Institution: Middlesex University

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

a. Overview

This submission presents work carried out in biomedical science area within the School of Science and Technology. 16 members of staff (14.8 FTE) are included (increased from 10.1 FTE in 2008) working in three research groups focused on the following areas; Biophysics and Bioengineering, Biomarkers, and Molecular Biology. There is also significant collaborative work being undertaken in the area of bioinformatics, including medical imaging, rehabilitation robotics and neuro-computation, but we have chosen to submit this to the computer science and informatics unit of assessment, as the contribution to that discipline (e.g. algorithm development) is more explicit in our publications. This statement alludes to aspects of this group, however, as our environment includes shared laboratories, infrastructure, policies and strategies and represents interdisciplinary collaboration resulting in impact of importance to healthcare.

We have developed and built on our existing strengths from 2008 but also extended into related areas. The recently constituted Centre for Investigative and Diagnostic Oncology, for example, provides a focus for research and development into diagnostic techniques and potential novel therapies for a range of common forms of cancer in the UK, including breast, prostate, brain and colon. The increase in researchers at a level suitable for REF submission, interdisciplinary working with the strong bioinformatics team in computer science, our excellent infrastructure and a strong emphasis on developing new researchers have moved us into a position with the stability and critical mass to build upon these foundations into a world-class research unit.

b. Research strategy

Our research strategy is firmly embedded within the wider strategy of the School and Institution. In 2010 the University identified the development of STEM subjects as a major priority leading to the creation of a new School of Science and Technology bringing together virtually all of the STEM provision across the institution, including biomedical science. The University sees a strong research base as essential to sustainability and competitiveness in STEM subjects.

The 2008 RAE placed biomedical science research at Middlesex University in the top half of UoA 12 nationally, giving the university confidence that this area, although new, had the potential to develop and grow. The income and internal support arising from that assessment, together with the relocation of biomedical science to the Hendon Campus with excellent new laboratory facilities and opportunities for synergy with computer science, engineering and mathematics provided an excellent foundation on which to build our research. Moreover, a period of sustained growth in student numbers has made biomedical science an area that is not only sustainable in the longer term, but central to the University's mission. The School is committed to working with the NHS to develop academic provision for Healthcare Scientists as part of the Department of Health's Modernising Scientific Careers agenda and is providing programmes in the areas of cardiac and neurophysiology, and, in collaboration with UCL, clinical and rehabilitation engineering and audiology. This has led to University investment in research aligned to these areas, so that research has developed alongside our curriculum and is a managed process, central to our future. This investment focused on:

i) Building research capacity in cognate research groups with defined research themes through investment in staff, research student recruitment, infrastructure and facilities;
ii) Increasing the potential for attracting research funding;
iii) Enhancing and extending research collaboration within the school and University and externally with academic, industrial and health care partners, including the NHS;
iv) Improving the quality of research outputs with evidence of impact on practice.

A unifying theme of our research is the development of new technology and new methods of diagnosis and therapy with the potential to improve outcomes for patients, and/or lower the cost of treatment. Capacity building has concentrated on strengthening research groups, ensuring that, while cognate and interdisciplinary, each provides a clear focus for our work as described below.

1) ***Biophysics and Bioengineering*** (Led by Professor **Bayford)** covers three areas; imaging

technology and its applications; nanotechnology for cancer diagnostics and therapy; and applied biomechanics, including innovative implant design. The development of Electrical Impedance Tomography (EIT) imaging technology is a core activity for this group (**Bayford)**. This work extends into the use of nanoparticles as a targeting contrast and treatment/delivery agent and the application of EIT and bio-impedance as a low cost alternative to optics in biosensors (**Bayford, Wildeboer**). Collaboration with researchers in both the biomarker group (**Butler, Roitt**) and in the bioinformatics group in computer science illustrates the interdisciplinary nature of these developments. The group is also investigating neurological disorders and is working in close collaboration with UCL on deep brain stimulation. The addition to the team of **Liu**, an ECR and Clinical Neurophysiologist with experience of clinical research in the NHS, supports future work in this area. The group is expanding into clinical and bio-engineering, reflecting new academic provision in this field and the synergies arising from the creation of the new School of Science and Technology. The recent appointment of Professor **Hua,** a specialist with an international reputation in designing custom-made hip implants for individual patients, adds strength in Orthopaedics and Biomechanics to the group. This complements current research by **Miller**, an ECR working in the area of applied biomechanics. **Hua's** research extends to bone tissue engineering and the use of mesenchymal stem cells to repair bone defects and enhance implant fixation and he is forging collaborations with others in the group to develop this area of his work. This work is being taken forward through collaboration with academic, clinical and commercial partners.

2) ***Biomarkers*** (Led by Dr **Butler** and Dr **Hills)** encompasses a large part of molecular pathology from cancer to bacterial infection, including diagnostics in reproductive, haematological, cancer, and immune disorders, with the application of proteomics and mass spectrometry to biomarker analysis and discovery. **Roitt** brings a wealth of expertise in immunology to the team and with **Wang**, a protein biochemist, collaborates closely with researchers in the Biophysics and Bioengineering group on biosensors and neurological disorders. **Shah** has joined the group from GlaxoSmithKline as a Reader in Bioanalytical Science to support metabolomic analysis. **Burczynska** and **Wen** have joined the team as full academic staff having previously been postdoctoral researchers here, contributing to the biology and genetics of human Chorionic Gonadotrophin (hCG) in reproduction and cancer. This work is world leading and has led to the development of a new anti-hCGβ cancer vaccine by the USA biotechnology company Celldex and a close collaboration with the hCG reference service in the United States. **Butler** has now published the definitive text on hCG with Professor Larry Cole. A related finding by **Wen** and **Ghali** has revealed that hCG can bring about the 'cancer-like' transformation of epithelial cells to mesenchymal cells. Other areas of research include investigation of alterations in pituitary renal metabolism correlating with sleep and learning disorders (**Hills**, **Butler**, and **Shah**), the role of proteolysed IGFBP-1 during late pregnancy and a role for glycosaminoglycans in the regulation of trophoblast invasion (**Hills**). The addition of **Clyne** has broadened research into the molecular mechanisms that control cell division. Her team has pioneered the use of quantitative proteomics approaches to analyse yeast meiosis, identifying proteins which have mammalian homologues that function during reproduction. The group will continue to focus on existing strengths in biomarker analysis and discovery. In particular, work will continue into hCGβ variants, their relationship to tumour progression and invasion and the potential of research in this field to provide treatment options for advanced cancers.

3) ***Molecular Biology*** (Led by Professor **Dilworth**) focuses on developing understanding of the fundamental biology underlying cancer initiation by viruses, and the application of this knowledge to tumours of non-viral origin. It has been enhanced by the appointment of a viral biology and gene transfection specialist (**Casimir**) and the development of a dedicated viral induced cancer laboratory. Recent work has demonstrated that assembly of a membrane nano-cluster is a novel requirement for oncogenic signalling by the middle T-antigen of polyoma virus (**Dilworth**). This has been shown to also be an essential component of signalling by most tyrosine kinase associated growth factor receptors. Investigations are underway into how viruses can be used in novel therapeutics through the development of new viral based vectors based on viral pseudo particles that contain therapy DNA but no viral genes, and can be targeted to specific cell types (**Casimir**).

Our staffing strategy (described below) focuses on quality, capacity building and sustainability, reflecting the School and University strategic goals of increasing research leadership and the number of staff who are research active. Through this strategy we have increased the number of staff submitted in the REF by 47% and have improved the quality of published outputs.

Increasing the potential for attracting research funding from a range of sources is also a core element of our strategy. The Centre for Investigative and Diagnostic Oncology has recently been established as an externally-facing projection of our research and has proved successful in attracting funding. We encourage staff to seek out clinical and industrial contacts and undertake collaborative bids for research funding with other universities and industry, exploiting links we have built up with placements for our Healthcare Sciences programmes. The principal user groups for our research are within the industrial medical sector, both at home and overseas. Our research impacts on a range of activities: pharmaceutical, medical instrumentation, measurement, imaging, telemedicine and rehabilitation robotics, which all include the need for clinical partnerships.

During the next five years we will focus on strengthening and expanding the current core of activity rather than diversification, including the development of clinical engineering in collaboration with colleagues in engineering, computer science and mathematics, with a major emphasis on translational research in orthopaedics and rehabilitation engineering. Investment in research leadership, enhancement of research capacity, strong collaborative links with colleagues in bioinformatics and strengthening external collaborations puts us in a strong position to excel as a centre for innovative translational research and to strengthen our performance in research funding and expand funding sources.

c. People, including:

i. Staffing strategy and staff development

Our staffing strategy is embedded in the University academic strategy which identifies a strong research base as essential to its sustainability and competitiveness and outlines clear objectives to strengthen leadership and staff performance. The strategy for the biomedical science area recognises the importance of building research capacity through investment in both new and existing staff. This strategy is informed by the objectives of enhancing research leadership, retaining and developing junior staff with high potential and fostering an inclusive approach to staff development to enhance individual and collective research capacities and career prospects. Promotion of equality and diversity is core to all of our activities.

Investment in key staff appointments has been central to our strategy, including recruitment to senior leadership positions. Professor Ivan **Roitt** FRS, previously at UCL, has been appointed to direct the Centre for Investigative and Diagnostic Oncology; Professor Stephen **Dilworth** from Imperial College, an oncogenic virus biology and gene transfection specialist, to lead the molecular biology group; Professor Jia **Hua** from UCL Division of Surgery and Interventional Science to enhance the growing area of clinical and bioengineering; and Dr Ajit **Shah** from GlaxoSmithKline as Reader in Bioanalytical Science. New appointments have also been made to bring specific expertise in specialist fields including in the following areas: in the biophysics and bioengineering group to support the development of novel biosensors (**Wildeboer);** in the molecular biology group to extend work into the fundamental biology underlying cancer initiation (**Casimir** and **Clyne**); and in the biomarker group to enhance our work, in particular on hCG (**Burczynska** and **Wen**).

We have strong peer support mechanisms, with junior staff and ECRs working alongside and being mentored by senior colleagues. All new staff members have a full induction programme and are allocated a research-active mentor who can support and help them with University systems for supporting research. All of our staff are embedded in research groups with a designated lead who also provides mentoring and support and is able to introduce new staff to colleagues with related interests. Existing academic staff who wish to further develop as researchers can take advantage of a University wide mentoring scheme, through which senior, experienced researchers provide guidance and advice to less experienced academics engaged in activities such as grant writing and building collaborative partnerships. Annual appraisal provides a vehicle for staff to report on research activity and to plan research and other responsibilities for the coming year. Staff development needs are considered as part of this; and promotions are made where merited

(**Butler**, to Reader). The University and School offer a wide range of development opportunities for all staff (many of which are also available to PhD students) including a commitment to support staff to attend conferences. In addition, there is a central research development programme which provides regular training events on all aspects of research including writing for publication, doctoral supervision, preparing funding applications, managing research and knowledge transfer projects, and ensuring that research has impact beyond academia.

The university has a number of specialist functions offered by the Research and Knowledge Transfer Office (RKTO) including support for contracts and grant applications, legal and IPR issues, procedures for our ethics committee and responsibility for all policies and procedures relating to good scientific practice. It manages the formal committee structures for research, including those for the governance of research policy and research degrees. The RKTO also facilitates access to a variety of external information sources and contacts, such as understanding of the latest EU funding policies and the priorities of national agencies and has an excellent research intelligence dissemination system for ensuring all staff are aware of funding and other opportunities, and collaborative bids across the institution are initiated and facilitated.

In order to foster an environment that enhances individual and collective research capacities and career prospects, we ensure careful management of workloads. Traditionally, we have followed the conventional post-92 university workload model based on teaching with remission but, as a school, we are moving towards all academic staff having a balanced workload comprising teaching, research and administration in approximately a 40:40:20 ratio. We try to ensure that most staff get either two clear days each week for research or blocks of time, depending on their preferences and the courses being taught. One of the ways this has been achieved is through the creation of a junior post of academic assistant to support staff in their teaching across areas such as laboratory supervision and providing workshops for support with assignments, but also to act as research assistants providing ad hoc support. These junior staff are typically registered for research degrees, and the University is implementing a new staffing structure that ensures there is a career path for them through to academic posts.

The University has a well established and comprehensive Code of Practice for Research which enshrines the highest standards of research conduct and integrity. Its principles and practices are based on the Research Councils' Statement on Safeguarding Good Scientific Practice (2000) and the Concordat to Support Research Integrity (2012). An independent University ethics committee ensures our research maintains this level of integrity through well established approval processes. The University Ethics Committee is a sub-committee within the Academic Board structure and therefore its remit is to report to Academic Board on ethical matters within the University.

Our staffing policies reflect processes for ensuring equality of opportunity. Maternity and paternity leave, flexible working to accommodate family, health or other circumstances, and a commitment to reintegrate staff on their return to work, are all supported by policies. The University no longer has a compulsory retirement age. Staff benefit from the University's sabbatical policy, entitling them to be considered for a 12 month break for every seven years of service, although the School usually facilitates breaks less formally through careful workload management.

Since RAE 2008 the number of staff entered has increased by 47%, demonstrating a growth of research active staff, with those not selected for entry this time typically still developing their research profile for future REF submissions and contributing to the research environment through collaboration in projects. The School has established a fund (approximately £50k in 2012/13) to cover the cost of laboratory consumables specifically for those developing in this way. Ten Postdoctoral researchers have also contributed during the period.

Our technical team is central to our staffing strategy and we are moving towards a position with more highly skilled roles and better progression opportunities. A deputy technical manager has been appointed with specific responsibility for biomedical sciences. Six technicians support the laboratories in specialist areas such as analytical instrumentation, microbiology, histology and tissue culture, with that number set to grow as facilities continue to develop. In addition,

biomedical science staff have call on technical staff to support areas such as high performance computing facilities.

ii. Research students

The School and University have invested heavily in PhD studentships to grow doctoral numbers, with 31 PhD registered students during the period, 15 supported by various internal scholarships. The university is increasing the support for studentships, in recognition of the growing numbers of research active staff.

The University Research and Knowledge Transfer Office (RKTO) has a Student Support Team that works with supervisors and research students to provide administrative support from initial enquiry through to award. There is a rigorous selection process in place and also a supportive monitoring scheme. Doctoral students are only admitted to undertake research programmes which match current research strengths and where the quality of supervision can be assured. We have successfully extended our research supervisory capacity through recruitment of senior and developing of junior staff, to complement our existing supervisory team, and are now growing our student numbers in a managed fashion to reflect new staff expertise and new directions.

All supervisors undergo a formal training course, provided by the RKTO, and the supervisory team (typically two people) must contain experience of successful supervision. ECRs will thus be coupled with experienced supervisors who mentor them through the process as well as ensuring excellent supervision for the student. The School enforces strict limits on the numbers of students supervised (6) and also takes into consideration supervisor's track record on time to completion.

Students are monitored via a formal six monthly board managed by the School Research Degrees Committee, alongside more informal monitoring of progress by supervisory teams, ensuring that problems are identified at an early stage. This provides an effective channel for both formal communication between students and staff and discussions relating to the academic experience of students. We have seen PhD completions continue to improve since 2008. We have now reached a position where expectations are that all students will complete within 4 years, and exception monitoring enables us to identify students who are failing to progress at very early stages so that immediate action can be taken.

The University runs a research student training programme conforming to the Vitae framework. Individual programmes of related studies are negotiated, such as attendance of taught masters modules to enhance specific skills. All research students are expected to attend and contribute to the research seminars held within the Department and are also invited to present their results at an annual School Summer Conference. This provides an opportunity to present their research in a supportive environment, but one with surroundings identical to those encountered at external conferences and workshops, and enables all students to become familiar with the extensive range of on-going research across the School. Students are also encouraged to present their research at national and international conferences to help prepare them for defence of their thesis and also to introduce them to academic networks. Funding is available to enable them to attend. Our biomedical science research students are located within our laboratory building, next to the where they carry out their work and alongside the academic staff who are supervising them, ensuring close supervision and support. All are provided with computers and University accounts that enable access to resources and facilities in the same manner as staff.

d. Income, infrastructure and facilities

This area has benefited from sustained investment and a focused estate strategy as the institution has consolidated all of its UK provision on a single campus at Hendon. In 2008 all biomedical related subjects moved into a purpose built £40 million science building at the Hendon campus. This enabled us to design facilities that were fit for purpose and suitable for modern biomedical research, rather than modify and adapt existing spaces. It also enabled the University to support STEM subjects by bringing together various disciplines in ways that supported interdisciplinary working, and the sharing of costly resources such as high performance computing facilities. This facility also houses psychology, environmental and computer science laboratories alongside the

full range of biomedical science laboratories, providing the basis for a truly interdisciplinary research centre, with biomedical science providing a central bio-analytical facility, licensed by the Human Tissue Authority to store human tissue for research.

The University Library, now consolidated on a single campus, provides access to 40,000 journals, a considerable expansion since 2008 reflecting increased University investment, and hosts our e-repository holding over 9000 of our published outputs, which was one of the first established in the country.

Researchers within this unit benefit from access to specialist infrastructure including state-of-the-art organic, inorganic, molecular biology, tissue culture and Class II microbiological laboratories, each of which is supported by dedicated technicians. This provides researchers with direct access to a wide range of analytical instrumentation including liquid chromatography (LC)-mass spectrometry (MS), LC-MS/MS, ion trap time of flight (ToF)-MS, triple quadruple-MS, matrix-assisted laser desorption/ionization-ToF-MS, gas chromatography-MS and flame ionisation detection, inductively coupled plasma optical emission spectroscopy and MS and graphite and flame atomic emission spectrometry (equipped with a hydride generator). Our molecular biology research laboratories provide facilities for real-time PCR, and gene sequencing, as well as gel free MULTINA microfluidic DNA/RNA separation visualisation and quantification. We also have proteomics laboratories with 2D gel electrophoresis and gel visualisation and analysis equipment and purpose built tissue culture research facilities for standard work and gene transfection studies with video and confocal microscopy plus fluorescence-activated cell biomarker analysis. The histology research laboratory contains cryostats, standard microtomes and fluorescence microscopy imaging equipment. We also have a GTEM heating system for nanoparticles. The running costs of these laboratories, including replacing outdated equipment, are met through dedicated research funding supported by ring-fenced University funding. For example, a capital investment of £500,000 has recently been made by the University in two new spectrometers (Maldi-Tof and LC-MS/MS). An e-science, informatics and bio-modelling centre, jointly developed with computer science provides additional facilities for high performance computing, complex data visualisation (including a high resolution, gesture controlled, power wall) and complex sensor networking facilities.

Research income for the period is approximately £2m submitted to this unit, largely derived from EU and UK government bodies, for example EPSRC EP/G061572/1 (£1.7m - New imaging methods for the detection of cancer biomarkers). The Centre for Investigative and Diagnostic Oncology has also been supported by funding from private sources including Jon Smith and Princess Sara Bint Talal through the Lee Smith Foundation, but this is not included here as it attracted HEFCE matched funding. 'In Kind' income over the period includes the donation of equipment including two API300 triple-quadrupole mass spectrometers, each of the value of £54,000, a binary gradient HPLC system, with two pumps, a degasser, an autosampler, a column oven and a UV detector (£10,000), 200 HPLC columns (£20,000), and a nanaoparticle heating system (£200,000). In addition, projects in bioinformatics (submitted to computer science and informatics) include EP/H031936/1 (£423,000) on evolutionary models, a BRIDGE project on PET imaging, (£35,000), an FP7 project (£350,000) on image warehousing in the digital hospital, and JISC projects on the sharing of medical images for research and education (£60,000). The RKTO and school work together to support the development of new funding opportunities, the governance of IPR, financial project management and ethics, and the quality control of funding applications.

e. Collaboration and contribution to the discipline or research base

The research reported under this unit of assessment is inherently highly interdisciplinary, requiring close alliance between developers (scientists and engineers), the end-users (doctors and patients) and commercial partners. Although research is organized within groups as identified above, research interests frequently extend across groups and staff routinely work together. Developing and extending research collaboration within the University and externally, with academic, industrial and health care partners, including the NHS, forms a central tenet of our research strategy.

This is particularly evident in the field of biophysics and bioengineering with work on novel medical imaging techniques depending on collaborative working between researchers in biomedical science and computer science who contribute to the development of algorithms for medical

imaging. Externally, application of medical imaging using EIT has built on collaboration with the Medical Physics group at University College London and work on breast imaging is developing with a team at Dartmouth College in the USA. Similarly, internal collaboration underpins work to investigate the use of nanoparticles as targeted treatment/delivery agents (Bayford, Roitt, Wildeboer, Butler) with the team working externally with Midatech, a biotechnology company translating its proprietary gold nanoparticle drug delivery platform into nanomedicines. Within the biomarker group, work on hCG has continued in collaboration with the hCG reference service in the United States, led by Professor Larry Cole, and with commercial partners, Celldex therapeutics, on the development of a vaccine directed against hCGβ.

The University is supportive of staff engaging with the wider scientific community, and facilitates such engagement with resources, viewing this as a strategic priority for staff at all levels. Several members of submitted staff hold visiting lecturer positions at other institutions, including; **Roitt** - Emeritus Professor, UCL; **Dilworth** - Honorary Reader, Imperial College; **Bayford** - Honorary senior lecturer, UCL; **Casimir** - Honorary Senior Lecturer, Imperial College. Staff also regularly examine PhDs at other institutions within the UK and overseas. Ongoing research collaborations with institutions internationally include work with the 1st Affiliated Hospital of Harbin Medical School on arsenic tri-oxide as a treatment for HPV-correlated cancers (**Wen**, **Ghali**); Tianjin University and Hebei University of Technology, China, and Al-Farabi Kazakh National University, Kazakhstan. Past research with Kazakhstan, which produced a NATO prize, has led to further collaboration.

Submitted staff also make recognised contributions to the discipline through learned societies, professional associations and other bodies, including: **Roitt** - elected fellow of the Royal Society and a Fellow of Balliol College, Oxford; **Bayford** - Fellow of the Institute of Physics, Institute of Physics, Engineering and Medicine, and the Society of Biology; **Dilworth** - member of the European Association for Cancer Research and British Cell Biology Society; **Shah** – member of the Royal Society of Chemistry and the Chromatographic Society, **Wen** – member of the British Pharmaceutical Society; **Casimir** - member of the British Society for Gene Therapy. **Wildeboer** member of the German Society for Biochemistry and Molecular Biology, Federation of European Biochemical Societies, International Proteolysis Society and the British Society for Matrix Biology.

Colleagues contribute to the wider international academic community though programme committee work for conferences and as members of editorial boards or reviewers of leading journals. For example, **Bayford** was a co-organiser of the 4th (UMIST) and 5th (UCL) conferences on biomedical applications of Electrical Impedance Tomography and **Shah** has been the co-organiser of several international chromatography symposia that include the Chromatographic Society's Golden Jubilee meeting. **Bayford** is editor-in-chief of the *Journal of Physiological Measurements*, and co-editor of Physiological Measurements special editions on EIT, as well as being a member of the editorial board of the *International Journal of Biomedical Imaging*. **Roitt** is on the editorial board of *Current Opinion in Immunology*, **Wen** for the *Journal of Fertilization*: In vitro, and **Clyne** has guest edited a special issue of *Proteomics*. Staff also contribute regularly to peer-review of funding applications submitted to UK research funding agencies (e.g. EPSRC, BBSRC, MRC, STFC, NIHR), UK charities (e.g. Wellcome Trust, Action Medical Research) or other funding bodies throughout Europe and beyond. **Bayford** is an ESPRC College member.

Members of the biomedical science group have been invited as keynote and guest speakers at leading international meetings. Recent highlights include the following: **Bayford** has given keynote lectures at the Young Researchers' Futures meeting on Neural Engineering at the University of Warwick, 2012; Systems Biology Europe conference and exhibition, Madrid, 2012; BIOSTEC 5th international joint conference on biomedical engineering systems and technologies, Portugal, 2012; 1st Symposium on Systems Approaches to Parkinson's Disease (SAPD) hosted by the Hamilton Institute, National University of Ireland, 2010; XIVth International Conference on Electrical Bio impedance and the 11th Conference on Biomedical Applications of EIT, Florida University USA, 2010. **Dilworth** is an invited speaker annually at the Small DNA Tumour Virus Conference. **Hua** has been an invited speaker at the 6th Shanghai International Congress on Orthopaedic Advanced Techniques and Clinical Translational Research and at the 7th International Congress of the Chinese Orthopaedic Association and International Orthopaedic Research Society and has delivered a keynote lecture at the 6th World congress of Bioengineering.