Institution: University of East Anglia

Unit of Assessment: 2 (Public Health, Health Services and Primary Care)

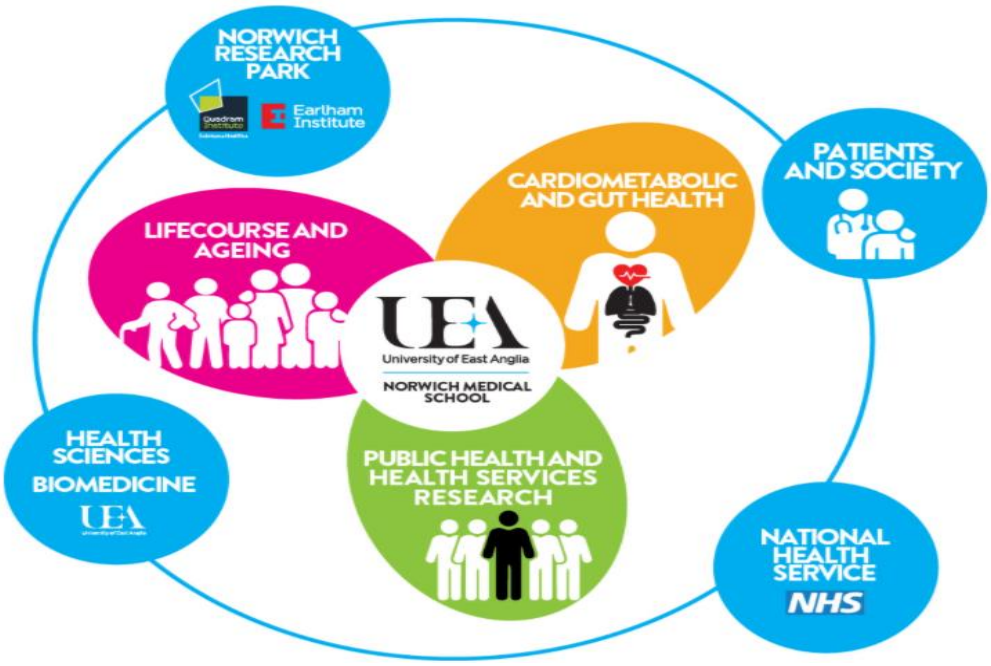
1. Unit context and structure, research and impact strategy

This submission reports on research led by 19 academic teaching and research (ATR) staff and one research associate (total 18.6 FTE) in Norwich Medical School. The purpose of our research is to improve the health of individuals and of human populations by increasing knowledge about the causes of preventable illness and death; to develop and evaluate practical ways to improve population health by tackling root causes and by improving health care; and to ensure delivery of effective, cost-effective and equitable health strategies at large scale in the UK and internationally. The research environment at Norwich Medical School and UEA has enabled us to concentrate our core strengths - in research methodologies and in major population health problems - while leading and supporting broader research consortia.

1.1 Organisational structure: Research groups and units

The 20 individuals in UOA2 are employed by Norwich Medical School and based in its Public Health and Health Services Research theme (until 2018 the Department of Population Health and Primary Care). They are located in the Medical School Building and the School's Bob Champion Research and Education Building. The Medical School, as part of the Norwich Research Park (NRP), is co-located with the School of Health Sciences within UEA's Faculty of Medicine and Health Sciences (FMH), all other UEA Schools, the Norfolk and Norwich University Hospital, and all other NRP research institutes (see Figure and section 3).

Figure. Norwich Medical School's research themes and local environment



The Public Health and Health Services Research theme comprises three research groups:

- Epidemiology and Public Health (Shepstone (group leader), Hunter, MacGregor, Clark, Jones, Alexandre, Skinner, Khondoker, Song, Notley, Milton)
- Health Services Research and Primary Care (Steel (group leader), Bachmann, Howe, Parretti)
- Health Economics (Wilson (group leader), Whitty, Barton, Turner, Davillas, Sach (UOA3)). This theme includes UEA Health Economics Consulting (see 4.3).

We also have lead roles in, and provide research support and collaboration through, four co-located units (see section 3):

- Norwich Clinical Trials Unit ((NCTU), Shepstone and Barton (associate directors), Clark)
- Norwich Institute for Health Ageing (MacGregor, Steel, Milton, Jones, Shepstone, Notley, Parretti, Howe, Whitty, Bachmann)
- Norfolk and Suffolk Research Design Service (Barton (deputy director), Shepstone, Turner)

The Public Health and Health Services Research theme cuts across the Medical School's other two research themes: Lifecourse and Ageing, and Cardiometabolic and Gut Health (Figure). Each of our studies therefore typically entail close collaborations between several groups within the theme, and with Medical School colleagues submitted to UOA1 (clinical medicine) and UOA6 (nutrition). The Medical School's critical mass of epidemiologists, clinical triallists and nutritional researchers submitted to UOAs 1 and 6 reinforces the research environment for public health, primary care and health services research. We also collaborate with health researchers from UEA Schools of Health, Environmental and Computing Sciences, and Social Work, from other UK and overseas universities, and with UK and overseas clinicians and governmental and multinational health agencies.

Most of our research is interdisciplinary, and many of our researchers are research methodologists, whose expertise in rigorous and innovative methods in epidemiology, clinical trials, health economics, qualitative research, medical statistics, evidence synthesis, and development and evaluation of complex health service and public health interventions, reinforces wider research programmes and projects in the region, country and overseas.

1.2 Achievement of strategic objectives

Our research environment, people and income have enabled us to achieve the **strategic objectives set out in REF2014**, that is, to:

- Develop, implement and evaluate innovative ways of strengthening health services in primary care and chronic disease management.
- Build research in diet, physical activity and diabetes prevention
- Carry out pragmatic trials of complex organisational and behaviour change interventions
- Expand international research in infectious disease and nutritional epidemiology, public health economics, and primary care health services research
- Integrate epidemiological and health services research

Demonstrating the excellence of our research, we have published our findings in world leading general medical journals (for example, Lancet (7 articles), New England Journal of Medicine (2), JAMA (1), JAMA Internal Medicine (1), Nature Communications (2), British Medical Journal (2), PLOS Medicine (2), BMC Medicine (1) and world leading specialist journals (for example, Nature Microbiology (1), American Journal of Clinical Nutrition (2), International Journal of Epidemiology (2), AIDS (1) and Gastroenterology (2).

Some highlights of our success in achieving these objectives are as follows.

i/ Development, and rigorous multidisciplinary evaluation, of large scale public health interventions

Several completed UK research programmes demonstrate our comprehensive approach to population health improvement, using economic and qualitative evaluation alongside randomised trials (RCTs), and natural experiments. For example:

- The SCOOP RCT (Shepstone PI, Turner, Howe; Lancet 2018) randomised 12,483 women at increased risk of fracture to DEXA screening for osteoporosis, or to usual care. This cost-effective intervention led to a 28% reduction in hip fracture incidence.

- The Norfolk Diabetes Prevention Study RCT (Clark, Bachmann, Barton, Howe, Sampson; JAMA Internal Medicine 2020), screened >12,000 adults at risk of type 2 diabetes, enrolled 1,000 into a randomised trial of diabetes prevention interventions, and 500 with screening-detected diabetes into another trial of the same interventions. These affordable scalable interventions were highly effective and cost effective.
- The SHARPISH RCT (Song, Barton, Notley, Bachmann; Addiction 2015) randomised 1,400 ex-smokers to receive educational materials aiming to prevent relapse to smoking, and found they had no effect.
- A natural experiment of the effects of lowering blood alcohol concentration legal limits on road traffic accidents in Scotland, found no effect (Jones; Lancet 2019).

ii/ Observational epidemiology and qualitative research on causes of, and solutions to, leading public health problems

Aiming to increase knowledge about social and behavioural determinants of health and disease, and to identify priorities and target interventions for health improvement and disease prevention, our researchers collaboratively researched physical activity and diet, musculoskeletal health, smoking and addiction, and infectious disease. For example,

- Jones and Milton lead a research programme on **physical activity** on health, in collaboration with the Centre for Excellence in Diet and Activity Research (CEDAR) and the European Prospective Investigation of Cancer (EPIC) cohort based at Cambridge. Findings include effects of urban environments on activity and health outcomes.
- Macgregor and Skinner work with nutritional epidemiologists (Welch and Cassidy (UOA6)) to investigate **nutritional determinants of musculoskeletal health** in cohorts, notably EPIC and UK Biobank. Findings include the effects of dietary flavonoids on body composition in women (MacGregor), and effects of the Mediterranean diet and micronutrients on skeletal muscle power and mass (Skinner).
- MacGregor is principal investigator (PI) of the **Norfolk Arthritis Registry** cohort and of the **Versus Arthritis Epidemiology Centre**. He has carried out numerous cohort and treatment outcome studies of people with rheumatoid and osteoarthritis, investigating, for example, determinants of disability, arthroplasty revision and death.
- Notley established the **Addiction Research** @UEA Group, producing multidisciplinary research evidence benefiting people affected by addiction, including service users, carers, health professionals and policy makers.

iii/ Development and experimental evaluation of complex interventions in health care

We work with clinical collaborators to develop innovative complex interventions to improve health care, and then to evaluate their effectiveness, cost-effectiveness, feasibility and acceptability during real world implementation. We are chief investigators of randomised trials (Shepstone, Song, Bachmann) and also provide methodological expertise for experimental evaluation of complex interventions and health technologies, especially in clinical trial design, statistical analysis, and health economic evaluation.

The Health Economics Group is one of the largest in the UK, and Barton, Sach, Wilson, Turner, and Whitty are lead health economists on multi-centre UK and international clinical trials, evaluating cost effectiveness (see 4.1). Similarly, Shepstone and Clark are lead statisticians on a wide range of UK trials, and Bachmann is statistician on trials in Africa and Brazil. UEA-led examples include:

- The ARRISA trial (At-Risk Registers Integrated into primary care to Stop Asthma crises in the UK) showed that this intervention reduced emergency hospital admissions, and was followed by the second ARRISA trial with an enhanced training component (Clark and Barton; PI Wilson (UOA1))

- The PERFECTED programme (Peri-operative Enhanced Recovery hip FracturE Care of paTiEnts with Dementia) has developed and is piloting this complex intervention in NHS hospitals (Shepstone; PI Fox (UOA4)
- The CHIPPS programme (Care Home Independent Pharmacists Prescribing Study) developed and piloted this complex intervention of pharmacist-led medication management in UK care homes (Turner, Barton, Shepstone; PI Wright (UOA3))
- Bachmann leads implementation research and trials of complex interventions to strengthen primary care in Africa and South America (see sections 1.3, 4.1 and impact case study).

iv/ Methodology and infrastructure for large scale and efficient trials and epidemiological studies

UEA's research environment, with concentrated logistical and methodological resources, enables such studies to be carried out rigorously, at large scale and at relatively low cost. We have exceptional expertise in using large clinical and epidemiological databases for randomised trials, quasi-experiments and cohort studies. This provides high statistical power to identify and precisely estimate effects of interventions and health determinants in generalizable populations and real-world settings, to follow up individuals for extended periods, and to complete studies rapidly and efficiently. Our skills in data management, longitudinal statistical analysis and epidemiological methodology underpinned studies such as these:

- Clinical databases for identification and follow-up of participants in randomised trials:
  - The SCOOP trial used NHS Hospital Episode Statistics (HES) to measure primary and secondary outcomes (Shepstone, Turner).
  - The ARRISA trial uses HES and GP records to measure outcomes (Clark, Barton)
  - The PACK Brazil trials used primary care electronic medical records to identify participants and measure outcomes (Bachmann)
- Clinical databases for cohort and case control studies investigating:
  - Effects of anticholinergic drugs on dementia, using Clinical Practice Research Datalink data (Steel)
  - Effects of lipid lowering treatment on cardiovascular risk, using The Health Improvement Network (THIN) data (Steel)
  - Effects of multi-morbidity on dementia, using UK Biobank data linked with HES (Khondoker)
  - Effect of antiretroviral treatment on tuberculosis incidence in South Africa, using medical records, disease registry, laboratory and mortality register data (Bachmann)
  - Age-related treatments, prognosis, and inequalities in care after myocardial infarction, using Myocardial Ischaemia National Audit Project registry data (Shepstone, Bachmann, Clark)
  - Quality of NHS care for older people, using English Longitudinal Study of Ageing data (Steel, Bachmann).

Future research strategy and objectives: 2021-2027

Our future strategy, building on these successes and responding to developments in the Medical School and NRP environment (section 3), will have the following priorities.

- We will invest in new principal investigators, especially in public health and primary care, including early career clinical academics, while continuing to support and promote methodologists in epidemiology, statistics, health economics and social science.
- We will expand public health and epidemiological research, supported by the Norwich Epidemiology Centre (to be launched in 2021), to integrate with the NRP and Quadram Institute's biological and translational research strategies and databases, and thereby advance research on:
  - Nutrition, obesity, vascular and gut health
  - Dementia, musculoskeletal disease and healthy ageing
  - Diet and activity

- We will develop and evaluate innovative patient-centred primary care interventions to address multi-morbidity and chronic diseases of ageing, building partnerships through the new Norwich Institute of Health Ageing.
- We will expand our global health services and epidemiological research in Africa, South America and Asia
- We will continue to apply innovative public health and health services research methodology, especially:
  - Clinical cohorts with big data linkage, longitudinal analysis, quasi-experimentation, innovative epidemiological causal inference, and linkage of biological, clinical and health outcome databases
  - Randomised trial design (such as cluster randomised, stepped wedge and adaptive designs)
  - Economic evaluation, outcome valuation and efficient trial design
  - Interdisciplinary methods integrating epidemiology, economics, social and behavioural sciences

1.3 Impact strategy

The primary purpose of our research is impact, that is, to change health policies, and to improve the health of populations and health care users and, thereby, to improve social and economic productivity and well-being. This matches our funders' objectives: NIHR, UK research councils and health charities, European Union, Wellcome Trust, UK Aid, and US National Institutes of Health all aim to produce impact in the UK and/or internationally. We have recently boosted impact through appointment of a) an Associate Dean of Innovation who sits on the FMH Executive and is responsible for developing and overseeing enterprise links and b) two impact champions in Norwich Medical School responsible for identifying new impact cases.

To ensure research impact, we engage strategically with targeted users of research findings to ensure that studies' objectives and findings will meet their needs (see section 4). Firstly, most studies are developed with public and patient involvement. Secondly, clinical researchers and practitioners are invariably co-investigators on clinical studies. Thirdly, engagement with health care providers is mandatory for NHS research, and for overseas health services and clinical research. Fourthly, we work with UK government (such as Public Health England, Department of Health, National Institute for Health and Care Excellence, local public health departments and Clinical Commissioning Groups), overseas health ministries, and with the World Health Organisation, to provide evidence and develop policies that match their priorities.

The two impact case studies submitted exemplify our strategy of co-producing research with government agencies and health professionals, in response to their needs and priorities. One case study describes how the England Global Burden of Disease study (PI Steel) guided and underpinned NHS England's Long Term Plan for 2021-25. It shows how UEA researchers worked with UK epidemiologists and world leading international methodologists, co-producing research with Public Health England, who then worked closely with NHS England to identify England's priority health challenges, and to address them through resource allocation and operational plans. The other case study demonstrates the global impact of our research to strengthen primary care in low and middle income counties. UEA researchers worked with academic colleagues in South Africa, Ethiopia, Nigeria and Brazil, who worked closely with health ministries to provide educational resources and clinical decision aids for large scale dissemination, guided and motivated by the evidence. International impact was enhanced through partnership with the BMJ Publishing Group. For other examples of impact see section 4. UEA support for impact-generating work included funding for international travel (Hunter and Bachmann), study leave (see 2.1) and prizes (Chancellor's Award for Impact and Innovation 2020 to Bachmann and UEA Enterprise Award 2020 to Hunter).

We are committed to open access publication and to sharing our research data with other researchers. Norwich Clinical Trials Unit is able to share trial data with independent researchers if approved by Chief Investigators and Trial Steering Committees. The forthcoming Norwich

Epidemiology Centre will have as a core function the collation and sharing of NRP datasets. Data from the ELSA Covid-19 study will be made available via the UK Data Service, alongside the main ELSA dataset (Steel). We have shared trial data with external investigators investigating the reproducibility of statistical analyses of landmark randomised trials (Bachmann).

Our research environment ensures that our research complies with rigorous ethical, legal and professional frameworks, obligations and standards. The Faculty of Medicine and Health Sciences Research Ethics Committee provides oversight of human subject research, including research not covered by NHS structures or conducted overseas. UK research involving NHS patients or personnel is overseen by NHS research ethics committees through the Integrated Research Applications System. Clinical governance of NHS research is supervised by research governance structures in each NHS trust involved. UEA is responsible for governance of research sponsored by UEA. Overseas human subject research must be approved and supervised by research ethics structures located in the countries where the research is carried out. All UEA researchers receive regular mandatory training in data protection, and clinical researchers are required to receive regular training in Good Clinical Practice, monitored by the Medical School and in annual appraisals.

2. People

2.1 Staff strategy

Academic staff: We prioritise the recruitment, career development and retention of both research leaders and early career researchers, and carry out extensive searches for suitable interested candidates before advertising positions. Six UOA2 members are strategic appointments to new posts established since 2014: a new chair, associate professorship and lectureship in health economics (Whitty, Wilson and Davillas, from Brisbane, Cambridge and UEA, respectively), a new associate professorship in medical statistics (Khondoker, from King's College London), a new clinical associate professorship in general practice (Parretti, from Birmingham), and a new associate professorship in public health (Milton, from Oxford). Seven of the 12 professors in UOA2 were promoted to chairs after joining UEA in more junior positions, including Notley who joined UEA as a research associate.

Continuing professional development (CPD) is supported by mentorship and annual appraisal, and includes professional development opportunities such as courses, conferences, collaborations and research grants. Norwich Medical School offers short CPD courses on teaching and learning topics. All UEA staff have access to >40 free short courses provided by UEA's Centre for Staff and Educational Development, which also offers tailor-made programmes. Training to support promotion applications is provided. New lecturers must complete UEA's part-time MA Higher Education Practice course, which includes academic mentorship and a dissertation. Mandatory training for Medical School staff, repeated every 1-3 years, comprises mostly online courses such as staff induction, staff appraisal, recruitment and selection, diversity in the workplace, unconscious bias, data protection, fire safety, health and safety, and use of display screen equipment.

To expand researchers' skills and horizons, and promote collaboration, we deliver regular research seminar series on: clinical trials, epidemiology and medical statistics; health economics; qualitative research; diet and health; and the medical research forum, which are open to all staff and students. Health Economics Group staff and students participate in the international Health Economics Study Group, and hosted its 2019 annual international conference.

Academic staff are eligible for 3-6 months study leave every 6 semesters. Howe, Steel, Hunter and Bachmann took study leave during this assessment period enabling them to work overseas, to expand the scope and impact of their global health research: Howe promoting international primary care research as President of the World Organisation for Academic Primary Care

(WONCA), Hunter working on water, sanitation and infectious disease epidemiology at WHO, Steel collaborating with the US Institute of Health Metrics to lead the Global Burden of Disease in England study, and Bachmann working on primary care trials and health services research in South Africa and Brazil (see 1.3 and impact case studies).

Supporting the career development of research associates (RAs): UOA2 and NCTU currently employ 43 research associates (33F:10M). Since 2016 Norwich Medical School has worked with RAs to implement 'Best Practice Guidelines for Research Staff' based on the National Concordat for Research Staff. Our commitment begins at appointment; all appointment panellists are required to undertake training in recruitment and selection. Once appointed, researchers undertake an induction programme including induction meetings with line managers, where objectives and responsibilities are agreed, and opportunities for training and development are identified. The School has since 2016 had a dedicated fund to support career development, including training opportunities and conference fees and travel costs for RAs, averaging £920 annually. RAs are entitled to five days per year to develop career opportunities by dissemination of their research, raising their profile and increasing their collaborative networks. Research and career workshops are encouraged, and include the Continuing Staff Educational Development Programme of Researcher Opportunities. Career development opportunities are also discussed during annual appraisals. Experienced mentors are offered to all RAs to support their professional development. Bridging funding for salaries is available to fill gaps between grants and, since 2018, we offer relocation expenses to new research associates.

RA contributions are recognised through prizes such as the annual prize for Best Paper from an Early Career Researcher, and the Team Science Award. Researchers are supported to teach and supervise students, including co-supervision of PhD students. Teaching and supervision are supported by mandatory training and development events.

We enable both academic and research staff to launch new research by encouraging applications for UEA Proof of Concept Funding (up to £20K), and Innovation Development Funding (up to £75,000).

Equality, diversity and inclusion are priorities for UEA, with continuing development of practices and processes to enable female, black and minority ethnic (BAME) staff, and people with disabilities, to achieve their full potential. The Medical School 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. Prioritised projects include (i) Bystander Intervention Training which addresses racism, microaggressions, sexism and trans/homophobia (ii) interventions to improve BAME mental health and improve mental health services for BAME students, and (iii) developing both BAME and international mentoring programmes. She held events in 2019 and 2020 to discuss differential attainment and solutions, with vital input from two paid BAME ambassadors and UEA-MED alumni deliver ongoing anti-racist work within the School. The School has signed up to the BMA Charter on racial harassment.

In 2019, Norwich Medical School renewed its Silver Athena SWAN Award; its application was cited as an exemplar to be shared among other Medical Schools. The School is particularly attentive to gender issues when considering staff rewards, such as payment of performance lump sums, salary increments, regrading and promotion. Equality and Diversity training is mandatory for all staff. All committees are gender balanced, and key school roles are monitored to ensure gender diversity. Unconscious Bias training is mandatory for all members of school committees and staff with key school roles. All appointment panels are gender balanced and our recruitment material for all new staff demonstrates awareness of equality and diversity issues. The impact of this work is evidenced in the School by the increases in female academics to more senior roles, including senior lecturers and readers by 55%, and female professors by 25%, from 2012 to 2018.

Norwich Medical School set up a Supporting All at Work fund to enable anyone returning from leave (including maternity/paternity/ adoption), or with caring responsibilities or ill health, to request funding to facilitate support in the workplace, including IT purchase, training, administrative support and conference attendance. All staff are entitled to request flexible working arrangements. In recent surveys, staff increasingly report being well-supported in preparing for maternity leave (73% compared to 60% in 2016) and when returning 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.

2.2 Research students

Doctoral research students: Public health, primary care and health services research is a major part of UEA Faculty of Medicine and Health Sciences' doctoral research programme. UOA2 ATRs were primary supervisors of between 17 and 33 doctoral research students registered every year since 2014, including 26 new registrations and 28 doctoral awards.

UEA's Doctoral College was launched in March 2019, with its own academic and social space, to oversee the management, training and co-ordination of activities for all postgraduate students at UEA. For each student, a training needs analysis is made with the supervisor eight weeks after appointment and revisited annually. Each student has access to >100 modules, including research methods and practice, and a training budget of £1000. Doctoral students are also entitled to take any modules of MSc courses offered by the Faculty, described below.

Students are encouraged to develop teaching skills and can be employed as undergraduate associate tutors. The Doctoral Training and Employability Group, reporting to the Doctoral College Executive, meets monthly to discuss employability development, and monitor student feedback and satisfaction. Postgraduate research students can participate in i-Teams, gaining experience outside of academia with training in commercial awareness. The Faculty's doctoral student body is encouraged to maintain a vibrant esprit de corps, with co-located research space, an annual postgraduate research conference, and social groups.

Master's research students: UOA2 ATRs have lead roles in teaching and supervising research on the MScs in Clinical Research and Health Economics (leading the modules Introduction to Research Methods, Quantitative Research Methods, Systematic Reviews, and Health Economics and Economic Evaluation). The MSc in Clinical Research is taught part time, primarily aimed at clinically active health professionals, and includes a research dissertation. The MSc in Health Economics is taught jointly with UEA's School of Economics. The Faculty of Medicine and Health also offers an MRes degree, based on supervised original research.

UEA's Mental Health and Wellbeing Strategy 2017-22 aims to create a culture centred on student wellbeing. Our students also benefit from:

- UEA Careers Service, with two advisers dedicated to supporting career development of PGR students for ≤3 years after graduation, including "PhD-to-Professional" training.
- UEA Mentoring Programme, offering six one-to-one sessions with a professional mentor to support working in a new environment, and reflection on placement experience.
- UEA's Student Services, which include wellbeing workshops, and initiatives following the Courage Project, a sector-leading £300K OfS Catalyst project responding to wellbeing challenges faced by postgraduate research students

Clinical professional researchers. The NIHR **Research Design Service** (Shepstone, Turner, and Barton as deputy director) supports NHS clinical researchers to plan and obtain funding for clinical and public health research in Norfolk and Suffolk, and for health economic research throughout the East of England (see 3.1). The **Norwich Academic Training Office** (NATO) provides support for academic training across a range of health professions, and facilitates liaison between the NHS Trusts, the Local Education and Training Board, NIHR and UEA on the allocation and award of Academic Clinical Fellowships (ACFs) and Clinical Lectureships. It supports both NIHR and locally funded integrated academic trainees in Norwich to provide a

pathway towards doctoral or postdoctoral research, and ultimately senior academic positions. NATO has a close relationship with NIHR Integrated Academic Training Programme trainees, their supervisors, and with Health Education England, East of England and NIHR Academy. It provides a mentoring scheme involving bi-monthly meetings with NATO academics, an annual local conference, and support for conference attendance.

Notably within UOA2, Alexandre progressed from a NIHR Clinical Doctoral Fellowship to NIHR Clinical Lectureship to UEA Consultant Senior Lecturer, and now co-ordinates NATO clinical training. Public health physicians Steel and Bachmann, and general practitioners Howe and Parretti, support the NIHR Academy and NATO by supervising academic training of clinical trainees at UEA. These include:

- NIHR ACFs, two of whom progressed to doctoral research, funded by an NIHR clinical doctoral fellowship and an externally funded doctoral fellowship. An ATS general practitioner employed by UEA also supports general practitioner ACFs.
- A NIHR clinical doctoral fellow, who progressed to an NIHR Academic Clinical Lectureship
- Foundation year 2 doctors during academic placements (supervised by Steel, Bachmann and Parretti who are NHS-accredited educational and clinical supervisors)
- Public health and GP registrars during academic placements
- Early career general practitioners gaining clinical research experience, funded by Collaboration for Leadership in Applied Health Research & Care (CLAHRC) East of England

3. Income, infrastructure and facilities

3.1 Income: Since 2014, UOA2 ATRs have held 437 active research and consultancy grants worth £68.5M, including 331 new grants worth £40.4M awarded since 2014, and including 247 grants worth £48.3M for which UEA was the lead institution. Of the 437 active grants, NIHR funded £35.1M (51% of total), UK research institutes funded £12.2M (18%), and the remaining 31% was funded by UK charities (£5.6M), UK government (£9.3M), UK industry (£2.3M), the European Union (£2.8M), and other UK (£0.5M) and non-UK (£0.7M) sources.

Our strategy for generating research income is based on promoting a culture of grant applications. Applicants are supported by the Faculty's Biomedical and Clinical Research Committee and the NIHR Research Committee, which provide internal peer review and improvement for all grants of £100,000 or more before submission. Norwich Medical School's grant application success rate (including consultancy projects) increased from 38% in 2010-2013 to 55% in 2016-2019. To achieve larger, multi-partner grants and consortia, we also use support structures set up since REF2014 to promote translational and interdisciplinary work, with administrative support from the International Research Project Manager and the European Funding Manager within the University's Research and Innovation Services (RIN). RIN provides a dedicated professional support service across all aspects of research and innovation. Three Project Officers are assigned to our School to support research grants, from the proposal stage through to final reporting. RIN Finance Officers deal with budgeting and financial reporting. Overall vision comes from the PVC for Research and Innovation, the Faculty Associate Dean for Research, and a Medical School Research Director.

Three UEA-based structures further enhance research funding, collaboration and impact:
UEA Health and Social Care Partners (UEAHSCP) comprises 12 Clinical Partner organisations in East Anglia, including UEA, Norfolk County Council and 10 NHS trusts. It was set up in 2018 to facilitate research impact in the local community and to ensure that ongoing research is focused on local clinical and social needs. It has three strategic areas: healthy ageing, young people's mental health, and living with long term conditions. UEAHSCP facilitates engagement and multi-agency collaboration, and provided £29,931 seed funding to four UOA2 pilot projects. During 2020 UEAHSCP co-ordinated and supported numerous local and regional responses to the COVID-19 pandemic (see 4.4).

NIHR Research Design Service for Norfolk and Suffolk: This NHS-funded service aims to increase the quality and quantity of health research in the region, especially NHS-based studies,

by providing methodological advice and support to NHS clinicians and academics preparing research grant proposals. It is a subgroup of the regional Research Design Service for the East of England, focusing on Norfolk and Suffolk and also supporting health economic research in the East of England. Barton is deputy director and Health Economics lead, and is assisted by Shepstone (statistics), Turner (health economics), and RA advisers. The Service is co-located in the School's Public Health and Health Services Research offices.

NIHR Applied Research Collaboration (ARC) East of England: This NHS-funded organisation brings together regional health and social care professionals, researchers, and communities of services users, to address priority health and social care needs. UEA leads the research themes on Health Economics and Prioritisation (Whitty) and Inclusive Involvement (Poland, UOA3)

3.2 University-wide infrastructure: UEA Library subscribes to 98,000 journals and holds 870,000 print books and 550,000 ebooks, costing about £4.2M annually, and invested £1.3M in additional online resources from 2013-2019. Information Technology Services provide a modern information system and, since 2018, has invested £16M in strategic technology initiatives. Its High Performance Computing cluster provides access of hardware for intensive computation, including high memory, GPU, parallel and standard compute nodes. The HPC team provides assistance with computationally challenging workflows in all areas of research, science and big data at UEA. UEA has institutional licences for software required for our research including statistical, economic, qualitative and geographical data analysis.

3.3 UEA and NRP health research facilities

Two UEA research facilities are most directly important for UOA2:

First, the **Norwich Clinical Trials Unit** (NCTU) is an academic clinical trials unit within the Faculty of Health at UEA linked to the Norfolk and Norwich University Hospital (NNUH). NCTU has been fully registered as a UK Clinical Research Collaboration Clinical trials unit since 2013. Swart (UOA1) is Director and Shepstone and Barton (UOA2) are Associate Directors. Its functions include developing funding applications, and design, management, quality assurance, analysis and reporting of trials. NCTU provides a forum for training and methodological advancement in trial design, conduct and analysis. It conducts trials across a broad range of clinical disciplines influencing clinical and research practice.

The NCTU has core competencies in statistics, health economics, process evaluation, data management, randomisation, trial project management and quality systems. It 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 has grown from five staff (2013/14) to over 30 staff in 2019/20. NIHR grants to NCTU have increased from £37,653 per year (2013/14) to over £2.5M per year (2019/2020). In early 2020, the NCTU had >8000 patients enrolled in clinical trials from >500 clinical sites throughout the UK and Northern Ireland.

Second, the **Norwich Institute for Healthy Ageing** was launched in 2020, and will see more than 200 UEA researchers working collaboratively with the community, local government, the Quadram Institute and other Norwich Research Park partners, across a range of projects to improve lives in the East of England. Its researchers include Howe, MacGregor, Steel, Milton, Jones, Shepstone, Notley, Parretti, Whitty and Bachmann from UOA2. It aims to build on our world-class research in the fields of nutrition, physical activity, smoking cessation, sleep, social activity and medication adherence and lead the way in helping people make healthier lifestyle choices. It will prioritise, plan and co-produce the research with local communities and local government, commercial partners and policy makers – to ensure that our research translates into real change for better local and wider public health. UEA researchers from Norwich Medical School and the School of Health Sciences will work with colleagues from Norwich Business School, the School of Biological Sciences and the School of Computing Sciences, with support

from UEA Health and Social Care Partners. They will also collaborate with NRP researchers – at the Quadram Institute, the Earlham Institute, the John Innes Centre and the Norfolk and Norwich University Hospital – and work with partners in the wider community such as Public Health Norfolk, Norfolk County Council, and the new Anglia Local Enterprise Partnership.

Beyond UOA2, the **Norwich Research Park (NRP)** environment enables linkages with world leading health, biological and environmental researchers. It inspires UOA2's future strategy of strengthening public health and clinical research through greater integration with NRP biological and data sciences (see 1.2). NRP comprises 115 businesses and 12,000 employees of whom 3,000 are scientists and clinicians. NRP leads the world in plant and microbial sciences and genetics, and in interdisciplinary environmental science, through the internationally-renowned research at UEA, John Innes Centre and Sainsbury Laboratory. It has strengths in food, diet and health at Quadram Institute Bioscience and Norwich Medical School, and distinctive research expertise and facilities at the Earlham Institute and Norfolk and Norwich University Hospital (NNUH). Its core strengths are underpinned by expertise in computing and mathematics, chemistry and materials sciences, pharmacy and biological sciences. It has state-of-the-art scientific facilities from clinical and nutritional trials units to bioimaging suites, life science and environmental analytical facilities to biotechnology and -omics technologies.

Two recent additions to NRP are particularly important for UOA2:

Norwich Medical School's £17 million **Bob Champion Research and Education Building** opened in 2015 and is managed by UEA in partnership with the neighbouring NNUH. It provides teaching facilities and state of the art laboratories. The building houses the NRP Biorepository, the Cancer Biomarker Diagnostics Laboratory, and the Mass Spectroscopy Bioanalytical Facility and is the site of research on prostate cancer, antibiotic resistance, musculoskeletal disease and gastrointestinal diseases. Since 2018, Norwich Medical School has invested £8.4M in equipment infrastructure.

The **Quadram Institute** (QI) is a new £80M Institute on the NRP that opened in 2019. QI delivers interdisciplinary excellence across the areas of clinical practice, clinical research, population health, and food and health research. QI targets 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. QI will be the first international centre of research and clinical excellence of its kind working on food and health research. It comprises three components: Clinical Research, Endoscopy, and Bioscience. The unique co-location of these three elements in the same building synergises interactions between basic, clinical and epidemiological research to deliver a step-change in understanding food, health and microbial food safety.

3.4 Norfolk and Suffolk NHS services

These NHS trusts serve a population of 1.7 million and enable local recruitment of participants and conduct of our clinical trials and related research. They include five acute hospital trusts: Norfolk and Norwich University Hospital (NNUH, with 1200 beds), James Paget University Hospital (Great Yarmouth), Queen Elizabeth Hospital (King's Lynn), East Suffolk & North Essex NHS Foundation Trust (Ipswich), and West Suffolk Hospital (Bury St Edmunds); Norfolk and Suffolk NHS Foundation Trust (mental health); and Norfolk Community Health and Care Trust. NNUH hosts the East of England Clinical Research Network, and has a dedicated Clinical Research Facility. We also work closely with Norfolk and Suffolk Primary and Community Care Research Office, based in Norwich, which supports primary care- and community-based research conducted through all seven clinical commissioning groups and two community trusts in Norfolk and Suffolk.

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

4.1 Research collaboration

Since 2014, UOA2 researchers have recorded collaborations with over 240 organisations in the UK and overseas, including 69 universities. In the UK we have leading roles in multi-institutional collaborations working on long term cohort platforms such as the English Longitudinal Study of Ageing (with University College London; Steel leads on Quality of Care), Norfolk Arthritis Register and Versus Arthritis Epidemiology Centre (with Manchester University; PI MacGregor). We collaborate with public health research consortia such as the Centre for Excellence in Diet and Activity Research (with Cambridge University; Jones and Milton lead geographical epidemiology and activity research), and the Institute of Public Health, University of Cambridge. Turner has a longstanding collaboration with the University of Southampton, leading economic evaluations alongside world leading randomised trials (e.g. Lancet 2017;389:2214-2225, Health Technology Assessment 2014,18:6, and Annals of Family Medicine 2017;15:209-216).

Internationally, Whitty has ongoing collaborations with the University of Brisbane and Griffiths University in Australia, leading economic evaluations alongside randomised trials (e.g. Lancet 2018;392:419-430 and NEJM 2020;378:1121-3). Steel's led the English Global Burden of Disease study, collaborating with the Institute of Health Metrics and Evaluation in Seattle, USA, and with leading UK epidemiologists and Public Health England (Lancet 2018;18:32207-4; see 1.3 and impact case study).

Hunter's research on epidemiology of water-borne infection includes long term international collaborations such as the European AQUAVALENS project which he leads, involving 39 academic and industrial partners from 13 countries improving methods for detection of pathogens in water for drinking and food, the INTERREG Health for Dairy Cattle project with colleagues in France, Belgium and the Netherlands, and the WASH working group of the Global Task Force on Cholera Control, a partnership of more than 50 non-governmental organisations, academic institutions, and UN agencies (producing, for example, Nature Microbiology 2019;4:826–83).

Song's collaboration with Wuhan University produced world leading research on epidemiology of COVID-19 in China (Nature Communications 2020). Bachmann collaborates with global research health networks, especially the University of Cape Town's Knowledge Translation Unit (primary care trials in South Africa and Brazil; see 1.3 and impact case study), the NIHR Global Health Research Group on Integration of HIV, Hypertension and Diabetes in Africa, the NIHR Global Health Research Group on Prevention of Asthma Attacks in South America, and the Southern African Research Consortium for Mental Health Integration. His collaborations involve universities in seven countries, with outputs such as PLoS Medicine 2016;13:e1002178, BMJ Global 2019; 4:e001921 and AIDS 2015;292261–2268.

Recognising these collaborations, Hunter is Professor Extraordinaire in Environmental Health at Tshwane University of Technology, South Africa; Whitty is Honorary Professor at University of Brisbane and Adjunct Professor at Griffiths University, Australia; Bachmann is Honorary Professor at the Universities of Cape Town and Kwa-Zulu Natal, South Africa; and Notley is visiting Fellow at London South Bank University.

4.2 Engagement with research users to develop impact

Our research is intended to improve public health and health care policies, influence evidence-based clinical decision making, and promote healthy behaviour. To ensure relevance and impact we engage with stakeholders while planning and obtaining funding, conducting research, disseminating findings, and supporting large scale implementation. In the UK, Steel's work with Public Health England, leading the English Global Burden of Disease study, provided the epidemiological basis for NHS England's NHS Long Term Plan 2020-5 (see 1.3 and impact case). His related research on multi-morbidity and doctor-patient communication in primary care provided the evidence base for a toolkit to promote shared decision making, distributed by the NHS to all general practitioners in England. The Norfolk Diabetes Prevention Study, conducted

over eight years, entailed ongoing communication with the NHS National Diabetes Prevention Programme and NHS England's National Clinical Director for Diabetes (Barton, Clark, Bachmann, Howe, with PI Sampson (UOA1); JAMA Internal Medicine 2020), with impact on screening methods and identification of effective and cost-effective behavioural interventions for the Programme.

Internationally, Hunter's work in World Health Organisation (WHO) committees and groups has influenced numerous international guidelines, standards and policies. He was a member of the WHO guideline development group on drinking water quality, the WHO guideline development group on sanitation and health, the steering committee of the WHO/UNICEF Global Action Plan on Water Sanitation and Hygiene in Health Care Facilities, the international scientific advisory panel for the RISE project (Reinvigorating Informal Settlements and their Environments), and the WHO Health Emergencies Program Experts Advisory Panel for Infection Prevention, Control Preparedness, Readiness and Response to COVID-19. With the latter panel he contributed to writing three WHO advisory documents, on water and waste management, use of face masks, and infection control in health care. During the 2014-2016 outbreak of Ebola in West Africa he worked with WHO and the UN interagency WATSAN group to produce guidance on sanitation and waste management.

Also working with WHO, Milton was a member of the Guideline Development Group for the 2020 update of the WHO global physical activity guidelines, and was a member of the Strategic Advisory Network for the development of the WHO Global Action Plan on Physical Activity. In the UK, Milton was a member of the Chief Medical Officer's expert group updating physical activity guidelines, then member of the expert groups on communication and surveillance, to support implementation of the new physical activity guidelines.

4.3 Engagement with diverse communities and publics through research

Norwich Medical School runs a comprehensive programme of public engagement coordinated by (i) the Associate Dean for Innovation, (ii) UEA's Academic Director for Innovation, (iii) UEA's Central Press Office team and (iv) UEA's Development Office. We work closely with two units to increase public and user involvement in our research:

We routinely draw on **Public and Patient Involvement in Research** (PPIRes), based in the Norfolk and Suffolk Primary and Community Care Research Office, to facilitate patient and public involvement in planning and monitoring UK studies, and in interpreting and disseminating findings. PPIRes supports a panel of 60 volunteers who work with researchers to research ideas, ensuring they are responsive to the priorities and needs of users and beneficiaries, and are ethical. Panellists collaborate on studies and serve on trial management and steering committees.

The **Institute for Volunteering Research** was established in the voluntary sector 20 years ago and is now based at UEA. The Institute supports Faculty of Medicine and Health Sciences researchers, providing training and networks to enable engagement with public and patient groups in health and social care. The Institute and PPIRes both work with the UEA-led **Inclusive Involvement in Research for Practice Led Health and Social Care** research theme of the NIHR Applied Research Collaboration East of England (see 3.1).

We also provide **contract research consultancies** for fee-paying clients, including private firms, government and non-governmental organisations, and charities. Since 2014 we carried out 130 consultancies for £1.8M fee income. Of these, Health Economics Consulting completed 72 consultancies for 36 clients, earning £1,036,000.

4.4 Interdisciplinarity and responsiveness to national and international priorities

We support government and international agencies in developing public health programmes and clinical policies in response to national and international priorities. During 2020 we worked on numerous **responses to the COVID-19 pandemic**. Song and Bachmann collaborated with public health colleagues in Wuhan, China on COVID-19 testing among 10 million residents after the end of lockdown (Nature Communications 2020;11:5917, accessed >1.31 million times). In the UK, Hunter engaged prominently to increase public awareness about COVID-19 evidence, which was reported 23,860 times in print, broadcast and online media in 2020. Hunter also

carried out a quasi-experimental analysis of effectiveness of non-pharmacological interventions against COVID-19, a scoping review of their effectiveness, and an epidemiological study of COVID-19 transmission in 248 care homes in Norfolk, and epidemiological modelling of COVID-19 vaccination strategies. Hunter's analysis of COVID-19 transmission in England during autumn 2020 showed that tier 1 restrictions on activities were ineffective, leading the UK government to switch almost all of England from tier 1 to tiers 2 to 5 from December 2020, citing Hunter's evidence as justification. MacGregor worked with NHS Improvement on a national survey of the impact of COVID-19 on rheumatology services in England, and on plans for service restoration. As PI of the Norfolk Arthritis Register (NOAR), MacGregor led COVID-19 antibody testing among NOAR participants with rheumatoid arthritis. MacGregor, Shepstone and Notley carried out a longitudinal study of effects of COVID-19 on wellbeing among NOAR participants, and collaborated on a national survey of shielding from COVID-19 among people with rheumatoid arthritis. MacGregor, Jones and Hunter collaborated on epidemiological modelling of COVID-19 transmission in Norfolk, and at UEA. Steel chaired the COVID-19 Specialist Advisory Group for Norfolk County Council Health Protection Board, and led two multi-agency COVID-19 testing programmes, among UEA staff and students, and in the Norfolk population.

4.5 Professional contributions to the discipline, esteem and recognition

We extensively support NHS- and NIHR-funded research, serving on several NIHR grant awarding panels. These panels include NIHR Programme Grants for Applied Research (Shepstone, Bachmann, Wilson), Evaluation of Mechanisms and Efficacy (Shepstone), Health Services and Delivery Research (Steel), Public Health Research (Jones), Research for Patient Benefit (Steel, Barton, Turner), NIHR Academy's clinical and non-clinical fellowships and lectureships panel (Shepstone, Barton), and NIHR's Dementias Portfolio Development Group (Khondoker).

Also supporting UK research nationally and regionally, Shepstone is a member of the Cross-Government Trial Advice panel; Barton is deputy director of the East of England Research Design Service and was health economics theme lead for the NIHR Collaborations for Leadership in Applied Health Research and Care (CLAHRC) East of England; Bachmann is Health Services Research Speciality Lead, NIHR East of England Clinical Research Network and member of the CRN Health Services Research National Steering Group; and Wilson is appraisal panel member, National Institute for Health and Care Excellence.

We contribute to research dissemination by editing and reviewing articles for peer reviewed scientific journals. Steel is a member of the editorial boards of Implementation Science and of Quality in Primary Care. Khondoker is a member of the editorial board of Statistical Methods in Medical Research. Notley is an Associate Editor of Addiction and Associate Editor of Nicotine and Tobacco Research. Milton is editorial board member for the International Journal of Behavioural Nutrition and Physical Activity. Wilson is editorial board member of Applied Health Economics and Health Policy. He is also Co-convenor of the Campbell and Cochrane Economics Methods Group and the Cochrane Agenda and Priority Setting Methods Group. All UOA2 ATRs continuingly review scientific manuscripts for peer reviewed research journals.

UOA2 clinical academics have leading roles in medical professional organisations. Howe is currently president of the Royal College of General Practitioners (RCGP) and was previously RCGP Vice Chair for Education and Professional Development. She was President of the World Organisation of Family Doctors (WONCA) (2016-2018), President Elect (2013-2016) and Past President (2018-2019). Parretti represents RCGP on the Royal College of Physicians' (RCP) Advisory Committee on Nutrition, Weight and Health; the RCP Joint Steering Committee for Endocrinology and Diabetes; the Centre for Perioperative Care's Diabetes Guideline Working Group, and the Society for Endocrinology's working group, Defining the Future of Endocrinology. Steel was Academic Lead on the Public Health Specialty Training Programme, School of Public Health, Health Education East of England.

We provide expert support to health charities and non-governmental organisations. Shepstone is a member of Versus Arthritis Treatment Subcommittee. Notley is a board member and European representative of the Society for Research on Nicotine and Tobacco (European representative, delegate elect), and a member of the advisory council for Action on Smoking in Health. Milton is

President-elect of the International Society for Physical Activity and Health, board member of the International Society for Physical Activity and Health, and Steering Committee member for the European Network for Health Enhancing Physical Activity.

In summary, these many roles and activities, extending beyond our own research, demonstrate UEA's commitment to public health, primary care and health services research and practice.