Institution: University of Bath

Unit of Assessment: 3: Allied Health Professions, Dentistry, Nursing and Pharmacy

a. Overview

Organisation/structure of unit. Bath's submission encompasses research from the Depts. of Pharmacy & Pharmacology and Biology & Biochemistry (Faculty of Science), and from the Dept. of Psychology and the Dept. for Health (Faculty of Humanities and Social Sciences).

Research groups and research structure (Figure 1). Pharmacy & Pharmacology, in conjunction with colleagues from Biology & Biochemistry, has a long-standing and internationally recognised reputation for high-quality and high-impact research in the pharmaceutical and pharmacological sciences, spanning the drug development process from target identification and drug discovery, synthesis and structural optimisation, through drug formulation and delivery, to pharmacovigilance, adherence and drug use. These major areas of interest encompass research in immunology, infection and inflammation; cardiovascular disease; neuropharmacology; medicinal chemistry of anti-cancer, antiviral and opioid drugs; oral, pulmonary and topical/transdermal drug delivery; formulation of biopharmaceuticals (including proteins, nucleic acids and antibodies); stem cell biology and tissue engineering; and pharmaco-epidemiology, drug use, and health psychology. The latter interfaces neatly with scientists in Psychology and Health, where research focuses upon psychological factors impacting upon pain, stress and anxiety, drug adherence, and comparisons between drug-based and psychology-based interventions. Furthermore, within the REF period, the creation of a new NHS-funded doctorate in clinical health psychology has added significant clinical expertise in autism, obsessive-compulsive disorders and post-traumatic stress disorder. As the majority of researchers in clinical-health psychology have been appointed within the last 2-3 years, inter-disciplinary collaborations across the breadth of the allied health professions represented at Bath are evolving. Figure 1 illustrates schematically the strategic rationale under-pinning this crucial research priority for the University.

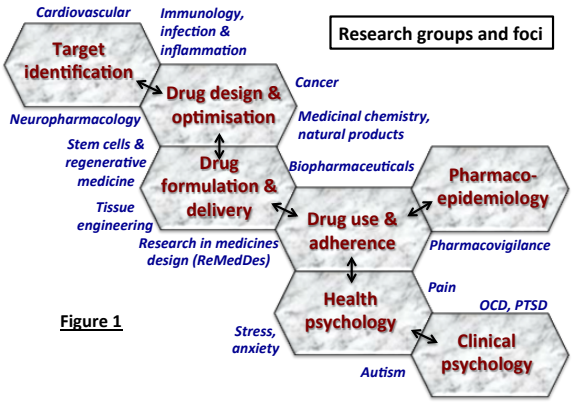

Figure 1

b. Research strategy

Achievement of specific research aims in REF period. Five major objectives were attained.

[1] A key goal - to embed and expand a culture of inter-disciplinary research with translational impact - has been successfully achieved in diverse areas. For example, international recognition in the design, synthesis and development of drugs to treat breast cancer and initiation of Phase I/II clinical trials (Potter); substantial increase in funding for prostate cancer research (Threadgill *et al.*); and significant advances in novel skin cancer-targeted strategies (Pourzand, Eggleston). In chemical biology, increasing collaborative research work (and co-supervised PGR) between pharmacologists and chemists has led to the generation of new intellectual property with the spin-off of the biotech company, Glythera, Ltd., (Watts, MacKenzie, co-founders) an outstanding example. Likewise, the neuroscience nucleus created in the last RAE period has evolved into a cross-disciplinary research activity with medicinal chemistry, especially in the opioid area, and translation of results into medicine design with the drug delivery group has been achieved via an MRC grant funding novel approaches to tackle opioid/cocaine/ethanol addictions (Husbands, Bailey). Similar developments are underway in respiratory disease (enhanced by Lindsay's appointment) via interactions between pharmacologists and formulation scientists focused on pulmonary delivery.

[2] Integration and development of drug delivery expertise has led to creation of the "Research in Medicines Design" (*ReMedDes*) unit, the over-arching goal of which is to develop *in vitro* experimental tools and *in silico* models to direct the rational design and optimisation of high-performance pharmaceutical formulations and thereby improve drug bioavailability.

[3] Catalysed by the inter-disciplinary and cross-faculty Centre for Regenerative Medicine, an enhanced research presence in stem cell science and tissue engineering has been realised

through Welham's MRC and Stem Cells for Safer Medicines (SC4S) awards focused on the regulation and differentiation of embryonic stem cells, De Bank's EPSRC supported work on photopatterned dendrons, and Pula's BBSRC funded research on regenerative angiogenesis.

[4] Another specific goal was to create a new research presence in pharmacoepidemiology: a large group led by the Chair (initially De Vries, now McHugh) and younger academic staff (McGrogan, Charlton) has been very successful in attracting substantial research support (approaching £1.5M) and rapidly establishing Bath as an internationally-recognised hub for this activity.

[5] Development of clinical-health psychology at Bath represents fulfilment of a long-term strategic aim. A new, NHS-funded doctoral training programme, which welcomed its first intake of 17 students in 2011, has been established and is already the second most popular clinical doctorate in the UK. Enhanced industrial interaction was identified as a goal for pain research at Bath, and this initiative has resulted in substantial funding from Reckitt Benckiser (>£0.75M) to better understand the psychological processes involved in analgesia and drug adherence.

Future strategic aims and research goals may be categorised in 4 areas as follows:

1. *Enhanced research integration into the drug development process:* The pharmaceutical industry is actively and increasingly building external research collaborations with academia. In response, the UoA, led by the Pharmacy & Pharmacology department, aims to sharpen the focus of its research into centres of excellence and attract both government and industrial funding to address and have impact upon the discovery, design, formulation, and delivery of drugs in disease targets such as cancer, immunology, and brain disorders. Two specific initiatives, one to be established in the next REF period, the other already operational, illustrate this strategy.

Firstly, capitalising on the medicinal chemistry, pharmacology and ion channel expertise within the UoA, a Drug Discovery & Design platform will be created for the development and screening of small molecule technologies (focussing on cancer and inflammation). It is envisaged that this facility will include a state-of-the-art multi-detection plate reader for target development, Clonepix to generate stable cell lines and identify those useful for drug screening, and an automated patch clamp set-up for hERG screening or evaluation of ion channel targets. In addition, an in-house compound library will be generated and existing tissue culture facilities expanded.

Secondly, the establishment of *ReMedDes* acknowledges that therapeutic efficacy is controlled by the potency of the drug *and* by the effectiveness of its administration to the body. The latter is controlled by drug dissolution, and the rate and extent of absorption at the site of application, factors that are common across essentially all routes of administration. While the physical chemistry of the medicine (i.e., the drug + its delivery system) can be manipulated during dosage form development, there are few *in vitro* tests, or computational tools, which provide relevant molecular information about these key events. As a result, expensive and time-consuming animal or human clinical studies may be required for the optimisation of medicines. *ReMedDes* aims, therefore, to address this challenge, accelerate the drug development process and enable products to be brought to market more rapidly and economically. Together with the planned drug discovery and design facility, *ReMedDes* completes the medicine development process and provides an important link to the regulatory process.

These unique initiatives represent a significantly broadened pathway to impact of the research and manifold opportunities for funding via traditional academic sources, through industrial partnerships, and from the regulatory agencies (that has, in fact, already been achieved with FDA).

2. *Strategic objectives in drug use, pharmacoepidemiology and drug use and adherence* are driven by a common desire to enhance the clinical translation and impact of the research effort. This new and strengthened team permits the psychosocial research in medicines use and adherence to be explored in much greater depth, particularly as it relates to how decisions about medicines are shared, and communicated, between pharmacists, clinicians and patients. The link to drug safety research (e.g., evaluation of medicines use in pregnancy and diabetes) and methods development in pharmacoepidemiology is clear. As a practising clinician, McHugh's recent appointment as Chair of Pharmacoepidemiology offers an outstanding opportunity not only to expand the disease areas of interest, especially in rheumatoid arthritis and other autoimmune disorders, but also to add a path for translation of basic science to the clinical setting. As articulated already, therefore, a key trajectory of the UoA is to create an environment in which the flow of discoveries in the laboratory to a tangible impact on the patient is facilitated.

3. *In clinical-health psychology*, the new doctoral training programme will fulfil a broad strategic aim to develop regional networks of expertise as illustrated by Salkovskis' collaboration with the Avon & Wiltshire Partnership NHS Trust to create, in 2013, a unique Assessment, Treatment, Training and Research Centre. This undertakes, on a regional and national basis, expert and highly specialist activities in a range of psychological problems. Further development of Bath's Centre for Pain Research is focused on several key strategic goals: to improve the translation of evidence-based pain management through guidance and guidelines development, to blend experimental, behavioural and neuroscience methods to investigate new analgesic targets, to translate individual differences in sex, age, and personality into personalized medicine outcomes, and to enhance telemedicine solutions focussed on medication adherence, and self-management of long term conditions. These objectives are facilitated by the recent award to Wiech, who studies mechanisms of analgesia, of a University Prize Fellowship, a permanent academic post that starts with a 2-year period of pure research and a full support programme for career development.

4. *Capacity building*: Bath invested significantly in new clinical-health psychology staff in the second half of the REF period. With the doctoral programme, and the expanding BSc and MSc Psychology courses, attracting outstanding students, a new dedicated building will open in 2015 and 14 additional, full-time, permanent academic appointments will be made over the next 4 years. Bath will also offer a new course in Biomedical Sciences from 2014, drawing upon teaching resources in Biology & Biochemistry, Health and Pharmacy & Pharmacology. Realisation of the projected growth of this course will create new academic appointments whose research falls squarely within this UoA. Further, in line with the drug discovery/design and *ReMedDes* initiatives, Pharmacy & Pharmacology is evaluating a novel training programme to address future workforce needs of the pharmaceutical industry. The envisaged course would encompass drug development from the identification of a therapeutic opportunity to regulatory approval and post-marketing pharmacovigilance. Success of this concept would again permit capacity to be built within the UoA. Notably, health research comprises a third of Bath's research portfolio sitting across a broad spectrum of engineering, life science and physical science themes. It is a declared and current ambition of the University to establish and invest in a core Institute of Health Science & Technology to maximise the cross-campus capability and competitiveness. At least two of the principal themes of this Institute, namely *'medicines design and delivery'* and *'regenerative medicine'*, are centrally based in departments core to the UoA.

Responsiveness to national/international priorities and initiatives. In drug target identification and drug design: Welham and Pula successfully responded to MRC, SC4S and BBSRC calls related to stem cells and regenerative medicine; addressing the NC3Rs' overall goal to replace, refine and reduce animal use in research, Jones is developing a chronic epilepsy model in organotypic brain slice cultures and collaborates within a national network (with Birmingham, Newcastle, London and Oxford) to extend this approach to human brain tissue; US National Institutes of Health (NIDA) and MRC calls for novel approaches to tackle opioid/cocaine/ethanol addictions, have respectively resulted in funding of ~£1M to Husbands and for a unique pharmacology-medicinal chemistry-drug delivery project (Bailey, Husbands, Delgado-Charro, Guy) on a novel naltrexone-buprenorphine therapy; Potter's notable achievement to be awarded a Wellcome Trust Senior Investigator Award; Watts attracted EU funding for a Marie-Curie Intra-European Fellowship; Eggleston, Lloyd and Tyrrell are involved in PROSENSE, an EU training network for engineering diagnostic devices for prostate cancer; Ward was awarded funding for flow cytometry equipment from a Wellcome Trust call. In drug formulation/delivery, Price, Fotaki, Delgado-Charro and Guy and US collaborators have successfully responded to FDA calls to develop new approaches to determine bioequivalence between innovator and generic drug products for treating lung and skin diseases. Fotaki has very recently received funding for a project led by AstraZeneca (with Pfizer, GSK, BMS, and several other industry and academic partners) from the TSB's "Formulated Products – Meeting the Product and Process Design Challenge" to accelerate paediatric formulation development through smart design and predictive science. In pharmacoepidemiology, De Vries *et al.* attracted major EU funding via calls from the Innovative Medicines Initiative and FP7 to facilitate the development of better and safer medicines.

Research groupings (see Figure 1) **– focus and achievements**

1. *Target identification*: The primary focus is to identify new targets and disease mechanisms in autoimmune/inflammatory, respiratory, cardiovascular diseases, and CNS disorders. Notable

research achievements, principally funded by the Wellcome Trust, Royal Society, BBSRC, MRC, NC3Rs, SC4S and UK pharma, include: Identification of PI3K-dependent pathways and regulatory mechanisms controlling leukocyte migration, activation and function (Ward, Mackenzie), and stem cell renewal and pluripotency (Welham). Discovery of a novel role for deoxyribose-1-phosphate in platelet function (Pula); development of new models to better understand the role of calcium channels in the renal vascular system (Smirnov). Characterisation of the role of CD8+ T cells in severe asthma (Lindsay). Demonstration of the PI3K-dependent signalling pathway in tracheal smooth muscle hyper-responsiveness (Watson). Identification of the role of protein arginine methyltransferases in leukocyte function (Ward). Characterization of naltrindole-derived ligands at the κ-opioid receptor as potential antidepressant and/or anxiolytic treatments (Bailey, Husbands). Elucidating the mechanism of ethanol reversal of cellular tolerance to morphine, and its implications for reducing risk in heroin overdose (Bailey). The role of kainate receptors in neuronal synchronization and as novel therapeutic targets in epilepsy has been demonstrated (Jones). A non-rewarding, non-aversive buprenorphine/naltrexone combination has been found that may be therapeutically useful in protection against opioid addiction relapse (Bailey, Delgado-Charro, Guy, Husbands). Developing, in organotypic slice cultures, a chronic epilepsy model of high sensitivity to clinically effective anti-convulsants, as a route to new therapeutics (Jones).

2. *Drug design & optimisation*: Research strength in drug discovery applies diverse techniques to direct compound synthesis, including structure-based design *in silico*, protein crystallography, biological evaluation *in vitro* and *in vivo*, and prediction *in silico* of pharmacokinetic parameters. Significant grants have been awarded by BBSRC, US NIH, MRC, Wellcome Trust, CRUK, Prostate Cancer UK, AICR, the EU, UK and international industry. Notable success has been achieved via the development of new chemical entities for the treatment of hormone-dependent breast, endometrial and prostate cancer (Potter), with compounds in clinical trials for all indications. Watts' expertise in protein/peptide functionalization and glycosylation technologies has generated the spin-out company Glythera, providing improved pharmacokinetic properties for the next generation of biotherapeutics. Novel light-activated caged iron chelators are being developed for topical therapy of non-melanoma skin cancer (Eggleston, Pourzand). New chemical entities are being synthesised that inhibit non-redox enzymes, which use NAD^+ (tankyrases and poly(ADP-ribose)polymerases), thus interfering with proliferation signaling and cell division and potentiating known drugs, and a new polymeric prodrug system is being developed for prostate cancer (Threadgill). Husbands' group is creating new treatments for drug abuse, including therapeutics to help prevent relapse, with compounds currently undergoing extensive pre-clinical evaluation by the US National Institute on Drug Abuse. Research quality is illustrated by publications in *Proc. Natl. Acad. Sci. USA* showing that inhibition of the NAADP signaling pathway can specifically and effectively modulate T-cell activation (and has potential in the therapy of autoimmune diseases), in *Nature Chem. Biol*. on inositol 1,4,5-trisphosphate receptor signalling (Potter), in *Nature Chemistry* reporting the discovery of antibiotics active against both gram-positive and gram-negative bacteria (Bolhuis), and in *Science* describing an entirely new class of mechanism-based covalent neuraminidase inhibitors with broad-spectrum antiviral activity in influenza (Watts).

3. *Drug formulation & delivery*: A major focus (via *ReMedDes*) is optimisation of drug formulations and development of predictive *in silico* and *in vitro* models of drug absorption and delivery via the oral, pulmonary, (trans)dermal, trans-ungual and subcutaneous routes of administration. Research has been funded by MRC, Wellcome Trust, US NIH, FDA and by the pharmaceutical industry in the UK, Europe and globally. Research achievements of note include: Elucidation, with surface science and particle engineering techniques, of the fundamental mechanisms of particulate interactions and stability in inhaled dosage forms to treat pulmonary disease (Price). The innovative use of *in vitro* screening tools for the prediction of oral drug absorption in specific patient populations (e.g., paediatrics) and development of *in vitro-in vivo* correlations (Fotaki). The novel, combined application of coherent Raman scattering, confocal, Raman and atomic force microscopies, to improve drug delivery to and through the skin and nail (Guy, Delgado-Charro). The physical and chemical stressors on proteins and peptides following subcutaneous (SC) injection are being examined using a unique *in vitro* model (Mrsny). In biotherapeutics, a novel fluorescence-based approach using single-walled carbon nanotubes has been used to image cancer cells (Tyrrell), while anti-cancer agents have been delivered to tumour cells by the peptide transporter hPepT1, aiming to rectify their polarized nature and induce apoptosis (Mrsny). Finally, in multidisciplinary research originating in Bath's Centre for Regenerative Medicine, the novel

chemically-directed differentiation of human embryonic stem cells to liver progenitors that can form hepatocyte-like cells has been reported (Welham); and, again considering induced pluripotent stem cells, reprogramming factors have been shown to require formation of intrachromosomal loops that juxtapose enhancer and promoter regions to reactivate endogenous pluripotent genes (Mrsny).

4. *Drug use/adherence, and pharmacoepidemiology*: Key research themes involve investigation of patients' experiences and how drugs are used by individuals and by patient populations. Major grants has been awarded by the Leverhulme Trust, Pharmacy Research UK, EMA, the EU FP7 programme, and the pharmaceutical industry. Specific examples include research examining pharmaceutical services for drug misusers (Scott), understanding how decisions about medicines are communicated, and evaluating pharmaceutical services involving medicines compared with general practice dispensing practices (Weiss, Taylor). The relationships between workload, dispensing errors and workplace stress, and the role of multi-disciplinary teams and community pharmacy, have also been elucidated. Patient safety, workload and medication errors are central to this group's research with a special interest in drug use in dementia and mental health. The importance of the patient's perspective has been demonstrated in work exploring the experience of doctors as patients (Scott, Taylor) and in the development of educational resources to support professional-patient communication (Weiss, Taylor). Drug utilisation and patient safety at the population level are the foci of pharmacoepidemiology research and its use of the general practice research database, which covers 7% of all UK general practice patients. This has resulted in new insights into the use and safety of medicines in pregnancy (De Vries, McGrogan, Charlton), and of the H1N1 vaccine (McGrogan), long-term conditions such as diabetes and epilepsy (De Vries, Charlton) and rheumatology (McHugh, Stone).

5. *Clinical-health psychology*: Principal themes are pain, health risk perception and communication, anxiety and a range of psychological disorders, including autism. Notable research funding has been obtained from the pharmaceutical industry, EPSRC, NIHR and the US NIH. The Centre for Pain Research (Eccleston, Keogh, Rodham, Taylor, Wiech) is focused on evidence-based pain management; paediatric pain, especially teenagers; individual differences (including gender) in pain behaviour and pain communication; attentional processes in pain perception and the discovery of new analgesic endpoints; e-pain and exploiting technology to provide support for people in pain. The impact of stress upon immuno-functioning (Turner-Cobb) and the effects of drug and alcohol dependence upon cognitive bias (Adams) have been elucidated. The incorporation of public/user perspectives within the development of health policy to maximise uptake and adherence has been addressed (Barnett). The new 'Specialist Psychological Treatments of Anxiety and Related Problems Clinic' (Salkovskis, Halligan, Gregory, Lomax, Russell) is exploring the nature and innovating the treatment of, and research into, a range of psychological problems (including obsessive compulsive disorder, hoarding, social phobia, post-traumatic stress disorder, generalised anxiety disorder, autistic spectrum disorders and health anxiety) and psychological aspects of physical health issues, such as the management and therapy of people with severe and complex problems, with carefully individualised "state of the art" NICE compliant protocols. This focus complements school-based interventions targeting depression in children (Stallard) and experimental research into autism spectrum disorder (Brosnan, Maras) and the collaboration of the South West Autism Group at Bath with educators and clinicians to better understand autism and to support those with the condition and their families. The neuroscience research within this area (Ashwin, Hinvest) complements the neuropharmacological theme of the 'target identification' group.

Mechanisms/practices to promote and disseminate research, and to sustain and develop an active, vital research culture. The UoA has adopted an aggressive approach to publish its research in journals of the highest impact; in the REF period, the submitted staff have collectively published over 1000 articles that have been cited on more than 10,000 occasions. The University's online publication resource (OPUS) disseminates research results from Bath to as wide an audience as possible, and Corporate Communication Services has extensively broadcast the UoA's research in the press and other media. Equally, the involvement of staff at important international meetings has been actively supported, and this is reflected in their roles in organising such conferences and by the large number of invitations to present plenary and other invited lectures. The UoA stimulates individual, interdisciplinary and collaborative research via manifold mechanisms, including: Active participation in, and leadership of, cross-departmental research

centres, such as the Centre for Regenerative Medicine (DeBank, Mrsny, Pula, Ward, Welham), which involves colleagues in both Chemical Engineering and Biology & Biochemistry, and the Centre for Pain Research (Eccleston, Keogh) involving both Psychology and Health. Departmental Executive and Research committees facilitate attainment of the UoA's strategic research aims by defining key performance indicators, targeting appointments and supporting (financially) scientific exchange and dialogue. The Research Development & Support Office (RDSO) closely tracks funding opportunities in all research areas, actively seeks collaborative links within academia and industry, both nationally and internationally, negotiates contracts and advises on intellectual property. RDSO administers the University Enterprise Development Fund providing grants for proof-of-concept of patentable IP, such as Pourzand and Eggleston's caged-iron chelators for skin photoprotection (£134K in total). Several bi-weekly seminar programmes involving high-profile external speakers take place across the UoA. Regular cross-faculty and inter-disciplinary meetings of the Bath-based focus groups, Cancer Research @ Bath and the Neuroscience Network at the University of Bath, are scheduled with clinicians from the Royal United Hospital (RUH) and the Royal National Hospital for Rheumatic Diseases (RNHRD) located in the city centre. The UoA has an extensive track record of interdisciplinary and collaborative research with academic, industrial and public sector partners from the UK and overseas. Further strengthening the research environment is a continuous stream of visiting scientists and research fellows. In addition to external national and international collaborations, academic staff are involved in funded collaborations with many other sectors of the University including Chemistry, Physics, Computer Science, Mathematics, Chemical Engineering, and Electronic & Electrical Engineering, and other university partners such as the Bath Institute for Rheumatic Diseases.

c. People

i. Staffing strategy and staff development

Personnel changes since RAE2008 - Arrivals: De Vries, McGrogan and Charlton appointed Chair, Lecturer and Fellow, respectively, in Pharmacoepidemiology; Mrsny to Professor of Epithelial Cell Biology (change from 0.2 to 1.0 FTE); Lindsay and Pula to Professor and Lecturer, respectively, in Pharmacology; McHugh to Professor of Pharmacoepidemiology; Barnett to a Chair in Health Psychology; in Clinical Psychology, Salkovskis to Chair, Halligan to Reader, Lomax, Russell to Senior Lecturer, Gregory to Lecturer; Adams, Ashwin and Hinvest to Lecturer in Psychology; Maras and Weich as University of Bath 5-year "Prize Fellows" in Psychology.

Promotions: Price, Husbands and Jones to Personal Chairs; Keogh to Reader; Lloyd and MacKenzie to Senior Lecturer; Caggiano to Lecturer.

Secondment: Welham for 2 years to the prestigious post of Director of Science at BBSRC.

Academic appointments have strategically supported key research areas within the UoA (Figure 1), specifically target identification in respiratory disease (Lindsay), cancer drug design (Caggiano), macromolecular drug delivery and regenerative medicine (Mrsny, Pula), pharmacoepidemiology (De Vries/McHugh, McGrogan, Charlton), and, in particular, clinical-health psychology (Barnett, Salkovskis, Halligan, Lomax, Russell, Gregory, Adams, Ashwin, Hinvest, Maras, Weich).

Departures: Garland and Dora to assume Professorial and Readership positions, respectively, at Oxford; De Vries to a senior position at the European Medicines Agency; Skevington appointed to a Chair at Manchester; Safrany was appointed Senior Lecturer at Wolverhampton; Lectureships for McNeish and Cottrell (both BHF Fellows) at Reading, and O'Neill at Aston; Laaksonen to an academic post at Helsinki University. Moss has retired.

Equalities & diversity. Bath aims to recruit a high quality workforce with appropriate expertise and experience. Equal opportunity underpins the recruitment/selection procedures to appoint the most capable and effective employees. Each department has a designated Equalities and Diversity Coordinator. The current demographic profile of research academics in the UoA is well-balanced in terms of age and, of the 17 professors, 5 are women; notably Wonnacott is Associate Dean (Graduate Studies) in the Faculty of Science and Welham is presently seconded to BBSRC. The UoA's two University of Bath "Prize Fellows" (Maras, Wiech) are female.

Integration of clinical academics and NHS-employed active researchers. The UoA's focus in clinical-health psychology illustrates the integration of clinically oriented academics with translational research in the NHS. For example, Eccleston and Keogh lead the Centre for Pain Research, with a research laboratory in the University and a clinic based at the RNHRD in Bath.

The Centre is part of the South West Pain Consortium, a group of expert academics and clinicians that collaboratively research the pressing problems in pain, in partnership with patient panels. Similarly, Salkovskis heads the Specialist Psychological Treatments of Anxiety and Related Problems Clinic in conjunction with the Avon & Wiltshire Partnership NHS Trust. Other chartered psychologists (including Rodham, Russell and Lomax) all practice within local NHS settings.

McHugh combines academic and clinical roles as Professor of Pharmacoepidemiology, and Consultant Rheumatologist at the RUH, where he heads a renowned connective tissue disease research team in autoimmune mechanisms and genetics of scleroderma, lupus and myositis. He set up and coordinates a bi-annual Bath/Bristol connective tissue disease meeting that over the past 8 years has become a major educational forum for clinical specialists in this field. He directs a specialist serology service that measures auto-antibodies serving as the central laboratory for numerous research studies in the UK and Europe. Stone is a specialist in Internal Medicine and Rheumatology and an expert in inflammatory arthritis. Clinically, at regional, national and international levels, she has led innovative treatment developments, such as the spondylo-arthropathy methodology research therapeutics program.

Integration of clinical fellows into the research laboratories of Ward and Lindsay is a further example of academic research translation into the practice setting. Equally, Guy's expertise in skin barrier function is being exploited in a NIHR-funded project (led by Bristol's School of Social and Community Medicine) concerning the choice of moisturiser in the treatment of eczema in children.

Effective development and support of research work of staff. The award of the 'HR excellence in research' badge from the European Commission recognized Bath's commitment to the Concordat to Support the Career Development of Researchers in Sept. 2011. Significant progress has been made to embed the Concordat principles led by the Research Staff Working Group (chaired by Guy 2010-12). The UoA leadership works closely with The Researcher Development Unit (RDU) to provide development opportunities to early career researchers and more established academic staff to evolve their research trajectories. A key component is The Bath Course in Enhancing Academic Practice, specifically designed for new and existing staff to enhance and hone their teaching and research skills. The success of the Bath Course led to the RDU being shortlisted for the THE Award for Outstanding Support for Early Career Researchers in 2011 and 2012. In addition, RDSO offers grant application surgeries, 1-on-1 direct support with grant writing, workshops on proposal preparation, and events, such as 'Ignite', which showcase the research of early career academics (Pula, Watts) and catalyse collaboration and inter-disciplinary work, "sandpits" on hot topics, Images of Research (an annual exhibition and competition highlighting the use of images in research across the campus), and mentoring circles that aim to provide a forum in which research and academic staff can talk with peers about their careers. Finally, the Public Engagement Unit actively engages with researchers to communicate their work beyond academia (e.g., outreach to local high schools (Caggiano, Lloyd, Thompson), Nuffield Foundation and In2Science summer studentship research placements (Bailey, Pula, Ward)).

In addition, academic departments contributing to this UoA have each implemented a formal staff workload model during the REF period. This has allowed Heads of Department to provide greater opportunity for early career academics to concentrate on, and to 'jump-start, their research programmes, by shifting modest increments of teaching and administrative duties onto more senior members of staff. Application of the workload model has also enabled incentivization of more established researchers who have demonstrated sustained success in winning grants; in this case, the University's resource allocation model permits Departments to contract (for example) teaching fellows to free the time of principal investigators to concentrate on their research. The University also runs a formal sabbatical scheme (exs. Smirnov, Jones) and encourages department Heads to allow (and facilitate) their members of staff to compete for prestigious fellowships. Potter's Wellcome Trust Senior Investigator Award (2013) is a prime example of this approach.

Development of early-career researchers and their integration into a wider research culture. The incontrovertible emphasis on inter- and/or multi-disciplinarity in research today, and the movement of funding bodies away from the classic "PI + postdoc" model of research grants, has led the UoA to encourage younger members of staff to seek out, and to engage in, collaborative research from the very outset of their careers. The University's Academic Staff Committee recognises that the criteria for junior academics to pass probation must acknowledge and support the involvement of researchers in collaborative, cross-disciplinary science from the very start.

Constructive and informed mentorship is a key to the success of early career academics and the availability and counsel of senior colleagues, who serve on RCUK, Wellcome and US National Institutes of Health grant panels (specifically, Ward, Potter and Mrsny), is a major strength. Introduction of a rigorous peer-review system prior to grant submission (for all staff, not just junior) is significantly improving the quality of proposals and grant capture success rate (e.g., the awards to Pourzand, Eggleston, MacKenzie and Lindsay in a 2012 round of BBSRC grants). Finally, the UoA makes available to new academic staff a PhD studentship within one year of appointment.

ii. Research students

Effective, stable doctoral research training. In the REF period 2008-13, 101 PhDs have been awarded to students supervised by academic staff in the UoA. Major sources of studentships during this period include RCUK (BBSRC/MRC/EPSRC doctoral training grants/accounts), UK and EU industry (including CASE awards, detailed below), University of Bath scholarships, and self-funded candidates from overseas. Specifically, academics have participated in the following RCUK training programmes that, by September 2013, have supported 24 studentships.

- MRC-doctoral training grant [Welham, Academic Lead] 'Developmental, Stem Cell and Neuro-Biology' ~£ 500,000 (2010-15).
- BBSRC Doctoral Training Grant: BB/D525921/1 [Guy, PI], £650,664 (2006-12).
- BBSRC South West Doctoral Training Partnership. Universities of Bristol, Bath and Exeter. [Hetherington, Bristol, Academic Lead], £4.2M total award (2012-17).
- ESRC South West Doctoral Training Grant: ES/J50015X/1. Universities of Bristol, Bath, Exeter. [Squires, Bristol, Academic Lead], £2.7M total award (2011-16).

Two other doctoral training programmes have supported a further 4 studentships, with lead or co-supervisors from the UoA:

- FP6 Marie Curie Fellowships in Early Stage Research Training (MCEST), University of Bath Centre for Regenerative Medicine [Welham, co-Director]
- FP7 Marie Curie Initial Training Network PROSENSE [Estrela, Bath, Coordinator]

Full-time PGR recruitment across the UoA has averaged ~20 per year during the REF period. The NHS South-West funded Clinical Psychology Doctorate (led by Salkovskis), which began in 2011, has an annual intake of 17 students (fully-funded @£20K per year); at steady-state, therefore, the annual budget for this training programme is approximately £1M. There has also been co-supervision of 6 PT students carrying out their PhD research alongside clinical work in local NHS hospitals (RUH and RNHRD). Ongoing strategies for maintaining and increasing the PGR student cohort include the identification of excellent candidates (home or overseas) for highly competitive University of Bath Research Studentships (URS), or Fee Waiver scholarships from the Faculties of Science and Humanities & Social Sciences. Pharmacy & Pharmacology, for example, has been successful in securing 9 excellent student URS awards since 2008, including 3 for overseas students (typically 6 overseas awards have been available annually across the entire university). Staff are particularly encouraged to develop partnerships with industry for MRC/BBSRC Industrial CASE studentships and fully-funded studentships (including with externally-based candidates).

All doctoral students are members of a Faculty Graduate School, which supports PGR throughout their lifecycle: admission, progression, thesis submission, and completion. The Graduate Schools also provide a forum for formal and informal interdisciplinary exchanges, including both academic and social activities. All students must perform annually at least 80 hours of training activities, which typically include generic skills courses recommended at specific stages of their studies. The RDU manages a large portfolio of courses and events for the skills and career development of all researchers, focussing on personal development, scientific writing, written and oral communication, team building, teaching skills, and use of on-line databases. Training seminars focus on techniques and methodology, ethics, intellectual property, research data management, health and safety, and funding opportunities. These are supported and aided by excellent I.T. and library facilities. PGR attendance at national and international scientific meetings is encouraged and supported financially by the Departments in this UoA. The Director of Postgraduate Studies, in consultation with the HoD, coordinates doctoral training. Individual 6-monthly student progress reports are scrutinised and discussed prior to submission to the Graduate School for faculty approval. Each student has a supervisory team comprising the lead

supervisor, and at least one co-supervisor, according to the nature of the project. Where the lead does not have experience of successfully supervising students to graduation, the team includes another member of staff who does. Two independent assessors, appointed for each student, are responsible for assessing the formal confirmation of PhD status, typically after 12 months study.

Strong, integrated research student culture. Programmes of (bi-)weekly seminars by high profile external speakers from a wide range of disciplines actively encourages PGR participation and forms an important part of their training. This is complemented by seminars presented by colleagues across the campus and other events, such as a new series of twice-yearly research days that are organised by postdoctoral research staff in Pharmacy & Pharmacology and at which early career researchers and PhD students in (years 2-4) may present their latest data. PGR in Year 1 are required to give a short presentation on their research after ~6 months study, as criterion for their progression. The record of publication of research results, first-authored by PhD students in peer-reviewed journals, is strong and it is not atypical to find already published articles integrated into submitted theses. The UoA believes that a contribution to teaching from PGR is an important component of their training and this is integrated into their research work appropriately.

CASE/industrial awards and other achievements of research students. Since 2008, CASE awards have been secured with various UK and international companies, either via conversion of DTG students to CASE, or through competitive MRC/BBSRC/EPSRC Industrial CASE schemes. Specifically, BBSRC (Industrial) CASE awards with Pfizer (2), Novartis (4); York Pharma, UCB-CellTech, Prosonix, Renasci, TMO Renewables; EPSRC Industrial CASE with Prosonix; MRC Industrial CASE with Janssen. Several fully- and partially-funded industrial studentships have also been secured from Actavis, DFE Pharma, Novartis, Pfizer, Prosonix, Great Western Research, Roche, MSD, Sterix, Leo Pharma, and Kudos.

PGR have been successful in securing funds and scholarships from charitable and other organisations to support their research activities, including: Ricardo Resende, who obtained an Abbey Santander Research Grant for a collaborative visit to Universidad de General San Martin, Buenos Aires, Argentina; Benjamin Kumpfmueller's award of a 6-month placement by the Deutscher Akademischer Austausch Dienst (German Academic Exchange Service) to work at the Riken Centre for Developmental Biology, Kobe, Japan; Hannah Family, who was a co-applicant on a successful grant application (worth £41,978) to the Pharmaceutical Trust for Educational and Charitable Objects; Ramesh Yadav's Leverhulme Research Fellowship (£18K) and his £5,000 award from the Harold & Marjorie Moss Charitable Trust to support his thesis work on community pharmacists' role in preventing drug misuse deaths; and Kunal Tewari's funding from the J.N. Tata Endowment to support his research on novel prodrugs of aminolevulinic acid for cancer therapy.

d. Income, infrastructure and facilities

Research income. In the REF period, research spend totalled ~£23.2M for the UoA (with nearly ⅓ from industry), corresponding to an average value per FTE per annum of £85,658. Extramural funding was obtained from governmental, charity and industrial sources (UK and international) across all research disciplines within the UoA. Significant awards during the REF period: in target identification, >£1M from MRC (Bailey, Jones, Ward, Welham); in drug design and optimisation, ~£0.65M from cancer research charities (Threadgill *et al.*), ~£1.25M from the U.S. NIH (Husbands), ~£0.8M from the Wellcome Trust and £4.5M from UK/EU industry (Potter); in drug formulation and delivery, ~£0.65M from EU industry (Guy, Price), ~£0.65M from NIH and US industry (Mrsny, Price), and >£0.5M from RCUK (De Bank, Pourzand); in drug use and pharmacoepidemiology, >£1M from UK and EU industry (De Vries), ~£0.45M from EU FP7 and the Leverhulme Trust (De Vries, Weiss); in clinical-health psychology, ~£0.46M from EPSRC (Brosnan, Eccleston), ~£0.89M from UK industry (Eccleston), ~£1.29M from NIHR (Taylor, Rodham).

Research infrastructure/facilities. During the REF period, Bath has committed significant and sustained investment in well-managed, expert-resourced, multi-user research facilities relevant to this UoA: The Bioscience Services Unit provides state-of-the art facilities for transgenic animals and *in vivo* pharmacology, including behavioural studies. The Chemical Characterisation and Analysis Facility combines cutting-edge analytical equipment (a range of X-ray diffraction, NMR and LC-coupled mass spectrometry apparatus) with extensive in-house expertise. The Microscopy & Analysis Suite offers a comprehensive range of imaging equipment (electron, confocal, high-content, Raman, and scanning probe microscopies, single-cell calcium imaging, flow cytometry

and cell sorting) and expertise essential for research at the chemistry-biology interface. Further, within the UoA, there is a dedicated NMR suite, molecular modelling workstations, and extensive tissue culture facilities, intra-cellular/patch clamp electrophysiology, and real-time PCR analysis; a state-of-the-art clinical-health psychology research suite includes stress, eye tracking and psycho-physiology laboratories (electro-encephalography, electro-myography, Galvanic skin response).

Significant infrastructure improvements during the REF period included: [1] A £600K investment in a new medicinal chemistry research laboratory with 10 double fume hoods; 50% funding from industry (Potter), 50% from Bath. [2] Renovation of substantial research space was funded by the University (~£500K) to consolidate all drug delivery and pharmaceutical technology laboratories, including the facilities for *ReMedDes*. [3] Refurbishment of space (£250K) for clinical-health psychology expansion, and to equip a new health psychophysiology laboratory suite.

Major pieces of equipment central to the research strategy of the UoA have been acquired, specifically: (a) A new 500 MHz NMR spectrometer with a Wellcome Trust grant of ~£375K (Potter). (b) The Wellcome-funded (~£336K) upgrade of Bath's protein crystallography facility (Lloyd, co-PI). (c) Cell sorting flow cytometry equipment (~£190K) again from Wellcome (Ward, co-PI). (d) A state-of-the-art meso-scale development platform technology for inflammatory cell biology research (~£100K from BBSRC to Ward). (e) LC/MS including accurate mass Q-TOF, dual ESI (multi-user, competitive equipment grant of ~£100K from the University, led by Watts). (f) GE In Cell Analyser high-content microscope and a state-of-the-art Raman microscope.

Cross-HEI shared/collaborative use of research infrastructure: Threadgill exploits the BBSRC-funded tandem mass spectrometer at Aberystwyth to determine chemical structures. Blagbrough uses the Wellcome funded cryo-TEM facility at Bristol. Guy, Delgado-Charro and De Bank work with the EPSRC-supported Multiphoton Imaging and Spectroscopy Laboratory at Exeter to study drug release and absorption. The Drug Use/Adherence and Pharmacoepidemiology groups have collaborated with the Institute of Psychiatry (S. London & Maudsley NHS Trust) and accessed the Clinical Record Interactive Search database (*viz.* anonymised records of >50,000 mental health patients) and used the National Grid Service to host the General Practice Research Database.

Major benefits-in-kind include, from Bath ASU, a grant to Watts of £109K for analytical equipment, full funding of a PhD studentship (+ a commitment for another in 2014), and additional funds towards the purchase of LC/MS; dissolution testing apparatus and analytical chemistry equipment (HPLC, UV/vis spectrophotometer) to Fotaki from Roche and Sotax, valued at >£50K.

e. Collaboration or contribution to the discipline or research base

28 academics (over 50% of submitted FTEs) in the UoA have h-indices greater than 20, and 4 have values over 45. Within the REF period alone, 7 individuals have h-indices >10. All academics have evidence of invited/plenary lectures, membership of journal editorial boards, and national/international research collaborations. An illustrative (and far from exhaustive) list of particularly notable contributions and esteem indicators includes:

Contributions to wider research base. Guy – Adjunct Professor of Bioengineering & Therapeutic Sciences, University of California - San Francisco; member, Expert Advisory Panel for Pharmaceutical Science, Royal Pharmaceutical Society (RPS). Potter - Visiting Professor, Oxford University; RAE and REF Expert Group panel member, 2009. Weiss - Chair, RPS Conf., 2010.

Peer review activities. Barnett - Editorial Board, Journal of Risk Research. Eccleston – Cochrane Review, coordinating editor, Pain, Palliative and Supportive Care. Mrsny – member, NIH "Gene & Drug Delivery Systems" Study Section. Potter – member, Wellcome Trust "Molecules, Genes & Cells" Funding Panel, 2006-11, and Peer Review College, 2012-15; Editorial Boards, Journal of Medicinal Chemistry, Molecular Cancer Therapeutics; Associate Editor, J. Steroid. Biochem. Mol. Biol. Salkovskis - Editor of Behavioural and Cognitive Psychotherapy. Tyrrell - Editor-in-Chief of Journal of Photochemical and Photobiological Sciences. Ward - Wellcome Trust Physiological Sciences Panel, 2008-11; MRC Non-Clinical Training Award and Fellowships Panel; Arthritis Research (UK) grants panel; editorial boards of J. Biol. Chem., Curr. Opin. Pharmacol. Weiss - member, Royal Pharmaceutical Society Practice Research Panel. Welham - Chair, BBSRC Grant Committee C, 2011-13; member, then Deputy Chair, BBSRC Grant Committee D: 2008-11.

Fellowships, awards. Guy – Fellow, UCL School of Pharmacy (2010); Controlled Release Society (CRS) Founders Award (2013) and Fellow (2010). Husbands – Fellow, Royal Society of Chemistry (RSC) (2012). Jones - Fellow, British Pharmacological Society (BPS) (2012); BPS Anglo-

Australian Visitor (2011). Mrsny – Fellow, CRS (2010). Potter – RSC George and Christine Sosnovsky Medal in Cancer Therapy (2007-08) and associated Endowed Lecturer (2008); RSC UCB-Celltech Award & Medal in Chemical Biology (2008); RSC Biological & Medicinal Chemistry Section's 4th Malcolm Campbell Memorial Prize & Medal (2009); RSC Interdisciplinary Prize and Medal (2010); RPS GlaxoSmithKline International Achievement Award; Fellow, Academy of Medical Sciences and Society of Biology (2008); European Life Science Award (2012). Ward - Royal Society Industrial Fellowship (2006-10); Fellow, BPS (2012).

Keynote/plenary/invited lectures (examples). Gordon Research Confs.: Blagbrough 2009, Brown 2008, Guy 2013, Mrsny 2012, Potter 2011; Int. Conf. Pharmacoepidemiology: Charlton 2012, McGrogan 2009; World Congr. On Pain, 2012: Keogh, Wiech; Ashwin: Israel Nat. Congr. Autism Spectrum Conditions 2008; Bailey: Eur. Opioid Conf. 2013; Barnett: O.E.C.D. 2013; Brosnan: Int. Mtg. Autism Res. (2013); Caggiano: Tufts U. 2011; Danson: Regensberg U. 2013; Delgado-Charro: Perspectives in Percutaneous Penetration 2012; Eccleston: World Cong. Pain Clinicians 2011; Eggleston: RSC Peptide & Protein Sci. Group 2012; Fotaki: Amer. Assoc. Pharm. Sci. (AAPS) 2009; Husbands: IUPAC Congr. 2009; Lindsay: U.S. N.I.H. 2009; Jones: Merck, Sharpe & Dohme Prize Lectureship, BPS 2010; MacKenzie: Cambridge U. 2009; McHugh: Int. Fed. Psoriasis Assoc. 2012; Pourzand: Eur. Soc. Photobiology 2009; Preston: Int. Bordetella Symp. 2013; Price: Respiratory Drug Delivery Conf. 2013; Pula: London Vascular Biology Forum 2011; Rodham: ISSS 2009; Smirnov: FASEB Sci. Res. Conf. 2013; Stone, Eur. League against Rheumatism Mtg. (2011); Threadgill: Indian Soc. Chem. & Biol. Int. Conf. 2013; Tyrrell: Karolinska Institute 2012; Ward: Drug Discovery on Target Symp. 2011; Weiss: RPS Conf. 2010; Whitley: Eur. Fed. Animal Sci. 2013; Wonnacott: Int. Symp. Cholinergic Mechanisms 2008.

Academic collaboration. In addition to joint publications and grant proposals from cross-department collaborations within the UoA, academic staff have also interacted tangibly (again, through co-authored papers and applications for funding) with members of the following departments at Bath: Chemical Engineering, Chemistry, Computer Science, Electronic & Electrical Engineering, Mathematical Sciences, and Physics. Externally, the range of universities, nationally and internationally with which academic staff have engaged in productive collaborations during the REF period include: Aston, Bristol, British Columbia, Cambridge, Colorado School of Mines, Dundee, Edmonton, Emory, Exeter, Florida, Frankfurt, Hamburg, Harvard, Hong Kong, Imperial College, Johns Hopkins, KCL, Leeds, Mahidol, Michigan, Monash, Montreal, NIH (NIDA), Nottingham, Oxford, São Paulo, Sapporo, Sydney, Toronto, UCL, UCSF, Warwick.

Collaboration/integration with external bodies. Barnett – member, Society for Risk Analysis Executive Committee; member, Wellcome Trust Monitor External Advisory Board; research support and expert advice to Health and Safety Executive, Food Standards Agency, Department of Health, the Environment Agency. De Vries - Expert Advisory Group member, European Medicines Agency. Delgado-Charro – member, International Association of Therapeutic Drug Monitoring and Clinical Toxicology (IATDMCT) Committee on "Alternative Sampling Methods in TDM"; member, Medicines for Children Research Network, Formulation Sub-group. Eccleston – member, Scientific Advisory Board, USA National Children's Pain Center. Fotaki – member, AAPS Steering Group on *in vitro* dissolution and release and oral absorption. MacKenzie, Ward – Council members, Bath Institute of Rheumatic Diseases. Mrsny/Guy – chair/member, Controlled Release Society Foundation Board. Threadgill – Chemistry, Pharmacy and Standards Expert Advisory Group, MHRA. Weiss - member, Dept. of Health, Pharmacy and Public Health Forum, Working Group 3. Welham - currently on secondment as Director of Science at BBSRC.

Summary: Vitality and sustainability are demonstrated by (a) the large number of FTEs (>50) and the 6 impact case studies submitted in this UoA; (b) the strong youthful component of the staff (including 2 University Prize Fellows) and the positive trajectories of these new academics; (c) the coherence of the UoA's research 'flow' from "bench to patient"; (d) the manner in which the applied research in allied health feeds seamlessly into tangible impact; (e) the excellent quality and quantity of publications in high-impact journals from all components of the UoA; (f) substantial research income from diverse sources, both within and outside the UK; and (g) a significant level of investment in the UoA by the University of Bath, and its commitment to create a flag-ship Institute of Health Science & Technology to develop, enhance and show-case the substantive and burgeoning research activity in this area.