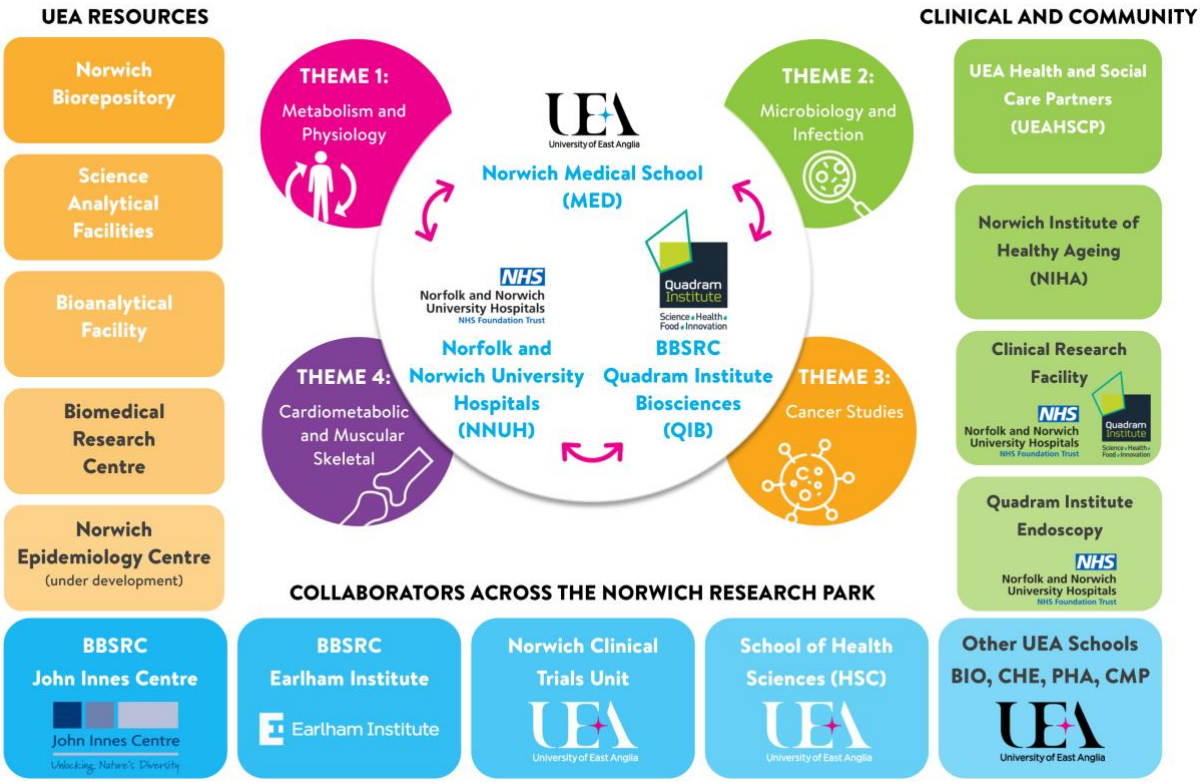
Institution: University of East Anglia

Unit of Assessment: 1 (Clinical Medicine)

1. Unit context and structure, research and impact strategy

1.1 Unique Context and Structure.

Figure 1. Unit Context and Structure



Our REF2021 return for Unit of Assessment 1 (**UoA1**) comprises 38 staff (38 staff, 30M:8F, 30.6 FTE) who work across two institutions:

- **Norwich Medical School** (UEA-MED: 26.4 FTE), which includes thirteen clinical academics working at the nearby **Norfolk and Norwich University Hospital** (NNUH), the **sixth largest acute hospital in the UK**.
- The **Quadram Institute Biosciences** (QIB: 4.2 FTE), a world-class centre for food and gut health established by UEA, NNUH and the **Biotechnology and Biological Sciences Research Council** (BBSRC) in 2019.

This UoA is embedded in the **Norwich Research Park** (NRP), home to

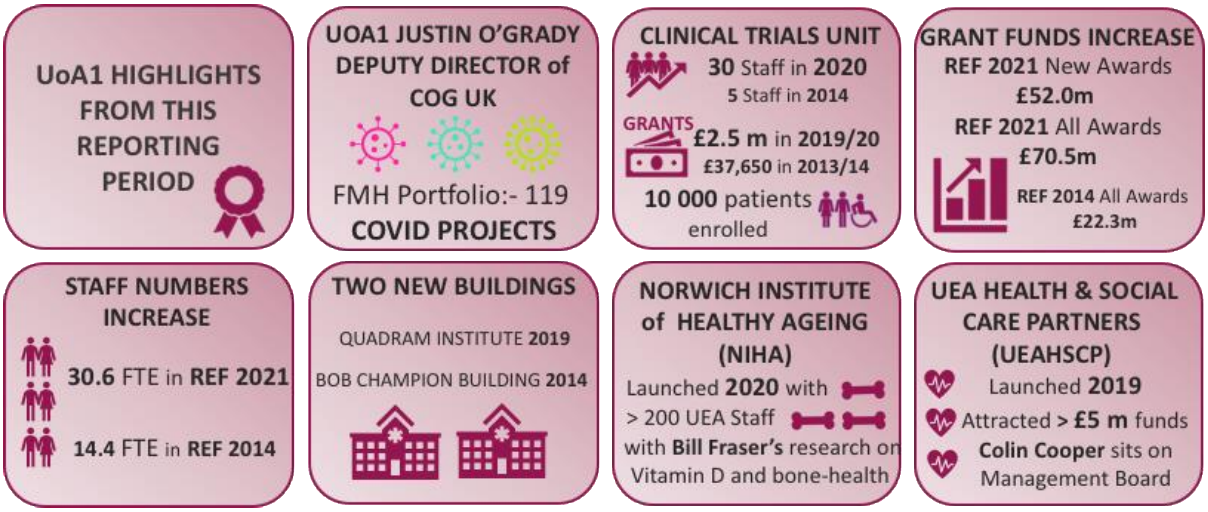
- One of the largest concentrations of life science researchers in Europe, that includes ten of the top 1% most highly cited researchers worldwide, including **David Livermore**[1] from this UoA, and nine Fellows of the Royal Society.
- **The Norwich Biosciences Institutes**, which includes QIB, the Earlham Institute, the Sainsbury Laboratory and the John Innes Centre, stimulating exceptional collaboration opportunities and scientific achievement.

[1] Staff submitted to this Unit of Assessment are highlighted in **BOLD.**

A summary of the Unit Context and Structure is shown in Figure 1. The Norwich Medical School (UEA-MED) and the School of Health Sciences (HSC) sit within the Faculty of Medicine and Health Sciences (FMH). We have developed strong links to our local community through the recent development of the UEA Health and Social Care Partners (UEAHSCP, 2019, Section 4.1) and the Norwich Institute for Healthy Ageing (NIHA, 2020, Section 3.2). Our response to the COVID-19 pandemic has been exemplary. Highlights include **Justin O'Grady** becoming Deputy Director of the UK COVID-19 Genomics Consortium (COG-UK), and **Kristian Bowles**, a UEA-MED employee and Associate Medical Director at NNUH, receiving an MBE for "Services to the NHS during COVID-19".

Our research has strong national and international impact and we value and nurture our excellent industrial links. Building on the successes of REF2014, **UoA1** has developed over this REF period through UEA-MED school investment as well as income-generating success. In a competitive environment we have increased our submitted academic research staff from 14.4 FTE to 30.6 FTE (Section 2.1); and our grant income (active awards) from £22.3m to £70.5m (Section 3.1). We carry out research under four translational research themes as shown in Figure 1: 1. Metabolism and Physiology; 2. Microbiology and Infection; 3. Cancers Studies; and 4. Cardiometabolic and Muscular Skeletal. Outputs from these studies have continued to be published in high-impact journals including Nature, Nature Biotechnology, Nature Genetics, Nature Microbiology, The Lancet, The British Medical Journal, and The New England Journal of Medicine (Box 1).

Figure 2. Highlights of the REF Reporting Period



1.2 Significant progress on past strategic goals for research and impact.

In our REF2014 Environment submission, we set out six goals for the coming five years. Here, we describe the progress we have made against these goals. Highlights of this REF Reporting Period are shown in Figure 2.

Objective 1. *Continue to grow the Unit including recruiting additional Clinical Academics using NHS and university funds.*

Progress: Thirteen **UoA1** staff have contracts with both **NNUH and UEA**, and we have made **five new joint Clinical Academic appointments** since the REF census end date. There are fifteen newly recruited **UoA1** staff (Section 2.1). The Norwich Academic Training Office provides support for academic training across health professions, providing a pathway towards further research (PhD or postdoctoral fellow) and ultimately senior academic positions. Since 2014, **50 integrated academic trainees** have joined the scheme: **44 Academic Clinical Fellows** (33

National Institute for Health Research (NIHR)-funded) and **6 Clinical Lecturers** (3 NIHR-funded). Three **Clinical Lecturers** have been appointed to a Senior Clinical Lecturer post and one has gone back to full SpR Clinical Training. Eight of the **Academic Clinical Fellows** who completed the training have continued with research activities, all but one postgraduate degree was funded by the Wellcome Trust, NIHR or the Medical Research Council (MRC).

***Objective 2**. Increase the flow through the translational pathway of science into clinical practice.*
Progress: Box 1 illustrates our progress with translational research on multiple fronts. Work from **David Livermore** and **Justin O'Grady** provides compelling examples of our progress on the translational pathway, through development of novel diagnostics.

- 2020 saw two new drugs receiving approval for clinical use in antibiotic resistant bacterial infections, as a result of **David Livermore's** research (**Impact Case Study**). These are Fetroja (Cefiderocol - Shionogi ltd) and Recarbrio (MK7655 - Merck & Co. Inc). Both drugs are considered as new antibiotics of last resort. This provides a direct response to the O'Neill report on antibiotic resistant bacteria which states *"We need a better supply of new drugs across a range of diseases where drug resistance is on the rise."*
- **A rapid metagenomics test** developed in 2019 by **Justin O'Grady** to diagnose lower respiratory infections (Box 1) enabled a **rapid and decisive engagement with the COVID-19 crisis** by joining COG-UK and delivering high-throughput SARS-CoV-2 genome sequencing. From April-December 2020, the Norwich site alone sequenced approximately 10,000 SARS-CoV-2 genomes, more than all but four countries in the world during that period (UK, US, Denmark and Australia).

***Objective 3.** Open the Norwich Medical Research Building and establish this as the centre of translational medicine.*
Progress: The £17m **Bob Champion Research and Education building** was officially opened in February 2015 providing state-of-the-art laboratory facilities (Section 3.2). The building is immediately adjacent to the main NNUH building, contains the storage component of the Norwich Biorepository (Section 3.2), and has been home to over half of the researchers returned in this submission.

***Objective 4.** Bring together Clinical Research Facility activity onto one site on the Norwich Research Park.*
Progress: The **NNUH-UEA Clinical Research Facility** (CRF) (Section 3.2) opened in 2019. The facility is housed in the state-of-the-art **Quadram Institute** (See Objective 6) and brings UoA1 clinicians and scientists together with researchers from the wider NRP.

***Objective 5.** Continue to develop aetiological epidemiology and health services research in the key priority areas.*
Progress: Box 1 presents our success in science including aetiological studies from **Andrew Hart** and clinical trials from **Ann Marie Swart**.

***Objective 6.** Collaborate in securing funding for a new £50M Centre of Food, Health and the Gut.*
Progress: Funding from the BBSRC, together with input from UEA, NNUH and the Institute of Food Research, led to the construction of the **£80m state-of-the-art Quadram Institute** (QI), which opened in early 2019 (Section 3.2). In addition to the CRF (See Objective 4), the QI also

houses **Quadram Institute Bioscience** (QIB, successor to the Institute of Food Research) and **Quadram Institute Endoscopy** (QIE)**,** one of the largest gastrointestinal endoscopy units in Europe. The **unique co-location** of these three elements in the same building greatly enhances our ability to carry out translational research (Section 3.2).

Recent years have seen many developments that are **enhancing our ability to do world-class research**:

- establishment in 2019 of the **UEA Health and Social Care Partners**. This is a formal partnership of 12 health and social care organisations with 45,000 staff working across East Anglia and has already attracted £5m of funding (Figure 2, Section 4.1). **Colin Cooper** sits on the UEAHSCP Management Board.
- expansion in early 2020 of the **Norwich Biorepository** funded by a £2.1m grant from BBSRC. **Louise Jones** serves as director (Section 3.2).
- establishment in early 2020 of the **Norwich Institute of Healthy Ageing** (NIHA, Section 3.2).
- rapid growth of the **Norwich Clinical Trials Unit** (NCTU, Figure 2) headed by **Ann Marie Swart** (Section 3.2).

During this period, we have conducted **eight themed reviews** with the objective of integrating UoA1 researchers with common interests in research and impact across the NRP. Our **Bioinformatics Review** has led to collaborations with the Earlham Institute to identify pathogens in human tissue, resulting in UEA (**Colin Cooper**) leading a Genomics England Clinical Interpretation Partnership (GeCIP). Our **Cancer Review** has led to establishment of a **Norwich Cancer Research Network** (now with >140 participants). This network has strengthened links through joint meetings with Cancer Research UK Cambridge Institute and *Cambridge* University Hospitals NHS Foundation Trust.

Since REF2014, we have established and joined international multidisciplinary networks including several **Human Genome initiatives** (e.g. the **Pan Prostate Cancer Group** (**PPCG**, the **International Cancer Genome Consortium** (**ICGC**), and ICGC-ARGO (ICGC Accelerating Research in Genome on Oncology)), bringing together expertise in mathematics, computing, oncology, histopathology, anthropology, epidemiology and clinical trials from multiple countries. We have joined the **East of England NHS Genomic Medicine Centre**, which brings together clinicians from multiple specialities for genome sequencing in human disease. We have also built collaborations across UEA Schools and Faculties including the **£1.8m CHIPPS study** (Care Homes Independent Pharmacist Prescribing Service) linking **UoA1** staff **(Ann Marie Swart**) to the School of Health Sciences (HSC) and Pharmacy (PHA).

In recent years, we have also **boosted research impact** through appointment of:

- an **Associate Dean of Innovation** (Michael Hornberger) who sits on the FMH Executive and is responsible for developing and overseeing enterprise links.
- an **Academic Director for Innovation** (Laura Bowater) who actively supports impact and engagement.
- **two impact champions** in UEA-MED responsible for identifying new impact cases. Cases are reviewed annually at the Faculty and PVC level. Of nine Impact Cases developed, three were selected for this submission (**Helen Murphy**, **David Livermore**, **Yoon Loke**)**.**

- a **Royal Society-funded Entrepreneur-in-Residence** (David Dent), former Chair of the BBSRC Follow-on Fund panel.
- **an impact manager** within QIB who works within the QIB Knowledge Exchange and Commercialisation team.

Our objective is to ensure that delivery of impact is an integral component of our ongoing research activities. We have therefore highlighted the **importance of the impact of our research** through

- rewards for Research and Impact made available through two new annual events: The FMH Faculty Prizes and the UEA Impact and Innovation Awards. In 2020, **Helen Murphy** won the UEA prize for Outstanding Impact in Health, Wellbeing and Welfare. In 2018 **Dmitry Pshezhetskiy** received the FMH Best Innovation Prize.
- inclusion of impact within staff annual assessments
- encouragement of staff to pursue local **Proof of Concept Funding** (up to £20,000), and **Innovation Development** Funding (up to £75,000) in exceptional cases to pursue industry-related UKRI funding, consultancies and iCASE PhD studentship funding. Since 2014 staff from this unit have been awarded £69,910 Innovation Proof of Concept Funding, and £167,200 Innovation Development Funds. **Examples: John Wain**, £19,210 for Diagnostic for Prosthetic Joint Infection**. Colin Cooper**, £69,960 for Prostate Cancer signature biomarkers**; Dmitry Pshezhetskiy**, £31,123 for nanoparticles targeting in prostate; and **Justin O'Grady**, £66,149 for validation of a patented host nucleic acid depletion strategy.
- pursuit of commercialisation opportunities by filing patents to protect our intellectual property with 13 patent applications, and two licensing agreements in the assessment period.
- active encouragement of staff to pursue industry-related UKRI funding and consultancies. For example, **William (Bill) Fraser's** research and development expertise in Bone Health and Clinical assays has generated £687,000 of consultancy income. **David Livermore** was seconded by Public Health England for 1.5 days a week for six years generating additional income
- holding **presentation and writing workshops** on impact case studies. For short-listed cases, individual writing, evidence sourcing and resourcing meetings have been held two-monthly since mid-2019.

Box 1. Our six-year narrative of success

This list of research highlights from **UoA1** is illustrative not exhaustive

Theme: *Metabolism and Physiology*

- In 2017, **Helen Murphy** reported that continuous glucose monitoring in pregnant women with diabetes results in better clinical outcomes, leading to a last-author paper in ***The Lancet*** cited >200 times (Scopus) (10.1016/S0140-6736(17)32400-5), an **Impact Case Study**, and a change in **NICE Guidelines**.
- **Kristian Bowles** showed how transfer of mitochondria to blood stem cells aids rapid response to infection in mammals (***PNAS***, 10.1073/pnas.1913278116).

Theme: *Microbiology and Infection*

- **Justin O'Grady** has pioneered the use of **nanopore DNA sequencing** for diagnosis of respiratory infection (***Nature Biotechnology***), including COVID-19 (10.1038/s41587-019-0156-5).
- **David Livermore** has carried out work leading to the development of new antibiotics of last resort and to UK guidelines for managing patients with AMR (**Impact Case Study**). His achievements have been honoured in 2018 by award of the **Garrod Medal** from the British Society for Antimicrobial Chemotherapy.
- **Kevin Tyler** has documented the evolutionary genomics of human cryptosporidiosis, a leading protozoan cause of diarrhoeal mortality worldwide (***Nature Microbiology***, 10.1038/s41564-019-0377-x).
- **Changjiang Dong** reported the structural basis of outer membrane insertion in bacteria, suggesting new antibiotic targets (two papers in Nature, 10.1038/nature13464 and 10.1038/nature17199).
- **Yoon Loke** identified underreporting of adverse events in systematic reviews, leading to change in Regulatory Guidelines: his methods form the basis of how UK Government calculates COVID-19 death rates (**Impact Case Study**).

Theme: *Cancer Studies*

- **Colin Cooper** has used whole genome DNA sequencing (i) to unravel the evolution of human prostate cancer (***Nature***, cited >600 times, 10.1038/nature14347 and two papers in ***Nature Genetics*** 10.1038/ng.3221 and 10.1038/s41588-018-0086-z) and (ii) to map the landscape of viral associations in human cancers (***Nature Genetics***, 10.1038/s41588-019-0558-9).
- **Ann Marie Swart** reported advances in **chemotherapy for ovarian cancer**, including improvements in outcome with pre-surgical chemotherapy (three ***Lancet*** papers, one as last author with >700 citations 10.1016/S0140-6736(19)32259-7, 10.1016/S0140-6736(15)01167-8, and 10.1016/S0140-6736(14)62223-6).
- **Andrew Hart** found that **statin** use protected against death in **oesophageal cancer** (***Gastroenterology,*** 10.1053/j.gastro.2015.12.039).

Theme: *Cardiometabolic Disease and Muscular Skeletal Disease.*

- **Marcus Flather** has published five ***NEJM*** and seven ***Lancet*** papers with combined citations of over 6000. Five are returned including a ***NEJM*** paper showing that **bilateral versus unilateral internal-thoracic-artery grafts** had no effect on survival at five years, but there was higher complication rate with bilateral grafts (***NEJM***: 10.1056/NEJMoa1610021).
- **William Fraser** has detected pathogenic changes for **Paget's Disease** in archeological bone specimens (***PNAS***, 10.1073/pnas.1820556116).

1.3 Future strategic aims and goals.

Our partner the NNUH is a busy 1,200-bed teaching hospital and foundation trust providing care to a population of around one million people from Norfolk, neighbouring counties and national referrals to recognised experts. Many of its services are amongst the largest in the country (e.g. the 5th busiest NHS cancer service in England). We intend that a key overall output of our future strategy will be to liberate the substantial as-yet unrealised potential to carry out **world-leading translational research and clinical research** within NNUH, linked to the QIB, to other key NRP partners and to external partners. Our Research Strategy for achieving this builds upon all four **Medical Research Council (MRC) Research Foundations**: ***Discovery Science***; ***Investing in People***; ***New Technologies***; ***Fostering Collaboration***, while also developing structures and links to maximise the impact of our research. Building on our 2014 submission and upon the four research Themes shown in **Figure 1** and **Box 1** our Research Goals are:

Goals:

- to expand our translational and multidisciplinary research programme, targeting key global and national health problems
- to create a research structure than can respond effectively to crises
- to ensure the impact of our research in the local community.

To achieve these goals we have set the following ten objectives over the next six years

Objectives:

1. establish a **Norwich Translational Research Centre** to co-ordinate research assets across the NRP, strengthening links to the NNUH and to the regional community.
2. make a decisive contribution to the **Norwich Institute of Healthy Ageing** (Section 3.2) by, for example, linking the work of **William Fraser** on **Vitamin D**, whereby the fundamental/efficacy research will be translated into community health benefits and product and services innovation.
3. contribute to a new NNUH Proposal to establish a **National Centre for Monitoring, Prevention and Control of Infectious Disease Outbreaks,** building upon the past work of **Justin O'Grady**, **John Wain** and **David Livermore.**
4. strengthen research collaborations between the QI, NNUH and UEA-MED fully exploiting the potential of the **Quadram Institute Endoscopy** (QIE, Section 3.2).
5. set up a **Norwich Epidemiology Centre** to facilitate and enhance analyses of existing and developing NRP datasets (e.g. from QIE, and from NNUH data via the **Cogstack** platform), to streamline access to publicly available datasets (e.g. UK Biobank, CPRD, ELSA, EPIC and ECLIPSE), and to enhance our ability to mine and utilise Big Data including Genomic Data. This initiative includes staff from the UEA School of Computing Sciences with expertise in Artificial Intelligence.
6. improve links to external partners, including expanding existing links to the **University of Cambridge,** to Cambridge Hospitals, and to **The Sanger Institute**.
7. to grow our capacity to support **Early Career Researchers** and **Clinician Scientists** engaged in biomedical research, improving recruitment and facilitating career development.
8. continue to increase our funding for **postgraduate research**: for example, via our MRC DTP application *Microbes, Microbiomes and Bioinformatics*, through Wellcome Trust and BBSRC funding, through charitable funding, and by continuing to invest in faculty provision for PhD students.

9. improve postgraduate training in translational research and in data management and informatics.
10. strive for best practice in equality, diversity and inclusion, building on our **Athena SWAN Silver status** to achieve Gold status (Section 2.4).

1.4 Our approach to openness, reproducibility and integrity in research.

Outputs are uploaded within three months of acceptance to the UEA Digital Repository allowing external access in compliance with REF requirements: 100% of this unit's submitted outputs are open-access compliant. We also make data available through international data repositories. For example, in the NCBI's nucleotide database there are over 30,000 sequences linked to UEA-MED. An example of data availability is provided by the large **ICGC Prostate Cancer** whole genome DNA sequence dataset (**Colin Cooper**). This was deposited at European Genome-phenome Archive (EGA) and has been used as part of the international PCAWG study. These datasets have now been used in over 40 publication relevant to prostate cancer. During the REF period we have enthusiastically exploited **BioRxiv.org** and MedRxiv.org to make information available prior to acceptance, with over 150 manuscripts from UEA-MED and QIB released to these preprint servers during the census period.

Researchers are strongly advised to register clinical trials and over two dozen from UEA-MED are listed on clinicaltrials.gov**.** In line with NIHR requirements results of trials are made available through publication in peer reviewed journals and NIHR monographs. Requests for access to individual patient data from trials in NCTU are considered by the relevant trials oversight committees or by the Chief Investigator and NCTU Executive Committee if the trial has completed.

At University level (see REF5a) UEA maintains a Research Integrity Office and is a signatory of the revised 2019 Universities UK *Concordat to Support Research Integrity and the Concordat on Openness in Animal Research*. In 2018, the University revised its Research Ethics Policy and all staff are held to its requirements. At unit level, research integrity and ethical standards are ensured via numerous mechanisms:

- revisions to the UEA level policies are highlighted in our weekly UEA-MED bulletin circulated by the Head of School.
- research involving human subjects and tissues is reviewed as appropriate by the FMH Ethics Committee and/or by the NHS Health Research Authority.
- A strong emphasis on the importance of research integrity and ethics is included in induction of new research staff and students.

UEA Animal Welfare and Ethical Review Body reviews all animal research applications.

2. People

2.1 Recruitment. We have pro-actively made **fifteen new appointment**s among the staff submitted from **UoA1**, who will remain during the next REF period and provide continuity of success as senior staff retire. **Efficiency and fairness** in recruitment are ensured by regular mandatory in house training in e.g. *Recruitment and Selection*, *Diversity in the Workplace* and *Unconscious Bias.* In addition, **all recruitment and marketing** material have been overhauled to **represent diversity and promote inclusion in our workplace**. Emphasis is placed on recruiting **Early Career Researchers** (ECR) and **Clinical Academics** based on research potential and realisation, strategic fit with our Four Themes and synergy with our NRP partners.

Details of New Academic Teaching and Research (ATR, team leaders) staff are shown in Figure 3. Reflecting the critical importance of translational links to the Norfolk and Norwich University Hospital (NNUH) and in line with our future research objectives, **thirteen of our 38 staff have contracts with both UEA and NNUH**, with five new joint NNUH-UEA **Clinical Academic appointments** since the REF census date. We are supporting, by mentoring and collaboration, over twenty research-active NNUH employees across the local region and, during the coming REF period, will put in place a more formal structure for supporting **translational research (Section 1.3). Four ECR are on fixed-term contracts** (**Darrell Green**, **James Mackay**, **Katharina Mattishent**, **Johannes Reinhold**) with review at 3-5 years. **Dmitry Pshezhetskiy** and **Max Yates** have moved from fixed-term to permanent contracts.

We have a strong record of **supporting career progression** with four new non-clinical academics being appointed from internal applicants in an open and transparent recruitment exercise: two returned in UoA1 (**Donnie Cameron**, **Darrell Green**) and two who, although arising from clinical medicine, have been submitted with other UoAs (Daniel Brewer, UoA20; Stuart Rushworth, UoA5).

For **Induction and Mentoring** new recruits at all levels receive a welcome pack, introductory online training (e.g. Data Protection (GDPR), Health & Safety, Fire Safety etc), familiarisation tours, and meetings with more senior managers. The objectives are to agree responsibilities and highlights opportunities for staff training and development. ATR and Research Associate (RA, Section 2.2) staff are assigned a career mentor.

Figure 3. New Academic Teaching and Research Staff include:

4 New Lecturers	2 New Clinical Lecturers	3 New Associate Professors
Donnie Cameron[a] Benjamin Evans Darrell Green[a,b] James Smith[a] 4M:0F	Katharina Mattishent[a,b] Johannes Reinhold[a,b,c] 1M:1F	Linda Troeberg Paul Crichton[a] Mark Webber 2M:1F
3 New Clinical Associate Professors	**1 New Professor**	**2 New Clinical Professors**
James Mackay[a,b] Vassilios Vassiliou Max Yates 3M:0F	Nicole Horwood 0M:1F	Louise Jones Helen Murphy 0M:2F
[a] Staff meeting the definition of ECR (7); [b] Fixed Term appointments (4); [c] NIHR Clinical Lecturer		

2.2 Staff Development. Progress, support and career planning are monitored and implemented by a dual system of annual appraisal and of research activity planning and reporting.

Annual Appraisals are **supportive and reflective** and carried out by the line manager (or alternative at the appraises request). Future objectives are agreed; assessment of issues that

hindered progress along with suggested solutions are discussed. Training requirements and career progression steps are identified.

For each researcher in UEA-MED **Research activity planning and reporting** is carried out with the Director of Research (Lee Shepstone, UoA2) who reports to the Associate Dean for Research (**Colin Cooper**) and the PVC for Research and Innovation (Fiona Lettice). This process provides a strategic overview of PhD supervision, grant activity, research impact, and outputs. For QIB, reporting is to the Institute's Science Strategy Board. Research activity reporting informs the development of strategic research objectives, and more recently on the impact of COVID-19.

For career progression, staff have access to over forty **on-site career development courses** provided by the Centre for Staff and Educational Development and since Sept 2016 have benefited from **development funds** (~£650 per person p.a.) to support external training and conferences. Since 2014, staff have been able to attend annual promotion workshops and speak to a promotion mentor to facilitate the promotion process. The success rate for internal promotions within UEA MED as a whole was 84%. Within **UoA1** there have been three promotions to Senior Lecturer, two to Clinical Professor, one to Professor, one to Professorial Research Fellow, and two promotions to Senior Clinical Lecturer on appointment.

We currently have nineteen **Research Associates** (10F:9M) who are integral to UoA1 research activities. Since 2016, we have implemented *Best Practice Guidelines for research associates* based on the *Concordat to Support the Career Development of Research Staff*. Our research associates have **protected time** (5 days p.a.) to develop career aspirations, attending career and grant writing workshops and conferences. From a dedicated fund for staff development beneficiaries within **UEA-MED received an average of £920 funding, since 2016,** to support career development including training opportunities and conference fees and travel costs. Bridging funding is available to bridge gaps between funding and, since 2018, we have offered relocation expenses to research associates. **A survey carried out in 2018 found that 74% of our research associates reported that UEA-MED is a satisfying place to work.** Within QIB the **Quadram Institute Post-doctoral Society (QIPS)** is open to and run by post-docs (also open to PhD students). QIPS also runs fortnightly Coffee Break informal sessions for its members (currently Zoom).

Early Career Researchers (ECR) (1F:6M) receive support where appropriate reflecting their central role in the strategy, culture and success of the school. Start-up packages were given in cases where kick-starting was appropriate. Major awards include PhD student to **Paul Crichton**, **Darrell Green**, and **James Smith** and equipment/consumables to **Paul Crichton**, (£101k) and **Darrell Green**, (£95k)**.** ECR are encouraged to join supervisory teams for PhD students in other groups. They are required to achieve a Postgraduate Certificate of Higher Education Practice, and have reduced teaching for up to 24 months. **ECR are** mentored on writing and submitting grant applications by staff experienced in grant capture and are encouraged to attend training on grant writing and research supervision.

2.3 Postgraduate Research Students (PGR). UEA takes pride in the delivery of doctoral training and research and is involved in **seven prestigious DTPs** and Centres for Doctoral Training, three open to **UoA1** supervisors. Our successes are:

- our highly successful **MRC Doctoral Antimicrobial Research Training** (DART) iCASE programme has provided studentships for **Penny Powell**, **John Wain**, and **Justin O'Grady**.
- Wellcome's recently funded **DTP EDESIA: plants, food and health**: a new cross-disciplinary PhD programme from crop to clinic has provided PhD studentships that are rotating through the laboratories of **James Mackay** and **Linda Troeberg**.
- the well-established **BBSRC NRPDTP,** now in its third incarnation—the previous programme hosted >165 PhD students. Successful student projects have been supervised by **Tom Wileman** and **Mark Webber**.
- **Kristian Bowles** was awarded a Wellcome Trust clinical PhD studentship through a programme run by the University of Cambridge.
- since REF2014, we have increased **the annual number of new registrations** over five-fold for PhD, MPhil, MDs and MScR (Master by Research) degrees within **UoA1** (from three in 2014/15 to 16 p.a. in 2019/20), with 45 new registrations in total. Total postdoctoral degrees awarded increased from one in 2013-14 to 16 in 2018-19, and to nine in 2019-20.

Additional funding sources include NIHR, Ministry of Defence, Asthma UK Centre for Applied Research, Oxford Nanopore Technologies Ltd, Versus Arthritis, Defence Science and Technology Laboratory, Big-C, and Prostate Cancer UK.

Measures to improve the success of our postgraduate research programmes include:

- Use of an application platform, Target X, which allows use of mobile phones and tablets.
- **Fully funded PhD students by FMH (Faculty) and UEA-MED** including for ECR. There were internal competitions in 2019 and 2020, continuing during the COVID-19 crisis: nine funded in **UoA1.**
- **Match-funding studentships**: with funding at 50% for an additional nine PhD studentships.
- March 2019 saw the launch of **UEA's Doctoral College,** with its own academic and social space, to oversee the management, training and co-ordination of activities for all postgraduate students at UEA.
- A dedicated Associate Dean of PGR in FMH, **Penny Powell.**

The training pathway for postgraduate researchers is informed by the **VITAE-Researcher Development Framework**. A collaborative training needs analysis is made with the supervisor eight weeks after appointment and revisited every year. Each student has access to over 40 modules as well as a training budget of £1000. Students are encouraged to develop teaching skills and can be employed as undergraduate associate tutors. **The Doctoral Training and Employability Group (DTEG)**, reporting to the Doctoral College Executive, meet every month to discuss employability development. They monitor student feedback as measured through Postgraduate Research Experience Survey (PRES). In 2019, 85% of students were satisfied with their experience of a research degree program. PGR students can participate in **i-Teams**, gaining experience outside of academia with training in commercial awareness. UEA has two career advisers dedicated to working with PGR students, including providing training sessions on "Self-awareness and Exploration", "Applying and Doing" and "Launching".

Our Research Students Forum captures students' views, needs and feedback and has led to a number of new initiatives, including lunchtime monthly **Bitesize seminars** with pizza and drinks provided. We provide a weekly **Breakfast Club** for networking, as well as an annual high profile

external speaker event and an annual FMH PGR conference. Within QIB Quadram Student Forum provide a student voice and helps integrate new and visiting students into the student body.

Originating from an **anonymous PGR student survey called the Honesty project** in 2015, UEA developed a comprehensive mental health strategy, the **COURAGE project**, which received £300K in external funding matched by UEA. In 2018 the COURAGE Project piloted new approaches to prevention, intervention and cultural change around **mental health and wellbeing among PGRs**. It is led by UEA and linked with UEA's Student Union and other partners. There were six strands with ten paid placements. An example strand is "The Lakeside View: PGR blog".

2.4 Equality, Diversity and Inclusion. This UoA1 submission is 30 male and 8 female staff**. This represents a fourfold increase in female staff since 2014** when only two female staff were submitted. QIB is a signatory to the Athena SWAN Charter and in 2019, UEA-MED renewed its **Silver Athena SWAN Award**, with an application cited as an **exemplar to be shared among other Medical Schools**. Feedback also stated that

"*The panel commends and encourage the school's continuing Athena SWAN work and note the beacon activities in the further information section. The panel recommends the school continue sharing good and exemplary practice in looking ahead to Athena SWAN Gold."*

Equality and diversity training and unconscious bias training are compulsory. There is ongoing monitoring of equality and diversity for membership of UEA-MED management committees, key roles including committee chairs, access to infrastructure resources, membership of recruitment panels and written material. The current average gender balance of our management committees is 47.6% female (range 33% to 67% female).

To address **gender issues in promotion and rewards**, since 2014, we have provided annual **Promotions Master Classes** for all staff with the intention of **encouraging and supporting females to apply for promotion**. As a direct result of attendance, we have **had 15 successful applications across FMH (13F:2M)**. **Female promotions** include five professorial appointments and eight Senior Lecturers with one of these in **UoA1**. There is regular signposting of policies on maternity/paternity and adoption leave and family friendly and flexible working. There was one request within **UoA1** for flexible working during the assessment period, which was granted.

The highlights of improvements in gender equality during this REF period are shown in Figure 4. The results of our commitment to supporting our female staff is evidenced in recent surveys (2019) of UEA-MED. Staff believe they have been **well-supported in preparing for maternity leave** (73% compared to 60% in 2016) and for **when they return to work** (60% compared to 50% in 2016). Female employees involved in research have access to ResNet, a contact, support and information network for women. ResNet promotes career development, provides inspiration and raises awareness of employment opportunities for women in research. Staff on maternity/adoption leave are encouraged to attend stay-in-touch days. After their return to work, they receive a **light teaching/administration load** for the first semester and are offered **flexibility in their hours**. They also have access to **breastfeeding rooms** and to a

Supporting-All-At-Work Fund that supports conference attendance, and career development opportunities.

Figure 4. Equality and Diversity Improvement in this REF Period to 2021

UEA-MED has appointed Dr Joanna Semlyen as (i) Lead for Diversity and Inclusion to address issues of inclusion across all protected characteristics, and (ii) Chair of a newly constituted **Black Asian and Minority Ethnic (BAME) Working Group**. Projects that have been prioritised include (i) Bystander Intervention Training which addresses racism, microaggressions, sexism and trans/homophobia, and (ii) interventions to improve BAME mental health and improve mental health services for BAME students. Dr Semlyen held events in 2019 and 2020 to discuss differential attainment and solutions, and with vital input from two paid BAME ambassadors and UEA-MED alumni deliver ongoing anti-racist work within the School. UEA-MED has signed up to the BMA Charter on racial harassment.

The REF2021 preparations followed the *UEA REF2021 Code of Practice* principles of **maintaining fairness and eliminating bias**: personnel involved in leading submissions were required to undertake a **course on Unconscious Bias**. Applications for Independent Researcher status solicited by an open call were assessed against REF2021 approved criteria. Outputs and Impact Case Studies have been selected after iterative, transparent assessments by multiple individuals within and outside the unit, with constructive feedback provided to authors at each stage.

3. Income, infrastructure and facilities

3.1 Research Funding. Over the past six years, we have made significant progress in securing research funding:

- **£97m** has been spent on the construction of **new buildings.**
- **£70.5m** in active awards funding UoA1 projects including **£52m** as **new grant awards** started during the REF assessment period.
- **£8.4m** has been spent on **equipment infrastructure**.

Figure 5. Grant Income

Grant Income **All Awards** in REF2021 Period								
BBSRC **£5.5m**	ESRC **£246,947**	EU **£4.4m**	MRC **£8.7m**	NIHR **£24.2m**	UK Charities **£16.6m**	UK Government **£8.2m**	UK Industry **£2.3m**	Other Sources **£4.5m**
Total Value Awards Female Principal Investigator: £8.1m Total Value Awards Male Principal Investigator: £36.6m								

Grant Income **New Awards** in REF2021 Period								
BBSRC **£2.6m**	ESRC **£246,947**	EU **£4.4m**	MRC **£3.4m**	NIHR **£22.5m**	UK Charities **£10.5m**	UK Government **£5.0m**	UK Industry **£1.4m**	Other Sources **£3.2m**
Total Value Awards Female Principal Investigator: £7.8m Total Value Awards Male Principal Investigator: £27.6m								

Our strategy for generating research income (Figure 5) is based on maintaining a culture of grant applications supported by the NIHR grant review committee, the BBSRC grant committee in the School of Biological Sciences and, from 2015, by the FMH Biomedical & Clinical committee providing both internal peer review and application improvement prior to submission. Overall success rate in UEA MED (based on application number and including consultancies) increased from 38% applications successful in 2010-2013 to 55% applications successful in 2016 -2019. QIB employs a Grants Facilitation Process (GFP) which includes a monthly ideas clinic, Academic Speed Dating events, a grants knowledge base folder, and a grantsmanship bootcamp. This is supported by mentorship and a regular grant review process that supports the development and submission of grants. To achieve larger, multi-partner grants (consortia), we applied the same mechanisms, aided by the setting up (UEAHSCP, Section 4.1) or expansion (NCTU, Section 3.2) of formal structures to promote translation and interdisciplinary work (Section 3.2), and supported by administration from the International Research Project Manager, European Funding Manager and **three dedicated Project Officers** within the University's Research and Innovation Services.

As a result, we are engaged in a number of competitively funded **large (>£1m) projects and consortia**:

- **Helen Murphy** leads the **£1.5m NIHR AiDAPT clinical trial** (Automated Insulin Delivery Among Pregnant women with Type 1 diabetes) involving seven UK centres (**submitted Impact Case Study**).
- **Kevin Tyler** is co-investigator and the genomics lead (with £**1m allocation**) within the **AQUAVALENS** project, a £9m EU Framework 7 consortium involving dozens of businesses, universities and research institutes from 13 countries across Europe. Over 100 papers have resulted from this consortium, including a **Nature Microbiology** paper from Tyler on the evolutionary genomics of anthroponosis in *Cryptosporidium* (See Box 1, Section 1.2).

- **David Livermore** and **Justin O'Grady** are Co-PI and work-package-lead, respectively, on the **£2.5m NIHR INHALE project,** with £1m to UEA for the potential of molecular diagnostics for hospital-acquired and ventilator-associated pneumonia.
- **Justin O'Grady**, **John Wain**, and **Mark Webber** are Co-PIs on the **£5m BBSRC Institutional Programme Grant** *Microbes in the Food Chain* awarded to QIB.
- **Andrew Wilson** leads the **£2.2m NIHR project ARRISA-UK** on asthma, the **£1.6m NIHR TIPAL clinical trial,** and the **£1.4m NIHR EME-TIPAC clinical trial** evaluating the treatment of idiopathic pulmonary fibrosis.
- **Colin Cooper** jointly leads the multidisciplinary **£1.3m PPCG** consisting of five UK groups and groups in seven other countries funded by Cancer Research UK, and Prostate Cancer UK.
- **William Fraser** leads the **RETURN study (Ministry of Defence: £2.9m)** to investigate the accelerated healing of fractures in Army Recruits through Vitamin D supplements and parathyroid hormone versus standard care.

UEA-MED has received two NIHR Doctoral Fellowship Research awards in *Gastroenterology* (**Andrew Hart**, £323k) and *Respiratory Medicine* (**Andrew Wilson**, £382k).

3.2 Infrastructure and Facilities. Our buildings infrastructure includes two new state-of-the-art constructions.

The £17m **Bob Champion Research and Education building** (Figure 1, Section 1), which opened in February 2015, provides facilities for translational research immediately adjacent to the NNUH. The building houses a lecture theatre and seminar rooms, a component of our Norwich Biorepository, the Cancer Biomarker Diagnostics Laboratory and the mass-spectroscopy Bioanalytical Facility. It accommodates laboratory-based research on prostate cancer, haematological malignancies, antibiotic resistance, musculoskeletal including bone health, and cardiometabolic diseases.

The £80m **Quadram Institute** (QI), which opened in 2019 to address global challenges in food and gut health, encompasses three components.

- **Quadram Institute Bioscience** (QIB, Figure 1, Section 1**)** conducting research on the composition and structure of food, human digestion and physiology, gut health, immunology, the impact of the microbiome on health and microorganisms throughout the food chain.
- **Clinical Research Facility** (CRF, Figure 1, Section 1) for human intervention studies conducting our clinical trials in metabolic medicine, cardiology, neurodegenerative diseases, cancer and gastroenterology.
- **Quadram Institute Endoscopy** (QIE, Figure 1, Section 1), one of the largest gastrointestinal endoscopy units in Europe with 40,000 procedures per annum.

Our **laboratory research infrastructure** includes the following facilities

- **The Norwich Biorepository—** headed by **UoA1** academic **Louise Jones**—has recently been upgraded with the aid of a **£2.1m grant from BBSRC**. A unique feature of the Biorepository is that equal focus is given to preserving **human tissue and the microbiota** within it. The investment included equipment to allow high throughput sample handing, nucleic acid extractions and storage as well as for bioinformatics, including the

Achiever LIMS and the **Cogstack** data-management system. The Biorepository is currently collecting samples and data for **research projects targeting COVID-19** including the development of an immunization strategy (Section 4.1). The Biorepository also accommodate large sample sets linked to molecular data from the **Norfolk Arthritis Register** cohort, a mirror of the national **Breast Cancer Now Biobank,** and from QIB's BAMBI, MOTION and PEARL studies, documenting the life history of the human gut microbiome.

- **The Bioanalytical Laboratory** containing state of art Mass Spectrometry.
- **The Diagnostics Laboratory** for human genomics, housing MiSeq, Affymetrix and Nanostring platforms (**Colin Cooper**)
- Promethion nanopore DNA sequencing (**Justin O'Grady**)
- UEA's IT/Computing Service Systems provides support for research computing including a High-Performance Computing cluster for analysing genome and transcriptome data, and underpinned research for **Colin Cooper**, **Darrell Green**, **William Fraser** and **Changjiang Dong**.
- The **Biomedical Research Centre**, which includes a mouse facility with intravital imaging and the first germ-free unit in a UK university.

We have access to a range of laboratory research facilities through partners on the **Norwich Research Park** (NRP)

- **Single Cell Analysis** at the Earlham Institute. The Earlham Institute houses the BBSRC National Capacity in Genomics and Single Cell Sequencing.
- 3T-MRI facility at the NNUH
- UEA's new £3.4m **Wellcome-Wolfson Brain Imaging Centre** (MRI facility)
- UEA's **Science Analytical Facilities**, which include facilities for Bio-imaging, Structural Imaging, X-Ray Imaging, NMR, Mass Spectrometry, Elemental Analysis and Stable Isotope Analysis.

Where appropriate, we have **outsourced analyses**. Since 2014, five hundred Human Genome Sequence datasets were generated by the company Illumina in the USA and by The Beijing Genome Institute in China. These data, obtained from UK patients, were then analysed at the Sanger Institute, as part of the **ICGC** and **PPCG** studies by **Colin Cooper**, through links to Professor Sir Mike Stratton. **Changjiang Dong** has used the Diamond Light Source national synchrotron facility at Harwell for X-ray crystallography and Cryo-EM at Sichuan University, Chengdu China.

During the REF period we have expanded and/or put in place the following structures to support our research and to ensure that our research link to and has impact in the community:

- **The Norwich Clinical Trials Unit** (NCTU) has been fully registered as a UK Clinical Research Collaboration trials unit since late 2013. Over the last six years the NCTU has grown from a small unit of five staff (2013/14) to over 30 staff (2019/20). Over the same period the total value of the NIHR grants to NCTU has increased from £38k per year (2013/14) to >£2.5m (2019/20). **For the year 2019/20 this was the 5th largest income** for a clinical trials unit within the NIHR support system. In June 2020, the NCTU had >10,000 patients enrolled in clinical trials and under active follow up from >500 clinical sites throughout the UK and Northern Ireland. The ARRISA, TIPAL, EME-TIPAC, AiDAPT and RETURN studies are all run from the NCTU resulting in multiple trial papers for this submission (**William Fraser**, **Helen Murphy**, **Ann Marie Swart**, **Andrew**

Wilson). The NCTU also provides a forum for training and methodological advancement in trial design, conduct and analysis. The NCTU has ongoing collaborations with researchers at UEA, NNUH, the Norfolk and Suffolk Foundation Trust (mental health), the Norfolk and Waveney CCG (primary care), the universities of Cambridge, Sussex, Nottingham, Hertfordshire and University College London. NCTU support of trials has led to impact from **Helen Murphy** and high-profile publications from **Ann Marie Swart** and **Andrew Wilson**. We will build on these successes in creating the **Norwich Epidemiology Centre** (Section 1.3).

- **The Norwich Institute of Healthy Ageing** (NIHA), established in early 2020, provides research links across the Norwich Research Park, including groups from the QIB, John Innes Centre and several schools within UEA. It is partnered with NNUH, Public Health Norfolk, local government and representative community groups. It is focused on strategies which target the complex social, economic, geographical and environmental determinants of health behaviour, such as eating/nutrition, smoking, drugs, exercise, sleep and alcohol and over-eating. Within UoA1, for example, linking to **William Fraser's** work on Vitamin D to inform strategies to benefit health of the community. The ultimate goal of the NIHA is to increase healthy life expectancy and reduce health inequalities.
- Since 2018 the **UEA's IT & Computing Service** has injected additional capital investment in support of a number of key strategic technology initiatives. This totalled £4m in 2018-19, £5m in £2019-20, and will total over £7m for 2020-21.
- **UEA Health and Social Care Partners (UEAHSCP).** This multidisciplinary academic, clinical, community partnerships is described in detail in Section 4.1.

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

4.1 Research collaborations. Collaboration underpins our interdisciplinary research tackling strategic challenges set by e.g. UKRI, NHS, WHO, UK Charities. As noted above, to enhance collaboration, we have established the Norwich Biorepository, Quadram Institute Clinical Research Facility and considerably expanded the NCTU (Section 3.2). We established **UEA Health and Social Care Partners (UEAHSCP)** in 2019 as a formal partnership of 12 health and social care organisations with 45,000 staff working across East Anglia. It aims to increase research collaboration across a wide range of research projects for the benefit of the 2 million-strong local population. Within two years, the partnership has invested £200k and attracted over £5m in research funding to institutes including UEA for activity aligned to the needs of our population; this includes UEA-led NIHR grants of £2.4m and £1.93m. A wide range of **COVID-19 support** has been provided through this partnership by members of this submission (**William Fraser**, **Justin O'Grady**, **Yoon Loke**, **Tom Wileman**) (Sections 4.2 and 4.3) and by RA staff.

The Eastern Arc is a collaborative initiative that links Universities in East Anglia, Kent and Essex. Over the last 24 months, we have injected £70k of funding into joint projects. For example, links between QIB and University of Kent underpin a project using **new approaches for COVID-19 vaccine delivery** engineering the ability of gut bacteria to generate nanoparticle sized outer membrane vesicles.

Examples of **national/international collaborations/networks** led and involving **UoA1** staff include (see Box 1, Section 1.2 for relevant outputs):

- **Colin Cooper** is joint lead of the **UK ICGC Prostate Cancer** project and of the **PPCG** with partners in USA, Belgium, Germany, Finland, Canada, Australia, France, South

Africa, and Hong Kong.

- **Changjiang Dong** leads multinational investigation of bacterial membrane proteins and drug resistance with groups in Sichuan, Zhejiang, Hubei and Guangdong, China.
- **Marcus Flather** leads international networks spanning UK, Australia, Spain. Sweden, Norway, Italy, Canada, USA, Poland, and Brazil assessing treatment of **heart disease,** with outputs in NEJM and The Lancet. He is health economics lead of the EUROSHOCK collaboration evaluating extracorporeal membrane oxygenation.
- **David Livermore's** outstanding contributions to the study of antimicrobial resistance through national and international collaborations are evidenced in our **Impact Case Study**.
- **James Mackay** supports osteoarthritis biomarkers and clinical trials as a member of the FNIH PROGRESS OA and APPROACH networks with investigators across Europe.
- **Helen Murphy** has run the highly influential multi-centre multinational CONCEPTT trial for continuous glucose monitoring in pregnant women (see **Impact Case Study)**.
- **Justin O'Grady** has pioneered the use of **Nanopore DNA sequencing**, with collaborators across the UK, USA, Canada, Russia, Italy, Saudi Arabia, and Germany and is Deputy Director of COG-UK (Section 4.3)
- **John Potter** is a member of the **RIGHT-2** trial in which 54 UK Hospitals and 13 Ambulance Trusts investigate the value of glyceryl nitrate in presumed stroke. He chairs the steering committee for the HTA-funded Asymptomatic Carotid Surgery 2 Trial (**ACST2**) and is a member of the Blood pressure in Acute Stroke Collaboration, stage-3 (**BASC-3**) involving USA, Scandinavia, Australia and Malaysia.
- **Ann Marie Swart** as NCTU Director participates in **multiple UK clinical trials networks**.
- **Kevin Tyler** has investigated protozoan causes of diarrhoeal mortality worldwide and is a member of Open Lab Africa, (Cameroon, Ghana, Nigeria, Kenya, Tanzania, Uganda, Australia and South Africa) and Help for Dairy Cows (H4DC: England, France, Holland, Belgium).
- **John Wain**, with collaborators at the George Mason University (USA) and the Child Health Research Foundation (Bangladesh), is using a £1.2m grant (£428,000 to QIB) from The Bill & Melinda Gates Foundation to study bacteria causing diarrheal disease.
- **Mark Webber** is member of EPSRC funded PREVENT study (Preventing prosthetic infections).
- **Tom Wileman** is a member of MRC and BBSRC funded national and international collaborations investigating the role of LC3-associated phagocytosis in pancreatitis, viral and bacterial infection and Alzheimer's disease. He is a recipient of a UKRI China Partnering Award on vaccine technology.
- **Andrew Wilson** is theme lead of the multicentre NIHR funded ARRISA-UK (At Risk Registers Integrated into primary care to Stop Asthma crisis).
- **Max Yates** is a member of the OMERACT **international Polymyalgia Rheumatica Working Group** of Outcome Measures in Rheumatology.

We have **collaborative links to countries in Africa** e.g. analysis of prostate cancer genomes from the northern bush areas of South Africa (**Colin Cooper**) and real-time diagnosis of lung infections in Kenyan villages (Nanopore DNA sequencing, **Justin O'Grady**).

4.2 Contribution to the Research Base. The unit's members have made contributions to the sustainability of the discipline through membership of expert committees

- **European Commissions**: **Justin O'Grady**, Detection of AMR; **Kevin Tyler**, Infectious Diseases; **David Livermore,** Detection and Prevention of AMR
- **WHO expert groups**: **Yoon Loke** and **Katharina Mattishent**, systematic reviews; **Mark Webber**, expert advisor for AMR.
- **Max Yates** wrote the initial draft of the **European guidelines** for ANCA associated vasculitis.
- **Helen Murphy** is Chair of the International Life Sciences **Gestational Diabetes Mellitus and Diet group** and a member of an **NIH(US) diabetes committee**.
- **David Livermore** has provided evidence to the **House of Commons** Science and Technology Committee and sits on the **UK Government Advisory Committee** on Antimicrobial Prescribing and a Public Health England working group on AMR.
- **Colin Cooper** served on the **Genomics England GeCIP board**.
- **Helen Murphy** is also Clinical chair of the **National Pregnancy in Diabetes** audit and the Diabetes UK research committee.
- **John Potter** (stroke) and **Vassilios Vassiliou** (valve disease) have served on **NICE guidance groups**.
- **William Fraser** was appointed to the **NICE review committees** for adult use of alfatase α and for Osteoporosis and Bone Disease.
- **Tom Wileman** is a member of the **UKRI-BBSRC COVID-19** cohort of experts.

Unit members have **served on grant awards committees** for MRC (**John Wain**, Infection and Immunity), BBSRC (**Mark Webber**, Panels B and E), NIHR (**Yoon Loke**) and the Food Standards Agency (**Mark Webber**), as well as for multiple UK charities (**Colin Cooper**, **Marcus Flather**, **John Potter**).

Thirteen unit members have **served as editors for 19 journals** including *Scientific Reports* (**Andrew Hart**, **Nicole Horwood**) and *Journal of Biological Chemistry* (**Linda Troeberg**). **Kevin Tyler** is Editor-in-Chief for *Virulence* and founding editor of *Parasites and Vectors* and **John Wain** was founding editor of *Journal of Infection in Developing Countries.*

In 2019, **Darrell Green** was designated as one of the ***Nation's Lifesavers – The exceptional 100 keeping us healthy*** by Universities UK. In June 2020, **Dmitry Pshezhetskiy** won the AstraZeneca Skolkovo Start-up Challenge for NANODOC, a biodegradable nanoparticle targeting breast and prostate cancer. **Colin Cooper** and **Michael Frenneaux** are Fellows of the Medical Academy of Sciences.

4.3 Contribution to the Economy and Society. The unit has a portfolio of nine active Impact Case Studies, of which three are submitted as full cases. Here, we provide highlights of the impact cases we are continuing to develop that are *not* submitted to this assessment but illustrate our wider contribution to the economy and society.

Justin O'Grady is Deputy Director of the **COVID-19 Genomics Consortium (COG-UK)** providing insights into the mechanism of community spread of SARS-CoV-2. He has developed technology to allow large-scale multiplexing of SARS-CoV-2 genomes using Nanopore sequencing. His results have also had direct impact in changing practice in local hospitals and COVID-19 Tier status in Norfolk.
Justin O'Grady has also developed **metagenomics methods** combined with **host DNA depletion** for rapid (≤2 hours) **detection of antimicrobial resistance** that

- addresses the priority for rapid diagnostics outlined in the O'Neill review,
- has been licenced to companies including Oxford Nanopore,
- is being marketed as a rapid diagnostic kit by the Simcere Pharmaceutical Group for use in >100 Chinese hospitals.

Kristian Bowles has revealed mechanisms underpinning the development of multiple myeloma and acute myeloid leukaemia (200,000 deaths globally per year), including alteration in the genes *BTK* (MM) and *FLT3* (AML) and the importance of mitochondria transfer in maintaining cancer growth. These discoveries have (i) formed the basis of seven clinical trials, particularly targeted at multiple myeloma for which there is no current cure and (ii) for Aptose Bioscience facilitated a $40m share purchase in Nov 2019.

John Wain has developed IP leading to an award of around £1m from a European commercial partnership deal. He is director of **Test&Treat**, developing diagnostics for urinary tract infections. He was founder and director of **Nana Therapeutics Limited**, developing treatments for mitochondrial disease that was sold to Astellas in Apr 2020. He was founder, director and CSO of **Discuva Ltd**., an antibiotic discovery company sold to Summit Therapeutics in Dec 2017. He is founder and director of a not-for-profit company JIDCUK, which supports scientific research in developing countries.

Colin Cooper has set up a diagnostics laboratory in UEA-MED to allow the application of the PUR Test (a non-invasive urine test that can more accurately diagnose aggressive prostate cancer) and the Tiger Test (a new biopsy test to identify aggressive cancers) to patients with prostate cancer.

William Fraser has pioneered the use of tandem Mass Spectrometry through contract research and development work undertaken with KRSS Ltd. Currently UEA has a member of staff embedded in the company's facility in Runcorn that is developing complex low throughput assays that investigate bone health.

Unit staff have **links to UK charities** serving on Advisory Boards or Scientific Committees.

- **Colin Cooper**: Tenovus, Prostate Cancer UK, Prostate Cancer Research Charity.
- **Helen Murphy**: Diabetes UK.
- **Darrell Green**: has served as charity trustee for the Bone Cancer Research Trust.
- **John Potter**: Alzheimers Society.
- **Linda Troeberg**: Versus Arthritis.
- **Kristian Bowles**: is a Trustee of the Norfolk cancer charity Big-C supporting fundraising and public events.
- **William Fraser**: Action Arthritis, Royal Osteoporosis Society

Unit staff have a wide range of **interactions with industry**:

- **Kristian Bowles** advises **Abbvie**, **Jannsen**, **Infinity** and **Kancera**.
- **Paul Crichton** collaborates with **AstraZeneca**.
- **Changjiang Dong** collaborates with **Hoffmann-La Roche** and **Bicycle Therapeutics**.
- **Marcus Flather** advises **Novartis**, **Astra Zeneca** and **UCB pharma** and is on the board of **Ablatus**.

- **William Fraser**[2] has consulted for **KRSS, Roche, Abbot Diagnostics, Diasorin, and Qiagen**
- **Nicole Horwood** collaborates with **Sanofi Genzyme**.
- **David Livermore**[2] has consulted for **20 companies** including **Pfizer**.
- **Yoon Loke** advises **Thame Laboratories**.
- **James Mackay** advises **GlaxoSmithKline** and is a member of **General Electric Healthcare** medical advisory board.
- **Helen Murphy** collaborates with **Dexcom** and is on the advisory board for **Medtronic**.
- **Penny Powell** collaborates with **Roche Diagnostics** on an MRC iCASE PhD studentship.
- **Dmitry Pshezhetskiy** works with **Oxford Biodynamics** on prostate cancer biomarkers.
- **Mark Webber** has MRC iCASE PhD partnerships with **Procter** and **Gamble** (x2), **Nestle** (x1) and **GAMA healthcare** (x1).

UEA MED runs a **vibrant programme of public engagement** overseen by the Associate Dean of Innovation (Michael Hornberger). We have engaged through the media and through direct contact with the local community. Our press releases have resulted in 2,943 articles and 117 TV/radio appearances in 63 countries. UoA1 staff (including **Colin Cooper** and **William Fraser**) have carried out £1.11m of direct fundraising in the local community, nationally and internationally for research on prostate cancer and bone disorders.

Our Academic Director for Innovation, Laura Bowater, has recently been **awarded an MBE** for science communication in microbiology. We regularly participate in community events promoting our work including the annual Norwich Science Festival, Norwich Science Café and the Science Café at the Cut Halesworth. Highlights include **Justin O'Grady** and **David Livermore** sharing their pioneering research around Anti-Microbial Resistance (AMR) at the Science Museum in London at an event named "Superbugs: The Fight for Our Lives" held in 2019. This was free to attend and sponsored by UEA, Pfizer, Shionogi and UKRI.

COVID-19: During **the COVID-19 crisis**, we have been engaged in relevant research as outlined above in this Section and in Section 1.2. More detail is now provided particularly for involvement of **UoA1** staff in community activities to combat infection and to better understand the impact of COVID-19 within the local community:

- UoA staff compared the use and effectiveness of PCR and antibody testing in NNUH and care homes. **Kristian Bowles**, **William Fraser** and Stuart Rushworth evaluated the FDA approved SARS-CoV-2 immunoassay (developed at Mount Sinai) for the identification of COVID-19 seroconversion, potential cross-reactivity of the assay in a UK NHS hospital setting, and for costs of producing the tests. They concluded that the Mount Sinai IgG ELISA assay is highly sensitive test for SARS-Cov-2 infection, however modification of thresholding was required to minimise false positive results.
- **James Smith** was involved in setting up PCR screening for determining the incidence of COVID-19 positive cases in the UEA student and Norwich communities.
- **Justin O'Grady** initiated a Norwich mass genome sequencing project, became a member of COG-UK, and more recently Deputy Director of COG-UK leading to the following comment:

[2] Total consultancy income for UoA1 is £876,000

'*Dr O'Grady's team have worked closely with Norfolk County Council Test and Trace, PHE and hospital clinicians to help understand and control outbreaks in the region. Their work on genomics of COVID-19 outbreaks in care facilities in Norfolk highlighted that transmission was likely caused by movement of staff between facilities and not movement of patients between hospitals and care facilities was less important. This was reported to PHE and SAGE and resulted in a genomics report presented to the SAGE Social Care Working Group'*
Sir Patrick Valance, Government Chief Scientific Adviser and Head of Government Science and Engineering Profession

- **Yoon Loke** developed a new way to analyse and calculate COVID-19 deaths that led to the Health Secretary Matt Hancock ordering an urgent review into how Public Health England (PHE) calculates daily COVID-19 death figures. This led to the number of deaths reported by the government to be calculated differently. This decision meant the UK death toll due to COVID-19 at the time was revised downwards by 5,377 to 41,329 in June 2020 (**Impact Case Study**).

- **FMH** has a portfolio of 119 COVID-19 projects ranging from setting up screening for COVID-19 infection to making (together with the School of Chemistry (CHE)) alcohol hand gel for local care homes.

Conclusions: The Norwich Medical School, founded in 2002, is undergoing a period of rapid development, realising its full potential to undertake research targeting key global and national health problems. We demonstrate here how our research environment can deliver excellent research, whilst being flexible enough to respond to the COVID-19 crisis. Working with key partners we have demonstrated our role as a Civic University that addresses the needs of our local community. We have significantly increased research income, postgraduate student recruitment and impact capacity with the recruitment of 15 inspiring new team leaders. A key success has been the integration of research with the QIB. Significant investments have been made to enact these changes including (i) investment in equipment, (ii) construction of two new buildings immediately adjacent to the NNUH, and (iii) the setting up of the NIHA and the UEAHSCP. We have already established world-leading translation research and leadership linked to the NNUH in selected areas: (i) the rapid detection of infections and new antibiotics development; (ii) prostate cancer; (iii) leukaemia, (iv) cardiovascular disease; and (v) clinical trials. Our vision for the next six years is to build on our successes and deepen our ability to carry out top-quality translational research by, together with the NNUH, by developing assets such as the Norwich Biorepository, the QIE, and the CRF and by putting in place additional facilitating structures such as the Norwich Epidemiology Centre and an NRP wide Norwich Translational Research Centre.

"The strong and thriving partnership between NNUH, UEA and Quadram Institute Bioscience, has already enabled us to deliver world-leading research to benefit our communities and the wider population and we are committed to continuing high quality, high value, research to improve health outcomes and people's lives for decades to come."
Professor Erika Denton MBBS, FRCP, FRCR, DSc
Medical Director, Norfolk & Norwich University Hospital