Institution: Manchester Metropolitan University

Unit of Assessment: A3 Allied Health Professions, Dentistry, Nursing and Pharmacy

a. Overview

Allied health professions research at MMU represents one of the highest concentrations of research excellence in the UK (7/63 RAE 2008 UoA12: Analysis Power Rankings, Research Fortnight). Since the 2008 RAE, the University has invested over £150M in capital projects to extend its support for allied health research. Research and knowledge exchange awards for the period exceed £6M (£4.3M for research grants) from more than 150 awards. Research excellence has been sustained and advanced further with evidence of research vitality demonstrated through a larger FTE return, higher impact outputs and, developing from 2008, a single coherent submission to the unit of assessment. Since 2008, MMU's Research Institutes, supporting allied health professions, have received £1.42M p.a. from QR funding impacting directly on the contributing groups' research activities. The strength of allied health at MMU is its international excellence across both biomedical sciences and allied health professions. This includes laboratory-based work in the life sciences as well as many disciplines of the allied health professions: nursing; nutrition; physiotherapy; and speech and language therapy. We also have extensive links with clinical practice allowing support for impactful innovative research for public health. Returned members of staff (n=61) have been selected from a wider group of active researchers (n=~90) who publish regularly but have a range of developing profiles and demonstrate the depth and sustainability of excellence in the university's allied health research groups.

There have been world leading impactful research achievements in this REF period. These include: (i) the development of ultrasound imaging for real-time analysis of muscle; (ii) the establishment of intermittent control as an appropriate paradigm for understanding sustained human physiological control; (iii) a greater understanding of the molecular and cellular mechanisms of stroke and the role of angiogenesis in its pathology; (iv) the development and validation of a unique self-report anxiety inventory for respiratory disease; and (v) the development of an online evidence base on augmentative and alternative communication (http://www.aacknowledge.org.uk). The first allows, for the first time, non-invasive analysis of deep muscle to enable a system level investigation of human muscle coordination. This research positions MMU as an internationally-leading research group in neuromuscular control relevant to diagnosis and rehabilitation in neurological disease, ageing, injury, and stress. The second provides for theoretical breakthroughs in adaptive control and human learning and for diagnosing and rehabilitating disorders in human motor control. The third demonstrates evidence for a greater understanding of the cell and molecular mechanisms in stroke to inform the diagnosis and treatment of vascular disease. The fourth provides clinicians with a non-somatic anxiety scale for assessing patients with chronic obstructive pulmonary disease (COPD). The fifth is a publicly available online evidence base accessible to all stakeholders, including therapists, service commissioners, family members and people who use augmentative and alternative communication (AAC).

Structure and Groups:

This submission highlights research from three Research Institutes across the University. The structure includes four well-defined groups. A fifth integrates knowledge exchange in allied health research by bringing together our applied research with our significant interaction with professional practice enabling delivery of world-leading research. A key factor in our research is interdisciplinary collaboration, with major themes in health being evident across all four groups: ageing; nutrition; and mobility. This has enabled us to offer unique knowledge exchange expertise across a range of disciplines in the allied health professions.

The five research groups work in collaborative teams forming a dynamic matrix of interdisciplinary research across three faculties. The groups are: Cognitive Motor Function; Genetics, Cell and Molecular Biology; Microbiology and Infection; Disability, Ageing and Quality of Life; and Innovations in Allied Health. Each group is led by a research professor (Loram, Slevin, Verran, Goldbart, Holmes). As Head of School of Healthcare Sciences, and Director of the Healthcare Science Research Institute, Gilmore provides management, strategic planning and overall coordination for allied health research in the University and this submission. Goldbart and Holmes are also Research Institute Directors, and Gilmore, Goldbart, Holmes and Verran act in Associate

Dean roles with direct responsibility for faculty research strategy within their respective Faculty Executive Groups.

i) Cognitive Motor Function (CMF: Led by Loram)
This group demonstrates international excellence in physiological, neurophysiological, biomechanical and functional characterisation of ageing human skeletal muscle and psycho-neurophysiological investigation of cognitive-motor function. This team has demonstrated an internationally-leading track record in novel ultrasound muscle analysis technology, a new intermittent control paradigm for motor learning and control, and motor cognition in rehabilitation. Exploiting strong internal and external collaborations in computing, imaging, modelling, control engineering, rehabilitation and clinical practice, these innovations have led and are leading new understanding, diagnosis and promotion of cognitive-motor health, mobility and performance through the lifespan. The targeted development of ultrasound as a new, automated, non-invasive technology for measuring contraction from individual motor units and whole muscles is underpinning current world leading progress in investigation of fasciculation in ageing muscle and motor neurone disease, regional variation in muscle contraction and coordination of the complete system of deep and superficial muscles. This enhances the well-established expertise of this group in healthy and ageing muscle-tendon function exemplified by the EU funded (2009-2012) MyoAge project, Wellcome Trust funding (2008-2011) investigating regional variation in muscle function, Motor Neurone Disease Association funding (2013-2016) and the MRC funded (2013-2016) motor unit remodelling project. Investigation of intermittent control, funded by EPSRC (2009-2012) has provided a rigorous, mathematically-principled demonstration of central selection processes associated with basal ganglia function in sustained manual control, movement and balance (Journal of Physiology, 2011; Frontiers in Cognitive Neuroscience, 2013; PLOS Computational Biology, 2013). Current application investigations include: neurological disease (Parkinsons); performance medicine (e.g., musicians and singers); mobility in stroke and ageing; and fear of falling. This purposeful underpinning enhances the well-established expertise of this group in whole body motor function, balance and muscle proprioception, exercise, stair negotiation, mobility and balance with diabetes, therapeutic approaches in cerebral palsy, with substantial EU (2011-2016), ESRC (2009-2012) and charity funding (Diabetes, Cerebral Palsy). Members present regularly as keynote speakers and act as consulting editors and associate editors for major research journals including: BMC Musculoskeletal Disorders (Reeves); Advances in Medicine: Rehabilitation; ISRN Rehabilitation, Journal of Mental Imagery (Holmes); and Journal for Musculoskeletal and Neuronal Interactions (Rittweger).

(ii) Genetics, Cell and Molecular Biology (GCMB: Led by Slevin)
This group carries out World leading research within the area of vascular biology encompassing both genetic and epigenetic mechanisms and investigating molecular mechanisms (targets) underpinning major disease onset and development. Working with both national and international universities and centres of excellence, the GCMB group operates in a highly interdisciplinary environment involving scientists, mathematicians, and engineers on a platform populated with clinical experts and non-clinical research specialists. Thus, we have are able to maximise the opportunities to facilitate translation of strategic laboratory-based studies into pre-clinical and clinical trials leading to advances in the diagnosis, prognosis and treatment of diseases of ageing. Our focused strategy has enabled us to publish work in high impact journals with the data contained within forming the basis of successful research grant applications in co-ordination with considerable interaction and collaboration with major pharmaceutical companies and industry (e.g., Smith and Nephew, Danone, Ferrer, Nutricia Foundation, Pfizer, CISCO-communications and ENDOR-Nanotechnology). For example, a Wellcome Trust funded project (2008-2012) allowed us to identify a potential neuroprotective and pro-remodelling peptide which may form part of a new combinational therapeutic approach to stroke with current on-going work being carried out by groups throughout UK and Europe (PLOS ONE, 2013). We have identified pathways linking the epigenetic programming of vasopressin and depression in response to early-life stress (Nature Neuroscience, 2009) and oxytocin and maternal behaviours in response to early-life care. Data from these studies are being extrapolated to on-going clinical studies of childhood development. Our research on the HIV envelope protein p17, together with its associated mutated variants, has determined that it is the most likely cause of early cognitive decline in HIV patients (P.N.A.S. 2012)

and current collaborative work has been focused on determining its clinical prognostic and therapeutic value. The group has made significant findings in the fields of vascular calcification and endothelial damage and repair and have identified biological targets for intervention (Diabetes, 2011). Overall, our current strategy enables us to focus resources on key translational projects most likely to reach pre-clinical trial phase over the next 5-10 years and which function in line with major WHO-recognised priority diseases of ageing (cardio- and cerebro-vascular disease, regenerative medicine, diabetes). GCMB has strong support within the Faculty of Science and Engineering, and will continue to expand and develop, thereby accelerating the production and translation of the highest quality research over the coming years. GCMB has a considerable World-class reputation, with members presenting regularly at major international congresses as keynote speakers, being committee members/chairs of numerous influential societies, editorial members of high impact journals including Editor–in-Chief of Vascular Cell, and reviewing for most of the major National and EU-based medical science foundations and charities.

(iii) Microbiology and Infection (M&I: Led by Verran)
The interaction of microorganisms with surfaces, its consequences and control, forms the focus of interest of this research group. Our interdisciplinary expertise enables fabrication and characterisation of surfaces to which microorganisms might adhere, and subsequently colonise. We are then able to identify surfaces with antifouling or antimicrobial properties, and thence assess their effectiveness *in vitro* and *in situ*. Applications have been explored in infection control, wound management, surface hygiene in food processing, dental technology, and medical/environmental/oral/food microbiology. Our unique interdisciplinary expertise has contributed to our world-leading reputation in the field. The global body which supports the development of stainless steel (the International Stainless Steel Forum) sought our advice and skills in terms of specifying the hygienic nature of the surface as part of a major new collaboration. Glaxo Smith Kline invited Verran to join their global forum on denture care, where we work to identify global needs and then to specify appropriate scientific and social approaches to enhance oral health. A long-term publication strategy recognises the necessity to publish in journals appropriate to an interdisciplinary audience. This has proved successful in terms of raising awareness of our expertise to funding bodies and industry. Thus, funding has derived from industry (e.g., Yakult, Unilever, GSK, Nabisco), research councils (EPSRC) and Europe. Our researchers work in vibrant laboratories where ideas are exchanged and expertise shared enabling us to be both proactive and responsive with respect to new projects. All of our work is translational. A recent project, funded by the Technology Strategy Board, encompassed the development of novel photocatalytic and antimicrobial coatings active under visible light, testing, characterisation and trialling in key brewing locations in Finland (a parallel project sponsored by Tekes in Finland enabled this international collaboration). We are also able to offer unique expertise to industry in terms of determining antimicrobial properties of surfaces via the development of realistic and valid testing methods. Exchange of knowledge across disciplines is essential to ensure that communication is accurate and interpretation of results is appropriate to the intended point of use. Indeed, a key part of our research philosophy is the dissemination of our work to a range of audiences – students, experts in other disciplines, and the general public. Thus, members of the group are in demand internationally as exemplars of cross-disciplinary research and education – for example on the executive committee of the Federation of European Microbiological Societies, the International Biodeterioration and Biodegradation Society, the International Biodeterioration Research Group, the Royal Society for Public Health, and, of course, as keynote speakers, conference organisers, journal papers and grant reviewers.

(iv) Disability, Ageing and Quality of Life (DAQ: Led by Goldbart)
This multidisciplinary research group (clinical biomechanists, psychologists, physiotherapists, nurses and speech and language therapists) applies its research expertise to inform and implement Evidence Based Practice (EBP), most notably in the areas of communication impairment, respiratory disease, learning disabilities, musculoskeletal disorders, mental health, typical ageing and long-term conditions associated with ageing.

The group has excellent links with UK and international universities, the NHS and third sector organisations. With extensive clinical expertise; many members are professionally registered. We

have expertise in a diversity of methodologies; systematic review, theory building research, development and validation of assessments and outcome measures, clinical trials, and qualitative research to identify facilitators and barriers to implementation of EBP, and to this end, members present their findings in high quality peer reviewed journals, professional publications, as keynote papers in academic conferences and to AHP and nursing practitioner groups.

Group members have developed assessments in under-researched areas; Anxiety Inventory for Respiratory disease (AIR, e.g., Willgoss, Goldbart, Fatoye & Yohannes, 2013), a disease-specific non-somatic anxiety scale to screen and measure anxiety in patients with COPD, the Viking Speech Scale to classify the speech of children with cerebral palsy (Pennington, et al., 2013), and the first single-item quality of life scale for adult patients with cystic fibrosis (Yohannes, et al., 2011), in collaboration with the North West Cystic Fibrosis referral centre. Joint posts have been maintained with the Manchester Learning Disability Partnership following from the Culyer funding obtained by Goldbart. This has led to significant contributions to innovations in communication and nutrition for people with complex learning difficulties (see Impact Case Study 6). Collaboration (Marshall, Goldbart) with the Underwood Trust's Speech and Language Therapy Research Unit (University of the West of England) on systematic reviewing in Speech and Language Therapy led to the successful joint NIHR Programme Grant: The development of an evidence based typology of Speech and Language Therapist led Interventions.

In addition, we participate in several national and regional collaborative activities that enhance health practitioners' engagement with research. These include: the North West Qualitative Research Group in Health (coordinated by Marshall) which provides training and support for health practitioners undertaking qualitative research, and the Greater Manchester Allied Health Research Network (coordinated by Yohannes) with a steering group from Greater Manchester universities and the NHS. This is one of the national collective of AHP research networks and provides a programme of capacity building opportunities including research methods training, writing for publication, and accessing research funding.
Research has informed national guidelines on management of COPD (e.g., Maurer et al., 2008, cited in 104 academic papers, including the 2012 GOLD Executive Summary on COPD management, with a further 100 other cites according to Google Scholar), dysphagia (Guidelines for the identification and management of swallowing difficulties in adults with learning disability), communication assessment of children and adults with profound learning disability (Routes for Learning, The Triple C: Checklist of Communication Competencies) and government policy in delivery of communication aids. Grogan's research on body image led to her advising an all-party special interest group in the House of Commons.

(v) Innovations in Allied Health (IAH: Led by Holmes)
This group exploits the interdisciplinarity of MMU's allied health research in order to bring innovative solutions to health challenges. All members of the other four groups are members of IAH. The group's vitality is, therefore, its knowledge exchange-focused interdisciplinarity; biomedical scientists, nurses, physiotherapists, psychologists and speech and language therapists working together on collaborative projects and doctoral teams to address complex research questions. Working closely with the Office for Research and Knowledge Exchange, the group engage proactively to meet the research requirements of external partners. The group brings together the expertise associated with a successful multi- and interdisciplinary research group. It operates across a thriving health-focused environment and has access to extensive clinical facilities, analytical equipment and a strong multidisciplinary professional practice expertise including the professionally registered individuals returned in this submission, These professional qualified individuals enable the group to offer a wide range of services encompassing excellent research and consultancy, education including CPD, knowledge exchange and research dissemination; the group has a particularly strong public engagement agenda in both the UK and internationally. IAH supports work with public and private practitioners, service delivery and support organisations across a range of client groups. These include: aphasia; cerebral palsy; learning disabilities; chronic respiratory disease; chronic low back pain; mental health issues; primary language impairment; people who use augmentative and alternative communication; and infection control and hygiene. The main emphasis of the group's research is the understanding of the

disease process and the client-patient experience through the involvement of service users and their families. We inform and innovate both biomedical and allied health-driven interventions and service delivery models. The group work closely with colleagues in computing and digital media to develop novel interventions for the allied health community. These include App-delivered programmes for stroke patients and pregnant women. The group also evaluate the impact of these interventions in order to contribute to sustainable, impactful health changes.

b. Research strategy

The research strategy is consistent with Government policy and the University's mission statement and, therefore has focused on: (i) improving the quality and impact of staff research; (ii) increasing postgraduate student numbers; and (iii) increasing external engagement. Allied health research at MMU was rated internationally-excellent in the 2008 RAE and placed 7th of 63 submissions in the Analysis Power Rankings, Research Fortnight. Research excellence has been developed further and is evidenced through: 607 journal articles; 80 book chapters; 8 reports to Government. Research and knowledge exchange awards exceed £6M, (£4.3M for research grants) from over 150 awards including MRC, NIHR, EPSRC, ESRC, Wellcome Trust, Nuffield Foundation, EU Framework 7 and Big Lottery. Our business and industry sponsors include: GlaxoSmithKline; Unilever; and Smith and Nephew. Following the successful submissions to UoA12a and 12b in RAE 2008, another important strategy for the university was to focus its health-related research further to develop a strong sustainable provision in the biomedical sciences and allied healthcare. As part of this strategy, and as evidence of the importance of health-related research to MMU, the University has relocated allied health professions and nursing to new £139M premises at Birley Fields in central Manchester, co-locating the team with the healthcare scientists located in the John Dalton Building. In addition, the MMU Hollings faculty, comprising researchers in nutrition science, have also moved to the central Manchester site. This larger, more focused healthcare research group will make a major contribution to the research and knowledge exchange strategy of the University through to 2020 and beyond. Researchers at the University's Cheshire faculty have also received additional investment of more than £12M for new genetics, physiology, biomechanics and neuroscience laboratories as well as allied healthcare research facilities. This dual site strategy allows the University's allied health research to have greater reach and significance supporting research opportunities south of Manchester, into the Midlands, Wales and beyond (e.g., NHS hospitals, GP teams and private clinics in Cheshire, Staffordshire, Shropshire, Powys). To further increase the focus and collaboration of research teams, research funding has supported multi- and interdisciplinary projects and postgraduate student supervisory teams. These strategic changes have been successful in integrating research into human movement and health with the biomedical sciences. They have also facilitated strong research collaborations with the University's expertise in computing and engineering. Importantly, staff based in Cheshire and central Manchester function together more effectively and are aligned with significant clinical links to the NHS teaching hospitals of Manchester's Oxford Road (Central Manchester University Hospitals NHS Foundation Trust), Salford Royal NHS Foundation Trust, University Hospital of South Manchester NHS Foundation Trust, Pennine Acute Trust, Barnsley Healthcare PCT, and Oldham and Manchester Learning Disability Partnerships, as well as supporting a strong presence in the counties south of Manchester: Leighton Hospital Crewe; North Staffordshire Hospital; Queen Elizabeth Hospital Birmingham; Frimley Park Hospital; and The Robert Jones and Agnes Hunt Orthopaedic Hospital Oswestry.

To attract funding, our research addressed the Research Councils' remit and funding priorities which include ageing, system approaches to the biosciences, healthcare technologies and assistive technologies. In addition to physical health, cognitive-mental function is particularly prioritised within the Cognitive Motor Function and the Disability, Ageing and Quality of Life groups' work. One of the main aims of research in our groups is the promotion of individualised physical and mental wellness throughout the lifespan. The research challenges for the groups over the next 7 years include: (i) fundamental understanding of biological systems, function and disease; (ii) how to sense and quantify the by-products of disease; (iii) designing sensors and detectors to identify biomarkers of disease; (iii) mathematical and computational modelling of function, disease and dysfunction; (iv) new methods of diagnosis; (v) design, implementation and monitoring of interventions; and (vi) the operationalization of interventions within health services.

c. People, including:

Appointments and promotion opportunities within the REF census period have allowed the university to restructure allied health research to meet the strategic aims mentioned above and provide leadership to the 5 groups. These include: 7 Professors (Alexander, Goldbart, Holmes, Krupinski, Loram, Reeves and Slevin); 6 Readers (Ahmed, Fatoye, Hodson-Tole, Pearson, Whitehead and Williams); and 5 RF/RAs (Bosutti, Harding, Lewis, Loporto, Van De Kamp). All appointments and promotions have been made to important strategic roles in the 4 main sustainable groups to provide capacity and vitality going forward to 2020.

Summary of external awards since 2008: Slevin was awarded a personal Chair of Pathology and Pharmacy at Targu-Mures University, Romania, and a Chair in Clinical Biomedicine, ICCC, St Pau Hospital, Barcelona. He is Chair of the International Research Promotions Council (Europe), Fellow of the Royal College of Pathologists, Fellow of the American Heart and Stroke Association and Fellow of the Institute of Biomedical Scientists. Slevin is also a council member of the American Stroke Association. Alexander was elected as a member of the Academic and Research Committee of the British Cardiovascular Society and is lead organiser for The European Vascular Biology Organisation Annual Scientific Conference, joint with The International Union of Physiologists, she is also a British Cardiovascular Society Press Expert; Goldbart was elected to the CSP Scientific Committee and BACD Strategic Research Group; Murray is an ISAAC Council Chair Elect and research committee member, former Communication Matters (CM) Chair and CM Outcome Measurement Committee Chair, and NICE WP on competencies in SLT; Grogan was made Academician of Social Sciences in 2013, for her outstanding contribution to research in the social sciences. Haigh is a member of the NICE Technology Appraisals Committee; Williams was appointed Honorary Senior Research Associate at UCL; Pearson was a member of the scientific organising committee for the 8th World Congress on Active Ageing, an invited member of the Cochrane Musculoskeletal Group, and a mentor for the Physiological Society's Women in Science Scheme. Yohannes was elected to be a Fellow of the American College of Chest Physicians and he is also a member of the NICE Committee Lung Cancer Guidelines Development Group. Promotions out include: Rittweger, who has become the Director of the Physiology Laboratory at the German Aerospace Research Centre but retains a active fractional position within the group; Baltzopoulous, who has taken a Chair at Brunel University; Narici moved to the Chair of Clinical Physiology at the University of Nottingham; Stewart and Maganaris have taken Chairs at Liverpool John Moores University; Chadwick took a Marie Curie Fellowship at Trinity College Dublin. Jones (Professor Emeritus), Kumar, P., Kumar, S., Mills, Roberts, Stirling and Sargeant have retired.

i. Staffing strategy and staff development

To support the strategic aims, the Office for Research and Knowledge Exchange, in consultation with group leads have: (i) implemented a new policy supporting faculty Deans to make strategic appointments where new staff are able to demonstrate, at entry, a minimum of an internationally-recognised research profile and strong potential to develop further; (ii) allocated QR income for staff development on increasing research output quality in focused areas; (iii) supported workload model co-ordinators to ensure research activity time is allocated strategically and equitably; (iv) balanced the QR funding for doctoral studentships with externally-sponsored bursaries and established the concept of the 'impactful PhD'; (v) focused new academic positions to areas of research excellence with experienced and successful supervisory teams; (vi) developed a new institutional policy for existing staff doctoral degrees to improve completion rates in the group's strategic research themes; (vii) considered a wide range of research and knowledge exchange metrics for appointing staff and monitoring progression, including HCPC registration and other professional qualifications; and (viii) increased clinical academic collaborations, demonstrated through the number of honorary positions and category C staff.

MMU has been a member of the Athena SWAN Charter since June 2009 and received the Bronze Award in 2012. A significant marker of the group's work to support women in science is the 35% increase in the number of women submitted compared to 2008. 26 women (46% of the total submission) are included in this unit of assessment and 7 of the 16 early career researchers being returned are women. In addition, 2 of the 5 research groupings in this submission are led by female

professors (Goldbart and Verran). The faculties supporting the groups in UoA3 have continued to invest in staff and the principles of the Concordat. Early career researchers are included in doctoral supervisory teams and a variety of research development opportunities are supported through the QR funding structures of the Research Institutes. Early and mid-career staff who have entered academia from clinical practice have been supported to gain doctoral degrees with 7 such staff included in the current submission (Fatoye, Loporto, Lewis, Marshall, McEwan, Webb, and Wright).

Category A Staff:
Since RAE2008 we have sought to build a critical mass of researchers in all areas to provide strong research leadership and enable researchers to enhance their internationally-excellent research. Importantly, a focus of the groups has been to enable new staff in the health professions to develop research capability in order to maintain a sustainable research culture in the unit. Research leads support those new to research by encouraging them to join current research projects and providing experienced mentors. The present submission includes 16 early career researchers 30 mid-career staff and 19 professors and readers. This profile of research active staff demonstrates a strong and sustainable group across the focus areas that will develop further and continue to lead excellent healthcare research at MMU. Faculties have taken a strategic approach to research during the appointment process by shortlisting and appointing staff who could contribute to this strategically-important research area for the university. For example, bioengineering researchers have been appointed in the School of Engineering, complementing and interacting with the Cognitive Motor Function Group. This process has improved the interdisciplinary nature of our research and will allow us to focus on specific impacts for our 2020 strategy.

Category C Staff:
A comprehensive University appointment scheme allows researchers, working mainly within the NHS and clinical practice, to collaborate in projects with staff to obtain honorary visiting research fellow status. More experienced individuals can be appointed to honorary professor posts. The groups each have Category C staff associated with the UoA. These staff are invaluable to the work of the research groups by providing clinical expertise on projects, creating access to participant groups, and performing an essential role in research informed teaching. In most cases, the partnerships with Category C staff have involved joint collaborations on research outputs and external grant bids. Category C staff are directly involved with the career development of MMU staff providing both non-clinical and clinical researchers with opportunities to access clinical research environments (e.g., Woby: Pennine Acute Trust for chronic pain and stroke rehabilitation projects with Holmes, Fowler, and Lewis ; Sampath: Computer-aided knee surgery data for Lewis, diabetes and elderly patients for Reeves).

ii. Research students
This submission includes data for a successful portfolio of internationally-excellent doctoral students who have completed a range of full and part time programmes of research training. Around 60 FTE students are enrolled annually to allied health postgraduate research degrees with almost 300 all-year numbers of full and part time students. 85 doctoral awards have been made in the census period. Many of the graduates from the doctoral programmes in allied health have progressed to post-doctoral research positions in our own and other internationally-recognised laboratories (e.g., Lewis, Loporto; McPhee and Wright: MMU; Ewan: Glasgow Medical School Eating Disorders Unit; Wilks: MIT; Bradshaw, Tizard Centre, Kent; Hughes, UCL; Willgoss, Abacus International; Body, NIHR Postdoctoral Research Fellow, Consultant in Emergency Medicine, Manchester; Lamb, Centre for Primary Care, Manchester). The four groups also have particular expertise in the supervision of individuals working in the healthcare professions. These students undertake research degrees part time and in conjunction with, and in relation to, their professional practice (e.g., in nursing, physiotherapy, speech and language therapy, clinical psychology, surgery). The examples of academic-clinical impact, public engagement and professionally-informed research-led teaching are numerous with many such students providing guest-lectures for undergraduate and master's students as well as increasing opportunities for staff research. Students typically complete their studies with strong publication records.

MMU has well established and commended processes for inducting, supporting, and monitoring research students, in particular, "good practice...contributing to the academic standards and the quality of learning opportunities in the...comprehensive training and development opportunities provided for postgraduate research students" (QAA Audit, 2010). The central Graduate School and faculty postgraduate research teams have continued to develop the structures and systems to provide comprehensive support for students. All students are provided with the full Vitae Researcher Development Framework support and receive guidance at induction and through on-line support and at their Annual Review. All scheduled meetings are recorded and signed by supervisors and students. This detailed approach to postgraduate student support has led to an increased completion return compared to 2008 and positive feedback recognised in MMU's postgraduate Annual Monitoring Reports.

The University provides dedicated postgraduate learning and social environments for its students and all faculties supporting our research have invested in postgraduate infrastructure as numbers have grown. The investments include: fully equipped office space; access to free printing facilities; and access to social space and kitchen areas. Postgraduate communities have representation of full-time and part-time students on appropriate Committees and Research Institute Boards. The Postgraduate Students' Forum is an independent group working closely with the Graduate School and managing the Annual Postgraduate Conference. The Forum members have desk and meeting spaces within the Graduate School Office. All students have full access to virtual learning environments on and off campus creating an important postgraduate community supported by a full-time e-learning manager. The Graduate School also provides a triaged clinic for urgent academic and personal issues. The faculty research groups host weekly research seminar series for staff and students. In these supportive environments, students are required to present their doctoral registration proposals or study updates to staff and peers alongside invited speakers from international research groups (e.g., Sanger Institute, Cambridge). All staff attend mandatory training in postgraduate supervision, examining and chairing a viva voce. As part of the sustainability and staff development strategy, and as further evidence of MMU's adherence to the Concordat principles, early career researchers and staff new to research degree supervision are recruited proactively to all new postgraduate registrations. They join experienced supervisory teams before progressing to mentored Director of Studies positions. In addition, and as an example of the further integration of the two submissions from 2008, PhD supervisory teams have increasingly included supervisors from across disciplines (e.g., biomechanics, psychology and physiotherapy staff on chronic low back pain research teams; motor cognition, physiology and physiotherapy staff on cerebral palsy projects). In many cases, an external clinical partner becomes a member of the supervisory team, reflecting the guidance from the 2012 Wilson Review; since 2008, the strategic focus of all research groups has been to appoint to and support 'impactful' doctoral programmes of study.

The support and training for MMU research students and staff is a major priority. Training is offered centrally and on-line and supported further from faculty teams and Research Institutes. In the latter, staff offer discipline-specific, equipment and technique training. They also complement the Graduate School and faculty offerings with more general research training in, for example, research methods and design, ethics, writing for publication, presentation skills and other Vitae-aligned topics. Students identify and agree their training needs through the Annual Monitoring Process. All student training costs are covered through their research council funding, fees extension of the Roberts' Review budgets or, in some cases, QR funding. MMU students have the opportunity to engage in the Graduate Teaching Scheme and work with external partners to meet the Wilson Review recommendations. A number of these activities strengthen students' abilities to present their findings at annual University Postgraduate and Faculty conferences as well as external national and international conferences and Research Institute and Departmental seminars. Attendance at national and international conferences is a priority and Research Institutes support the students to present at one external conference each year of study with one of these being a major international event.

Equality and Diversity

The University's commitment to equal opportunities is set out in MMU's Equality and Diversity

Policy, Vision for Equality and Diversity and Single Equality Scheme (SES). The implementation of these policies is supported in the Single Equality Scheme Action Plan including extensive staff development activities, and has informed other strategies such as the Human Resources Strategy. These policies, along with the Equality Act 2010, guide and inform our approach to supporting the Research environment within MMU.

Our approach to Equality and Diversity in research is underpinned by principles including transparency, consistency, accountability and inclusivity. The University provides a range of courses in support of its Equality and Diversity Policy which are mandatory for staff, including designated members of staff appointed to perform functions in relation to Research Management. These include the following courses:

• "Equal Opportunities and Diversity Essentials" (mandatory for all staff); • "Managing Diversity e-learning" (mandatory for all managers and supervisors); • "Disability Equality Action Training for Managers" (mandatory for all managers and supervisors); • "Disability Equality Action Training for staff " (mandatory for all staff). Participation in these courses is reviewed through the Professional Development and Review (PDR) Scheme. The University is also providing staff awareness sessions on the REF 2014 Code of Practice. These sessions will ensure that the principles of transparency, consistency, accountability and inclusivity have supported the development of the Code. The sessions also provide an opportunity for staff to understand the changes from the RAE 2008 Code, become familiar with the revised Code of Practice, eligibility and the guidance on submissions in terms of complex cases.

d. Income, infrastructure and facilities

Income: Within the 2008-2013 period the groups have attracted significant external funding. Research and knowledge exchange awards exceed £6M, (£4.3M for research grants) from over 150 awards. Research council funding has been obtained from MRC (including a recent £600K award to McPhee), EPSRC, ESRC, Wellcome Trust, and EU Framework 7 and totals £1.4M in the census period. International recognition for excellence in ageing research has been recognised by the €6million EU MoveAge (www.move-age.eu) award made in collaboration with Amsterdam and Leuven. Goldbart and Marshall are co-applicants on the first NIHR Programme Grant in Speech and Language Therapy (£1.2M to N Bristol Trust). Further European grants have also been awarded (e.g., Spain: BBVA award of 125K during 2008-2010). Teams can also demonstrate significant funding from: Charities; Big Lottery; Mencap, Nuffield Foundation; Sparks; The Diabetes Research and Wellness Foundation; The Nutricia Foundation; Nestle; The Royal Society; The Pathological Society of GB and Northern Ireland; Diabetes UK; The European Foundation for the Study of Diabetes; and UK Sport, as well as many NHS Trusts.

Infrastructure and facilities: All laboratory research activity is based in state of the art facilities. These have been enhanced by the imminent strategic move of the Faculty of Health, Psychology and Social Care to the £138M Birley Fields campus. This move adds to the extensive laboratories on the central Manchester sites with world leading cellular and molecular biology facilities and physiology laboratories housed in recently refurbished or newly built accommodation. Many of the laboratories have been designed to conduct research on normal functioning human participants as well as those with disease. At Cheshire, the new £12M laboratories include specialised labs for: Genetics; Phlebotomy; Bone; Environmental and Applied Physiology; Biomechanics; Cognitive Motor Function; Psychophysiology; and Body Composition. Each area contains state of the art equipment to conduct high quality research. There has been direct funding from QR income to support capital bids and working consumables. As an example of the quality of the infrastructure supporting world-class research, UK colleagues from Northumbria, Aston, and Birmingham as well as Catholique Louvain, Holland and Victoria, Australia have been trained in transcranial magnetic stimulation techniques and methods in the Cheshire Cognitive Motor Function laboratory using equipment and staff supported by QR funding. These cross-HEI teams collaborate on a number of major motor rehabilitation projects that are evidenced through research outputs included in this submission (e.g., Holmes, Loporto, Wright).

e. Collaboration and contribution to the discipline or research base

(i) Cognitive Motor Function. The group has collaborative links regionally, nationally and internationally. It works with hospitals in central and regional Manchester, Salford Royal Hospital

(Loram), Royal Preston Hospital (Loram, Tole), Leighton Hospital Crewe, North Staffordshire Hospital, Oswestry Hospital, Glasgow Southern General Hospital (CRE, QUENSI)(Loram), Frimley Park Hospital and Bristol Infirmary. Internationally, teams in CMF work with the University Medical Centre Göttingen (Loram), Politecnico di Torino (Loram), Victoria, Australia (Loporto and Holmes), Rome (Smith and Holmes), Catholique Louvain (Holmes); Melbourne (Loram), Glasgow (Loram), Birmingham (Loram), Manchester (Loram, McPhee, Reeves), Simon Fraser Canada (Tole) and with the British Association of Performing Arts Medicine (BAPAM, Loram). Group members are involved on 30 editorial boards including high-ranking clinical journals. Since 2008, group members have presented 20 keynote papers at National and International Conferences (e.g. "Integrating cognitive and physical therapies for more optimal rehabilitation" 2012 Society for Research in Rehabilitation, Holmes). Additionally, Holmes and Smith are founder members of the Research in Imagery and Observation Group (http://rio-group.weebly.com), an international recognised forum that is "world leading" (Hale, 2012: Penn State University) for research in motor cognition and stroke rehabilitation.

(ii) Genetics, Cell and Molecular Biology. GCMB has a strong foundation of interdisciplinary research collaboration both within the University and beyond. Co-operation of experts from outside MMU with those of GCMB and in particular, strong and detailed participation of interlinking scientists within individual projects has made/and is making a considerable contribution to the research base (demonstrated by the majority of our outputs: P.N.A.S, 2012; Neurology, 2012; EMBO, 2008; ATVB, 2012; and Nature Protocols, 2013 et al.). One example is the creation of an ex-vivo neuronal circuit to act as a biological computer for analysis and drug/therapeutic testing of damaged neurons related to Alzheimer's disease. Within the University, mathematicians, biologists, engineers and material scientists have combined their knowledge to form the core framework of the project. Outside the University, partners from Illinois, USA (mCRP), Brescia, Italy (p17) and Targu Mures, Romania (stroke combinational therapy). Staff from GCMB work with other excellent institutions where external members of the team are co-supervisors and co-PIs on projects covering a range of major vascular diseases. These include UK-based institutes such as University of Manchester, Kings College, London, Southampton and Reading; European collaboration at the Cardiovascular Institute (ICCC) and Vall D'Hebron Hospital, Barcelona, Spain, and the University of Brescia, Italy; Griffith University, Brisbane, Australia. Within industry, GCMB has consultancy agreements with Smith and Nephew (USA), and project collaborations with the Sanger Institute the Nutricia Foundation, Nestle Foundation Pfizer, Genzyme and UCB Pharma Ltd. Contribution to the research base is made via access to the technical expertise, knowledge of clinical trial set up (FDA/MHRA requirements) and finance from these companies.

Our clinical colleagues e.g. from the NHS (Salford, Manchester) and EU (Barcelona, Spain Sulmona, Italy) are highly research active and besides providing patient samples and data are intimately engaged in project design, conducting experiments and management. In order to maximise the quality of our research outputs, our research networks contain all the elements required to move from basic science research-through in vivo and pre-clinical work-to translational medicine and clinical trials. Our current research strategy reflects these directions. We are members of research networks such as the Diabetes and Obesity Research Network, Greater Manchester Academic Health Science Network and the North West Vascular Biology Forum and regularly interact with patrons of leading charities in order to understand and appreciate their needs (e.g., Diabetes UK; BHFs 'mending broken hearts').

Senior members of the group hold and have been awarded personal chairs at World-leading institutes including the Institute for Cardiovascular research-ICCC, Spain, the University of Targu Mures, Romania, and Griffith University, Australia. Others are peer-reviewed members of societies (e.g., Chairman for the British Society for Cardiovascular Research (BSCR), founder member of the European Vascular Biology Organization (EVBO), Fellows of the Royal College of Pathologists and the American Heart and Stroke Association). Members have served on organising committees for societies and conferences for example the scientific organising committee for EVBO, and Frontiers in Cardiac and Vascular Biology (2012). GCMB members have been chairs for scientific research symposiums for example at BSCR/BAS/BCS (2010) and have run workshops on PhD Education, training and supervision, for example, the International Union for Biochemistry and Molecular Biology (IUBMB, 2012). Group members are journal editors including Vascular Cell

(Editor-In Chief), Brain Pathology, Frontiers in Clinical and Translational Physiology. They are also amongst the review board for the Wellcome Trust, Romanian and Polish National grant agencies, EU-ERANET and the Einstein Foundation. The group includes editors of more than 15 scientific and medical book titles since 2008 including; Therapeutic Angiogenesis (Springer, 2009); Cardiac arrhythmias (Springer 2013); Biomedical Science Practice: Experimental and Professional Skills (Oxford University Press, 2011); Clinical Biochemistry (Oxford University Press, 2011).

(iii) Microbiology and Infection. In addition to the significant cross-disciplinary collaborations ongoing within the faculty of science and engineering which underpin our research, every project this group is involved in also includes external collaborators. Much of the work is funded by industry, and the research scientists from the companies are integral members of the research team, for example, Glaxo Smith Kline, Yakult, Teer Coatings, VTT (Finland), Cristalglobal, Rockwood. Colleagues from other universities and professional societies have also worked with this group on a range of projects, often as co-supervisors of research students, and co-authors of papers (led by the group), for example, Universities of Newcastle, Glasgow, Liverpool, Manchester, Society for General Microbiology, Danish Technological University of Copenhagen. Organisations with interest in collections/standards have advised us, and collaborated on a range of projects – Health and Safety Executive, North West Film Archive, British Film Archive, BAM (German Standards Agency). We also have consultancy projects, for example with Rentokil, Medical Wire, GSK. The unique expertise of the microbiology and health research group, combining surface fabrication, characterisation and assessment of interaction with microorganisms, coupled with a keen interest in education means that our contribution to the discipline and research base is far-reaching. We are often approached by industry, charity and other academic institutions in this context. Our international collaborators are evidenced by the large (approaching 50 partners) EU FP6 Pathogen Combat project, which led into subsequent projects with Danish and Finnish academic, governmental and industrial organisations. Our expertise as microbiologists is especially valued by industry; because we are familiar with research carried out by material scientists, surface engineers, polymer and dental technologists, we are aware of the differences in technical language used, and are also careful to be precise and clear in our microbiology terminology, which is often bewildering to non-microbiologists. We have, therefore, co-supervised students supported by EPSRC CASE studentships, an EPSRC visiting scientist grant, and in several grant applications, and are in demand to review papers, other grant applications, and to present at/organise conferences/symposia.

Industry has supported much of our research work. In addition to key work in hygienic and antimicrobial surfaces, we have more clinical-focused experience in oral microbiology, particularly denture care and hygiene, and cross-infection control. We have used the latter experience to provide practicing dental technologists with infection control seminars; we have worked with local hospitals screening high touch surfaces for contamination, and again through our teaching and research –informed teaching via undergraduate and postgraduate programmes, project work and resultant publications, we are disseminating good practice across the Biomedical Science profession. Indeed, Verran was recipient of the Heads of University Biomedical Science 2012 Mike Pitillo award for Research-informed teaching. She also received the Society for Applied Microbiology 2011 award for Science Communication and previously the Society for General Microbiology award for Innovative Microbiology Education. Within the group, there are several relatively new members of staff. Mentoring and collaboration is key to the development of these early career researchers, evidenced by joint student supervision, publications and project applications.

We are also keen to raise awareness of our work to external audiences, and have developed, delivered and evaluated a range of public engagement events that focus on aspects of microbiology and health, some directly informed by research projects. In other cases, the public engagement activities themselves have become research projects (for example using fiction to encourage engagement with epidemiology and disease transmission), resulting in publications and modest event-related funding. Appearances on television (e.g. One show, Feb 2012) and radio (e.g., Radio 5 Live Science Night, 30.12.12) related to microbiology and cross-infection have been increasing. Thus our collaboration and contribution to the discipline and research base is wide-

ranging, relevant and dynamic.

(iv) Disability, Ageing and Quality of Life. The multidisciplinary strengths of this group are enhanced by close collaborations with the NHS, universities in the UK and abroad and with the charitable and voluntary sector. For example, Murray chaired the national campaigning charity, Communication Matters (CM), until 09/12. She was a partner in a Big Lottery funded project with MMU, Sheffield University and Barnsley Hospital NHS Trust), leading the development of a template to enable the collation of robust AAC case study data which is providing group data for researchers and building up the AAC evidence base (see Impact Case Study 1). Collaborative projects with NHS Trusts include: Grogan; Appearance and Smoking, Stoke Primary Care Trust (£132k 2009-2011); Haigh; Christie NHS Trust for HIEC project on communication on chemotherapy for vulnerable clients; Yohannes & Goldbart: Wirral PCT, evaluation of COPD services. Links with statutory and third sector providers in mental health (Staffordshire Drug and Alcohol Team; Turning Point, Manchester) have resulted in funded partnerships and consultancy (Webb) in addition to training partnerships with NHS Trusts (Cumbria and Pennine Care Trusts).

DAQ group members have extensive international and national research collaborations, for example, the Indian Institute for Cerebral Palsy, Kolkata, resulting in funded projects to develop culturally appropriate researches and services (see Impact Case Study 4); Leeds University: MRC/National Preventative Research Initiative funded project, Smoking prevention in young people: a cluster of randomised controlled trial of implementation intentions (£1.3m). Makerere University, Uganda, the development and enhancement of the first Speech and Language Therapy qualifying programme in East Africa (see Impact Case Study 4); Augmentative and Alternative Communication researchers in 15 countries for the "Becoming an Aided Communicator" (BAC) project, (see Impact Case Study 1); North Bristol Trust, and Universities of the West of England and Bristol on the first NIHR Programme Grant in speech and language therapy (https://www.speech-therapy.org.uk/child-talk-what-works); Charles Sturt University and University of Wollongong, Australia, to edit a special edition response to the World Report on Disability for the International Journal of Speech-Language Pathology; Manchester Royal Infirmary, Emergency Medicine, Isfahan University of Medical Sciences: Musculoskeletal Research Centre.

Members act as editors and associate editors for major disability and applied research journals including: Journal of Clinical Nursing (Haigh, Acting Editor-in-Chief), British Journal of Health Psychology (Grogan, Associate Editor), AAC (Associate Editor: Murray, Special Edition Editor: Goldbart); International Journal of Speech Language Pathology (Special Edition Editor: Marshall); Body Image, British Journal of Learning Disabilities, BMC Geriatrics; Case Reports in Orthopaedics; Current Gerontology and Geriatric Research; International Journal of Disability, Development and Education, Journal of Health Psychology , Journal of Intellectual and Developmental Disabilities; Journal of Interactional Research in Communication Disorders; and World Journal of Translational Medicine. DAQ members have been scientific committee members for the 8th World Congress on Active Ageing, Cochrane Musculoskeletal Group and Physiological Society's for Women in Science Scheme (Pearson); Guest Editor: Journal of Ageing Research, Journal of American Podiatry Medical Association (Reeves). Murray and Goldbart were Highly Commended Award Winners at the Literati Network Awards for Excellence 2012 for Murray and Goldbart (2011) "Emergence of working memory in children using aided communication" published in Journal of Assistive Technologies, and Goldbart was winner of the UKLA/Wiley-Blackwell Research in Literacy Education Award 2013, for Lawson, Layton, Goldbart, Lacey and Miller (2012) 'Conceptualisations of literacy and literacy practices for children with severe learning difficulties.' Literacy, 46(2), 101–108.