Institution: Cardiff University (CU)

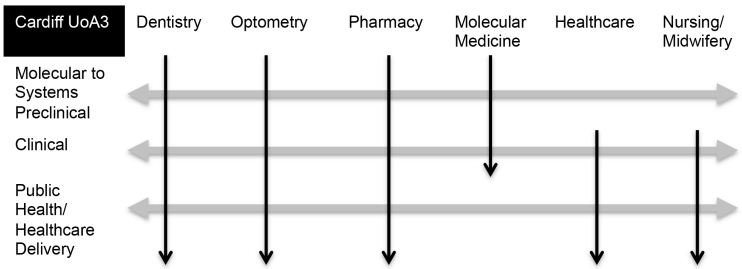
Unit of Assessment: UoA3

a. Overview

***Overall Structure*:** In the latter stages of the REF period, under the leadership of the new Vice Chancellor Professor Colin Riordan, Cardiff University was re-structured into three colleges each led by a Pro-Vice Chancellor. Research work carried out in Cardiff's UoA3 Unit lies within the College of Biomedical and Life Sciences (the 'College'). Cardiff's UoA3 unit (the 'Unit') comprises researchers from six groups which are aligned in most cases to University Schools: Dentistry [D]; Health Care Studies [H] and Nursing and Midwifery Studies [N] both now within a newly formed School of Health Care Sciences; Molecular and Experimental Medicine [M] - representing investigators working in cardio-metabolic, ionic signalling, matrix biology and pharmacology research from the School of Medicine; Optometry and Vision Science [O]; Pharmacy and Pharmaceutical Sciences [P]. In addition to the UoA3 unit the College also integrates the research of the Cardiff Schools of Biosciences and of Psychology, and the School of Medicine's 'Cancer Genetics' and 'Infection and Immunity' groups.

Research Groups and their activities: While each of the UoA3 groups has distinct discipline-related research challenges, e.g. ocular disease, pharmaceuticals, rehabilitation etc., the scholarship has a common focus toward benefiting human health and welfare. Research is inter-disciplinary spanning the full translational spectrum across three overlapping spheres of operation:-

Molecular to systems-level preclinical research - addresses mechanisms of disease, therapeutic targets and interventions (e.g. drugs, diagnostics, tissue regeneration) in a range of disease areas (dental, cancer, cardiovascular, endocrine, infection, musculoskeletal, neurological, ocular); *Clinical Research* - which integrates with the Unit's preclinical studies, e.g. new drug candidates, but can also be conducted independent of preclinical research, e.g. clinical rehabilitation research. Clinical studies are conducted both within the Unit accessing particular patient cohorts, e.g. chronic non-healing wounds [H, M], low vision special needs patients [O], or in conjunction with the NHS e.g. dental clinics, or externally with partners e.g. drug trials; *Public Health / Healthcare Delivery research* - addresses epidemiological, quality of life (QoL), pharmacoeconomics, workforce and practice-based investigations. The research activities characterising the groups include:



- Dentistry [D]: Tissue repair in disease and injury, role of stem cells in tissue regeneration, influence of infection and intervention strategies; epidemiology and dental health; management and prevention of violence-induced trauma.
- Health Care Studies [H]: 'Recovery & Rehabilitation' which addresses independent living following injury, surgery and chronic conditions such as wound healing.
- Nusing & Midwifery Studies (N): Evidence-based influence to healthcare practice focussing on 'Workforce', 'Education & Innovation'; 'Maternal, Child & Family Health'; 'Emotional, Supportive & Palliative Care'.
- Molecular and Experimental Medicine [M]: Cardiovascular biology; ionic cell signalling; matrix biology/nephrology.
- Optometry [O]: Structural biology of the eye in health/disease; molecular to systems level investigations of eye disease and therapeutic interventions; psychophysical/clinical investigations of the visual system in health/disease; delivery of eye-care services.
- Pharmacy [P]: Design and synthesis of drug candidates; identifying drug targets, mechanisms of drug action; drug delivery systems; microbial infection and resistance mechanisms; 'Pharmacy Practice'; pharmacoeconomics.

b. Research strategy

Research strategy is developed collectively within the College structure against a common mission of delivering world-leading discoveries and distinct national/ international healthcare benefits. The agenda is facilitated by collaborations and shared facilities (sections D and E).

Strategic Aims for post RAE2008: The overriding aim shared by the UoA3 groups was the delivery of high quality innovative research contributing significant discoveries to the respective discipline area(s), and which had translational capacity for human health and welfare.

The post-RAE2008 objectives embodied by the UoA3 groups included:

- Investing in research facilities and investigator support mechanisms.
- Recruiting senior research staff able to integrate with, and develop the strengths of, existing groups and lead on new areas of investigation.
- Increasing recruitment and development of ECRs toward a sustained research culture.
- Building capacity in clinical and non-clinical pre- and post-doctoral researcher communities concurrent with enhancing the mechanisms for their support, training and career development.
- Exploiting the synergies of new organisational structures, shared facilities and interdisciplinary working as a means toward international competitiveness.
- Realising the translational potential of the research.

Main achievements - Staff and Estates research environment: The Unit has seen investment in its research infrastructure (ca £28M) through a range of funding streams, including direct University capital, HEFCW strategic development funds (£1.43M), SRIF3 (£1.48M), NHS-University partnerships (£2M), and other external sources. For example:

- Relocation of [O] to new purpose-built facilities (£20M) has accommodated both preclinical and clinical research into one areas including patient clinics.
- Enhanced specialist pharmaceutical facilities [P] (£2.1M), e.g. new in-silico molecular modelling suite (227m^2), increased medicinal chemistry capacity (7 additional fume hoods), new sterile/non-sterile formulation Good Manufacturing Practice "GMP" suite (308m^2 part-funded SRIF3), and new 368m^2 *in vivo* facilities (part-funded SRIF3) [P,O,M].
- Creation of a world-leading clinical research facility in 'movement analysis' to enhance quantitative movement and rehabilitation research [H], including a state-of-the-art 'Gait Real-time Analysis Interactive' laboratory (£400K) allowing study of movement disorders and their management within a virtual reality environment.
- Expansion and upgrading of preclinical facilities across the Unit to increase general multidisciplinary capacity (e.g. cell biology/microbiology/histology [D,P,M]).
- Investment in equipment ca.£3.5M including specialist instrumentation such as super-resolution Total Internal Reflectance Fluorescence (TIRF) microscopy - £150K; [P,M,D] and establishment of a lipidomic facility (£890K; [M]) housing a rapid scanning mass spectrometer.
- Expansion and upgrading of interview rooms for healthcare delivery research [H,N] (£380K; 540m^2) and a new clinical skills laboratory [N] for research in educational methodologies.
- All groups across the Unit have seen improvements in the quality (group space, silent study rooms, individual study areas) and capacity (ca. 950 m^2) for their PGR communities.

Research leadership is enhancing ongoing programmes and new opportunities. For example:

- Six new Professorial staff have been recruited in the assessment period with 36 internal promotions to Professor/Reader. For example, the recruitment of Prof. Song [D] (Royal Society University Research Fellow) has facilitated establishment of a stem cell biology research programme (Song, Stephens, Sloan) attracting £3M (2011 onwards) of RCUK/European Research Council awards and seeding the University's MRC Stem Cell Doctoral Programme (jointly led by [D] and Biosciences) as well as an EPSRC 'Novel Technologies for Stem Cell Science' initiative ([D] with cross-College/HEI partners). The clinical academic appointment of Prof. Morgan [O] joins Vortruba [O] as ophthalmologists with part-time NHS portfolios that are realising collaborative research in the Unit that more fully embeds the entire scope of translational ocular science, e.g. leveraging £0.54M Wellcome Trust/DOH funding (2012-15) for research underpinning minimally-invasive eye surgery (Quantock [O]). Four recent Professorial appointments in [N]: Kelly, Hunter, Gould, Hopkinson, and (by promotion) Lowes, are bringing new direction and capacity in the research themes of workforce and innovation, patient safety, maternity and end of life care, and integrates with on-going College programmes ranging from those in the biomedical area e.g. NISCHR funded infection control projects, through to social science.

Over the assessment period the Unit has invested in 13 FTE ECR appointments (section C) aligned

to established or developing research areas of the College and to international priorities.

Main achievements - Research performance: Indicators in the assessment period include:

- Research awards of ca.£60M and an income ("spend") of £41.36M (averaging £8.20M spend per annum) which represents a 40% increase compared to the combined spend of the same research groups in the RAE2008 period.
- Significant collaboration with external partners on projects of direct translational significance, for example 41% of the Unit's research spend is from awards made by commerce, government, and NHS, with the remaining 49% from RCUK, medical charities and EC.
- Licence income £1.45M and fifteen patents granted
- Graduation of 222 PhD / MD doctoral researchers
- Publication of 2041 peer reviewed articles yielding 16328 citations (12-09-2013 scopus)

Research performance and inter-disciplinary working: Strategy, structures, support mechanisms and culture underpin inter-disciplinarity (sections C,D,E). Amongst many examples:

- The University's £10M Arthritis Research UK Biomechanics and Bioengineering Centre (ARUK-BBC) of Excellence (ARUK £2.5M and Cardiff University £7.5M 2009-2014) promotes collaborations between biomedical scientists and practitioners. The UoA3 Unit has significant input and has appointed to the ARUK Centre five cross-group ECR or first appointment Lecturers:- Jones [M, Personal ARUK Fellowship], Dewitt-Par [D], Ferguson [D], Prokopovich [P], Roos [H], whose collective research spans immunology, tissue regeneration, bio-nanomaterials, and musculoskeletal biomechanics. NHS researchers also contribute, e.g. Button (Cat C) physiotherapist and NISCHR Fellow. The Centre has been invited to apply for non-competitive renewal (2015-2019).
- The University interdisciplinary Research Institute in Neuroscience and Mental Health brings cross-college expertise that promotes not only the preclinical and clinical activities of the Unit but also research into mental health services, e.g. cross-HEI NIHR/'Child and Adolescent Mental Health Services' funding £500K – Hannigan [N]).

Research performance and involvement of research-users (section E): UoA3 research has been partnered by a wide range of user-groups which enhance the significance and translational success of the work. In the assessment period ca. £17.16M of research spend (41% of the Unit's total spend in the assessment period) has been awarded from commerce (78 different partners), government or NHS sponsors. Amongst many examples:

- Polymer therapeutics for wound healing (Hill, Thomas [D]) have reached clinical study supported by a consortium of industry (Algipharma, USA), Norwegian Research Council, MRC, Wellcome Trust and the EC. The technology is undergoing lateral exploitation (US Dept. of Defence - $1.3M and EU Eurostars programme - €4.5 M) for use in respiratory infections.
- User engagement is fundamental to the Unit's clinical research, e.g.:- Clinical optometry and ophthalmic staff are working with government, professional and patient groups on improving the clinical management of a range of visual defects (e.g, Woodhouse [O] - Impact Case). Similarly researchers within the rehabilitation theme are working with patients and medical charities to reveal the beneficial effects of exercise on Huntington's Disease symptomatology (Busse-Morris [H], Huntingdon's Disease Association).
- The Unit's Public Health and Healthcare delivery research necessarily depends upon engaging directly with the service, its users and policy makers, e.g. research seeking to reduce alcohol-related violence (Moore [D], Shepherd [D] - Impact Case) has attracted funding from a range of bodies, e.g. central government, MRC, NIHR (£815K 2012-15), and benefits from working with the cross-HEI Public Health Research Centre of Excellence (DECIPHer) led from Cardiff.

Research performance and responsiveness to national/international priorities: The Unit has responded to the research priorities of a range of bodies. Amongst many examples:

- Engagement in a number of EC-funded consortia comprising commercial and academic partners, for example: *microneedle technology* - delivery of peptide vaccines and other potent biological molecules to skin epidermis (Allender, Birchall, Coulman [P]), (EE-ASI €6M 8 partners; HIPODERM €1M 3 partners); *nanomedicines* - (Jones, Gumbleton [P]) (ALEXANDER €13M 15 partners; COMPACT €21M 22 partners).
- The work of Meek [O] in a MRC funded (£1.74M) programme grant on ageing and eye disease is revealing new perspectives on supramolecular protein packing.

- Cardiovascular teams in the Unit ([M],[P]) bring together researchers with distinctive global expertise and synergy. A BHF programme grant (£5M led by Williams [M]) is addressing physiologic and biophysical investigations of myocardial receptors controlling calcium signalling.
- The healthcare delivery agenda of medical charities is addressed by the Unit's work, for example, 'Service improvements at healthcare interfaces' (£297K The Health Foundation Allen [N]), 'Psychosocial interventions in diabetic children' (£222K Diabetes UK Lowes [N]).

Effective mechanisms for the development and promotion of research: Research Strategy is informed by internal drivers, the International/National discipline demands and by external stakeholders, e.g. Government, Commerce, NHS through the NISCHR-Academic Health Science Collaboration (NISCHR-AHSC). Strategy is developed in a collective manner within the College structure and is effectively informed from the 'bottom-up' through cross-College Heads of School/Directors of Research meetings. The research of the Unit is operationally supported in the research groups through their respective School Research Committees which has the representation of theme leaders, ECRs, post-doctoral researchers and technical staff. The Schools benefit from external advisory boards (drawn from academic/practice/commerce) and by representation on cross-HEI/NHS research bodies e.g. South East Wales Academic Health Sciences Partnership.

In open competitive calls researchers can access funds allocated through the College or the groups, e.g. [P] typically spend £175K per annum on matched 50% PGR scholarships to lever inter-disciplinary and/or external PGR opportunities. Competitive calls support career development requests (e.g. international laboratory study leave) and equipment bids (small items directly or as joint bids to the College for large items >£120K). Groups individually or in partnership directly invest in major strategic enterprises, e.g. recurrent investment in ECR appointees and PGRs to the ARUK Centre. Return of grant overheads to PIs allows investigator-led reinvestment in research support (e.g. conferences, open access publishing, minor facilities/equipment). School-based support staff (50 FTE across Unit) underpin research activities locally, e.g. PGR monitoring, equipment maintenance, financial/HR/purchasing administration etc. Cross-College operational meetings share information and good practice and assist integration with the University's central provision.

Future strategic plans: Under the leadership of the new Vice Chancellor Professor Colin Riordan, the University is committed to provide over the next assessment period major investment (ca. £50M per annum) in staff, PGR students and capital development to support the delivery of research excellence and impact. The University strategy includes the creation of a series of University-level interdisciplinary research institutes (building upon the two institutes already created in the current period, 'Neuroscience and Mental Health' and 'Cancer Stem Cell'), which will concentrate on the major global challenges and physically locate together cognate investigators.

The principles of UoA3 strategic plans are: conducting research of the highest quality; supporting and developing researchers toward excellence; delivering benefits beyond academia. The following high-level five-year objectives have been identified.

1. *Prioritisation of inter-disciplinary working to address the more complex scientific and societal problems in the biomedical and healthcare environments*. Achieved through:

- Integration of the Unit's research within new University-level Research Institutes which will expand internal research synergies and external user network opportunities. It will realise enhanced RCUK prospects (currently 16% of overall research income) in science that is aligned to the relevant bodies and driven by UoA3 researchers, e.g. regenerative medicine, therapeutic technologies, point of care tests, ageing, synthetic biology.
- Building effective cross-HEI research collaborations. For example, Institutional agreements have led to the formation of the Great Western 4 (GW4) research alliance (Bath, Bristol, Cardiff, Exeter) which develops further the already extensive collaborations that Cardiff has with the University of Bristol, e.g. Severnside Alliance for Translational Research (SARTRE) (sections D and E). The GW4 arrangement enhances significantly the sharing of specialised facilities and resources and serves as a model for International arrangements. Amongst other initiatives the Unit [M,P] is developing a 'Joint Cardiovascular Strategy' for the GW4 to share resources, e.g. PET and MRI (Cardiff), regenerative medicine (Bristol, Bath), vascular biology (Exeter, Bristol, Cardiff), pharmacy/pharmacology (Bath, Cardiff).

- Increasing the proportion of overseas inter-disciplinary funding through Institutional-led initiatives and PI-led working, for example with BRIC countries (Universidade do Estado Rio de Janeiro [D] *Science without Borders programme*). Wider investigator participation in EC consortia will be targeted to at least double the current 4.4% of income from this stream. Transnational networks will be fostered through supportive mechanisms such as the Unit's financial and administrative support for hosting international symposia, e.g. Gumbleton and Jones [P] *Cellular Delivery of Therapeutic Macromolecules* biennial series which led to participation in recent FP7/IMI programmes.

2. Increase proportion of research informed by non-academic users. Achieved through:

- Exploiting cross-discipline networks to appoint non-academic users to internal advisory boards to inform the Unit's research and translational strategy. Conversely promote greater researcher engagement with the advisory bodies of external organisations. The latter to be facilitated by College level processes and through senior staff already holding such positions.
- Increasing membership and strategic influence in research-user networks (section D) such as NISCHR, NIHR, South East Wales Academic Health Science Partnership (SEWAHSP). To include identification of non-academic users whose needs align to the Unit's research capacity and direction toward partnerships accessing infrastructure, patient and funding resources.
- Increasing the proportion of research directly aimed at translational activities (commerce, government, NHS) from its current level of 41% to 60% of Unit research spend.

3. Recruit, support and develop excellent researchers. Achieved through:

- Recruitment to areas of high promise aligned to College strengths, external initiatives and discipline needs, with appointees bringing capacity for inter-disciplinary working. Priority areas for recruitment being clinical/pre-clinical staff in regenerative medicine, rehabilitation, imaging, nanosciences and cancer/infectious disease drug discovery. Capacity in Health Care Sciences ([N],[H]) is to be strengthened with imminent appointment of 15 new lecturers (ECRs and SLs) in Nursing (adult, child and mental health) and three Professors in allied health more broadly.
- Growing the Unit's ECR staff base by external recruitment and internal development of post-doctoral researchers and clinical researchers of high potential (see IRS scheme - section C) and also through the clinical academic training schemes (WCAT) hosted by [M] and [D], but which is increasingly involving [P] and [O] as partners in the research training.
- Provision of consistent and outstanding PGR training and mentorship programmes with the aim to double PGR enrolment over the period. Integral to success are PGRs working within College-/University-wide Doctoral Training programmes promoted through University investment. Leverage of external PGR funds will involve direct Institutional matched funding initiatives such as President's Research Scholarships, or the Sêr Cymru Life Sciences and Health Network in Drug Discovery (section C). The focus on the major global challenges and enhanced access to specialised facilities and expertise will develop longer term partnering with PGR sponsors.

c. People, including:

i. Staffing strategy and staff development

Staffing strategy: Developed initially in the Schools the strategy is integrated at College level to maximise cross-disciplinary working. The strategy aims to:

- Foster a high quality inter-disciplinary environment affording critical mass and sustainability in priority research areas, while enabling growth in promising new areas of investigation.
- Maintain a balance between senior staff and early career researchers.
- Safeguard effective research support mechanisms.
- Ensure high quality provision across all academic portfolios – research/clinical/educational.

In the period 8 FTE Professorial staff and 9 FTE at SL/L level have retired or otherwise left the Unit. In addition to newly recruited Professorial (6) staff and senior (Professor/Reader) promotions (36 FTE) the Unit has recruited 13 FTE ECR Lecturers/Fellows (>10% of REF eligible staff) to promote inter-disciplinary working. Beyond the ARUK ECR positions (section B), the appointment of Davies [D] has brought additional capability in matrix biology. Appointments of Gale [H] (exercise and chronic health conditions), Sheeran [H] (chronic musculoskeletal conditions), Barlow [H] (surgical rehabilitation) have increased research capacity at the patient-practice interface. Recruitment in areas aligned to national priorities of the 'ageing eye' has seen ECR lectureships

[O] to Acton (age-related macular degeneration), Boote, (biophysics of glaucoma), Redmond (visual fields) and Wood (retinal imaging). Recruitment of ECR Castell [P] under the University's 'Serious Brain Power' scheme (£5M Institutional investment) brings membrane biophysics and super-resolution microscopy expertise to the College. The ECR appointments of Lane [P] and Twohig [M] bring, respectively, expertise in neurological cell-based therapy and in the immunology of inflammatory disorders.

Career development of all research staff: The University's commitment to the 'European Charter and Code for Researchers' and the 'Code of Conduct for the Recruitment of Researchers' has been recognised by the EC through a 'HR Excellence in Research' accreditation. Schools are benchmarked on their implementation of the 'Concordat to Support the Career Development of Researchers'. Staff benefit from annual Research & Scholarship reviews requiring critical self-reflection on research plans and performance, and which feeds into annual appraisals. Training opportunities are varied and range from School-/College-based (e.g. core skills training, inter-disciplinary seminar programmes) through to recurrent University staff development programmes (e.g.137 courses offered in 2012-13). In the assessment period the Unit has invested in developing high-level leadership skills for 78 of its research staff who have each gained accredited 'Institute of Management & Leadership' qualifications.

Developing Early Career Researchers: The mentoring of ECRs focuses on the research agenda while still developing their wider academic role. ECR lecturer non-research workloads are managed (e.g. < 20 hrs teaching contact per year). Internal funding calls are discriminating toward ECR bids (e.g. 'seed-corn' and small equipment) and at start-up ECRs are allocated a fully-funded PGR studentship (co-supervised with a secondary but experienced colleague). Multi-user laboratories assists their integration of into the research environment.

There are ca.70-80 post-doctoral researchers across the Unit at any one time. Through representative groups (e.g. 'Postdoctoral Colleges') they have regular meetings (every 2 months) with senior academic staff (HOS or Director of Research) who can oversee implementation of the Concordat. Research reviews and appraisals identify their training needs, which are accessed locally in the research group, through the University's Graduate College/Centre as well as through the University's staff development programme. In 2012 the UoA3 Unit launched a competitive 'Independent Researcher Scheme' (IRS) to enhance the skill set (e.g. teaching, independent scholarship) of this category of staff in preparation for their pursuance of Fellowships or full academic appointments. The scheme awards fixed term 0.2 FTE lectureships (funded jointly through the Unit and College) to highly promising candidates in order that they can conduct independent research. External sponsors are full partners in the scheme which is now operational across the College with matched central funding. Some 31 IRS appointees (£278K p.a. central investment) are in post across the University with 7 appointees (equivalent = 1.4 FTE) to UoA3. For example, Slusarczyk, Serpi, Pertusati [P] are developing independent medicinal chemistry programmes in cancer and infectious disease, Rhian Thomas [P] is working in neurodegeneration and Joshi [P] in microbiological resistance. A similar scheme active during the RAE2008 period has seen staff (Taylor and Gee [P]) progress to obtain prestigious 5-year senior Fellowships (Wellcome Trust/Breast Cancer Campaign).

Equality and Diversity (E&D)*:* Underpinning sustained academic competitiveness the E&D agenda and ethos is led at the local School level supported by central College resources. Staff E&D training is compulsory and is recognised to engender good practices. In 2011 the University was the first Russell Group member to secure an Institutional award of 'Investors in People.' The University holds an Athena SWAN Institutional Bronze Award with role models in the Unit of women progressing to senior positions, e.g. Price ([H] Pro-VC, 2012-date), Treasure ([D] Deputy VC 2010-date). Athena SWAN Silver status is held by the newly combined [H&N] school and by both [O] and [P] groups, while [D] and [M] hold Bronze. A 'Women-in-Universities Mentoring Scheme' addresses cognate professional issues. Stonewall recognises the University to be a top 50 employer (2012) and in the top three of UK Universities.

Integration and Role of clinical researchers: Through a range of mechanisms clinical academics and practitioners benefit each of the Unit's research groups.

Clinical researchers within and external to the Unit provide context to early-stage research, e.g. breast oncologist Barrett-Lee brings clinical context to the breast cancer biology and experimental

therapeutics research of Hiscox, Gee, Nicholson, Taylor [P]). Clinical interactions are fostered in collaborative networks e.g. NISCHR-funded All Wales Kidney Research Network led by UoA3 researchers (Fraser [M]). Clinical academics are also embedded within the groups, for example, ophthalmologists Morgan [O] and Vortruba [O] both undertake research from the molecular level through to the patient. They are forerunners in co-localising academic ophthalmology/optometry within the Unit aligned to hospital-based service delivery. Patient-facing clinical academics in [O] (e.g. Woodhouse Wild, North, Sheen, Margrain) investigate the management of a range of visual defects. Similarly, in [D] there is an approximate 50% balance of clinical academics (the vast majority also holding honorary NHS clinical contracts) who are integrated across the full spectrum of research from preclinical (e.g. Thomas - prototype polymer therapeutics) through to public heath (e.g.Chadwick and Chestnutt - oral health). Both [D] and [M] have a training role hosting the Welsh clinical academic training scheme (WCAT); currently these two groups host 12 WCAT trainees.

The academic research base within the [H] and [N] groups is intrinsically practitioner-based and patient-facing with potential for rapid impact upon practice. For example, Barlow [H] is a joint University/NHS appointee whose research is nutritional feeding and recovery from GI surgery. Her NHS role as 'All Wales Lead for the Enhanced Recovery Programmes' provides an effective route to deliver direct patient benefits and influence the research agenda. Academics in [N] work closely with practitioners across several health boards and government agencies. For example, Hopkinson's [N] research in collaboration with Macmillan Cancer Support and other cancer charities has provided evidence on nutritional interventions to palliative care patients. Lowes [N] (Florence Nightingale Chair) holds a joint appointment in the NHS where she works as a diabetes specialist nurse, a role that informs her research in paediatric diabetes services. The links with service users are formalised through their involvement in the research process from the point of design onwards, e.g. 20 NHS clinical nursing staff hold associate lectureships in the group.

ii. Research Students

Effective training and integration of postgraduate research (PGR) students: The Unit is committed to the provision of high quality PGR training consistent with QAA, the Roberts Review, and the Researcher Development Framework of Vitae. The personal effectiveness of PGRs is developed in an interdisciplinary environment in a partnership between the Schools, College, the Research Institutes and the University Graduate College http://www.cardiff.ac.uk/ugc. The training environment offers access to a wide range of expertise, supported technologies and library resources (also section D).

Critical mass provides peer support opportunities with at any time approximately 135 FTE PGRs enrolled in the Unit against a typical enrolment for the College as a whole of 475 FTE. The UoA3 Unit has graduated 222 doctoral researchers in the assessment period (total College cohort of 787 graduants). Prior to student recruitment PhD projects undergo independent peer review for internationally competitiveness and resource-feasibility. Each student has at least two supervisors to enhance support and team-working, and to develop the supervisory skills of less experienced staff. Cross-School and joint clinical/non-clinical supervisory teams are actively encouraged. As part of the scientific development the Schools commit financially to support PGR attendance at National and International (at least 1 during the course of the studentship) conferences. A PGR Monitoring Panel within each host School oversees the quality of supervision and student progression. Through internal University processes or external surveys students provide confidential feedback on difficulties they are experiencing or deficiencies in resources. The Postgraduate Research Experience Survey (PRES) (2012) found Cardiff exceeded the Russell Group average for PGR satisfaction in facilities provision, financial support for research, and in the goals and standards expected.

The supervisory team and School or College-led programmes provide training in discipline-specific skills, e.g 'Biomedical Research Techniques'. This is supplemented by activities through inter-disciplinary centres such as ARUK-BBC or the University Research Institutes. Training in more generic skills is delivered through the University Graduate College (UGC) which also hosts student-led events (e.g. PGR conferences such as 'Speaking of Science' – in its 11th year as a PGR-only event involving cross-HEI participation). The UGC programme itself is comprehensive (211 courses in 2012-13) and maps to the 'Researcher Development Framework', and is acknowledged nationally as providing 'Outstanding Support (2010 THES Awards).

Sustainability and capacity building: More than 90% of the Unit's PGRs have external funding (in-part or in-full) demonstrating doctoral student projects that are engaged with external stakeholders. A strength is the diversity in funding streams: Government has supported 21% of the Unit's PGRs through, for example, clinical academic WCAT schemes, Knowledge Economy Skills Scholarships (KESS), Welsh Government, UK Home Office and Department of Health; Charities have supported 17%, for example, CRUK either directly or through CRUK's Cardiff University-based Centre, Cancer Research Wales, Leukemia Research Appeal; Industry 20%, for example, involving 19 different commercial partners with some involved in multiple studentships through long term arrangements (e.g. AstraZenca, Inhibitex, GSK); Overseas government scholarships 15% with these increasingly through international strategic partnerships, e.g. Iraq (Bagdad University); Professional bodies 5%, for example, Royal College of Nursing, Florence Nightingale Foundation, Royal Pharmaceutical Society, College of Optometrists; RCUK 9%, for example, involving direct EPSRC or MRC scholarships, the MRC Stem Cell Capacity Building programme, the EPSRC-DTC based in Engineering, and the ESRC Public Health Research Centre in Social Sciences. In addition the Unit currently holds four major EC grants recruiting PGRs (8 FTE) and three active RCUK-CASE Awards in the areas of pulmonary disease models and drug delivery, i.e. BBSRC-CASE Norvatis and MRC-CASE GSK [P,M] and a BBSRC-CASE GSK [P]. These were obtained following long-term relationships and strategic fit of the project to the needs of the commercial partner.

PGR capacity building is delivered through a number of mechanisms. Internal monies are used to lever cross-School or wider strategic capacity building initiatives. Inter-disciplinary working is an increasing feature reflected with approximately 19% of the Unit's PGR enrolments involving formal cross-School supervision, including those outside the College, e.g. with Computer Science *('Perception in Stroke patients'*), Physics *('FTIR of Biomaterials'*), Social Science *('Living with the risk of genetic disease'*). The period has also seen a number of joint studentships (6 FTEs) in the area of *'microfluidics and biosensors'* with Engineering's EPSRC Doctoral Training Centre. Wider University PGR programmes such as the ARUK-BBC (9 FTEs to the Unit) or the President's Research Scholarships build capacity. The latter has involved £4M University investment (supplemented by Schools/PIs) to fund PGRs across the University with the Unit benefiting from 14 FTEs to date. The Sêr Cymru Life Sciences and Health Network in Drug Discovery (2014-18) is aligned closely to UoA3 activities and will be supporting 100 PhDs (50% funding) across four partnering HEIs - Cardiff, Swansea, Bangor, Aberystwyth. The forward success in growing PGR numbers will be augmented by the new inter-disciplinary College structures (section B) which will foster increased funding opportunities by high level initiatives and natural synergies.

d. Income, infrastructure and facilities

i. Income £41.36M over the assessment period

Spend from charities represents ca.33% with one-quarter of the respective charity awards supporting inter-disciplinary work across the Unit or the University as a whole. All research groups and spheres of activity were funded, for example: clinical research in ocular sciences (e.g. National Eye Research Centre for clinical studies [O] £210K) or Public Health/Healthcare delivery research (e.g. Health Foundation - patient safety [N] £330K). Approximately 18% of income supported cancer research involving all the major relevant charities in studies ranging from mechanisms of disease, biomarkers, design and clinical trial of new anti-cancer agents, through to patient rehabilitation and their emotional support needs. Other main areas of charity funded research included: heart disease (30%) with grants from BHF 11 PIs [M, P]; matrix biology and inflammation (35%) [D,H,M,O,P] in areas of arthritis, kidney disease, lung disease, neurodegeneration, immunity and infection. New awards of ca £1M were notified in 2012-13.

UK Government and NIHR/NISCHR funding represent ca. 21% of income, and has been relatively more substantive for the clinical and public health/healthcare delivery spheres of the Unit's activities. For example, NISCHR/NIHR funding has supported clinical research projects [H] in rehabilitation following stroke, in Huntington's disease and in wound healing. Clinical trials in child oral health [D] have been funded (£1.4M) by NIHR in collaboration with Welsh Government, ESRC and Wellcome Trust. Violence prevention research [D] has seen Knowledge Transfer Partnerships with the NHS, and Welsh Government has pump primed (£144K) cross-school 'workforce' research ([N] with Schools of Business and Medicine).

Industry and commerce represents ca. 20% of income which has mostly supported preclinical work, although funding of clinical research in wound healing (Harding [M] and Price [H]) is notable (section E). Long term partnerships have provided continuous funding before and throughout the assessment period, e.g. AstraZenaca (£0.8M) for cancer studies or Frensius Kabi (£0.65M) for parenteral formulations. Research in infectious disease has included point of care assay development, design and synthesis of new anti-infectives, resistance to antimicrobials and biocides and attracted significant industrial partnering. For example, anti-candida dental research (£0.6M,GSK), biocide research (£0.30M, Unilever), design of anti-viral drugs (£0.75M, Inhibitex).

RCUK funding represents 17% of income with support from all RCUK bodies but the majority (72%) from MRC and EPSRC. Approximately one-third of the number of awards were interdisciplinary, including external to the College e.g. Physical Sciences (Engineering, Chemistry, Physics, Computer Science) or Social Sciences. Income has supported principally preclinical research with areas of particular prominence tissue regeneration and repair led by [D], structural and molecular biology in the vision sciences led by [O] and drug design and delivery led by [P]. Public health research e.g. violence prevention [D], clinical research, e.g rehabilitation [H] has also seen support. Approximately £2M of new RCUK awards to [O,P] were notified in 2012-13.

EU Commission represented ca. 5% of income which has funded predominantly preclinical programmes [D,O,P] including a £1.4M award in neural stem cells. Four recent awards (2012-13) have seen drug delivery staff [P] partnering in EC networks with a combined funding of ca €50M.

Benefits in-kind: includes most notably access to national particle accelerator facilities (Albon, Boote, Meek, Regini [O]) to conduct unique biophysical experiments (capital value £1.6M). The facilities include: Science and Technology Facilities Council Diamond light source (Oxford), and the Institute Laue-Langevin (ILL; neutron source) and ESRF both at (Grenoble).

***Research governance*:** All Schools in the Unit comply with the University's Research Governance Framework with responsibilities reinforced at researcher induction events and through PI supervisory practices. The arrangements for project management of research awards are formally reviewed and approved with the University's Research, Innovation & Enterprise Services (RIES) before the project can begin and with monitoring thereafter. On a cross-Wales basis NISCHR is responsible for developing NHS research governance and ethics. School-based research ethics committees review all non-NHS related research. A Human Tissue Authority (HTA) 'Person Designate' ensures compliance when the use of human tissue is required. Animal procedures are conducted under licence through the Animal Procedures Act (1986).

ii. Infrastructure and Facilities (see also section B)

As expected by a research-intensive University, researchers in the UoA3 Unit have access to a range of modern facilities allowing multi-methodological investigations, e.g. radiation, genetic-manipulation, whole systems/tissue work, cell/molecular biology, microscopy, biophysics, chemistry(synthetic/analytical), material science. Many are within dedicated specialist or managed suites. Some facilities hosted by the Unit and accessed widely across Cardiff University (and by external users) include: Atomic Force Microscopy (part of Centre for NanoHealth collaboration with Swansea University), Circular Dichroism, state-of-art SEM/TEM, optical coherence tomography, and super-resolution TIRF microscopy.

Of relevance to UoA3 and external collaborators are centrally serviced Cardiff University research facilities staffed by experimental officers, and which include, amongst others: (i) ARCCA - advanced research computing, e.g. modelling of drug docking into receptors, bioinformatics, muscoskeletal biomechanics; (ii) Central Biotechnology Services - proteomics, genomics, cytomics, surface plasmon resonance etc.; iii) Spectroscopy - Electron Spin and Electron Paramagnetic Resonance, MS, NMR, X-ray diffraction etc.; (iv) Whole systems imaging - Cardiff's Brain Research Imaging Centre (CUBRIC) hosted in Psychology, Cardiff's Experimental MRI Centre (EMRIC) hosted in Biosciences, Wales' Research & Diagnostics Positron Emission Tomography Imaging Centre (PETIC) hosted in Medicine. PETIC (founded in 2010 with £16.5 million investment - Cardiff University, Welsh Government and NHS) provides both clinical and pre-clinical PET/CT/SPECT scanners and radiopharmaceutical production capability.

The University's Information Services has seen the addition (2011) of a new 6,200m^2 24hr access unit - Cochrane library. The Services' recurrent annual budget for electronic journals is ca.

£3.9m (2011/12) with greater than 22,000 journal titles (exceeding Russell Group average). The Service also hosts the 'Support Unit for Research Evidence' (SURE) which has an international reputation in systematic review methodology. SURE provides research services and holds a comprehensive collection of primary source materials in evidenced-based medicine.

Interdisciplinary support structures: Collaborative working across the University and with other HEIs, NHS and commercial partners, is supported by a number of inter-disciplinary research structures. Below are just a few examples (see also sections B and C).

- The 'Campus Horizon' capital expenditure programme led to the creation of University level Research Institutes with cross-school membership and working practices. The Institutes particularly pertinent to the work of the UoA3 Unit are: 'Neuroscience & Mental Health Research Institute and 'European Cancer Stem Cell Research Institute'.
- Cardiff Institute of Tissue Engineering and Repair (CITER) led by Stephens [D] links 131 PIs (across 11 CU Schools) and is realising many cross-discipline research synergies, e.g. 'finite element 'modelling (a numerical technique) developed by engineers exploited in the modelling of knee injury rehabilitation [H].
- ESRC Public Health Research Centre of Excellence – DECIPHer is addressing cross-cutting public health issues, e.g. nutrition, alcohol, relevant to research of participating UoA3 staff. Led by Cardiff it is a cross-HEI Centre (with Swansea and Bristol).
- ESRC Centre for the Economic and Social Aspects of Genomics (CESAGen) - is a collaborative research centre between the Universities of Lancaster and Cardiff (Social Sciences) impacting the health-related social science research of [D], [H] and [S] in particular.
- Other relevant interdisciplinary centres for UoA3 researchers are Medical Engineering e.g. laser micromachining for microfluidic-based diagnostic sensors, Institute of Society, Health and Ethics, and Cardiff's CRUK Cancer Centre which is a partnership between CRUK, Cardiff University and the University Health Board.

Support for multi-disciplinary work is also provided through the many active research networks/alliances that exist ranging from internal University-level networks in cancer, primary care and public health, infection and immunity (involving also NHS staff) through to cross-institutional models of inter-disciplinary working, for example:

- NISCHR-AHSC develops in consultation with partners (HEIs/LHBs) across Wales a strategy for NHS and social care research.
- South East Wales Academic Health Science Partnership' (SEWAHSP) hosted by Cardiff University is the regional arm of NISCHR-AHSC, an alliance between HEIs and LHBs to locally integrate research strategy. All CU health schools are contributors to this grouping as are health economists, statisticians and social scientists.
- Wales School for Primary Care Research (WSPCR) based in Cardiff is a partnership with Swansea, Bangor and University of South Wales, to progress multi-disciplinary collaboration across primary care disciplines (general practice medicine, optometry, dentistry, nursing, pharmacy, allied health). The grouping shares clinical expertise, qualitative research, health economics/pharmacoeconomics, and practitioner and patient behaviour research. It has generated £3.35M of grant awards in the period.
- Severnside Alliance for Translational Research (SARTRE) created in 2009 between the Universities of Cardiff and Bristol aims to accelerate translational research and provide a focal point for interactions with the Bio-Pharmaceutical industry. The alliance is funded by the Welsh Government and the MRC (Developmental Pathway Funding Scheme - DPFS).
- South East Wales Trials Unit: Based at Cardiff University Hospital is a NIHR and UKCRC registered clinical trial unit funded by the NHS/MRC/UK Clinical Research Collaboration and which undertakes early- to late- clinical studies (typically 40 trials at any one time). This has many cross-cutting links with NISCHR-AHSC, SEWAHSP, the UHB and University researchers.

To bridge more effectively the early translational gap between prototype discovery and development, Cardiff University formed a partnership with Fusion IP. A new entity 'Fusion Cardiff' works with researchers to identify potential commercial opportunities arising from their work. Staff are supported in drafting business plans and a commercial strategy and can access initial investment funding (£8M ring-fenced); two spin-outs have been formed from UoA3 in the last 12 months.

e. Collaboration and contribution to the discipline or research base

Research Collaboration and Interdisciplinary Research - The external interdisciplinary collaborations are extensive (sections B, D and Impact cases and REF3a for other examples).

Collaborations outside the Unit: Many staff engage through cross-HEI/NHS NISHCR networks which bring a wide range of synergies. For example, the NISCHR-funded 'Microbiology and Infection Translational Research Group' (MITReg) has seen UoA3 investigators [D, N,H, M, P] gaining >£3.6M awards in inter-disciplinary work with the NHS and Swansea and Bangor Universities. The work spans the full breadth of translational investigations - microbial resistance, anti-infectives, sepsis point-of-care, through to control of environmental infection and public health.

Similarly the Unit has an active involvement with multiple university interdisciplinary structures, e.g. CITER, and has taken a lead on cross-HEI grants which by their very nature promote collaborative research outside the Unit. For example, EPSRC 'Novel Technologies for Stem Cell Science' involving the Cardiff Schools of Medicine, Biosciences, Chemistry, Physics, Social Sciences and Engineering (Swansea University). Researchers in the rehabilitation theme interact with other HEIs and NHS through, for example, clinical research networks (e.g. WSPCR, NeuroDem, OPAN, WARN) as well as European wide Dementias and Neurodegenerative Diseases Research Networks (e.g DeNDRoN, European Huntington's Disease Network).

Collaborations with Industry and the health-sector: The unit has demonstrable engagement with the above sectors, e.g. 41% of income in the period from commerce (78 different bodies), government and the health sector. For example, four Cardiff-designed anti-viral and anti-cancer drugs have progressed to clinical evaluation (phase I-III) through research actively partnered by industry (McGuigan [P]) (Impact Case). The Unit co-leads the Welsh Government's £7M Sêr Cymru award (2013) founding an All-Wales Life Sciences and Health Research Network in Drug Discovery within which users are fully embedded in the network's management and projects.

User engagement is fundamental to the Unit's clinical research, e.g.:- Wound Healing research led by Harding [M] and Price [H] (Impact Case) has seen extensive partnerships with commerce and NHS, e.g. £2.1M income during the period from industry and NISCHR/NIHR. Recently, £4.2M has been awarded (Welsh Government 2014) to establish a National Wound Healing Centre. NIHR-funded interdisciplinary collaborations are widespread in health care delivery research. For example Featherstone's [N] NIHR-funded collaborations with Bristol and UCL Universities and St Bartholomew NHS are influencing nationally the training of cardiac genetic counseling.

Wider Influence to discipline or research base:

Positions of influence - Staff activities have a wide influence with a particular focus on providing research-led expertise to healthcare providers and government bodies. The embedded nature of translational and clinical research across the unit brings inherent engagement with NHS and service user groups. Amongst **many other** examples:

European Commission: European Taskforce on early diagnosis of cachexia (EONS) - **Hopkinson [N];** Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) and Consumer Safety (SCCS), AHRAI/HIS Task force on sporicidal disinfectants - **Maillard [P]**.

UK Government: Advisory Council for Misuse of Drugs (Home Office), Specialist Advisory Committee for Antimicrobial Resistance (DOH) - **Lewis [D**]; NICE - Public Health Advisory Committee (lead on Oral Health Needs Assessment**)** - **Chestnutt [D];** National Steering Group and Workstream, Midwifery 2020 (DOH) - **Hunter [N];** BP Commission Health Protection Agency's Rapid Review Panel on novel infection control agents - **Denyer [P];** Home Office Chemical Biological Radiological and Nuclear (CBRN) Science and Technology Advisory Group **- Baillie [P].**

Welsh Government: Child Poverty Reduction Group (oral health) – **Chestnutt [D**]; National Steering Board, Older Peoples' Commissioner - **Kelly** and **Jones [N]**; National Service Advisory Group (NSAG) for Diabetes - **Lowes [N];** Chief Optometric Advisor (seconded) - **Ryan [O]**; Children's Vision Services Advisory Group - **Woodhouse [O];** Chief Pharmaceutical Officer (seconded) - **Walker [P**].

NIHR/NISCHR/NHS: NISCHR - Health Care Grant Committee - **Chestnutt [D];** NISCHR Infrastructure Support Group - **Richmond [D]**; NISCHR Advisory Committee (PhD Studentship Panel) - **James [M];** NISCHRS - All Wales Kidney Research Network - **Fraser [M**]; NISCHR

primary Care Board - **Van Deursen [H];** NIHR - HSRD Commissioning Board - **Allen [N]**; NCRI Palliative Care Clinical Studies Group - **Hopkinson [N];** Steering Group Member, NISCHR Patient Safety and Healthcare Quality - **Hunter [N**]; NHS Engineering and Science Advisory Committee on prion decontamination (ESAC-Pr) - **Denyer [P**].

Medical Charity: Diabetes UK Science and Research Advisory Group, Diabetes UK Wales Advisory Council - **Lowes [N];** Eye Care Trust, Down's Syndrome Medical Interest Group, Clinical Expert Panel Down Syndrome Educational Trust, Advisory Board Down's Syndrome Association - **Woodhouse [O];** Tissue Bank Access Committee for Breast Cancer Campaign, Scientific Programme Committee British Breast Group - **Gee [P];**

Funding agencies grant review panels: NC3Rs grant committee – **Stephens, Sloan [D]**; Action Research, Chartered Society of Physiotherapy, Physiotherapy Research Foundation, Arthritis Research UK - **Sparkes [H]**; College of Radiographers Industrial Partnership Scheme - **Courtier [H]**; British Heart Foundation - **George [M];** MRC College of Experts - **Lai [M]**; Lung Injury, Repair and Remodelling Study Section of the NIH USA - **James [M**]; ESRC, Ireland Research Training Fellowships for Healthcare Professionals - **Hannigan [N]**; European Oncology Nursing Society Research Award Committee - **Kelly [N];** Diabetes UK (Allied Health Professional, Midwife and Nurse) Training Fellowship panel - **Lowes [N]**; National Eye Research Centre Grants Committee, British Council for the Prevention of Blindness Fellowship Committee - **Morgan [O]**; Diamond Synchrotron Users panel, ALBA, EPSRC College - **Meek [O**]; BBSRC UK-Japan Partnering Consortium of Hierarchical Biostructures panel, Japan Society for the Promotion of Science Fellowship Panel, EPSRC Physics Prioritisation Panel, EPSRC Fellowship Panel – **Quantock [O]**; Fight for Sight - **Vortruba, Meek [O]**; Science Foundation Ireland, MRC Doctorial Training Grant Panel, Programme Review Team for CNRS - **Gumbleton [P]**; Wales Office of Research and Development for Health and Social Care - **Hiscox [P]**.

Professional and Scholarly Bodies: Where staff occupying executive role on policy forming group. World Federation of Orthodontists - **Richmond [D];** British Dental Association, Royal College of Surgeons - **Chadwick [D];** British Society of Oral and Dental Research, European Tissue Repair Society – **Stephens, Thomas [D]**; European Wound Management Association, American Wound Healing Society - **Price [H];** Life Sciences section of the Royal Microscopical Society - **Hallet [M];** International NO Society **– James [M];** The European Oncology Nursing Society, The Royal College of Nursing Research Society - **Kelly [N];** Royal College of Midwives Campaign for Normal Birth, International Confederation of Midwives Expert Advisory Group, Academy of Nursing, Midwifery and Health Visiting Research - **Hunter [N];** European Association for Vision and Eye Research - **Vortruba [O]**; College of Optometrists (Chair Low Vision Qualifications) - **Ryan, North [O];** International Glaucoma Association – Morgan [O]; British Association for Cancer Research - **Hiscox, Westwell [P**]; Network of European CNS Transplantation and Restoration - **Lane [P]**.

Editorships and Associate Editorships: During the assessment period staff have served as Editors, Associate Editors and on Editorial Boards of prestigious discipline-related journals. Here we limit ourselves to the 19 Editorships/ Associate Editorships.

Journal of Disability & Oral Health - **Thomas [D]**; *Dentistry: Current Research* - **Song [D]**; *Journal of Dentistry, European Journal of Prosthodontics & Restorative Dentistry* - **Lynch [D]**; *International Endodontic Journal* - **Dummer [D]**; *Journal of Endocrinology* - **Ludgate [M]**; *European Journal of Oncology Nursing* - **Kelly [N]**; *Sociology of Health & Illness* - **Allen [N];** *Women & Birth* (Journal of the Australian College of Midwives) - **Hunter [N]**; *Acta Ophthalmologica* - **Vortruba [O]**; *PLoS One* - **Boote [O];** *Photochemistry & Photobiology* - **Rozanowska [O]**; *Biosensors Bioelectronics* - **Allender [P]**; *Crit.Rev. Ther. Carrier. Sys.*- **Birchall [P]**; *Autonomic & Autocoid Pharmacology* - **Ford [P]**; *Lett. Applied Microbiol.* - **Maillard [P]**; *Antiviral Chem. & Chemother (chemistry)* - **Brancale [P]**; *Adv. Drug Delivery Rev.* - **Gumbleton [P]**. In addition staff currently sit on the editorial boards of 71 different research journals spanning the wide research activity of the groups.

Awards: 2008 Stockholm Prize in Criminology, 2010 Queen's Anniversary Prize - **Shepherd [D];** Pearce medal for outstanding contribution to Ophthalmology (UK Society Cataract and Refractive Surgery) - **Meek [O]**, first non-Ophthalmologist to receive this honour; William Prusoff Young Investigator Award 2013 - **Brancale [P]**. Endowed by International Society for Antiviral Research.