Institution: University of Nottingham

Unit of Assessment: UOA3 (Pharmacy)

a. Overview

Research within the School is organised into 5 Divisions aligned with our 'Bench-to-Society' vision: Molecular and Cellular Science; Medicinal Chemistry and Structural Biology; Drug Delivery and Tissue Engineering; Laboratory of Biophysics and Surface Analysis and Social Research in Medicines and Health. Interdisciplinary cross-divisional and external collaborations, clearly evident from our many joint publications, patents and peer-reviewed funding, facilitate core activities in drug target identification, drug discovery, formulation, *in vitro/ in vivo* studies, clinical trials, medicines use and public health. A number of integrated committees lead operational and strategic developments in the School, including: School Management Committee (SMC); School Research Committee (SRC); Postgraduate Committee (PGC); Knowledge Transfer Committee (KTC); Equality and Diversity Committee (EDC); Grant Academy (GA); and Researchers' Forum (RF).

The School provides a supportive open collaborative environment for world leaders, mid-career and early stage academics, ambitious research fellows and PhD students by providing strategic, personal and financial support alongside open access to world class facilities, high quality training, and professional development opportunities. We disseminate our research through journals, learned societies, conferences, the media, and public and industrial engagement. This is evidenced by the 2013 QS World University Rankings showing that the School of Pharmacy is 15th in the world for Pharmacy and Pharmacology – based on academic and employer reputation, H index and research citations (note the University of Nottingham has no School of Pharmacology).

Since 2008 we have: published 662 peer-reviewed papers; received >30,000 citations for all papers (6004 for papers published in the REF period); given over 300 invited talks, received research income of over £28.9M (versus £19M in the longer RAE2008 period); and graduated 202 PhDs (ca. 40 p.a. versus 22 p.a. for RAE2008) with a 4 year submission rate of 93%.

b. Research strategy

Building from our RAE2008 'Bench-to-Clinic' strategy, our portfolio of multidisciplinary scientific and social research is focussed on developing treatments for some of the most complex challenges in healthcare from discovery, through to the clinic and now to society. We have built on our strong research base with a new research structure centred on excellence at all levels, supported by targeted School and University resources and complemented by a global network of leading academic, health service, government and industrial collaborators.

The University of Nottingham (UoN) was the first in the UK to establish overseas campuses (China, Malaysia). The School of Pharmacy in Malaysia is fully integrated with our research structure in Nottingham. In collaboration with the East China University of Science and Technology in Shanghai, we have launched a major new initiative - the Shanghai Nottingham Advanced Academy. Joint postgraduate programmes in Pharmacy will be available from Sept 2014.

Research Divisions and Their Key Achievements

Research in the School is divided into 5 complementary Research Divisions, reviewed on a rolling basis in terms of research outputs and impact. For each we describe their rationale and core strengths and provide some research highlights from 2008 onwards.

Molecular and Cellular Science (MCS) *(Head: Prof. D Barrett)*
Mission: To understand biological processes through basic and applied biological sciences.
Strengths: Drug target identification, bioassay development, bioanalysis and translational research. Biological processes are investigated at the molecular, cellular and organism level.
Highlights: Characterisation of the role of the protein unfolding response in treating neurodegradation (*Nature, Science Translational Medicine*), microRNA function in DNA damage and oncogene regulation (*PNAS*), and obtaining an MHRA licence for clinical trials manufacture.

Medicinal Chemistry and Structural Biology (MCSB) *(Head: Prof. P Fischer)*
Mission: To design and develop biologically active compounds through integration of chemical

biology and drug discovery, and collaborate with industry on preclinical drug discovery.
Strengths: Synthetic and computational chemistry and structural and functional biology applied to molecular recognition and the design of new therapeutics.
Highlights: Clinical candidates for concomitant cardiovascular and respiratory disease and first-in-class protein blockers as potential anti-angiogenic /metastatic therapeutics (both *J. Med. Chem*.).

Drug Delivery and Tissue Engineering (DDTE) *(Head: Prof. C Alexander)*
Mission: To develop new therapeutics using novel drug and cell delivery systems exploiting nanotechnology, smart materials, synthetic biology, stem cell research, and tissue engineering.
Strengths: Basic and applied research targeted at new therapeutic areas using polymer chemistry, formulation, imaging, cell biology and materials science.
Highlights: Developing novel materials that extend the life-time of embryos in culture (*Nature Com*.), and control bacterial expression of quorum sensing phenotypes (*Nature Chem.).* The synthesis of viral mimics for delivery of nucleic acids (*Molecular Pharmaceutics*).

Laboratory of Biophysics and Surface Analysis (LBSA) *(Head: Prof. M Alexander*)
Mission: To address the shortfall in formulation and scale up strategies for medicines/devices by using nanoscale material and single biomolecule analysis and biomaterials discovery.
Strengths: Research into fundamental and applied biomolecular, biomaterial and formulation problems at the nano and micro scale.
Highlights: High throughput identification of new materials for expansion of populations of pluripotent human stem cells (*Nature Mat.*) and polymers resistant to bacteria (*Nature Biotech.*). Ink-jet printing as a new route for manufacturing solid dosage forms (*J. Control. Release*).

Social Research in Medicines and Health (SRMH) *(Head: Prof. C Anderson)*
Mission: To influence health policy to improve the safety, efficacy and efficiency of medicines use, and global pharmacy education and workforce policy.
Strengths: Advancement of knowledge about medicines and pharmacist's role in improving public health. Influence practice and policy for the improved health of patients.
Highlights: Economic analysis of complex interventions to improve prescribing and safety monitoring (*Lancet*), and evaluation of patient reporting of adverse drug reactions via the UK Yellow Card System (*NIHR HTA*), leading to changes in patient reporting to the MHRA.

Achievement of Previous Strategic Aims
In 2008 the School's ambition was to maintain a vibrant curiosity-driven research culture, build on our research structures to deliver world-class science that promotes knowledge and wealth generation, to promote interdisciplinary science, and to foster the talent of our early career researchers (ECRs). The achievement of these goals is conveyed throughout this document and has been underpinned by the restructuring of the School's management with new committees focussing on research, knowledge transfer, grant writing and equality and diversity.

Developments in School Research Strategy - In 2009 the School established the SRC (annual budget ca. £100k) to manage and promote a pipeline of research, the GA to support staff in grant application strategy and writing, and the KTC to manage impact activity (see impact template). With the PGC, these are the key School structures for supporting research staff and delivering the vision developed by SMC. The SRC invests in research activities (eg. proof of principal data, conference attendance, sabbatical activity, equipment, strategic alliances), with applications competitively assessed for quality, impact and fit to strategic vision. In excess of £0.5M has been invested in around 90 projects since 2009. SRC funds have been strategically used to develop our Nottingham-Monash (Australia) Alliance programme, whereby joint research programmes are promoted between the two Schools of Pharmacy. Funds of £29k (since 2008) have been used to support staff exchanges, sabbatical visits and research projects. The GA draws from a team of senior academics and our Business Development Officer to enhance the quality of grant applications. The GA identifies areas requiring strengthening to improve specific grant applications and works with SRC to provide funds to address identified shortcomings. This scheme has aided our academics in gaining peer-reviewed funding in new areas. For example, following guidance from the GA, £8.1k of SRC support helped *De Moor* secure a BBSRC Project Grant in 2012

(£550k) and £2.3k from SRC helped *Dreveny* secure a Leverhulme Trust award of £150k (2013).

The PGC provides matched funding (typically 50%) for externally sponsored PhDs (24 PhDs since 2008, ca. £560k). The School also has two EPSRC Centres for Doctoral Training (CDT) bringing in 10 PhDs p.a. The Targeted Therapeutics CDT (*C Alexander*) started in 2006 with AstraZeneca (50:50 funding). Since 2011 we have expanded the CDT to bring in UCL, GSK, Pfizer, Alliance Boots and Quotient Biosciences. The second CDT with Loughborough and Keele in Regenerative Medicine (*Shakesheff*) began in 2009.

Interdisciplinary Research - Pharmacy is a highly multi-disciplinary subject and the SRC actively promotes collaborations across disciplines through sandpits, workshops and targeted funding. Since 2008 we have held the Directorship of the Centre for Biomolecular Sciences (CBS, *Shakesheff, Fischer*), the UoN's £40M research institute spanning the Faculties of Medicine, Science, and Engineering, and the Nottingham Nanotechnology and Nanoscience Centre (NNNC, *Roberts*). This has led to collaborations in drug discovery for cancer and cardiovascular disease, bacterial biology, structural biology, stem cell technology, new antibiotics, and nanomaterials. Since 2011 the School has also held the Directorship of the Wolfson Centre for Stem Cells, Regenerative Medicine and Modelling (*Shakesheff*), which brings together clinicians and scientists from across the UoN. Our interdisciplinary working is evidenced by approximately 2/3 of research grants awarded (since 2008) having applicants from outside the School.

National Centres and Major Awards - A major success since RAE2008 has been securing national centre status and major competitive programme awards driven by our desire to lead national agendas and to build innovative strategic collaborations. The School co-directs (*Shakesheff*) with Loughborough and Keele the £5.8M EPSRC Centre for Innovative Manufacturing in Regenerative Medicine, founded in 2010 and supported by 28 partners from industry and the public sector. In 2013 the School established the cross-institutional National Centre of Excellence in Mass Spectrometry Imaging (*M Alexander*) with the National Physical Laboratory (NPL) and GSK to expand on a UoN strategically funded (2012, £410k) collaboration (ISAC, Interface and Surface Analysis Centre). This Centre recently secured £4.3M from the National Measurement Office to build the world's first 3D Nano-SIMS to study drug transport in cells. Also of note is the award of the RCUK Regenerative Medicine Platform Hub in Acellular Technologies and associated capital equipment funding (MRC) in 2013 to *Shakesheff* and *Rose*. The first tranche of funding until 2017 is £5.4M (£2M to the School). Other major grants (all amounts are to the School not total award) include a €2.5M European Research Council Advanced Investigator Grant (*Shakesheff*); £1.3M EPSRC Stem Cell Grant (*M Alexander*); £1M EPSRC Leadership Fellowship (*C Alexander*); £1.2M Wellcome Translation Award (*M Alexander & Davies*); £1.5M MRC Senior Non-Clinical Fellowship (*Bushell*) and £1M Wellcome Trust Seeding Drug Discovery (*Fischer & Kellam*). In addition, institutional awards led by the School include the EPSRC Impact Acceleration (*C Alexander*) (£2.6M) and Equipment (*Tendler*) (£4.5M) Accounts.

Dissemination of Research - Dissemination and translation of research are key performance indicators for the School and its staff, with an emphasis on quality of output. Pathways to dissemination are varied (publications, conferences, media, public engagement, books, YouTube, iTunes, etc) and supported via SRC funding (ca. £37k), workload management for staff, and provision of regular sabbaticals. The School has an Outreach Coordinator (*Dreveny*) with engagement activities including:

- After-School Science Club with regular contributions by staff and students in local Schools.
- NanoWhat 2008 East Midlands Roadshow seen by ~23,000 people including 1,296 school children from 40 schools. Teacher's Lesson Plan (yrs 7 & 8) used in 15 Schools.
- UoN as part of the ZED Pavilion (only UK HEI) at World Expo 2010 (Shanghai, total attendance 73 million; 200,000+ visitors over 6 months to UoN Pavilion); activities included a drug discovery conference for over 100 leading Chinese academics and industrialists.
- Pharmacy Research Exhibit at Cheltenham Science Festival, 2010.
- Talks to teachers, "Nanotechnology in Healthcare" World ORT, 2009; "Frontier Science Lecture Programme" ASE, 2010; IOM3 "Nanotechnology - Small World, Big Ideas", 2010.
- Animal Planet TV "Monsters Inside of Me" featuring the Parasitology group, 2010.

- EPSRC IMPACT Exhibition – Royal College of Art, London, 2010.
- 'Flights of Fancy' nano-exhibition at the Nottingham Contemporary Art Gallery, 2011.
- BBC TV "Scientific Mavericks" on Prof Pritchard's work on hookworm therapy, 2012.
- 'What is Nanotechnology' (www.youtube.com/watch?v=gYR8lV23Pow 104,000 hits)
- Public talks at Café Scientific: York, 2009; Nottingham, 2009, 2012.
- World's smallest periodic table (http://bit.ly/hSdDR4, 316,000 hits) featured in Guinness Book of Records 2011, on TV in UK (BBC), Italy, Canada and in the journal Science.
- BBC Radio 2 Jeremy Vine Show discussed the PINCER trial on medication errors, 2012.
- 'Biology Builders' Stand at Royal Society Summer Exhibition, 2013 attended by 12,505 people including 2,618 school children. BBC World Service, Guardian, Fox News and Huffington Post.

Research Plans For Next 5 Years

The School has integrated research plans designed to deliver its 'bench-clinic-society' mission. As evidenced by our impact case studies, the School has a deep understanding of the academic, clinical and industrial sectors enabling it to respond to challenges in developing effective medicines. We align this knowledge with advances in smart materials, stem cells, drug discovery, nanotechnology, high-throughput technologies and new capacity in areas such as synthetic biology, pharmacokinetics and clinical pharmacy. Our plans are built upon strategic alignment between School and Research Division goals, UoN and national priorities, and global healthcare needs. Indeed as members of the UoN Management Board (*Tendler*, 2009-present), the Shanghai-Nottingham Advanced Academy Task Force (*Shakesheff,* 2009-11), UoN Senate (*Anderson*, 2008-12; and *Rose,* 2012-present) UoN Innovation Board (*Davies,* 2011-present) and PVC for Research (*Tendler*, 2012-present) we have played an important role in developing UoN vision. The School aims to remain internationally leading in our established areas and to build new capacity in areas identified to meet our vision. Our main strategic objectives are detailed below.

Research Pipeline Management - All academics have an agreed 5 year research plan aligned with Divisional targets and the School vision. This includes detailed plans for grant submissions over a rolling 12 month period and a clear vision of research funding strategy out to 3 years. This ensures horizontal integration within each Division and vertical integration of individual plans to the School strategy and the targeting of resources.

Capacity Building - The School has had a net increase of 8 staff at Lecturer and Associate Professor level since 2008 in areas designed to build capacity in drug discovery, formulation, bioanalysis, regenerative medicine, pharmacokinetics, clinical and social sciences (see section c for further details). Longer term succession and new positions are planned in areas including synthetic biology and bioformulation. To increase long-term clinical pharmacy capacity, we have initiated a Research Practitioner programme from 2013 whereby Pharmacists spend 2-3 days a week in the School studying for a PhD, whilst continuing in their community and/or hospital roles.

Research Student Recruitment - Individual staff and Divisions have targets for PhD recruitment to ensure critical mass is maintained or grown in strategic areas. This is dependent upon maintaining diversity in funding (RCUK, Charity, Industry, EU) and continued School leadership in EPSRC CDTs and BBSRC DTPs. As part of our future planning the School successfully submitted a renewal of our EPSRC funded CDT in Targeted Therapeutics for the period 2014-22 (£7M) with expanded industrial support (AstraZeneca, GSK, Boots, Pfizer, Merck Sharp Dohme, UCB Pharma, Novartis, Kuecept, and Syngenta).

Future Development of Infrastructure - The School reviews space and equipment allocation to ensure appropriate resource versus activity and ensure capacity for growth in identified areas. This is now aligned under the new UoN Facilities and Equipment Management Committee (*Roberts*). Several on-going initiatives are in place to secure funding, including a £700k bid to BBSRC for Mass Spectrometry, a £1M bid to EPSRC to develop digital manufacturing methods for drug eluting implants for cancer therapy, and a UK Research Partnership Investment Fund bid of £30M.

c. People, including:

i. Staffing strategy and staff development

Building a Sustainable Staffing Structure - Research staffing strategy is the responsibility of the

SMC, informed by the SRC. The School has funded new posts to implement its research strategy since 2008, including 15 academics, a Research Business Manager and new technical staff. New academic staff have been supported with significant start-up consumables funding (ca. £10k each) plus prioritised SRC funding and in most cases one or more fully funded PhD students (ca. £60k each). We have three new Associate Professors (Health Economics (*Smith,* 2010), Medication Safety (*Gray,* 2013) and Treatment of Pain (*Knaggs,* 2011)) and one new Lecturer (Health Economics and Policy (*Chen,* 2010)) in the SRMH division. To support new initiatives in drug discovery and greater links to clinical sciences, two Lecturers (Structural Biology (*Dreveny, 2008*) and Pharmacokinetics (*Gershkovich,* 2012)), an Associate Professor (Industrial Drug Discovery (*Stocks,* 2012)) and a Chemical Compound Collection Manager have been appointed. To reflect new priorities in biopharmaceuticals, bioanalysis, cell based therapeutics and drug delivery for unmet clinical needs, four Lecturers (Biologics (*Mantovani,* 2009), Metabolomics (*Kim,* 2013), Cell Electrochemistry (*Rawson*, 2013 Leverhulme Fellow), and Cell Delivery (*Yang*, 2013 Nottingham Advanced Fellow)), and an Associate Professor (Clinical Drug Delivery (*Marlow,* 2012)) have been appointed. We have also secured a permanent post for *Jopling* when her BBSRC Fellowship ended (Sept 2013). Two new Research Officers have been strategically funded, through sustainable business plans, to grow our work in surface chemical analysis and molecular biology, the former post being instrumental in securing £410k to support our collaboration with NPL (recruiting two joint academics (*Bunch & Zelzer,* 2013) and a dedicated Business Manager). To build upon emerging links with the School of Physics and NNNC, a Senior Research Fellow has also been internally funded. With the appointments outlined above, and a number of internal promotions (discussed below), the School has a sustainable balance of academic staff at all levels of their career, with an average age of 45.2 years (range 32 to 66). As succession planning for our vital research support staff, in 2012 we implemented an apprentice scheme recruiting one technician in the first instance.

Staff Development - Personal development and research career progression are reviewed on an annual basis through UoN's formal Personal Development and Performance Review process. Individual targets are agreed with the Head of Division or School. Staff are further encouraged and supported in their development though a number of schemes:

- A mentoring scheme, launched in 2012 for all staff, to run alongside the pre-existing scheme for new academics. The scheme is of particular value to ECRs and new lecturers who have the opportunity to gain knowledge from more experienced members of staff. UoN programmes such as the annual Leadership Programme (e.g. *Rose*) support this activity.
- An inclusive sabbatical programme whereby staff are on sabbatical for one semester every 4 years (54 in total since 2008). Funds are available from SRC for initiatives to develop new skills. Academics have reported a relationship between their sabbatical activities and development of their research, including grants awarded (*Emsley*, BHF, RG/12/9/29775, £885k and *C Alexander*, Australian RC £250k (£47K from School)).
- Staff at all levels are encouraged and supported through management of workloads to take leadership roles in developing UK and international research strategy.
- A Staff Development Officer (*Bosquillon*) arranges regular training events and a support group, the Pharmacy New Academics Club (Chair: *De Moor*), was set in 2013 up to help ease the transition into academic life and/or working in a School of Pharmacy.
- A transparent promotion procedure with 14 School academic staff being promoted since 2008; 6 to Professor (*Williams, M Alexander, Barrett, C Alexander, Emsley, Kellam*), 7 to Associate Professor (*Buttery, Rose, De Matteis, Aylott, Winkler, Spriggs, De Moor*), *Bradshaw* to Lecturer and 2 promotions for ESRs based on excellent performance (*Scurr, Ortori*).

Concordat to Support the Career Development of Researchers - The School is committed to supporting researchers by implementing the key principles of the Concordat. In addition to the opportunities outlined above, the School ensures that researchers engage with University-wide career development programmes and industrial research partner training opportunities. The UoN Graduate School (inclusive of the new £10M Engineering & Science Graduate Centre) supports PDRAs and aims to improve the employability of researchers through the dedicated Researcher Development Programme, including innovative training courses, careers sessions and seminars. UoN offers a wide range of training and development opportunities to enable all staff to extend

their professional skills and knowledge. These are delivered by several training providers, including Professional Development, the Careers and Employability Service and Information Services. Access to the Vitae Midlands Hub is also available, whereby researchers can attend short courses that are not offered at Nottingham.

The Researchers' Forum, a consultative committee of PG students, PDRAs, academics and administrative staff, organises events to support ECRs (e.g. workshops on Fellowships) and is consulted on new School initiatives (e.g. mentoring scheme, space allocation). It also organises regular social events (>4 p.a.) aimed at building an integrated School-wide network of staff and students. The School also organises an annual training course on Careers in the Pharmaceutical Industry highlighting the breadth of careers available and bringing in representatives from big pharma, SMEs and academia. Over 170 PG students/PDRAs have attended the course (since 2008) with contributions on each course from at least 8 different commercial organisations.

Equality and Diversity - The School's EDC considers how to promote and manage a research environment that is fair to all staff and applicants. We hold an Athena SWAN Silver Award (since 2009) for our commitment to strategies to create a supportive environment for female academics and research scientists. Since 2008 we have implemented new policies and initiatives, including:

- A conference support fund to finance additional costs incurred by any member of staff or PhD student due to caring responsibilities or any other reasonable reason.
- A balance of male and female speakers on our external seminar programme, and arrangement of networking events around these seminars.
- We continue to encourage a flexible working environment where people can request modest changes to working hours to fit with individual needs.
- All School meetings and social events are held within core hours (9.30am–3 pm) and are now held on differing days allowing part-time staff the opportunity to attend.
- Monitoring of gender balance of our decision making committees and interview panels.

ii. Research students

Effective and Sustainable Postgraduate Training - Postgraduate strategy is overseen by the PGC (Chair: *Chan*), which is responsible for PG recruitment, new course recommendations, investment of School funds in PhD training (ca. £250k p.a.), and governance of our PhD programmes. Since 2008 we have graduated 202 PhDs (ca. 40 p.a. versus 22 p.a. for RAE2008), with an average 4 year submission rate of 93%. Funding is attracted from the EPSRC, BBSRC, EU, MRC, industry and major charities. With research councils focussing PhD funding on centres and training partnerships, we have been pleased to secure 2 EPSRC Centres for Doctoral Training (Targeted Therapeutics (2006-17, £4.8M) and Regenerative Medicine (2009-17, £1M)) and to have played major roles in the UoN's successful bids for a BBSRC Doctoral Training Partnership (2012-18, £5.7M) and an ESRC Doctoral Training Centre (2011-19, £6M). The School is also the UK lead and on the Management Board of the NanoFar Erasmus Mundus Joint European Doctorate in Nanomedicine and Pharmaceutical Innovation (2012-20, ~€6M). In addition, we were instrumental in the establishment of a UoN-wide doctoral training activity in Interdisciplinary High Performance Computing to facilitate inter-departmental PhD training. The School has hosted 87 industrial studentships (including CASE awards) over the REF period, with the support of 35 companies - AstraZeneca, GlaxoSmithKline, Alliance Boots, Abbott Vascular, Novartis, Baxter Healthcare, 3M Health Care, Medimmune, UCB Celltech, C S Bio, Novozymes, Archimedes Pharma, Quotient Clinical, Syngenta, NPL, Critical Pharmaceuticals, Molecular Profiles, RegenTec, Eminate, Pfizer, Novo Nordisk, Ipsen Biopharm, KuDOS Pharmaceuticals, Grunenthal, Merck Sharpe & Dhome, Psioxus Therapeutics, D&R Sharpe, Mars, Pharminox, Cyclacel, Unilever, Bristol Myers Squibb, Plant Biosciences Ltd, Cosmas-Damian and Dow Corning. The School has recruited an average of 53 PhD students per annum since 2008, leading to impressive numbers of registered students. The School has a target of 1 new PhD student per academic per year, which we have exceeded every year since 2008, providing a strong indicator of research vitality in Pharmacy at Nottingham.

	2008-09	2009-10	2010-11	2011-12	2012-13
PhD students recruited	48	48	54	51	62
Number of academic staff	43	44	43	43	44

Codes of practice for the supervision, monitoring and appraisal of students are set out in the UoN's Quality Manual. The School implements these procedures, and encourages the acquisition of new skills and personal development via UoN (Graduate School) and School based training programmes. All PhD students present their work 3-4 times annually, to the entire School at weekly postgraduate seminars and within divisional research meetings. The School also has an external seminar programme which brings in high profile speakers (e.g. Prof Peter Parker FRS, CRUK LRI; Prof Hagan Bayley, Oxford; Prof David Grainger, Utah; Prof Stephen Soumerai, Harvard). Student attendance at seminars is compulsory to ensure an understanding of the inter/multi-disciplinarily of the research field. A poster day for 2nd year students (and Post-Doctoral Researchers Day) is also hosted by the School with prizes for the best presentations. Students are actively encouraged to attend at least one international conference to present their work, with travel funds available through the Graduate School.

Research Outcomes and Outputs from Postgraduate Students - PhD students make a major contribution to our research portfolio. We note the significant contribution of PhD students in underpinning a large volume of our world-leading research activity at Nottingham with a significant majority of the School's publications submitted to REF2014 involving at least one PhD, many as first author. Examples of exceptional outcomes of PhD research are:

- *Ghanami* contributed to the invention of a thermo-reversible colloid gel with a *Soft Matters* paper and international patent application (PCT/GB2013/051894).
- *Mistry,* for the first time, used rational design of subtype-selective beta-adrenoceptor antagonists, which led to a major drug discovery project funded by the Wellcome Trust and a patent application (WO2012004549).
- *Patankar* developed a new material for stem cell culture that led to breakthrough embryo patterning research in collaboration with the Gurdon Institute, University of Cambridge (*Nature Comm.*). Patent application submitted (WO2013001315).
- *Abdelghany* correlated global histone modification in breast cancer tissue to tumour immunophenotypes (*Cancer Research*).
- *Serumaga* revealed the failure of pay-for-performance in hypertension treatment, published in the *British Medical Journal* and cited globally including in BBC Health News, NY Times and Time Magazine. He was also interviewed on BBC Radio 4 about his findings (March 2011).

d. Income, infrastructure and facilities

Summary of Income – Since 2008 the School has secured research income totalling over £28.9M (versus £19M in longer RAE2008 period) through a broad portfolio of sources (RCUK contributing 52%, charities 22%, industry 10%, UK Government 8% and EU 8%). Our research awards for the same period total over £34.5M, with approximately a third of this amount awarded in 2012 and 2013, confirming a sustained level of research funding going forward.

Nature and Quality of Infrastructure and Facilities - The School has access to excellent facilities across three buildings that have been built or refurbished in the last 15 years. The Boots Science Building (opened in 1999) is a dedicated research facility housing the LBSA and parts of DDTE and MCS. The CBS is a cross-faculty research facility (opened in 2003, Phase 2 in 2007) housing MCSB and parts of MCS and DDTE. These buildings house state of the art facilities in molecular biology, cell culture, mass spectrometry, medicinal chemistry (inclusive of an 80,000 compound library), structural biology, molecular modelling, microscopy, parasitology and formulation (inclusive MHRA licence). The School of Pharmacy building is home to SRMH and our PG Support Office, and was refurbished and expanded in 2009-10 and 2013.

Other important facilities we access include the NNNC, the Biomedical Support Unit within the Queen's Medical Centre and the UoN High Performance Computing (HPC) facility. The School was actively involved in the procurement of this facility (£1.2M SRIF, 2008) and the latest HPC system (£1.5M UoN), which was launched in January 2013.

Effective Equipment Use and Renewal - We have contributed to the UoN's initiative on equipment sharing by leading EPSRC Open Access projects in Materials and Nanotechnology and

spearheading the recent UoN reviews of Electron Microscopy, Mass Spectrometry and BioImaging Facilities. An online equipment database (Kit-Catalogue™) for all equipment with a purchase cost over £30k has also been created to allow sharing across the UoN.

The School has also invested in equipment since 2008. Funds for new equipment are managed via the SRC, taking into account School and UoN strategic priorities and ensuring open access and sustainability, inclusive of renewal strategies. Small equipment (and upgrades) funded by SRC includes: microscopes, HPLC, PCR, particle sizing, plate readers, centrifuges, ellipsometry, protein crystallisation tools, modelling software and medical databases (ca. £300k since 2008). In addition, the School has been involved in RCUK and CIF equipment awards totalling £13.9M since 2008, with awards led by the School totalling £4.9M. Equipment includes: Medicinal Chemistry Compound Library, 800 MHz NMR, X-Ray Diffraction and Mass Spectrometer.

Cross-HEI Shared Facilities - The School contributes facilities into a number of national and regional schemes to promote shared access. The EPSRC Centre for Innovative Manufacturing and Regenerative Medicine (*Shakesheff*) and the sister CDT for PhD training allow mobility of staff and students across Loughborough, Nottingham and Keele Universities. This has resulted in sharing of facilities for imaging, polymer science, flow cytometry and bioreactor culture.

The NNNC (*Roberts*) provides a hub for nanoscience research, training and outreach and has grown significantly since its founding in 2007. New facilities (in addition to the £13.9M above) include an advanced high speed confocal Raman system (part of a £663k EMDA investment), Nanosight LM10-HS (Nanoparticle Tracking Analysis), IZON qNANO nanoparticle analysis, LiPPS and standard XPS (£700k). The Centre has also led two EPSRC Open Access programmes (EP/F056478/1 (09-11) and EP/F019750/1 (08-12)), whereby academics from UK HEIs (35 institutions) had free access to equipment at the NNNC and across the UoN.

The UoN, led by the Schools of Pharmacy (*Williams*), Chemistry, Computer Science, Physics, Maths and Engineering, is also one of four Universities (with Birmingham, Queen Mary and Warwick) in the £3.5M EPSRC (EP/K000128/1 and EP/K000233/1) supercomputing hub MidPlus that promotes interactions with business along the M1/M6 corridor. Additionally, the Kit-Catalogue has been extended to include the M5 Group of Universities (www.m5universities.ac.uk/facilities/) to allow equipment sharing and access across the Midlands.

Significance of Major Benefits-in-Kind - A number of staff regularly access Diamond and the European Synchrotron Radiation Facility funded via STFC (£281k and £69k respectively) and use the UK supercomputer HECToR via EPSRC funding (EP/G004455/1; £589k). Other in-kind support includes loans or access to equipment from industrial partners, staff time donated to supervision of projects by industrial collaborators, and time donated to the School by external consultants and industrial colleagues in providing strategic advice to the School (e.g. Prof Mike Eaton ex. UCB Celltech, 4 days p.a., member of KTC).

Policy and Practice of Research Governance - The UoN Code of Research Conduct and Research Ethics provides a framework for the governance of research throughout the UoN, requiring adherence to the highest standards of performance and ethical conduct. It gives specific guidance on areas such as data, publications, intellectual property, ethical review, etc. All Schools are required to appoint a Research Ethics Officer (*Falcone* in Pharmacy) to act as a source of advice for colleagues, and to manage and monitor School procedures. The Research Contracts and Governance section of the UoN Research and Graduate Services provides the academic community and other professional services with contract advice and reviews all research and related contracts to ensure compliance with legislation, regulation and best practice.

e. Collaboration or contribution to the discipline or research base

All members of the School are proactive in undertaking activities that support the research base. A variety of activities which allow us to effectively communicate our research findings, build collaborative networks, and influence wider scientific policy are outlined below.

National and International Collaboration - Academics in the School collaborate with academic

and industrial groups (see section c.ii) locally, nationally and internationally as evidenced through our grant portfolio, patents, invitation to conferences and publications. The School has catalogued over 60 substantive academic international collaborations, including with MIT, Cornell, Harvard, the Indian Institute of Technology Kanpur, ETH Zurich, Technion Israel, Queensland University of Technology, University of Toronto, University of Pisa, Rutgers University, Swiss Federal Institute of Technology, Indian University of Technology New Delhi, University of California, Irvine, Pohang University of Science and Technology, South Korea, KU Leuven, Monash, University of Oslo, Universities of Otago and Auckland, New Zealand, and Dhaka University, Bangladesh. Research networks we contribute to include *Shakesheff* who is the Lead of the UK-India Science Bridge BioPharm 2020 (www.biopharm2020.org); *Falcone* a founding and council member of European Mast Cell and Basophil Research Network (www.embrn.eu); *Anderson* who is Lead on WHO UNESCO FIP Pharmacy Education Taskforce (www.fip.org/pharmacy_education); and *C Alexander* is UK Lead of 'NanoFar' – the first European Joint Doctorate Centre in Nanomedicine (www.erasmusmundus-nanofar.eu).

Conference Activities - Our Staff are regularly invited to speak at international conferences. Since 2008 over 300 invited talks - many as plenary - have been given, including:

- 99th Annual Meeting American Assoc. for Cancer Research, San Diego, USA, 2008 (*Fischer*)
- 55th American Vacuum Society Congress, Boston, USA, 2008 (*M Alexander*)
- International Society on Thrombosis and Haemostasis Congress, Boston, USA, 2009 (*Emsley*)
- 36th Controlled Release Soc. Annual Meeting, Copenhagen, Denmark, 2009 (*Roberts*)
- MicroRNAs and Human Disease, St Kitts, Caribbean, 2010 (*Jopling*)
- Allergy and Immunology in the Tropics, Tanzania, 2010 (*Pritchard*)
- Annual International Pharmacy Conference, San Paulo, Brazil, 2010 (*Anderson*)
- Respiratory Drug Delivery 2010, Orlando, Florida, USA, 2010 (*Bosquillon*)
- Life at Different Scales: Symposium to Honour Evan Evans, Boston, USA, 2010 (*Williams*)
- Nordic Pharmacy Practice and Health Services Conference, Reykjavik, Iceland, 2011 (*Elliott*)
- Int. conf. on Regulatory Network Architecture in Bacteria, Thanjavur, India, 2011 (*Chan*)
- 241st ACS National Meeting & Exposition, Anaheim, USA, 2011 (*Mantovani*)
- 4th Asian Forum on Chromatin, Transcription & Cancer, Hyderabad, India, 2012 (*Heery*)
- World Congress on Pain, Milan, Italy, 2012 (*Knaggs*)
- Nanotechnology for Healthcare Conference, Arkansas, USA, 2012 (*Shakesheff*)
- 4th International Nanomedicine Conference, Sydney, Australia, 2013 (*C Alexander*)
- APS UK PharmSci Conference, Edinburgh, UK, 2013 (*Davies*)

Staff also regularly contribute to the organisation of global conferences. Of particular note is that Nottingham hosted the inaugural APS Pharm Sci conference in 2010 (as well as in 2011 and 2012), the main annual meeting for academic and industrial pharmaceutical scientists (Chaired by *Shakesheff*, >600 attendees) and that *Davies*, as President of the Controlled Release Society, led the organisation of their 2012 annual congress in Canada (1,300 attendees). Further examples of the 40+ conferences we have helped to organise since 2008 include:

- Organising Committee for FIP World Pharmacy Congress, 2008-present (*Anderson*)
- Co-organiser for Chemistry and Biology of Peptides Annual Symposium, 2008-present (*Chan*)
- Organising Committee for the Health Services Research Networking/Service Delivery Organisation joint Annual conference, 2008-present (*Elliott*)
- Organising Committee for 14th European Conference on Applications of Surface and Interface Analysis (ECASIA'11), Cardiff, 2011 *(M Alexander*)
- Organising Committee 15th EU Microscopy Congress, Manchester, 2012 (*Roberts*)
- Focus Topic Organiser for the 59th AVS International Symposium, Tampa, USA 2012 (*Allen*)
- Co-Chair of ACS PMSE Symposium, New Orleans, 2013 (*C Alexander*)

Informing National and/or International Policy - Academics serve on committees involved in shaping research and health policy both in the UK and across the globe, including:

- NICE Committee memberships: Technology Appraisal Committee, 2006-present (*Elliott*), 2010-present (*Smith*), Patient Safety Advisory Committee 2007-10 (*Elliott*)
- EU COST UK Representatives: Biomedicine and Molecular Biosciences, Member 2006-11 (*Rose*), Member 2012-present (*Winkler*), Expert 2012-present (*Falcone*); Materials, Physics

and Nanoscience, Member 2008-12 (*Roberts*); Chemistry and Molecular Sciences and Technologies, Expert 2011 (*Fischer*)
- Member of International Pharmaceutical Federation (FIP) Executive Committee, Board of Pharmaceutical Practice, 2007-10 and Lead for Academic and Institutional Capacity for the FIP Global Education Development Team, 2006-present (*Anderson*)
- Member of the Chemical and Biological Metrology Program, National Measurement System, Department for Business, Innovation and Skills, 2007-present (*M Alexander*)
- Member of Food Standards Agency Expert Workshop, 2008 (*Barrett*)
- Member of Biologicals & Vaccines Expert Advisory Group of MHRA, 2010 (*Shakesheff*)
- Chair of NIHR Research for Patient Benefit East Mid. Committee, 2010-13 (*Anderson*)
- Non-Executive Director of Nottinghamshire Healthcare NHS Trust, 2010-present (*Tendler*)
- Member of English Pharmacy Board and National Assembly of RPS, 2012-present (*Anderson*)
- RPS Faculty Panel Members: Professional Accreditation Committee 2013 (*Knaggs*); and Professional Curricula Panel Committee 2013 (*Kellam*)
- HEFCE Healthcare Advisory Committee 2013 (*Tendler*)

Services to Advisory Panels, Grant Committees, and Other Bodies - Staff have taken roles on Research Council and charity grant awarding bodies and strategic committees, including: **EPSRC:** High Performance Computing Applications Panel; Follow-on Translation Panel; Chemistry Prioritisation Panel; HECToR Distributed CSE Support Panel; Strategic Advisory Team on Healthcare; and Strategic advisory team on Nanotechnology. **BBSRC:** Research Committees C & D Core Members; Bioscience Skills and Careers Strategy Panel; Healthy Organism Strategy Panel; and Expert Review Panel "Computational requirements for the Biosciences". **MRC:** CASE Studentship Panel; Research Leader Fellowship Panel; Molecular and Cellular Medicine Research Board; and UK Stem Cell Bank Steering Committee. **Other:** CRUK Discovery Committee, Breast Cancer Campaign Scientific Advisory Board; Technology Strategy Board Regenerative Medicine Advisory Group; Royal Society of Chemistry, Chemistry Biology Interface Forum Executive Committee member; Hong Kong/China Innovation and Technology Fund; South Africa National Research Foundation International expert reviewer; Commonwealth Scholarships Panel of Advisors; and Chair of EPSRC/MRC/BBSRC Discipline Hopping Panel.

Journal Editing - Our staff serve on the Editorial Boards of journals including: The Biochem. J., J. Mat. Chem., Am. J. Blood Res., Scientific Reports, Cell Death & Disease, Future Med. Chem., J Molecular Modeling, Am. J. of Pharm. Education, Pharmacoeconomics J., Indian J. Pharm. Practice, Pharm. Practice, Int. J. Clinical Pharm., J. Med. Use in Developing Countries, J. Am. Pharmacists Association, Bioanalysis, The Open Spectroscopy J., J. Experimental Nanoscience, Therapeutic Delivery, Peptide and Protein Letters, Surface and Interface, Biomatter, J. of Pain Management, British J. Pain, International J. Pharmaceutics, BioDiscovery, Anti-Cancer Agents in Med. Chem., J. Med. Chem., Current Protein & Peptide Science, The Biologist, J. Pharm. Sci., Euro. J. Cells and Materials, J. Pharm. & Pharmacology, J. Controlled Release, Euro. J. Pharm. Sci., Pharm. Nanotech., and Drug Delivery and Translational Research.

Fellowships and Awards -Since 2008 our staff have held a number of prestigious Fellowships and awards, including: *Jopling* - BBSRC David Phillips Fellowship (2008-13); *Davies* - Distinguished Service Award from The Controlled Release Society (2008); *C Alexander* - EPSRC Leadership Fellowship (2009-14); *Stolnik* - Royal Society Industrial Fellowship (2007-10); *M Alexander* and *Shakesheff* - Royal Society Wolfson Research Merit Awards (2012/13); *Davies* - President of the Controlled Release Society (2011-12); *Stevens (Emeritus)* - Fellow of the Royal Society (2009); *M & C Alexander* and *Melia* - Fellow of the Royal Society of Chemistry (2008, 2009, 2011); *Shakesheff* - Fellow of the Royal Pharmaceutical Society (2011); *Spriggs* - Fellow of the Higher Education Academy (2012); *Roberts* - Queen's Award for Industry (2011 for NanoPASS^{TM}); *Shakesheff* - Biocompatibles Prize, UK Society of Biomaterials (2011); *Davies* - Fellow of the Academy of Pharmaceutical Scientists (2010); *Anderson* - Fellow of Royal Society of Public Health (2012); *M Alexander* – AVS Fellow (2013); *Yang* - Nottingham Advanced Fellowship (2013-16); *Rawson* - Leverhulme Trust Early Career Fellowship (2013-16); *Anderson* – Faculty Fellow of the Royal Pharmaceutical Society (2013).