Institution: Nottingham Trent University (NTU)

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

a. Context

We present strong exemplars of research impact on *health and welfare, commerce*, *public policy* and *public services* during the REF period from our excellent underpinning multi-disciplinary Biomedical Sciences research under its two platforms: 'Health and Disease' and 'Enabling and Cross-cutting Technologies'.

Health and Disease

- Pathogen research: Research on *Cronobacter* (led by S Forsythe) changed international legislative guidelines for the organism in infant formula, namely FAO-WHO risk assessments and the Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment. The team contributed to establishing guidelines for safer production of feeds from infant formula and the development and commercialisation of a chromogenic agar for *Cronobacter* isolation which lowers the level of detection and is compliant to ISO and FDA standards. Impact is on *health and welfare* by *reducing* the incidence of fatal disease (neonatal meningitis) and also *commerce* (case study 1). A McNally and his team also had a strong influence on *commerce (*case study 2*)*. Working in a consortium involving international SMEs and a large international company focussing on producing healthcare solutions (GE Healthcare), they influenced the development of rapid diagnostics for bird flu and a commercial product being launched by a French SME (Genewave). The team has also worked on the detection of the food poisoning organisms *Salmonella* and *Campylobacter* in poultry with a PCR-based diagnostic company (Enigma Diagnostics). This has led to the launch of a multi-platform technique by Enigma with substantial investment from GlaxoSmithKline. McNally has also developed a novel genetic typing scheme for *Yersinia* in human samples, now piloted by reference laboratories (eg Pasteur Institute) and used routinely by the Public Health England enteric reference laboratory, Colindale; thus influencing *public services.*
- Tumour biology: Research at The John van Geest Cancer Research Centre (JvGCRC, Director R Rees) has influenced vaccine formulation by an SME (Immune Targeting Systems) leading to a *pre-clinical investigation*. Rees' collaborations with The Anthony Nolan Trust led to the establishment of the Anthony Nolan Cell Therapy Centre (ANCTC) for banking cord blood (*a public service*) at the NTU Clifton campus.

Enabling and Cross-cutting Technologies

- Bioinformatics and biomathematics: Bioinformatics techniques for identifying clinically-relevant biomarkers have been developed by the G Ball/R Rees team (case study 3), notably re-defining the Nottingham Prognosis Index for predicting prognosis and defining therapy for breast cancer. Four patents have been filed and a spin-out company with contracts from large pharmaceutical and diagnostic companies (Astra Zeneca, Oxford Biomedica, Diagenic) launched. International clinical trials are underway. Impact is therefore on both *health and welfare* and *commerce.* S Richards is developing techniques to fit experimentally generated neutron data at the Science Facilities Council; thus influencing user community and impacting on *public services*.
- Pharmaceutical chemistry, analysis and imaging: The development of nanomaterials led by G Cave is providing improved methods for delivering micro-nutrients in the diet (notably iron, calcium and zinc) via the fortification of food crops (e.g. potatoes with the Agriculture & Horticulture Development Board [AHDB] and BM-Tek Ltd), drinks (sports drinks with Clear Motivation Ltd) and supplements (vitamin uptake in partnership with Co-Formulate Ltd). These are being exploited by both government agencies and industry; *knowledge* is *being transferred* via EU funded projects (ERDF funded Future Factories) and TSB Innovation vouchers (Ref. nos 1752 & 2377). Cave and co-workers have patented a low cost MRI device offering a viable alternative to conventional superconducting MRI scanners and a potential point of care analytical tool); technology being further developed via FP7 funding (SME-2013-606326). S Allin is CEO of Charnwood Molecular Ltd., a company offering synthetic chemistry support for chemical/pharmaceutical/biotechnology industries, employing 22 staff at Loughborough and BioCity (Nottingham) sites; turnover of £1.7M.
- Proteomics: Evidence on the impact of establishing food authenticity is increasing. Working with Defra novel methods have been developed by E Billett's team to determine the authenticity of meat products; this addresses a need given that available assays could not monitor whether products adhere to the law. Patents have been filed and a number of companies (manufacturers

and retailers) and Public Analysts are using the service to monitor meat authenticity. A spin-out company has recently been formed to capitalise on the technology (ProFitN, 8514524).

b. Approach to impact (Note: publication numbers of patents are cited below)

The Unit has benefitted from institutional support and established its own additional mechanisms to both create opportunities and achieve national and international impact. These include:

- Engagement with a **Business Development Manager** who provides support for the identification, protection and exploitation of Intellectual Property (IP), oversees agreements (material transfer, non-disclosure, confidentiality), and interfaces with venture capital investors. The University provided funding for a number of patents during the REF period: cancer diagnosis markers (WO20/0046625A1); detection of albumin (WO2013027023A3); coating metal oxide particles (WO2013/136082A2); data anlysis method and system (WO2010/046697, US-2011-0282819A1, CN102282559A, EP235120A); optical microscopy with NMR (WO 2010/038038A1).
- Support for securing **local venture capital investment**. In 2009 Ball /Rees secured £250k from the Lachesis Fund to launch the spin-off company CompanDX Ltd. *Lachesis Pathfinder* funding (£15k) and HEIF funding '*Stimulating Innovation for Success'* (SIS, £10k) was awarded to Billett to assess the use of meat authenticity testing by SMEs, resulting in Technology Strategy Board (TSB) proof of market funding for ProFitN. Cave attracted SIS funding to work with an SME to formulate food-grade nanoparticles and from the ERDF Future Factories Initiative and an Innovation Fellowship to offer nanotechnology-based solutions to improve absorption of vitamins; data supported a BBSRC CASE studentship with the AHDB Potato Council (BB/K012878/1).
- Grant alerts and support from the Unit's '**Charity and Industry' Officers** (supported by HEIF Research and Innovation Funding (2010-11), and from the **NTU Research Grant Capture Team** (2012-date) which brokers relationships/collaborations with industry and other end-users, providing support for translational collaborative research. This is evidenced by Technology Strategy Boards (TSB) awards (to McNally for developing a portable, rapid, automated DNA analysis point of care system [joint funding with MRC]; to Ball for TB diagnosis; to Cave [feasibility vouchers for nano-particle formulations]) and grants for collaborative research between HEIs and industry/NHS, including salaries and a new mass spectrometry facility (>£500k via ERDF supported Health and Bioscience/Food and Drink Innovation Networks based in the East Midlands to Ball, Billett, Cave, Forsythe, Manning, Rees, Verderio-Edwards).
- Engagement with **University's Development and Alumni Relations Team** for fundraising initiatives such as accessing funds for a Beckman Coulter MoFlo Cell Sorter plus salaries (£500k) for the JvGCRC, (Ball, Pockley, Regad, Rees), and CompanDX Ltd (Ball, Rees).
- Involvement **in internal and external events**: Research Showcases at NTU, the annual School Research Conference, KTN and regional networking events, Conferences and workshops, including TSB workshops (e.g. Nano KTN meetings) and Special Interests meetings (e.g. East Midlands Infectious Diseases Research Network, McNally being a founding member).
- **Use of Unit QR funding for collaborative travel and research costs** (e.g. for DNA sequencing of bacterial isolates; Forsythe, McNally, Manning), support **of studentships which led to impact** (Cave, Ball, Forsythe), and co-funding of a joint Chair and a PhD studentship with The Anthony Nolan Trust, likely to result in procedural changes in cord blood banking.
- Provision of **Unit funding to host NHS employees**; three of our visiting clinical scholars (M Khan [Leicester University Hospitals Trust] and D Powe and R Parkinson [Nottingham University Hospital Trust] provide specialist advice for the JvGCRC on prostate and breast cancer.
- Use of **Unit QR income to part-fund joint projects with relevant users**; for a joint studentship with the Veterinary Laboratories Agency (Manning), industry (Charnwood Molecular Ltd, Allin) and to support staff engagement in the Industrial Innovation Fellowships scheme (Cave).

For engagement with the NHS, the Unit has capitalised on its own network of clinical collaborators to secure joint funding from Hospital Trusts; Nottingham University Hospital Trust has funded 2 projects, 'Nottingham Prognostic Index Plus' (£190K, Ball, with Prof I Ellis at the City Hospital) and 'Biomarkers in Prostate Cancer' (£37K, Rees, with Prof M Bishop, City Hospital). This has led to impact (health and welfare/commerce, outlined in case study 3, and support from the charity 'Prostaid' for a clinical programme via Prof Masood Khan, Leicester University Hospitals Trust).

c. Strategy and plans

In line with the University strategy to support the development of research with impact, the Biomedical Sciences Unit will promote and support end-user engagement in order to increase

exploitation of its research and increase its influence on health and welfare and public policy/services. It will further embed the culture that recognises the importance of impact, involving both academic and research staff (RAs/PDRAs) in the process, ensuring that our 8 ECRs are fully conversant with the philosophy of impact. It will continue to access University-based initiatives and further enhance its own initiatives to deliver impact, particularly where these have been successful. Working with Heads of Departments to provide staff with the time to deliver impact; delivery of impact will be included in the annual Personal Contribution Development and Review process.

In collaboration with the ANCTC, the JvGCRC team has evaluated the quality of cord blood products from different sources following storage at different temperatures **(**DOI: 10.1111/trf.12006). Plans to implement changes in CD34 stem cell preservation will eventually impact on *health and welfare*. CompanDX will continue to negotiate with large pharma and diagnostic companies and to exploit their technologies. ProFitN will form partnership agreements with companies to combat food fraud. New opportunities exist to use nanoparticles for enhancing the nutritional value of a range of food staples, and to improve micronutrient formulations, building on the BBSRC CASE studentship. Patents filed in this area will be exploited via a spin-out company and licencing agreements (a number of large companies/retailers are exploring potential routes to market under NDAs). The Unit will attempt to **capitalise on its close links with companies at BioCity Nott. Ltd** (the UK's largest bioscience innovation /incubation centre) **and on consultancy work** to develop partnerships which could lead to collaborative research and opportunities to secure further funds (TSB, CASE studentships, clinical investigations etc). Note that consultancy with Immune Targeting Systems led to funding for a pre-clinical investigation.

The services of the **NTU Research Grant Capture Team** will be utilised more widely within the Unit, notably to facilitate relationships with companies and other end users in order to attract funding, and to identify companies and organisations offering contract work in areas that complement our expertise within our 2 platforms. By liaising with companies throughout the early development stages of projects, our research teams will continue to focus their research strategies towards the end user. During 2012 the Unit's Advisory Group established an '**Impact Task Force'** (ITF) to identify 'early impact' within Biomedical Sciences, and to start working with staff to identify ways in which the impact could mature. The ITF includes Directors of the Biomedical Life and Health Sciences Research Centre and JvGCRC, academic staff with established impact, staff whose research has the potential to deliver impact, the College Business Manager, the Head of the NTU Research Grant Capture Team and a representative from PDRA/RA staff. In future the ITF will be expanded to involve at least two external representatives to provide additional advice and to encourage collaborations that will deliver impact. External members will include an NHS representative (e.g. the Director of NHS Innovations East Midlands), and an industrial representative (e.g. a Director of an SME, since the government is currently providing financial support and other incentives to develop innovative and high growth SMEs). Members of the Visiting Professors Academy will be invited to join the ITF, thus providing further insight into the pathways for delivering impact. The purpose of the extended ITF will be to review research activities across the Unit, to produce an **'impact prospects list'** which can then be fully assessed; measures will be put in place to enable impact (e.g. contingency funding for collaborative travel and research costs; identification of companies which could take forward technology/procedures to the market place).

d. Relationship to case studies

For a brief descriptions of the case studies please refer to section (a). Case Study (CS)1 = 'Forsythe', CS2 = 'McNally'; CS3 = 'Ball'.

QR funds for PhD studentships with impact underpinned CS1 (3 studentships 2001-date, Iversen, Caubilla-Baron and Joseph) and CS3 (2 studentships, Lee and Lemetre) and supported 6-month sabbaticals for key staff (Forsythe and McNally) in CS1 and CS2. Travel funds were made available to key staff involved in all CSs. The Business Development Manager (BDM) assisted with securing start up investment money, IP protection/licencing and the legal process of company formation in CS3; and provided general advice for CS2, Funds were made available to support patent filing in CS3, and for time relief for the CS2 lead to attend pre-proposal submission meetings for his successful EU and TSB grants (Paris and London respectively). Media training and support for media engagements were provided to support CS2. The Development and Alumni Relations Team and the BDM assisted in securing funds for a mass spectrometer, cell sorter and salary/running costs to support the spin-out company CompanDX Ltd (CS3).