Institution: Middlesex University

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

1. Overview and mission

Our mission is to use cutting-edge technology and population research to solve important health problems. In order to achieve this our unit draws on expertise from the Biomedical Science, Public Health, together with experts from the areas of Nursing practice and Computer Science.

In order to realise this mission, researchers are aligned to four strategic research themes - Biophysics and Bioengineering, Biomarkers and Molecular Biology, Global Public Health Policy and Nursing Practice. Such diverse expertise within the unit enables us to address research problems from a unique integrative perspective. As a result of this approach we had significant impact on important and diverse health issues:

- Developed new technologies to monitor impaired neonatal lung function and to detect and treat cancers
- Identified novel molecules to diagnose and treat early stage cancers and hypertensive disorders
- Led the development of the World Health Organisation metabolic risk factor for non-communicable diseases database.
- Instrumental in the inclusion of no vitamin K anticoagulants for the treatment of non-valvular atrial fibrillation (NVAF) into the latest WHO Model List of Essential Medicines (EML)

In our REF2014 submission all aspects of our research environment were judged to be conducive to producing internationally excellent and internationally recognized research and 67% of our submission met the requirements for 3* or 4* research. In particular, our research strategy and people section, together with our strong links within the NHS and considerable infrastructure investment were considered as providing a strong focus for building capacity and sustainability. Middlesex University prioritised the development of STEM subjects including the creation of a new Faculty of Science and Technology. Within this, research capacity was built within defined research themes by substantial investment in infrastructure, facilities and staff. As a result, the University jumped 15 places from 2008 in the power rankings and became the best modern university in London for research power.

We have addressed important health issues through active engagement with institutions, healthcare providers, and a range of government bodies as well as industrial, public and voluntary organisations. For example, in our work on the application of electrical impedance technology for monitoring neonatal lung function we are working closely with The Royal Hospital for Children, Glasgow, Oulu University Hospital, Finland and Amsterdam UMC, Netherlands as well as several industrial partners. Our epidemiological research aimed at reducing the global burden of metabolic disease and obesity involves collaboration with key international agencies, but notably the World Health Organisation.

These actions together with a continuous research engagement, have led to significant improvements in our performance across several metrics. For example, we have greatly increased the number of research active staff. Yearly doctoral completions have increased

by over 40% and our strong level of external research income has increased in this REF period from £1.96M in REF2014 to £4.9M submitted for REF2021. This income is from a diverse range of organisations that includes European Union's Horizon 2020 research and innovation programme, UK Research Councils (EPSRC), overseas governments and seven UK-based charities including the Academy of Medical Sciences. We have also received research income from several industrial partnerships including VWR and Pharmidex. This wide variety of funding sources will provide a more sustainable income stream into the future. The journal titles included in our outputs reflect the wide breadth and scope of our research. Examples include Nature, New England Journal of Medicine, Journal of Biomechanics, Plastic & Reconstructive Surgery, Journal of Physical Chemistry, The Journal of Environmental Chemical Engineering, The Lancet, Biosensors and Bioelectronics; and Disability, Journal and Rehabilitation: Assistive Technology

Our unit has an equal gender balance and a diverse community comprised of 31% from Black, Asian and Minority Ethnic (BAME) backgrounds, thus bringing a breadth of expertise and experience. This is higher than the University average and significantly higher than the UK HEI average (9.8%). Several members of our unit have participated in the women's leadership programme Aurora and so far, approximately 20% of UoA3 have completed the programme and benefitted from this opportunity and are now engaged in leadership roles (e.g., Research group leadership, programme leadership, chairing internal committees). The University has recently submitted an application for an Athena Swan Bronze award and is currently preparing a submission for the Race Equality Charter. Our gender pay gap is one of the smallest in the higher education sector at 7.6% (March 2019). The sustainability of this growth has been cemented by embedding research leadership within our unit and throughout the Science and Technology faculty.

1.1 Research structure

Our unit's research governance and leadership structures reflect the strategic importance of promoting research, building capacity, and enhancing its leadership and management. It is led by the Natural Sciences Research and Knowledge Exchange Committee which comprises the head of department, research co-ordinators, student co-ordinator, representatives across the four research areas and the head of the departmental ethics committee. This committee has a key role in integrating our research within the wider Faculty and University strategy; overseeing research and knowledge exchange (RKE) activities, disseminating information arising at Faculty and University level, and supporting research needs to underpin research sustainability. Progress towards reaching our targets is informed by income and student data supplied by the University's Research and Knowledge Transfer Office (RKTO) and by detailed annual research plans completed by all academic staff and in consultation with postgraduate students. Where appropriate our research is also organised through the Centre for Investigative and Diagnostic Oncology. Research clusters promote interdisciplinary and cross Department/Faculty working focused on societally relevant research areas. These organisational groupings are fluid and any individual academic might be a member of multiple groups.

Table 1: Research group membership Unit of Assessment 3. Bold italics denotes group leaders

Biophysics and Bioengineering	Biomarkers and Molecular Biology	Global Public Health	Nursing Practice
Bayford	***Dilworth***	***Di Cesare***	***Traynor***
Hua	***Hills***	Aceijas	Bayford
Appiah	***Shah***	Stordal	Di Cesare
Bardill	Appiah	Tobi	Liu
Gomes de Almeida	Bayford	Van Wyck	Hills
Hills	Bell		Van Wyck
D. Li	Burczynska		
J. Li	Casimir		
Mutter	Ghali		
Roitt	Gomes de Almeida		
Shah	D. Li		
Stefanov	Loizidou		
Wen	Magoulas		
	Mutter		
	Novoselova		
	Outram		
	Roberts		
	Roitt		
	Pachenari		
	Ring		
	Stordal		
	Van Wyck		
	Wen		
	Yagnik		

The word-cloud below shows the 50 most frequently occurring words in the abstracts of publications in our output submission (excluding words such as study, research, findings). It clearly evidences our strong embeddedness and demonstrates our emerging strengths in innovation and strategy and emerging interdisciplinary research.

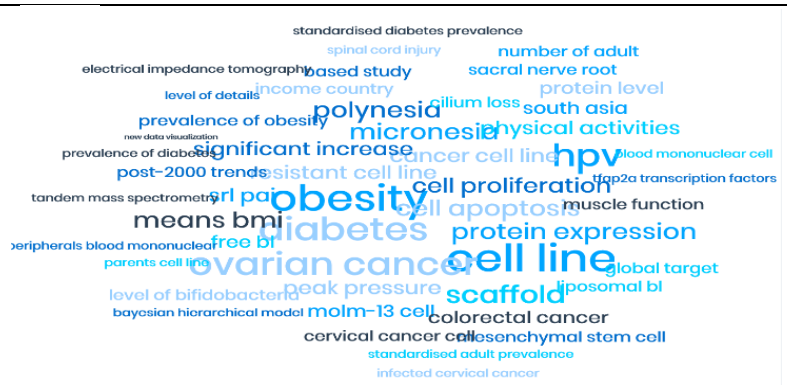

Figure 1. Word cloud derived from top 50 words appearing in abstracts from research outputs submitted to REF2021

1.2 Research strategy

Realising our 2014 strategic aims

The chief aims of the REF2014 strategy were to increase staff research capability and enhance collaborative research both internally and externally to strengthen and expand our core research activity. Since our highly successful REF 2014 submission we have used and increased this investment to achieve these objectives. Using focussed investment, we have achieved each of these aims in the following ways:

Investment in core research activity

Since 2014 the University has invested £2.4M on research-related funding specifically for research within our unit. This incorporates investment in new laboratory facilities which focus on our core research activities, including new fully equipped cell culture and microbiology laboratories and a new molecular biology suite (Section 3). These enable us to strengthen our core activities to support our growing need for *in vitro* models of understanding cell behaviour, biomarker characterisation and biochemical synthesis for drug targeting. Further investment has also been made to existing infrastructure. For example, over £700K has been invested to extend the analytical instrumentation supporting our core research. All laboratory facilities in our £36M Hatchcroft building are fully maintained by a technical team overseen by a Technical Manager. The team includes five dedicated technical tutors assigned exclusively to support our research facilities. Laboratory technology evolves rapidly and our technical team undertakes an annual programme of equipment assessment so that it may be upgraded or replaced, as necessary.

£18M has been invested within the Faculty on shared infrastructure heavily utilized by researchers within our unit of assessment. This includes the Ritterman Building – an innovative space for the Faculty of Science and Technology and the Faculty of Arts and Creative Industries. The facilities are extensively used by our researchers. For example, the new 3D printing, laser and water jet cutting technologies have enabled us to construct complex 3D models for hip implantation **(Prof Hua)**. Alongside this, the Ritterman laboratories are equipped with blade servers which have enabled us to carry out high-end computations required for a £3M project to develop an imaging device for continuous non-invasive bedside monitoring of infant's lung function (CRADL). Our researchers have also made extensive use of Redloop, our faculty-run innovation and design collaboration centre. This facility has enabled us to receive prototyping assistance, through our internal

innovation centre; a method that ensures focussed, efficient and timely production of the devices through the iterative phases of the project.

Our research strategy is closely allied to that of the University. Middlesex University's 'enabling plan' for research (2017) required that institutions 'Create learning resources informed by our academics' research and practice that can be used to enhance student learning'. Within our unit synergies between research and teaching have been exploited and developed to enhance research capacity. New programmes have been developed at both BSc and MSc level that utilise our research expertise. This has enabled us to expand research capacity by investing in £2.24 M of new equipment central to our research. This includes next-generation sequencing technology, NanoPore devices and an Illumina sequencer, Agilent TapeStation, Qubit fluorometer and NanoDrop spectrophotometer. Furthermore, staff within our unit have access to a high-performance LightCycler real-time PCR system. These new programmes provide experienced students for future post graduate work, continuing a virtuous teaching research cycle to increase sustainability. Several of our graduates have completed PhDs because of this cooperation and are now embarked on successful careers in the academic and commercial sectors. The success of this initiative is also reflected in our 40% increase in doctoral completions from our previous REF submission.

Increase our staffing capability

We have greatly increased the number of research active staff from 14 in REF 2014 to 33 in the current submission. The total staff number within the Department of Natural Sciences has increased substantially since 2014 to 53.9 FTE currently. Hiring of research active staff has been fundamental in increasing research capability and is also supported by several initiatives from the University. In 2015 the department launched a Research Initiative Fund to directly provide seed-corn funding for pilot research projects within our core research areas. This funding was available to all staff within the unit up to £5,000 per FTE per year. This has directly led to staff securing active collaborations and external research funding. For example, **Dr Appiah** has used this money to establish a research group investigating photochemical-modulated signalling pathways supporting four PhD students, one of whom has now successfully completed. This group is also actively collaborating with researchers at the Department of Biochemistry, Genetics, and Microbiology at the University of Pretoria, South Africa. In addition, staff have attended a series of research support workshops by the University Impact Officer to identify impact and focussing research to achieve it.

To maximise staff research potential, we ensure that these initiatives are undertaken in a way that reinforces equality, diversity and inclusivity. These are core values across the University. Indeed, they are enshrined within our values; 'we act fairly, with integrity, respect and purpose'. Staff members in our UoA play leading roles in the four university-wide equalities forums (LGBT+, Race Religion and Belief, Disability and Gender) and several networks (e.g., The Race Network) which provide a supportive and safe environment for all staff. For example, staff in our unit of assessment are members of the University- Equality, Diversity and Inclusion working group, the steering group of the University Race forum and the University Race Charter Self-Assessment team. In addition, a grassroots group, HAREDIN (Healthcare Academic Race Equality and Diversity Inclusivity Network) emerged

as a staff response to the need to improve diversity within the University, along with a sister group for students, SHAREDIN. These groups have organised a series of seminars aimed at staff and nursing undergraduate students, a significant proportion of whom are from BAME backgrounds. The University's Equality and Diversity Policy is monitored at the highest level and overseen by the Academic Board and Board of Governors. In relation to research, the University REF Equality and Diversity Panel ensures this policy is followed in all matters relating to the REF. All staff involved in our unit submission have completed mandatory training in equality, diversity and unconscious bias.

Strengthening collaborative links (internal and external)

We have made numerous collaborative links with institutions within the UK and Worldwide. This is ably demonstrated in our research outputs where 88% of our published peer-reviewed research articles include authors from collaborating institutions and there are over 120 collaborating institutions named. However, our external collaborations extend significantly beyond publication of research articles. Significant research income has been secured through collaborations with our external partners in academia, industry, government and international policy makers. These are detailed in section 3 (Collaboration and contribution to the research base, economy and society).

Our drive to strengthen collaborative links also applies to connections within the University. These have focussed on the development of collaborations with colleagues within the faculty (Engineering and Computer Science) and elsewhere. The strength of research collaborations between different faculties within the University is well demonstrated by the range of impact case studies that make up our REF submission. In each case the impact has been achieved following strong and sustained collaborations from different research areas - most notably between Biomedical Science and Computer Science (Electrical Impedance Tomography and nanoparticle imaging). Our work on design and advanced manufacture of patient specific medical implants fits in well with the robotics group within Computer Science, making use of group expertise in finite element models. Algorithmic support from Computer Science colleagues has been vital in our development of biosensors utilising electrical impedance tomography for biomarker detection in developing imaging devices for targeted drug delivery. Collaborations between Biomedical and Sports Science have spawned a series of collaborations with external institutions including Saracens Rugby, British Olympic Fencing and GlaxoSmithKline. Internal collaborations between our public health and nursing practice have enabled us to assess knowledge of healthcare support for care workers. This work has been funded jointly by the Burdett Trust for Nursing and the faculty research initiative fund and our work in this area has resulted in coalescing of internal and external collaborative links. In pursuing these aims, our strategy was to significantly increase research funding overall and expand the range of funding sources (see section 1.1).

1.3 Open Science

Throughout this REF period awareness of the issues surrounding Open Research, including open access and research data management have increased significantly within the Faculty of Science and Technology.

Our commitment to Open Science is evidenced from outputs submitted. Within our unit of assessment 43% of our outputs submitted for REF are published in online open access journals. The remainder are self-archived within the University Eprints Research Repository. The Faculty has strongly supported Open Science initiatives including ORCID (Open Researcher and Contributor ID) registration with all submitted staff registered, and actively supports open access publication for all 3* and 4* journal publications. This scheme was highly popular with staff and contributed to our strong citation performance.
We work closely with the Research Support Services team based in the Sheppard Library, to ensure REF compliance and aid with Open Access publishing via the repository, and in advocating various issues in open research. The Middlesex University Figshare Repository for research data is increasingly used by researchers in our unit, demonstrating awareness of the need to improve research data management practice and make research published online findable and citable. This repository supports discovery of digital research outputs beyond traditional research output types and ensures works are discoverable and citable using digital object identifiers (DOIs).

1.4 Research integrity
The University has a well-established and comprehensive Code of Practice for Research, enshrining 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).

Within our Faculty, research integrity is overseen by the RKTE committee and governed through a departmental Research Ethics Committee (REC) structure. This is chaired by a senior colleague and supported by a team of trained reviewers. REC approvals are audited on an annual basis and Chairs report to the University REC which is chaired by a Deputy Dean. All research projects, including those conducted as assignments within taught undergraduate and postgraduate modules, must attain approval from a local REC before commencement of work. All applications are reviewed by up to three reviewers and researchers must provide evidence of REC approval for assessment of their work. The governance function of the RECs is underpinned by a secondary educative function to support integrity in research practice. Students, supervisors and staff who are active in research all receive access to a wide range of training resources, including bespoke forms to support applications related to consent and participant information and 'flipped-classroom' training in REC applications supported by tailored training videos on application processes and 'key application mistakes - and how to avoid them'. This training is also embedded within our teaching at undergrauate and all postgraduate levels as well as at PhD level and includes external presentations from the UK Health Research Authority. There is a continuing dialogue between the REC, researchers and research students focussed on streamlining the ethics application process. Applications requiring resubmission receive detailed written comments from reviewers on the changes needed to support the reapplication process and develop applicants' understanding of the requirements of ethical research practice

1.5 Advancing our research strategy
Under the leadership of our new Vice-Chancellor and British Academy of Management President, Nic Beech, Middlesex University is currently formulating its ambitious 2031

research strategy with the intention of becoming world leading in Technological Innovation. The research and impact in this unit will aim to contribute strongly to that mission. In the next seven years, the foremost goal for our unit will be to build on recent achievements and current dynamism. We will seek to consolidate and sustain our performance on our key objectives of further strengthening of our four main research areas, developing even stronger international collaboration and strengthening our pathways to impact. With the appointment of the new Academic Dean of the Faculty reflecting a greater focus on research more broadly within the University, there are plans to use future research income to support funded PhD studentships and Research Fellows. Our long-term strategy also involves further development of our multi-disciplinary expertise and profile nationally and internationally, enabling us to develop innovative proposals for MRC, EPSRC and BBSRC funding. A feature of our research strategy to date has been our growing and successful collaboration with numerous industrial partners. We plan to build on this and make more use of funding streams that support these partnerships, including Innovate UK.

We have identified new areas of research growth that fit well within our existing expertise including Pharmaceutical Chemistry and Neuroscience. Much of our research fits well with an interdisciplinary context and therefore suits submission for joint projects between councils, a development indicative of many recent research calls. This will be achieved through sustaining our strong leadership and staff development.
Specific indicators to benchmark our progress in achieving these objectives over the next 3 years include:

- Continue to increase and diversify sources of external funding, contract research funding: target 20% increase in both of amount of funding secured and number of funding sources
- Attract and inspire new research active staff that complement research aims
- Investment in infrastructure to significantly expand existing research facilities, new research areas identified and new interdisciplinary collaborations
- Increase postgraduate research student recruitment and enhance completion rate by increased focus on funding applications that incorporate studentships into funding applications and further developing support services for postgraduate students: target increase postgraduate student numbers by 20%
- Providing leadership and advice on further raising the quality of publication outputs and achieve further impact through identification of IP and patents
- Setting up a new working group to further improve external research collaboration across our unit by actively engaging, monitoring, and sharing and supporting best practice
- Further promote our research through increased engagement at national and international levels by participating and hosting international symposia and conferences.

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2. People: Staffing strategy and staff development
Staffing strategy

The key objectives of our staffing strategy are to improve the balance of our staff profile, to develop junior researchers, reinforce our current research groupings, and lay the foundations for developing new areas. These have been pursued through a combination of external recruitment and a strong emphasis upon staff development. This strategy is informed by the basic principles of the Concordat to Support the Career Development of Researchers: to promote an inclusive approach to staff development which enhances individual and collective research capacities to attract and retain research leaders and junior staff with high potential; and to promote equality and diversity. Our future strategic development will be pursued in line with the University's current formulation of its people strategy to 2030, entitled "*Changing lives – A world class community in a world class University*".

The strategy for the unit recognises the importance of building research capacity through investment in both new and existing staff. Since REF 2014 the total number of staff in our unit has more than doubled from 16 to 33 staff, demonstrating a growth of research-active staff. In the previous REF period, we made a key appointment in Oncology with **Prof Roitt** leading the Centre for Investigative and Diagnostic Oncology. This has led to significant growth in our research and impact within this area. To sustain and build on this we have made several new appointments for REF2021 in oncology bringing expertise in ovarian cancer **(Dr Stordal)**, osteosarcoma **(Dr Roberts)** and immuno-oncology (**Dr Outram**). Additionally, new appointments have been made in neuroscience and in pharmaceutical chemistry and molecular modelling (**Drs Loizidou and Mutter**) to build on our collaborative research within the unit, with colleagues in Computer Science and externally. Since REF2014 we have also greatly enhanced our research in Public Health as demonstrated by the recruitment of three new appointments in this area (**Drs Di Cesare, Tobi and Aceijas**). This has strengthened our impact in this area as can be seen in our impact case studies.
Our Faculty Director of Research is a member of key academic selection panels and contributes to all staff promotion applications. This helps to ensure that our people and development strategy is closely aligned with that of the University.

Staff Development
This strategy is informed by the objectives of enhancing research leadership, retaining and developing early career researchers (ECRs) and other junior staff. Promotion of equality and diversity is core to all our activities. We have numerous initiatives that promote these values and objectives:

(i) Junior Staff and Early Career Researchers
We have strong peer support mechanisms with junior staff and early career researchers working alongside and being mentored by senior colleagues. All new staff members have a full induction programme and our unit's new researchers are allocated a research-active mentor who supports them with their research development within our existing framework. This is supported financially through the Faculty Research Initiative Fund (section 1.3). All staff are embedded within research groups with a designated lead who provides mentoring and research support. Existing academic staff who wish to further develop as researchers can take advantage of a University wide mentoring scheme. Through this scheme senior, experienced researchers provide guidance and advice to less experienced academics engaged in activities such as grant writing and building collaborative partnerships. New

researchers are also provided with generous time allowances for their research to support their career development.

(ii) Laboratory Access

Our unit has a strong and passionate commitment to provide ready access to all laboratory equipment to researchers from a diverse range of disciplines and expertise. For example, costs of common consumables within each laboratory are met centrally from within the Faculty. This means that novel studies can be piloted easily. The diversity of access also prevents equipment being siloed within a specific discipline. For example, cell culture and mass spectrometry facilities are used by researchers in pharmaceutical chemistry, environmental science, sports science and biophysics as well as the traditional areas of cell biology and cancer research. A full programme of hardware and software induction, training and technical support is provided to facilitate this commitment. In addition, most of the staff's class contact is limited to approximately half a calendar year and Heads of Department are encouraged to configure teaching commitments appropriately to create concentrated time for research. Our technical staff 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.

(iii) Career Progression and development

Annual appraisal provides a vehicle for staff to report on research activity and to plan future research alongside other responsibilities for the coming year. Staff development needs are considered as part of this, and promotions are made where merited. Our current submission reflects improved career progression for existing junior staff composed of 9% Lecturers (was 31%), 56% Senior Lecturers (was 31%) and 16% Associate Professors (was 13%) and 12% Professors (was 25%).

The University and Faculty offer a range of development opportunities for all staff, many of which are also available to PhD students, including a commitment to support conference attendance which includes at least one international conference per year. In addition, our research development programme 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.

To foster an environment that enhances individual and collective research capacities and career prospects, we also ensure careful management of workloads. All staff in our unit have permanent academic contracts and academic staff have a 40:40:20 workload ratio of teaching: research: administration. We aim to ensure that staff get blocks of time for research where needed. One of the ways this has been achieved is through the creation of junior posts of graduate academic assistants, technical tutors and student learning assistants. These posts 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 staff are typically registered for research degrees, and the University has implemented a new staffing structure that ensures a career path for them. Within our unit, several of these have advanced their careers through to Associate Lecturer and full Lectureships.

Our technical team is central to our staffing strategy and new positions of technical tutors have been established to provide progression opportunities for the technical team and recruiting new talent. The technical tutor role comprises technical and academic aspects with the technical tutors also having supporting roles in research.

Research students

Research students are integral to our research community and vital for our research sustainability. The number of students on PhD and Professional Doctorate programmes has increased through the current REF period with 22 doctorates awarded compared to 17 for the REF2014 period. The PhD student body is highly diverse. 51% of our 47 current post graduate research students are female, and 60% are from Black, Asian and minority ethnic groups.

Applications for doctoral research programmes are reviewed by the Departmental Research Degrees Co-ordinator and allocated to match with potential supervisors to subject speciality. Applications are then reviewed within each speciality and candidates selected based on the merits of the research proposal and the potential of the applicant to undertake doctoral research. Doctoral students only undertake research programmes which match current research strengths and where the quality of supervision can be assured. Supervisors receive training in candidate selection to ensure fairness to protected characteristics and undergo a formal training course. The supervisory teams contain those with experience of successful supervision to completion along with ECRs. This policy of collective supervision permits the development of supervisory capacities post initial training, broadens the skills and knowledge available to students, and provides continuity of supervision in cases of absence or movement of supervisors to other institutions. The Faculty enforces strict limits on the numbers of students supervised (6) and takes into consideration a supervisor's record of accomplishment on time to completion.

The Research degree Co-ordinator and Research Degrees Committee are responsible for overseeing the quality of the student experience and monitoring progress in six-monthly formal doctoral progression boards, as well as supervisor/academic advisor selection. Professional Doctorate students have an academic adviser and may choose to have additional support from an external consultant, usually from the professional context within which the student works.

Progression boards are managed by the Faculty Research Degrees Committee (RDC), alongside more informal monitoring of progress by supervisory teams, ensuring that problems are identified at an early stage. Students' progress through an early registration process and then transfer before entering their final year of PhD studies. This provides an effective channel for communication between students and staff. The University has procedures to avoid research students being disadvantaged because of ill health or other circumstances disruptive of their studies. Students can request an interruption to their studies of up to 12 months.

Postdoctoral completions have increased steadily through the REF period (Table 2).

Table 2: Postdoctoral completions by academic year

Academic year	2014-15	2015-16	2016-17	2017-18	2018-19	2019 -20	Total
PhD completed	1	2	4	2	5	4	18

Our PhD students participate fully in the Faculty's research culture and are supported in this. Students are aligned to departments by virtue of the departmental affiliation of their Director of Studies. Additionally, Middlesex University's Work and Learning Research Centre provides additional expertise and support to our Professional Doctorate students. Our students are accommodated in high quality, dedicated office accommodation shared on a hot-desking basis, with good computing facilities. These are located close to the laboratories where they carry out their work and alongside the academic staff who are supervising them, ensuring close supervision and support. During the recent COVID-19 pandemic the University has provided software permitting remote access to instrument controlling PCs. This allows students to access, process and analyse research data remotely when laboratory access is not possible. We endeavour to continue this practice in the future.

The University runs a research student training programme conforming to the Vitae framework which promotes researchers' skills and prepares students for the academic and professional world. The Faculty runs a tailored Researcher Development Programme for our doctoral students including a programme of induction for new students and a range of courses and workshops on topics including learning, teaching and assessment, employability, research design and integrity, and presentation skills. Attendance at core and specialist MSc taught masters modules is encouraged. Core elements here are research design and statistical analysis, literature search and review, research ethics, advanced bioanalytical techniques and scientific communication. This training enhances their knowledge and specific skills related to their project and provides wider transferable skills.

All research students attend and contribute to the weekly Departmental research seminars and weekly journal club and are also present their results at the annual University Research Student Summer Conference. These provide opportunities to present their research in a supportive environment and enables students to become familiar with the extensive range and interdisciplinary nature of research across the University. PhD students from our unit have been highly successful at our Summer conference with several winning Best presentation awards. Students are also encouraged to present their research at national and international conferences to help prepare them for defence of their thesis and to introduce them to academic networks. Internal funding is available to enable them to attend up to two external conferences during their PhD studies.

Equality, Diversity and Inclusivity

Equality, diversity and inclusion are core Middlesex values, both in the University and in our unit. Middlesex was the first UK university to receive Corporate Gold/Embedded Charter Mark from UK Investor in Equality & Diversity. We have robust arrangements to ensure 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. 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 Faculty usually facilitates breaks less formally through careful workload management. The University has high retention rates after maternity, paternity and adoption leave. In our unit, three of our academics have been on paternity or maternity leave. Family-friendly policies with initiatives supporting remote and flexible working are reflected in our staff development programme. Staff often worked from home several days per week and key meetings are being held between 10am-4pm to allow staff with children to drop off and collect from childcare. This support has been critical during the COVID-19 pandemic where all staff were working from home and many had caring and home-schooling responsibilities for children.

We have a fully transparent processes for research funding applications, access to internal funds, conference attendance, sabbaticals and training. We operate with standard workload models in which research and practice allowances are allocated transparently on a yearly basis, based on past performance and credible work plans. All staff can view the annual work programmes of colleagues within the unit.

Staff within our unit are engaged in promoting diversity at a high level within the University. **Dr Bell** is a key member of the University Equality, Diversity & Inclusion Committee which shapes, informs, develops and implements planning and policy on equality, diversity and inclusion for the University. **Dr Bell** also played a key role in organising Middlesex University International Women's Day. This annual event showcases the huge contribution made by women across the University and encourages staff and students to make their pledge for gender parity. **Dr Stordal** is a member of the University Athena SWAN self-assessment team (SAT) which identifies and implements necessary actions to improve gender equality at Middlesex. **Dr Appiah** is a member of the University Race forum steering group and the Race Charter Self-Assessment Team. Our academics participate in the various Staff Equalities Fora. These fora have been reviewed and are now constituted as Equalities Networks, including Race, Interfaith, LGBT+, Gender, Disability, and Carers.

Equality, diversity and inclusion in the REF submission

Our commitment to equality and diversity which informs our extensive programme of staff development is reflected in our REF submission. 53% of our submitted staff are female and 31% of academics within our unit have a BAME background. This is fully represented in our outputs for REF2021. The selection of publication outputs was conducted by a REF UoA Panel composed of five members. It included two professorial members, three mid-career researchers and one early career researcher. Three of the five members were female and two were from a BAME background. The selection process for outputs was fully transparent whereby staff were asked to nominate their top-5 publications based on REF quality criteria. Staff could draw on other criteria to evidence the quality of their outputs and were explicitly encouraged to do so.

To encourage transparency and inclusivity, staff in the unit were asked to identify and rank their best outputs and supply a short statement of justification. Their assessment was based on the originality, significance and rigour of each output. Staff with relevant expertise within the unit reviewed outputs and provided a score against criteria above. Significant divergence was discussed with staff individually. The numerous resources and strategies (outlined above) that we have put in place to support our research illustrates that most staff had many high-quality outputs to choose from.

3. Income, infrastructure and facilities

Income over the census period has been £4.5m received from EU, UK government bodies, health authorities, hospital authorities, charities and industrial partners. The consistent funding received from these bodies is a testament to the success of our approach and our focus on areas of research that are important to them and their beneficiaries. This represents an income of £123K for each FTE in this unit of assessment. **Prof Bayford** and **Dr Bardill** have been highly successful in securing funding for several projects; in 2016 **Prof Bayford** was awarded £898K from the EU for Continuous Regional Analysis Device for neonate Lung (CRADL) to develop the use of Electrical Impedance Tomography (EIT) to monitor lung function to reduce morbidity and mortality in pre-term neonates due to lung failure. In 2020, **Prof Bayford** and **Dr Bardill** received a £773 K from EPSRC for Preterm Neonatal Embedded Universal Microelectronic Wearable Acquisition for Cardiorespiratory Intensive Therapy (PNEUMACRIT). This was a continuation of the CRADL project. In 2018 **Prof Bayford** was a recipient of £250,000 award for the Bright Ideas call by EPSRC to develop the use of EIT and nanoparticles to track drugs in the body. **Prof Shah** was awarded £60K in 2019 to develop a strategy for enhanced analysis of the glycoprotein from Partnership for Clean Competition. **Prof Shah** also received an in-kind donation of £250K from Applied Surface Technologies Analytics in 2017 to support development of MALDI-TOF MS (Mass Spectrometer) hardware and software. The instrument was accessible to groups at Royal Free, Kings College London and University of East London. In addition, **Prof Shah** and **Dr Hills** received £10K income from contract research work over the assessment period. **Dr Roberts** was awarded £10K in 2017 by the Bone Cancer Research Trust for project MicroRNA regulation of autophagy-induced chemoresistance in osteosarcoma, £9K from the PetPlan Charitable Trust in 2018 to investigate chemoresistance in canine osteosarcoma, and has recently been awarded £87K from the osteosarcoma charity Hannah's Willberry Wonder Pony to investigate the role of the bone microenvironment in metastasis. In 2017 **Dr Di Cesare** was awarded £49K by The Academy of Medical Sciences Springboard - Health of the Public 2040 Award. She also received £28K in funding in 2018 from Imperial College London for Inter-institutional collaboration Inequalities in cardiovascular risk factors. Recently, **Dr Di Cesare** was awarded £2.8M for a study to detect SARS-CoV-2 virus in the wastewater of schools to provide a useful early warning system of infection levels and 'Healthcare assistants' knowledge, attitudes and experiences of preventing pressure ulcers: a mixed method study'. Funder: Burdett Trust for Nursing Grant. PI, (£8,540). **Dr. Li** was awarded £22K from the British Council to work on Design and advanced manufacturing of patient-specific implant. The diversity of income sources demonstrates the range of domestic and international collaborative links with industrial, academic, charities, health, and public policy bodies.

Infrastructure and Facilities

The interdisciplinary Natural Science Research Facility comprises of laboratories that are devoted to cell culture, microbiology, bioengineering, general biomedical, analytical, synthetic chemistry, and a core mass spectrometry laboratory.

In addition to the investment in laboratories resulting from shared facilities (section 1.3) the University has made a significant investment during the current REF period in expanding the infrastructure and facilities that specifically support our research. Several new laboratories have been built to support expanding research in several areas. The University has invested in a fully equipped additional cell culture laboratory to support the growing need for *in vitro* studies for several fields of research. A new microbiology research

laboratory has been built to support and facilitate the growing number of projects in this area. The laboratory is fully equipped for culturing, preparing, and storing microorganisms. Investment has also been made in building a purpose built molecular biology suite. In addition to these new facilities an existing laboratory has been expanded to provide space for synthetic and preparative chemistry. This now provides the infrastructure to synthesise, purify, and carry out structural characterisation work. Existing space has been converted to house a confocal microscope. All projects within our multidisciplinary research environment can access resources available within our laboratories. Specialist facilities purchased within the current REF period include a recently purchased confocal microscope (£177K), a Biosciences Cell Analyser (£52K), bench top nuclear magnetic resonance spectrometer (£60K) and Fourier transform infrared spectrometer (£30K). The University has also invested in its health science research unit and purchased a material testing unit (£50K) and cardio-pulmonary exercise testing – gas exchange analysis system (£45K). In the previous assessment period, the University has made considerable investment in mass spectrometry equipment including purchasing an LC-MS (£125K) and MALDI-TOF-MS (£335K). These core resources have been utilised for many existing and new projects. This includes the development and application of methods for qualitative and quantitative analysis of biomolecules in a diverse range of sample types. The MALDI-TOF instrument has also been used for characterisation of clinical and environmental strains of microorganisms and for detection of antibiotic resistance both in house and by our collaborators from Kings College London, Public Health England, University of East London and Tokyo Women's Medical University. To complement the existing chromatography and spectroscopy facilities further investment has been made to extend the analytical instrumentation which include a capillary HPLC with Q Exactive high resolution mass spectrometer (£300K). This instrument has been used in numerous proteomics studies to investigate protein expression, regulation, function and post-translational modifications such as glycosylation. This has also led to collaborative work with the Institute of Neurology, University of London, Kings College London and University of East London. Recently a HPLC with triple quadrupole mass spectrometer (£200K), HPLC with diode array detection (£30K) was added to the suite of mass spectrometers. Investment has also been made to replace equipment that was damaged or past its useful date (£230K). These investments have provided support for a wide range of internal and collaborative projects. They have also provided opportunity to embark on new projects, foster new collaborations and apply to more funding calls.

Our close collaboration with the London Sports Institute and Saracens Rugby has allowed some of our research facilities to be accommodated at the Allianz Park stadium as part of the £22.9 million development of the West Stand. This investment will facilitate further and closer collaborations.

4. Collaboration and contribution to the research base, economy and society

In the current REF period we have extended and increased research collaboration within the University and externally, with academic, industrial and health care partners, including the NHS, which forms a central tenet of our research strategy. Our researchers now have a well-established partnership with colleagues in Computer Science which has been fundamental in developing algorithms for the medical imaging technology that we have developed. From this, we have established effective collaborative research with partners at University College London and Dartmouth College in the USA for the application of this technology. We have also established collaborative links with several industrial partners

based on this research. This includes Printed Electronics Ltd and Emergex Ltd. Similarly, internal collaboration underpins work to investigate the use of nanoparticles as targeted treatment/delivery agents with the team working with Midatech, a biotechnology company translating its proprietary gold nanoparticle drug delivery platform into nanomedicines. As a result of this work, a bioimpedance device has been developed which produces real-time data of clinical relevance. Pilot data suggests that it is able to discriminate between benign and malignant tissue and clinical trials are planned.

Our collaborations also extend to other applications including virus detection. Currently we are engaged in a research project supported by the Royal Society UK in collaboration with Leicester University and Nanjing University of Science & Technology for Human papillomavirus virus detection using super-resolution microscopy and deep learning. This collaboration aims to develop and launch a novel, rapid and non-invasive method for screening and monitoring specific virus-related diseases for early diagnosis and management.

We are working with several hospital departments to identify novel glycan biomarkers for the prediction of pre-eclampsia. Our partners here include Kings College London, University of Auckland and Iduron Ltd. As a result of this collaboration we have identified a series of candidate biomarkers which show good specificity and sensitivity (PPV>60%). We are currently filing patents for these and arranging large scale studies to validate these promising results. We are also utilising our expertise in glycan research in a collaboration with the University of East Anglia and University of Oxford to identify the role of specific glycans in immunomodulation. Our glycan research also extends to examining potential glycan biomarkers to identify cancers at an early stage which we do in partnership with the University of Poznan and Maria Sklodowska-Curie Institute – Oncology Center. Indeed, we collaborate widely on a range of cancer projects. Our researchers are working with Imperial College, the University of Glasgow, The University of Adelaide and University of Dublin on a project aimed at discovering novel biomarkers that will identify patients who later will develop resistance to first line chemotherapy drugs for ovarian cancer treatment. As a result of this work we have characterised a resistance profile for ovarian cancer tissue from over 250 patients and identified candidate biomarkers that show unique expression in chemoresistant cancers. This ongoing exchange means that we are now a centre of excellence in several research areas including models of chemoresistance in cancer and clinical applications of mass spectrometry and electrical impedance tomography.

Our unit also leads two projects with Queen Mary University of London and the London Spinal Cord Injury Centre, Royal National Orthopaedic Hospital aimed at identifying early detection and intervention methods for pressure ulcer prevention in people living with spinal cord injury. Researchers in our unit are also engaged extensively in work with Public Health England in several key areas. These include identification of mechanisms of antibiotic resistance, novel methods for detection of norovirus in clinical samples and variation in bacterial species from different clinical units across the UK. As a result of the work on antibiotic resistance we have identified a means of rapidly detecting peptide produced MRSA that can be used to identify strains of *Staphylococcus aureus* that are methicillin resistant.

Other ongoing cancer research collaborations include work with the 1st Affiliated Hospital of Harbin Medical School (China) on arsenic trioxide as a treatment for HPV-correlated

cancers (**Drs Wen** and **Ghali**). New collaborations between Middlesex and two pharmaceutical companies (Life Science Group and Proxima Concepts) were established based on developing a patented orally delivered HPV vaccine (**Roitt** and **Wen**). Further collaborations with University Rey Juan Carlos of Madrid and the Institute of Odontology at Goteborg University and in association with Proxima Concepts also extended to projects on synthesizing biomolecules to target hCG secreting cancers and HPV associated cancers (**Prof Bayford**, **Drs Outram** and **Wen**).

Within the area of Global Public Health we collaborate extensively and widely. Researchers in our unit are members of the NCD Risk Factors Collaboration and the Global Environmental Health Centre and have worked with the International Agency for Cancer Research Working Group (IARC-WHO) to evaluate links between diet and cancer, the Economic Commission for Latin America and the Caribbean – United Nations to investigate regional trends in adolescent fertility. **Dr Di Cesare** is also a member of the Global Nutrition Report's Independent Expert Group which works to hold national stakeholders to account on their commitments towards tackling malnutrition worldwide and a member of the World Heart Federation Emerging Leaders 2018 Programme. As a result of this work, Di Cesare and colleagues presented their Global Nutrition Report to the United Nations-supported 2019 Scaling Up Nutrition Global Gathering and this report is now used by WHO to monitor progress for the global nutrition targets 2025. In addition, Dr Di Cesare has also coordinated a collaboration of partners worldwide to improve the availability of treatments for atrial fibrillation. This collaboration has led directly to the successful inclusion of non-vitamin K anticoagulants (NOACs) for the treatment of non-valvular atrial fibrillation (NVAF), into the 2019 WHO Model List of Essential Medicines (EML).

Support for our collaborations

The faculty supports research collaborations, partnerships and public engagement with research across the different layers. Overall leadership for research and collaboration comes from our Research Director Prof Richard Comley and is supported by our Deputy Dean for Research Prof Balbir Barn. Between them they have many years of research leadership experience at a high level. At a unit level, senior researchers provide dedicated support in relation to our research themes. Within each research theme senior and mid-career researchers provide leadership to develop collaborative, interdisciplinary and relevant research areas. Research groups hold regular meetings to discuss their research and exchange research ideas. Staff increasingly work across these themes in the pursuit of interdisciplinary research. A staffing strategy that combines expanded research activity by existing staff combined with the arrival of new highly research active staff has led to significant strengthening of all these thematic groups.

Open data

Middlesex University is committed to an open data environment. This is evident from activities in our unit of assessment. As part of our bioimaging research we contributed to the largest freely available data store for EIT clinical data (>50TBytes), the Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software (EIDORS public domain tool, eidors3d.sourceforge.net/). This has been utilised internationally in the development of imaging solutions to clinical problems including for neonatal lung function analysis as detailed in one of our impact case studies.

We have led the development of the freely available World Health Organisation metabolic risk factor database for non-communicable diseases. This is part of the WHO Global Health Observatory used by governments and other international organisations for health policy development in assessing the effectiveness of disease prevention worldwide. In addition, we regularly use our research data to update publically available gene databases including GenBank.

Engagement with society

Each year we work with thousands of school students across the country, delivering activities, talks and events designed to increase understanding of higher education study, research and career opportunities. We do this in many ways. Every year Middlesex University hosts the MDXSTEM festival. This event welcomes school children and the local community to the exciting world of science at our University. In 2018, staff and PhD students attended Thorpe Park for its first ever Middlesex Science Week with over 20 STEM activities for school children from across London. We have also been leading a yearly event called "Mayor of Enfield Science Award 201X - Biology Challenge" since 2016 in collaborating with schools from Enfield borough.

Each year, our researchers are involved in New Scientist Live, an event which introduces children and adults to the wonders of University science. We are passionate about promoting Women into Science within our local community and are involved in many activities in this area. For example, in May 2019 staff presented at the Women in Science Careers Event at Queen Elizabeth's School Barnet. In the same year we hosted an International Union of Pure and Applied Chemistry Women's breakfast events to engage and expand their networks. In March 2020 we hosted our Biomedical Science International Week. We hosted 30 staff and students from 4 Universities across Europe. The aim was to facilitate short-term student mobility between partner institutions to improve the students' teamwork as well as language and cross cultural and communication skills.

Professional Engagement

External Engagement

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 University College London (**Prof Roitt** - Emeritus Professor, **Prof Bayford** – honorary Senior Lecturer, **Dr Outram** – honorary Associate Professor), Imperial College (**Prof Dilworth** - Honorary Reader, **Dr Hills** and **Dr Casimir**, Honorary Senior Lecturer) and **Prof Shah**-King's College London-Honorary Associate Professor). Staff also regularly examine PhDs at other institutions within the UK and overseas including Imperial College, University College London, City University of London, Kingston University, the University of Leeds, University of Sheffield, and Queens's University of Belfast amongst others.

Unit members have been invited to deliver key presentations at international conferences and symposia. These include keynote lectures at the University of Cambridge, Nanjing University of Science & Technology and the European Conference of Paediatric & Neonatal Mechanical Ventilation and at the Shanghai International Congress on Orthopaedic Advanced Techniques and Clinical Translational Research. We have also given television

interviews about our research. For example, **Prof Bayford** was interviewed by a German National Science TV programme to talk about the impacts from our nanotechnology projects by using novel imaging detection system on international industrial and research communities. In addition, **Dr Di Cesare** has given many interviews on national and international radio and television about our work fighting childhood and adult obesity. For example, on BBC World, BBC Radio 5 live, CTV news and La Republica (2017).

Staff in our unit (**Prof Shah**) have co-hosted, in partnership with Public Health England, several international conferences and workshops held at Middlesex University on Proteomics and Genomics. In addition, we have organized a China-UK joint workshop with Dalian University and Southwest Jiaotong University in China on design surgical implants.

Internal engagement

Our research environment is strengthened through regular seminars to allow our staff to engage with students to exchange and develop ideas. A Biomedical Science Journal club runs weekly allowing the staff of UoA3 and their PhD students to share knowledge on a recent journal article. Our weekly departmental seminar series features regular contributions from our staff and from outside institutions. Recent key collaborators who have presented include Dr. Tammaryn Lashley from University College London, Andy West, Head of Imaging at GlaxoSmithKine (**Prof Shah**) and Prof Janice Aldrich-Wright from the University of Western Sydney (**Dr Stordall**). We have integrated these activities into our teaching timetable to enable staff and MSc students to attend. A strategic aim of the unit has been to develop collaborations through the exchange of research students. Through the Erasmus programme we have developed exchange partnerships with Uppsala University (**Dr Hills**), the University of Lund (Sweden) and the University of Kiel (**Dr Ring**).

Engagement with Professional bodies

Submitted staff also make recognised contributions to the discipline through learned societies, professional associations and other bodies. These include: **Prof Roitt** - elected Fellow of the Royal Society and a Fellow of Balliol College, Oxford; **Prof Bayford** – Fellow of the Institute of Physics, Institute of Physics, Engineering and Medicine, and the Society of Biology; **Dr Appiah** – Fellow of Royal Society of Chemistry; a member of Royal society of Biology; **Prof Dilworth** – member of the European Association for Cancer Research, British Cell Biology Society and American Society for Microbiology (ASM); **Prof Shah** – Fellow of the Royal Society of Chemistry and the Chromatographic Society, **Drs Wen** and **D.Li** – member of the European Association for Cancer Research ; **Dr Casimir** - member of the British Society for Gene Therapy; **Dr Hills** Member of the Biochemical Society.

Journal Editorships

Professor **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. **Prof Roitt** is on the Editorial Board of Current Opinion in Immunology, **Dr Wen** for the Journal of Fertilization: In vitro. **Dr Di Cesare** is associate editor of the International Journal of Public Health, Notas de Poblacion and Revista Economía de la Salud-Chile.

Grant review

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. In addition, a member of our unit (**Prof Bayford**) is an ESPRC College member. Others are grant reviewers for Research Executive Agency (EU) for Academy of Medical Sciences (**Prof Dilworth**) as well as for MRC, Children with Cancer UK, and the Bone Cancer Research Trust (**Dr Roberts**).

In summary, by utilising our diverse research base we have had an enormous impact. Our strategy moving forward focusses on our unique strengths and will certainly ensure a sustainable future for our unit and its capacity to solve important global problems. We have evidence of this already. After our submission to the current REF our unit (**Drs Di Cesare and Burczynska)** has been awarded funding for a £2.8M multi-centre study to detect SARS-CoV-2 virus in the wastewater of schools to provide an early warning system of infection levels. This endeavour involves many UK partners including Test and Trace's Joint Biosecurity Centre, University of Bath, Imperial College London, and The London Assembly Health Committee. The study has begun collecting evidence on the safety of schools reopening and additional insights on transmission of coronavirus from children-to-children and children-to-adults. As part of the same project we are leading a pilot study with Her Majesty's Prison & Probation Service (HMPPS) of this approach in prisons, to improve health outcomes of prisoners, staff and the public. We have currently provided evidence of the feasibility of this approach in schools and based on our work the DHSC is currently embedding wastewater surveillance in schools into the national wastewater surveillance. Data collected and analysed in prisons are currently used by HMPPS to identify outbreaks and trigger mass testing in UK prisons.