targeted investment in staff and infrastructure and grant support in niche areas, ensuring that ECRs are supported to nurture their potential. The JvGCRC has received further funding to increase its translational activities from the John and Lucille van Geest Foundation (£7.5M). The focus is on linking biomarker discovery and immunotherapy and this is supported by patient group involvement and established clinical links (to include 2 clinical fellows). 'Pathogen' researchers will focus on genomic epidemiology and within host diversity of clinically important organisms. 'Cell Biology' researchers will continue basic research (cell cycle/death and tissue transglutaminase) and capitalise on the existing access to cord blood samples (Anthony Nolan facility) and increased expertise in diseases linked to mitochondrial and metabolic defects. In 'Neurobiology/Pharmacology' emphasis on G-coupled receptor signalling and a systems approach to brain organisation, in collaboration with our biomathematicians, will increase. 'Therapeutic chemistry, analysis and imaging' research will increase its industrial engagement and the use of STFC facilities, and interactions with the General Engineering Unit. We are recruiting a Chair/Reader in Cell and Molecular Biology, with expertise in disease mechanisms and pharmacological interventions and junior posts in clinical immunology, molecular microbiology and pharmacology; and plan to recruit additional technical support (proteomics/cell culture) and support for unit-specific grant capture and interactions with charities and industry. The acquisition of a TripleTof 5600+ LC/MS/MS (AB Sciex, November 2013) has increased our capacity for biomarker discovery and quantification.

c. People

i. Staffing strategy and staff development

Staff strategy and sustainability and new appointments*:* Staffing levels are continuously reviewed and new posts created via a restructuring programme according to research needs in a prioritised area. Evidence of sustainability through recruitment and staff development is provided by the age profile, with ca. 29% of staff being under 40, and 70% under 50. The Unit contains 8 Professors, 3 Readers plus Senior Lecturers/Lecturers. Eight new appointments are ECRs (already noted, b.iii), all appointed since 2010, two in 2013. Four external senior appointments have been made: Chairs in Biomedical mathematics (Chuzhanova) and Chemistry (Allin), a Reader in Biomedical Sciences (Turner) and an Associate Director for the JvGCRC (Pockley).

Career development and its support: Staff developments since 2008 include Readerships for Hanley (2011) and Verderio Edwards (2013) for their internationally-recognised work on respectively bio-molecular analysis using fluorescence imaging and tissue transglutaminase. Three ECRs (De Girolamo, Montiel-Duarte, Regad) were on short term contracts before securing permanent posts; our philosophy is to develop existing staff into excellent researchers. The co-ordinator of the Biomedical Sciences Unit and the Directors of BLHS and JvGCRC share responsibility for developing and nurturing staff, ensuring that mentoring is available, notably to support integration of new staff and to assist with personal research plan development and funding applications. Mentors are Principal Investigators/academics with experience of quality outputs, grant capture and research management/supervision. Research themes, as defined, encourage collaboration and sharing of best practice; the network of external collaborations into which new staff is introduced enhances the opportunity to work at an international level.

All staff have teaching responsibilities and a University-wide Managing Academic Workload Framework is used to ensure sufficient time is dedicated to research endeavour; ECRs have reduced teaching/administrative loads during their probationary period. Subject to an acceptable plan, new appointees have access to a Research Contingency Fund which is held by each Head of Department to support quality outputs and grant applications. RAE QR funds, managed by the Biomedical Sciences Advisory Group (see di), are also used to support new staff. Research studentships are generally awarded to junior staff linked with a more senior member who acts as mentor. In RA2 many ECRs are submitting publications deriving from work conducted at NTU,

confirming the supportive nature of their new environment.

Implementation of the Concordat to Support the Career Development of Researchers: The University has signed up to the Concordat to Support the Career Development of contract Researchers, and holds the European HR Excellence in Research Award, in recognition of its commitment to enhancing working conditions and careers for researchers. Staff participate in Performance Development and Contribution Review, ensuring that their research development needs are ascertained and addressed. The NTU Researcher Development Framework is used to aid career planning. The University "Learning and Development" Strategy and associated policies apply to all staff including researchers. Our Research Fellows develop their teaching skills/portfolio with up to 3 hours/week of laboratory supervision, seminars, or lecturing.

Support of equalities and diversity: The University adheres to and implements an 'Equality and Diversity' Policy and a 'Dignity at Work' Policy and Procedure. Our School has an Equality and Diversity Champion who participates in the Vitae network and we are committed to Athena Scientific Women's Academic Network participation and Bronze submission in Jan 2014. All members of the Biomedical Sciences Advisory Group have completed level 1 and level 2 courses on Equality and Diversity (with material provided by the Equality Challenge Unit).

Appointment of clinical and academic visiting scholars: Visiting Fellows (2) and Professors (10) were appointed via the University's academic 'Awards and Titles' procedure and provide regular support for our research. **Fellows** include Dr S Gomez (Laboratory Manager, Anthony Nolan Cell Therapy Centre, Nottingham), who provides cord blood samples for *Rees* and *Hargreaves;* R Parkinson (Head of Urology Centre, Nottingham University Hospitals Trust, NUHT) supports prostate cancer research of *Pockley/Rees.* **Visiting Professors** include: G Pawelec (University of Tuebingen) working with *Barnett* on immune function; T Sayers (Center for Cancer Research National Cancer Institute, Frederick MD, USA), works on cancer immunotherapy directed to stem cells with *Regad/Rees/Pockley*; S Chan (Consultant Oncologist, NUHT), breast cancer with *Ball*; M Khan (Consultant Urologist, Leicester University Hospitals Trust) works with *Pockley/Rees* on prostate cancer; D Powe (Principal Research Scientist, Cellular Pathology, NUHT) supports prostate and breast cancer research (*Ball, Cave, Pockley, Rees*); Vivienne Watson (Consultant Microbiologist, NUHT) supports microbiology research (*Forsythe, Manning, McNally*).

ii. Research students

Biomedical PGRs belong to a large vibrant community in SST, which organises journal clubs and social events. The NTU University Graduate School has overall responsibility for governance matters relating to SST PGRs, including their admission, registration and progression, and provides advice on these matters. The Graduate School implements the University's 'Regulations for Research Degrees' that comply with the QAA Code of Practice and HE Qualifications Framework. For international students for whom English is not their first language, additional English classes are provided. PGRs are mentored by the School Postgraduate Research Tutor and PGRs are represented on School Research and University Research Degrees Committees, and the School Health &Safety Committee. PGRs are provided with workstations and office space.

Recruitment, support and monitoring: Student recruitment is fair, rigorous and transparent. Projects are advertised openly, with clear qualification and other selection requirements. Shortlisting and interviews are conducted by the DoS, the Postgraduate Research Tutor plus another experienced supervisor and training needs identified. Supervisory teams consist of two NTU staff, including the DoS, with a minimum of two supervisions to completion. Supervisors are required to attend a 'Research Student Supervisors' workshop run by the CPLD team, who also organise training programmes for Independent Chairs and Examiners for PhD *viva* voce examinations.

In the first year PGRs attend an induction programme (including Health and Safety), a 2½ day Research Methods workshop, a Project Approval writing workshop, a 2 day vitae 'Effective Researcher' course and a laboratory demonstrators course. Subject-specific training is undertaken as advised by their supervisory teams; PGRs can attend relevant M-level modules. Training on transfer report writing and PhD completion, including the *viva voce* process, is given in the second and third years respectively. Students are expected to attend School research seminars and Conferences, including the Annual School Research Conference, and present their work at these events. The training programmes are complemented by a range of CPLD courses in project

management, appointment and interview processes and procedures, planning for publication and equality and diversity awareness. Research student progress is formally monitored on a six monthly basis, via a panel of supervisors and an independent assessor, with key milestones and deliverables at month 6 (Project Approval) and month 18 (transfer from MPhil to PhD). PhD students are required to submit their theses within four years of registration.

Funding and achievements: In 2006/07 and 2007/08 88% completed to Ph.D. demonstrating the success of our postgraduate recruitment and support policies. Biomedical Sciences maintains a robust base of cohort of research students, funded through a range of funding sources including competitive QR and Vice Chancellor Scheme bursaries and self-funded (mainly international) research students. Since RAE 2008 the number of non-EU government funded scholarships has grown due to increased recruitment from countries that have developed formal links with the Unit. The average headcount of enrolled students/annum over the period is 34.3 (1.44/FTE submitted), compared to 29/annum in RAE 2008 (2.1/FTE). Student numbers/FTE have declined in part due to visa problems. However 39 students have already registered in 2013-14, and an additional 8 have offers. Since our submission includes 8 ECRs who are still establishing their research careers, the student number is expected to increase in the near future.
PGRs who completed during the period have been appointed to PDRA posts in various Universities including: A Baig (School of Veterinary Medicine, Cambridge), M Javed (Universities of Edmonton & Saskatchewan, Canada), S Laversin and A Linley (Southampton), K Murray (Gastrointestinal MRI, Nottingham); in Research Institutes/NHS: F Burte (National Inst. Medical Research, Mill Hill), G Clark (Trainee Clinical Scientist, NUH NHS Trust), C Lemetre (New York Bioinformatics Inst), S Marthandan (Leibniz Inst. for Age Research, Jena , Germany), S Reuter (Welcome Trust Sanger Inst. Cambridge); in industry: A Scarpellini (Product Specialist, Nikon Instruments Europe, Amsterdam), D Muñoz (Lonza, Slough). Technologies developed by PGRs have transferred to subsequent posts (eg proteomic methods for biomarker discovery [Vafadar-Isfahani, DOI 10.3233/JAD-2011-111505] and analysis of molecular pathways [Burte, REF 2 *De Girolamo* output 2], the clinic (bioinformatics methods [Lemetre, REF 2, *Ball* output 1, *Rees* output 2), and industry (BBSRC CASE studentship, AHDB Potato Council, *Cave,* Ref. BB/K012878/1).

d. Income, infrastructure and facilities

i. Research Governance policy
Biomedical research operates under 5-year strategic and financial Academic Plans which are updated annually and approved by the College of Arts and Science. From 2009 the College used RAE QR funds to support strategic initiatives (via the 'The College Strategic Investment Fund'), staff with key management roles within Schools (Research Co-ordinators and PGR Tutors), staff time on grants without full economic costing (of particular importance for Biomedical research), in addition to directly supporting the activities of individual UoAs. The School's Research Committee (SRC), chaired by the School Research Co-ordinator, has executive responsibility for development of research strategy within the School, resource allocation, staff development and coordination of bids for external/internal funding. This committee comprises senior staff across the School, including the Dean, Directors of the RCs, Directors of the REF Units, and Heads of Departments (HoDs); decisions made by the SRC are transmitted to the School Executive Group for approval and action. The Biomedical Sciences Unit is co-ordinated by Professor E Billett and managed by a Unit of Assessment Advisory Group which contains key staff representative of activities across the Unit, including HoDs and Directors of BLHS and JvGCRC. In recognition of its high priority, biomedical research has been directly allocated around £2.1M of QR income 2008-2014. Allocation of funding is coordinated through the Advisory Group via an annual call for Expressions of Interest; funding is allocated to support projects with a clear alignment to the Unit's strategy. This includes support to areas of strength, for developing researchers, and to underpin new strategic collaborations. Funds have supported postgraduate bursaries (16), research staff (2 FTEs/annum), consumables and travel to facilitate collaborations.

ii. Physical infrastructure and facilities
Biomedical research is housed in bespoke laboratories in several buildings on the Clifton Campus. The Interdisciplinary Biomedical Research Facility (opened in 2002) provides purpose-built accommodation for six research groups working in cell biology, toxicology and pharmacology, whilst The Interdisciplinary Natural Sciences Research Facility (opened in 2006, total cost £5.4M)

includes laboratories dedicated to imaging and analytical/synthetic chemistry and microbiology research. Our laboratories are serviced by containment level 2 cell culture suites and the usual range of equipment to support analytical, molecular and genomic research. Since RAE 2008 one highlight was the opening of the JvGCRC (total floor space 954m^2) and a new animal facility (floor space 268m^2) with barrier rooms for transgenic animals (floor space 180m^2) and a surgical suite with bespoke equipment at a total cost of **£5.15M** (£2.8M from John and Lucille van Geest Foundation). In October 2012 the Rosalind Franklin Building was opened (total cost **£4.4M,** total area 2227m^2). This facility provides customised research space for x-ray imaging/diffraction, multinuclear NMR, new chemistry research laboratories (240m^2), and other analytical equipment; and provides a showcase of research capability and expertise as part of the School's industrial engagement strategy. The Erasmus Darwin Building (recently refurbished, **£1.8M**) houses our radiation and microscopy suites.

Examples of specialist facilities: (Note: Equipment with costs provided (in bold) was purchased in this REF period; this is not a comprehensive list. Total value **>£2.6M**).
Microscopy/imaging: Electron Microscopy: Transmission (JEOL JEM-2010 TEM, x-ray analyser and cryogenic stage) Scanning (JEOL JSM-840A SEM and x-ray analyser). Confocal Microscopy: Leica DM-RBE upright and Leica DM-IRBE inverted confocal microscopes (**£215k**). Biospace Micro Imager (for cell level autoradiography). Magnetic Resonance Imaging: Biospec MRI (Bruker, 2.35 T, 72 mm bore), Portable NMR-MOUSE (ACT), Halbach MRI (ACT, 0.5 T, 40 mm bore**, £72k),** JEOL (400mHz) & Brucker (300mHz, **£80k**) multinuclear NMR equipped for solution (variable temperature and sample changer) and solid state work (Doty probe). X-ray Diffraction: Philips X'Pert Pro x-ray Powder Diffractometer (spinner, powder furnace and bracket stages) and an Agilent Xcalibur Single Crystal Diffractometer (with Mo and Cu sources) (**£190k**). High-speed spectrofluorimeter, electroporator and monochromator-based system for calcium measurements. High content Image Express Micro imaging system with environmental control (Molecular Devices, ex-demo £80K, value **£200k**). Laser capture microdissector (Zeiss, **£130k**). MoFlo XDP Cell Sorter (Beckman Coulter, **£250k**).
Proteomics: Bio-Rad Dodeka system for running and staining 20 cm polyacrylamide gels; Fuji FLA-7000 laser scanner for ECL **(£31k**); FujiFilm FLA-5100 Fluorescent Image Analyser (3 lasers allowing DIGE analysis); Bruker Daltonics Ultraflex III MALDI-TOFTOF mass spectrometer (**£280k**); Bruker Ultraflextreme **(£300k**); Thermo Scientific and Waters (2x, **£120k each**) LTQ linear ion-trap (LC-MSMS) mass spectrometers connected to HPLC; 2x Bruker Easy nLC/Proteineer 1 (**£100k)**; Bruker Daltonics ImagePrep system for MALDI imaging; Proteome Systems Xcise 8 channel liquid handling robot/gel scanner/cutter; FluidX XPS-96, 96 channel liquid handling robot **(£50k**); Beckman Coulter MoFlo cell sorter (**£200k**)**;** CTL Elispot S5 UV analyser (**£42k**); Beckman Coulter Gallios Flow cytometer (**£105k**); Agilent 2100 Bioanalyzer.
Analytical and Synthetic Chemistry: MBRAUN Unilab inert atmosphere glove box and solvent drying facility, CEM Discovery microwave equipment for synthesis, 2x microwave peptide synthesizer (CEM, Liberty), automatic medium pressure chromatography system (Biotage 09492) and GC separation facilities (Agilent, **£24.5k**), IR and UV spectrometers. An analytical package from Perkin Elmer (**£98k**), including inductively coupled plasma optical emission spectrometer (PE 2100 DV), Flexar PDA, Flexar fx-15 UHPLC, atomic absorption spectrometers (PE 1100 B).

iii. Research Income
Over the REF period income was received from a range of sources including: **charities** (the most significant, John and Lucille van Geest Foundation, [£960k/annum, cancer research], Countess Dowager Peel [£75k, urinary tract infections], The Wellcome Trust [£147K, kidney fibrosis], Alzheimers Research Trust [£178k, disease biomarkers], Breast Cancer Campaign, Diabetes UK [£92k, glucolipotoxic islet cell death], Kidney Research UK [£67k, Transglutaminase in kidney fibrosis], City Hospital Trust [£78k, cancer biomarkers]); **Research Councils** (EPSRC [£118K, cell imaging in 5-dimensions, EP/E013422/1; £203k, NanoActuate, EP/H00694X/1], MRC (DPFSDP003) £90k, Nottingham Prognostic Index Plus], MRC/EPSRC [£205k, rapid diagnostics for MRSA]), Technology Strategy Board (£180k, Validation of prognostic biomarkers for Sepsis); **Government Agencies** (FSA [£276k] and Defra [£178k], food authenticity], EMDA [>£250k, various projects], NIHR [£53k, infection control], ERDF [£226k, biomarkers]), **EU** (PortFastFlu, 8 partners [€2.967M], £53k at NTU; Fluoromag, 6 partners [€2.5M], £132K at NTU).

iv. Cross HEI collaborative use of infrastructure/benefits in kind

During the period the Unit has had access to equipment and facilities in other institutions: to high-performance computing at the University of Nottingham (UoN), to the Single crystal x-ray crystallography service at the University of Southampton, and to whole genome expression array facilities at Queen Mary College, London. UoN has utilised our proteomics facilities (DIGE analysis of protein, and peptide mass-fingerprinting). The University of Sheffield has had access to a transgenic mouse colony; NTU and the UoN have shared costs for the development of a DNA microarray for *Campylobacter jejuni.* The University of Bologna (Biological Sciences) has regular access to our microscopy suite. The Unit has benefited from industrial facilities; examples include tableting at Co-Formulate/BioCity, particle analysis using focused beam reflectance measurement at Pfizer and hydroponics at BM-Tek. We have a reciprocal agreement with BioCity to use NMR facilities and access to ISIS beam time at STFC.

e. Collaboration or contribution to the discipline or research base

i. Supporting for interdisciplinary and collaborative research (also see section b.i above)
Initiatives include:
• Themed research meetings/cluster meetings, organised in BLHS and JvGCRC across disciplines
• A programme of research seminars presented by external visitors, members of staff, postdoctoral researchers, with at least 3 seminars a week
• Funding for members of other research laboratories to visit NTU for short periods. Examples: Dr J Flaskos, School of Veterinary Medicine, Aristotle University of Thessalonik (*Hargreaves)*; Dr C Ufer, Charité University, Institute of Biochemistry, Berlin (*Billett)*; Prof Soichi Kojima, RIKEN Advanced Science Institute, Tokyo (*Verderio Edwards).*
• Appointment of Visiting Scholars from Centres of Excellence with whom we collaborate. The Unit has 8 clinical Visiting Professors, 1 clinical and 1 industrial Visiting Fellow (see section ci details).

Publication data (http://wos.mimas.ac.uk) show co-authoring organisations across 39 countries, including clinical centres (see eiv): Algeria, Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Czech Republic, Denmark, Egypt, Finland, France, Germany, Greece, Hungary, Iran, Ireland, Italy, Japan, Jordan, Latvia, Malaysia, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, S Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Tunisia, Turkey, USA.

ii. Honours, awards and international recognition
Allin: Fellow of RSC; **Barnett**: President of Heads of University Centres for Biomedical Science; **Ball**: Visiting lecturer in bioinformatics University of Auvergne; Fellow of Royal Society of Medicine, Honorary Chair Nottingham University Hospitals Trust; **Billett**: Organising committee, International Amine Oxidase Workshops (2012-2014); **Hanley**: Visiting Fellow Ludwig Institute for Cancer Research (2009); **Hargreaves**: Eurodoctorate External Examiner, Centro de Biologia Molecular Severo Ochoa, Spain; **McNally**: Da Vinci Highly Commended Newcomer award for innovation in healthcare; Soc. General Micro. Committee; **Pockley**: President, Cell Stress Society International (2013-2014), Invited Organiser/Chair of Organising Committee, VI International Congress on Stress Responses in Biology and Medicine (Sheffield, UK, 2013), International Scientific Program Committee member, Third Woods Hole Symposium on Heat Shock Proteins in Cancer and Immunology 2010), Co-Organiser Cell Stress Society International Workshop on Extracellular Chaperones and their Plasma Antibodies, Boston, USA (2010); **Richards**: Associate member Centre for Process Analysis and Control (2011-present); **Rees:** external member "Professorial Conferment Panel", University of Wolverhampton (2011-4), Member Scientific Advisory Board of Cancer Vaccine Institute, London**.**

iii. Participation in the peer-review process
During the assessment period most submitted staff have reviewed papers for a number of respected journals and/or reviewed grant applications for national and international funding bodies. The following staff are members of important committees, panels and boards:
Allin: EPSRC Chemistry College**,** member of refereeing panel Tetrahedron Journals, Board of editors of ARKIVOC; **Billett**: reviewer HRB Health Research Awards 2009 (Southern Ireland) & Canada Foundation for Innovation, member Research Advisory Committee Nottingham University Hospitals Charity; **Bonner**: Editor *ISRN Chromatography*; **Forsythe**: member FSA Advisory Committee on Animal Feedingstuffs (2010-) and Microbiological Safety of Foods (2013-), CONSOLIDER programme- Ministry of Education and Science, Spain (2009-2011), *BMC Microbiology* Sector Editor Applied Micro.; **Hargreaves**: Editorial Board member *The World Journal*

of Pharmacology and *Journal of Integrated Omics*; **Manning**: *BMC Microbiology* Associate Section Editor Applied Micro.; **Pockley**: Chair, Novel and Emerging Technologies Grant Panel of Heart Research UK (2008-11), Scientific Advisory Board member Breast Cancer Campaign (2013-), Editorial Board, *Frontiers in Molecular and Cellular Oncology (*2011-), Academic Editor, *PLoS ONE (*2007-), Section Editor, *Cell Stress & Chaperones (*2006-); **Turner:** Editorial Board member of *Biochem. Soc.Trans. (*2010-2012), *Bioscience Reports* (2008-present), *Biochim. Biophys. Acta. - Mol. Cell Res*. (2007-); **Rees**: Editor for *Cancer Immunology and Immunotherapy* (1986-), Editorial Advisory Board member *Current Cancer Therapy*, Editorial Board member *The Open Cancer Journal* (2007-), PIVAC committee member; **Richards**: National Science Centre Panel, Poland; **Verderio Edwards:** Editorial Board member *World Journal of Biological Chemistry* 2010-).

iv. Relationship with the public sector and other end users

Health service: The Unit has excellent collaborations (joint publications, grants and PhD supervisions) with **local NHS hospitals** (Derby and Nottingham Univ. Hospitals Trusts); London hospitals (Guys, Hammersmith, Royal Free, Royal London), **other UK hospitals** (Belfast City, Cambridge Univ. Hospitals NHS Trust, Derriford Plymouth, NHS Tayside, Newcastle Hospital NHS Trust, Leicester Hospitals NHS Trust, Oxford Radcliffe, Royal Hospital for Sick Children Glasgow, Royal Liverpool, Sheffield Univ. Hospital, St. James's Univ. Hospital Leeds, St. Mary's Hospital Manchester, Surrey and Sussex NHS Trust, Univ. Hospital of North Staffordshire), and with **hospitals abroad** (Belguim: Ghent Univ. Hospital, Univ. of Antwerp Hospital; Canada: Calderdale Hospital; Finland: Helsinki Univ. Central Hospital; France: Hopital Cochin [Paris], Hopital Morvan [Brest]; Germany: Children's Univ. Hospital Charité [Berlin], Univ. of Tubingen Medical School; Univ. Hospital Hamburg Eppendorf and Regensburg; Greece: St Savas Cancer Hospital Athens; Norway: Oslo Univ Hospital; Spain: Reina Sofia Univ. Hospital, Cordoba; Taiwan: China Med. Univ. Hosp. Taichung; USA: Mayo Clinic, Rochester). Also many projects on the taught MSc/MRes courses are based at/in collaboration with academic/clinical departments of local hospitals.

Other end users and/or funders: Defra (pesticide toxicity; food authenticity); Food Standards Agency (antibody and proteomic methods for food authenticity; bacterial safety of powdered infant formula); Anthony Nolan Trust (haemato-oncology); FAO-WHO and European Food Safety Authority (advice on emerging pathogens); Public Health Protection Agency (antibiotic resistance in *Staphylococcus aureus)*; STFC (eg. neutron Compton scattering applications); Animal Health and Veterinary Laboratory (Avian *influenza* and *Campylobacte*r research). In addition some funds/services have been provided by a number of companies (eg Astra Zeneca, Charnwood Molecular Ltd and GSK Pharmaceuticals [organic synthesis], Life Technologies Co. [*Cronobacter* sequencing], 3M [rapid detection of foodborne pathogens], Quotient Bioresearch Ltd [high throughput LC/MS analysis of serum).

v. Conference chairs and invited lectures.

Staff have chaired sessions at >15 conference and presented approx. 50 invited lectures/keynotes during the period, many outside the UK. **Ball**: invited speaker Hellenic Society of Computational Biol. & Bioinformatics FORTH (Crete, 2012); IEEE conference Biomedical & Health Informatics (Hong Kong and Shenzhen, 2012); invited speaker & session Chair 4th International Congress of Molecular Medicine (Istanbul, 2011); conference co-chair & plenary speaker International Conf. on Applied Informatics for Health and Life Sciences (Istanbul, 2013); session Chair & plenary speaker, 6th International Congress on Stress Proteins in Biology and Medicine (Sheffield, 2013); **Billett:** session chair International Amine Oxidase Workshop (Edmonton, 2010); **Cave:** invited speaker Institut Catala de'Investigacio Quimica (Spain 2011), 14th Int. Seminar on Inclusion Compounds (Edinburgh 2013); **Chuzhanova:** invited speaker Annual Meeting of the German Association of Gene Diagnostics (Berlin, 2011); **Crofts:** invited speaker Network Architecture of Brain Structures and Functions Workshop (Univ. California, 2011); **Pockley**: session chair The Third Woods Hole Symposium on Heat Shock Proteins in Cancer and Immunology (2008 & 2010), International Congress on Stress Proteins in Biology and Medicine (Japan, 2009 & Canada, 2011), session chair Cell Stress Society International Workshop on Extracellular Chaperones and their Plasma Antibodies (Boston, 2010); **Richards:** invited speaker Chemometrics for Analytical Chemistry (Montpellier, 2008); **Turner**: invited speaker OMICS Int. Conf. Clinical & Cellular Immunology (Chicago, 2012), FASEB Conference (Scottsdale, USA, 2010); **Verderio Edwards**: Gordon Conference invited speaker (2010) & session chair (2012), invited speaker RIKEN Institute and Nagoya University (Japan, 2013).