Institution: University of Warwick

Unit of Assessment: A1 Clinical Medicine

1. Unit context and structure, research and impact strategy

1.1 Unit context

1.1.1 Overview

Warwick Medical School (WMS) was established in 2000 with an initial focus on health science research and delivery of an innovative graduate entry MBChB programme. Since that time WMS has built on the outstanding multidisciplinary research environment at the University of Warwick (UoW) to develop a research strategy **focussed on niche areas of biomedical discovery research and on developing translational clinical research strengths in a small number of areas of unmet need**. Our outputs were recognized in REF2014 (ranked 8th), and over the last 7 years we have dramatically strengthened our research environment (by doubling research income per FTE, establishing multiple research centres of excellence, new PhD and research-led UG programs, and MRC and Wellcome funded strategic awards). This development is reflected in the election of **Achtman** to the Royal Society of London (FRS), the award of the BSCB Hooke Medal to **McAinsh** (2018) and **Royle** (2021) and the emergence of significant research impact.

We have streamlined our biomedical research activities into a single entity, establishing **the Division of Biomedical Sciences (BMS)** in 2015. This structure provides a more efficient platform to deliver world-class discovery science, acts as a hub for interdisciplinary biomedical research across UoW and supports our ambition to further develop translational medicine programmes in partnership with the University Hospital Coventry & Warwickshire (UHCW). BMS holds research culture and inclusivity at the centre of all of its activities and is a strong advocate for open science.

BMS now sits alongside the Division of Health Sciences and the Warwick Clinical Trials Unit (WCTU) within WMS creating a vibrant collaborative environment that cuts across traditional research boundaries thereby facilitating our ambition to increase translational research activity in distinctive areas and generate significant impacts in health. Together with the School of Life Sciences (SLS), and other departments within the Faculty of Science, Engineering and Medicine (REF5a-1.6) there is now deep interdisciplinary strength in fundamental and applied biomedical research across UoW; evidenced by collaborations with physical and engineering sciences and clinicians. We believe this interdisciplinary strategy puts us in a strong position to address major current and future global medical challenges.

1.1.2. Major strategic developments

- £54M Warwick/Wolfson-funded Interdisciplinary Biomedical Research Building (IBRB, completing January 2021 – REF5a-4.2).
- £4M expansion of the Centre for Mechanochemical Cell Biology (CMCB) with 4 Wellcome Investigators.
- New cross-UoW multidisciplinary research centres – the Centre for Early Life (CfEL) and Cancer Research Centre.
- Joint academic appointments with Chemistry (Gibson, Perrier) and Physics (Kantsler, Polin) to hard-wire our interdisciplinary approach.

- £4M Warwick-Wellcome Trust funded Quantitative Biomedicine (QBP) program to support new early-career Investigators and public engagement and the £0.8 million Wellcome-Warwick Translational Partnership (W-WTP) to support translation of discovery research (REF5a-2.7).
- New Tommy's National Centre for Miscarriage Research, Enterobase Microbial genome database and PathLake Centre of Excellence.
- New Institute of Digital Healthcare in partnership with Warwick Manufacturing Group with a view to the future of medicine.
- Recognition of Health as a global research priority within UoW through a Health Global Research Priority (GRP), a cross-campus vehicle to support collaboration and innovation (REF5a-2.9.1).
- Renewal of our interdisciplinary MRC Doctoral Training Partnership (DTP) and expansion through MRC iCASE and National Productivity Investment Fund.
- New PhD program in partnership with A*STAR Singapore.
- Athena Swan Silver Award and sustained capacity-building through internal promotions, maintaining good gender balance.

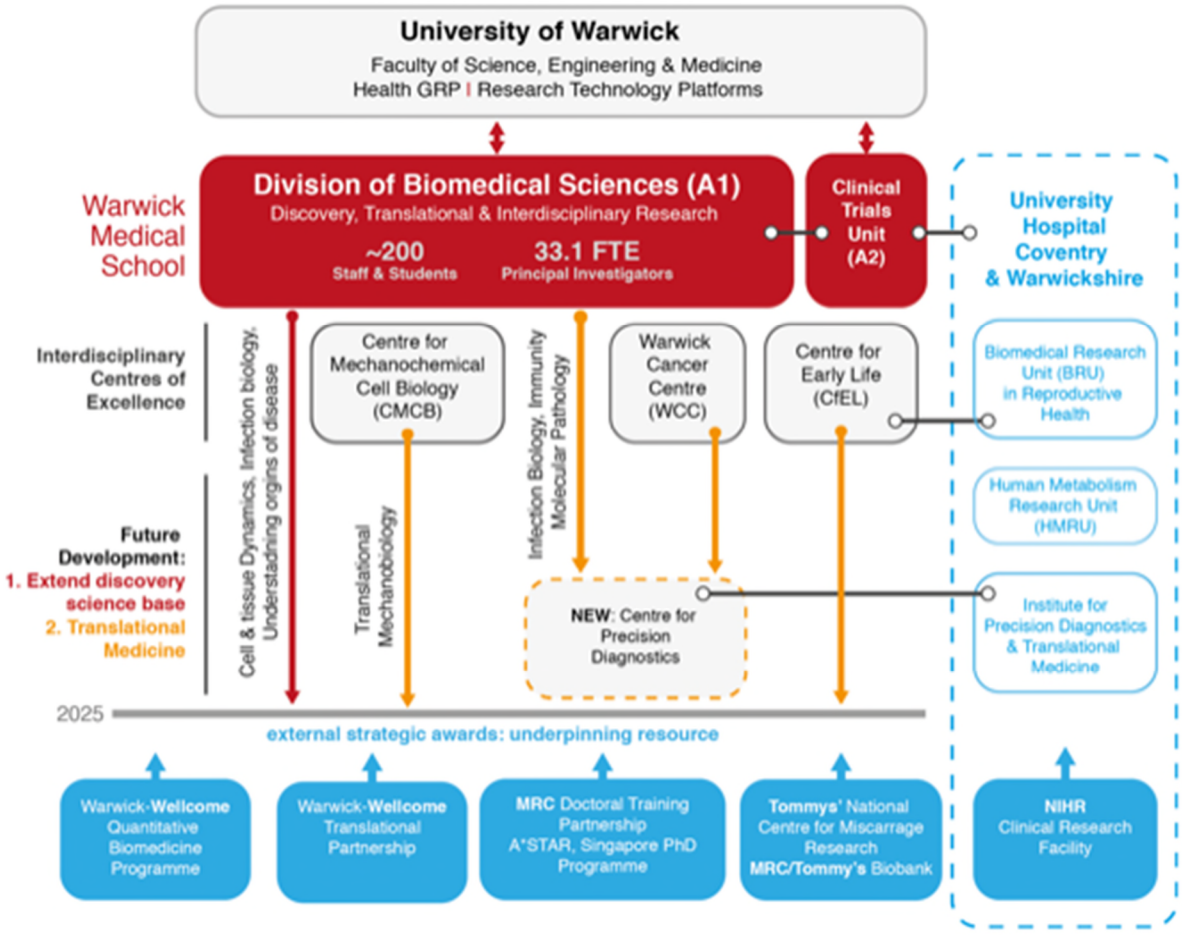

Fig 1. A1 Research Stratagy in Discovery, Interdisiplinary and Translational Research and interface with University Hospital Coventry & Warwickshire.

1.1.3 Impact and collaboration with external bodies

Our staff seek to maximise the impact of their research, contributing to the national and international research environment via collaboration, engagement with industry and the promotion of public engagement; see Sections **4.2/4.3**. To achieve this, we work with other academic departments in UoW, our local partner hospital (UHCW) and other NHS Trusts as well

as national and international funding bodies and agencies such as Wellcome, British Council, and A*STAR-Singapore. The important contribution to these organisations from many of our staff helps ensure that we deliver the highest priority research with the maximum possible impact on discovery and translational research. Building an outstanding academic environment brings new ideas, and then research impact, not only those included as our three case studies (**1.** Enterobase-a platform to trace disease outbreaks, **2.** Prevention strategies for recurrent pregnancy loss, **3.** New therapeutics for neurological disorders), but also many more emerging cases including two new spin-outs (Nanosyrinx and Cytoswim), SARS-COV-2 diagnostics, cryoprotectants for biologicals, repurposed drugs for preventing miscarriage, Oxytocin receptor antagonists for treatment of preterm labour, and the digitisation of routine histopathology.

1.1.4 Setting within University and local healthcare environment

UoW creates a lively interdisciplinary research culture through its strong departments, network of research centres and nine GRPs (REF5a-2.9.1). WMS forms a single department within the Faculty of Science, Engineering and Medicine facilitating the collaborative working both within WMS and with other departments that we see as an essential part of our interdisciplinary research activity. The Health GRP (co-led by **Young, FMedSci**) 'pump-primes' collaborative interactions with an emphasis on supporting the development of early career researchers (ECRs) in areas that span traditional disciplines. The Health GRP interacts with our other Centres and engages with a range of external stakeholders (*e.g.* UHCW) as well as providing a vehicle for collaboration with industry. As described in Section 4, we have a strong and successful partnership with UHCW. Our close collaborations have allowed us to appoint to posts of shared value and to invest in integration with frontline clinicians. We have an established laboratory base at UHCW, our Clinical Sciences Research Laboratories, which is currently home to eight research groups and actively engages with frontline clinical staff across our priority research themes.

1.2 Unit structure and strategy

1.2.1 Division of Biomedical Sciences

All staff included in the Warwick UoA A1 return are based in the **Division of Biomedical Sciences (BMS;** head, **McAinsh**) which is home to almost 200 staff/research students making up approximately 33% of Warwick Medical School. Our 39 principal investigators (PIs; 33.1 FTE eligible) include both clinical and non-clinical academics alongside four that are jointly appointed with other UoW departments in support of our interdisciplinary ethos (returned in UoA B8/UoA B9). PIs and their research groups are supported by a strong dedicated administration team (12.1 FTE) and extensive technical services group ensuring efficient laboratory operations.

1.2.2 Leadership and governance

Research strategy in WMS is led by **Balasubramanian** (Pro-Dean, Research) who chairs the WMS Research Committee and is a member of the University Research Committee chaired by the PVC (Research) (REF5a-2.4). He works closely on a day-to-day basis with the Head of Division, BMS (**McAinsh**). Both **McAinsh** and **Balasubramanian** also sit on the WMS Senior Management Group; this leadership group includes the Dean (Kumar), Pro-Dean Education, Heads of Governance, Administration, Finance, Marketing, MBChB, Career Development, Postgraduate Research and the Heads of the WCTU and Division of Health Sciences. Within BMS **Brosens** provides clinical leadership, while **Blanks** oversees industry/impact development and is a member of the University Research Impact Advisory Group, chaired by the PVC (Research) (REF5a-2.6). Our research is closely integrated with education as **Straube** is deputy director of WMS postgraduate research, while BMS also takes responsibility for medical student

and undergraduate education.

1.2.3 Strategy

Our priority during this REF period has been to: **1. consolidate and extend our discovery science base**, and **2. develop distinctive areas of translational and experimental medicine** by strengthening our partnership with UHCW. To achieve this, we set out to establish and develop a number of defined research programmes and centres (see sections **1.2.4** and **1.2.5** for detail – **Fig. 1**). The latter are interdisciplinary in nature with members from multiple University departments and benefit from a degree of autonomy, undergoing review on a three–year cycle by the University Research Committee to ensure continued research success. Catalysing the activity of these centres and nucleating new collaborative research programmes demands: (i) developing a world-class faculty that is capable of sustaining high-quality externally funded programmes in discovery and/or translational research; (ii) winning large external strategic awards; (iii) supporting the expansion of clinical scientist led research with hospital partners and (iv) establishing the necessary infrastructure, enabling technologies/facilities and support/leadership structures.

Our strategy is also nimble and adapts to address current health needs. We have made significant contributions to the diagnosis of COVID-19. **Balasubramanian** and **Sampath** generated thermostable enzymes used in COVID-19 diagnosis, which have been sent to CDC-Africa (Ethiopia), Sfax (Tunisia), EMBL (Germany), Isfahan University (Iran), and IndX program (India). Gibson and **Straube** have developed a new test based on sugar binding of SARS-CoV2 spike protein and **Robb** a single molecule imaging-based diagnostic for SARS-Cov2 - both currently undergoing technology transfer. The work of **Randeva, Young** and **Grammatopoulos** in COVID-19 testing and prognosis is described in **1.2.4. (Translational Research Section).**

1.2.4 Core Research Programmes

- Our **Discovery Science** (20.2 FTE) work involves viral, prokaryotic, and eukaryotic systems and in many cases works at the interface of mechanism and disease. One focus is to understand the molecular mechanisms and rules that enable cell duplication, movement and repair and the self-organisational events that produce and pattern organs and multi-cellular organisms. At the heart of this effort are 12 PIs that form the core of the Centre for Mechanochemical Cell Biology (CMCB**,** see **1.2.5**). A second focus is Infection biology which explores the population structure and evolution of pathogenic bacteria (**Achtman**, **Quince**), alongside mechanistic work on bacterial invasion (**Unnikrishnann**, **Waterfield**), Virology (Robb), Parasitology **(Dean**) and cellular imumunoloy (**James**). All this work benefits from access to cutting-edge high-throughput approaches, including robotics, genomics, metagenomics, bioinformatics and imaging to understand the biology of key pathogens, host interactions and their communities. Success over the REF period is highlighted by 5 Wellcome Investigators, a Henry Dale Fellow, 2 collaborative grants, an ERC advanced grant, CRUK (programme grant and fellowship) and a large number of project grants from MRC, BBSRC, and Leverhulme Trust. These research programs have led to significant discoveries, as evidenced in the outputs as well as one of our impact cases and other esteem indicators.

- Our **Translational Research** (12.9 FTE) activity is focussed on exploiting our discovery science base to grow our applied research (and impact) portfolio with our main clinical partner, UHCW, while benefiting from the distinctiveness afforded by our cross-campus interdisciplinary strengths. These activities are principally focussed in key niche areas:

1. **Reproductive medicine:** This strong research cluster (Five PIs, **Brosens, Quenby, Blanks, Greaves and Ott** working alongside Hartshorne -Scientific Director, UHCW IVF clinic, investigate the physiology and diseases associated with the processes of reproduction. This is coupled to developing interventions to tackle recurrent miscarriage, preterm labour, endometriosis and persistent reproductive failure. Significant impact has already been achieved in this area: (i) a novel pre-pregnancy test to identify women at risk of higher-order miscarriages and to target treatments to specific underlying defects; (ii) novel treatment strategies focussed on enhancing the endometrium prior to conception by optimising recruitment of uterine stem cells; (iii) influenced guidelines and policy through the European Society of Human Reproduction and Embryology group; and (iv) developed, in collaboration with Glaxo SmithKline, second generation oxytocin receptor antagonists, currently in phase three clinical trials, for the treatment of preterm labour. The success from this activity has led to the MRC-Tommy's Biobank, Tommy's National miscarriage Centre, the new Centre for Early Life and a second impact case study.

2. **Development of novel drugs, devices, and treatments**. To this end, we work closely with the departments of Chemistry, Maths, WMG, Computer Science. We have developed cancer therapeutics (**Dallman**, **Levi**, **Young**, Perrier, and Sadler in Chemistry and Rand in Maths), cryopreservation of biologicals (Gibson) and SARS-CoV2 diagnostics (Gibson, **Robb**). Continued success of the spin-out company Neurosolutions Ltd which is driving the development of treatment for neurological disorders, including pain and neurodegeneration providing a third **impact case study**. Working in partnership with UHCW (**Grammatopoulos**, **Randeva**) have spearheaded the COVID-19 testing base for Coventry and Warwickshire. A recent Innovate UK award (**Young, Grammatopoulos** with Celentyx Ltd) is developing high throughput screening for agents that block SARS-CoV-2 infection.

3. **Establishment of a digital pathology** research programme in collaboration with Computer Science (Rajpoot) and UHCW, the first NHS hospital to fully digitise its pathology services. This work exploits our imaging expertise for the digital analysis of histological material and the use of artificial intelligence (AI) to develop algorithms for the automation of pathology screening. A product of this work is the PathLAKE (Pathology image data Lake for Analytics, Knowledge and Education-led by **Snead**) Centre of Excellence supported by Innovate UK which, working with Philips Healthcare, has created a national centre of excellence in AI in pathology, linked to five other digitised NHS pathology labs with a total of £29M in grants.

1.2.5 Centres of Excellence

- ***Centre for Mechanochemical Cell Biology (CMCB)*** (led by **Cross**): Established in 2010, the CMCB has grown into a **world-leading University Research Centre** that is home to four Wellcome Investigators (**Cross, McAInsh, Balasubramanian, Straube)**. The first phase of CMCB expansion was supported through a university-funded £4M extension to the Mechanochemical Cell Biology Building in 2015. The CMCB drives basic scientific understanding of the natural molecular and cellular machinery that generates force and movement; processes that are frequently disrupted in various diseases. The Centre is also home to two research groups jointly appointed with Physics, and other members from Physics, Computer Science and Mathematics. The Centre has an outstanding track record in

quantitative molecular cell biology and biophysics as well as experimental molecular cell biology, all with an increasing focus on disease-associated mechanisms. We have built an outstanding interdisciplinary environment regarding both through physical environment for experiments and our scientific culture. We have begun expanding the CMCB research focus to include tissue-scale mechanobiology through the recruitment of three outstanding Assistant (**Smutny, Ratheesh**, Austrian Institute of Technology; **Koester**, National Institute of Biological Sciences, Bangalore) and Associate (**Saunders**, Mechanobiology Institute Singapore) Professors. This has been facilitated by the Warwick-Wellcome Quantitative Biomedicine Programme (see below) and through the Wolfson investment in a Tissue mechanobiology and human disease laboratory within IBRB.

- ***Centre for Early Life (CfEL)*** (led by **Brosens**/**Quenby**): Established in 2020 the CfEL will focus on biomedical challenges encompassing conception, pregnancy and infant development. Designed to capitalise and expand on existing research strengths including the Tommy's National Miscarriage Research Centre; the Biomedical Research Unit embedded in UHCW which serves as a catalyst for both early-phase and large-scale multicentre clinical trials; the dedicated NHS Research Implantation Clinic for couples experiencing persistent reproductive failure, and the MRC-funded Tommy's Biobank. The breadth of scientific expertise means that the Centre can translate the science of embryo implantation into novel tests and treatments that lead to healthy infants with minimal disability. In keeping with our interdisciplinary ethos, the Centre is institution-wide including principal investigators from WMS, School of Life Sciences (SLS), Institute for Digital Healthcare, Engineering, Chemistry, Psychology, Mathematics and Physics. It is envisaged that the CfEL will generate translatable outputs in basic science, drug discovery and novel diagnostics as well as healthcare policy in the treatment of infants, interacting with our Division of Health Sciences and Clinical Trials Unit. Expansion of faculty and our research base is evidenced by recruitment of MRC-funded Assistant Professor (**Greaves**, from MRC centre, Edinburgh) award of a joint Wellcome Investigator award (**Brosens, Ott**) and a Wellcome Collaborative Award (**McAinsh** with Hartshorne (UHCW) and Burroughs (Maths).

- ***Warwick Cancer Research Centre (WCRC)*** (led by **Young**): WCRC has provided a focus for multidisciplinary cancer research. It has resulted in new collaborations and research funding between departments (e.g. WMS and the Department of Chemistry with funding from CRUK, EPSRC and Royal Society), contributed to regional developments in medical technology and clinical trials (e.g. PathLake digital pathology project led by **Snead** and interactions with regional clinical trials units), and supported improved engagement with hospital trusts. WCRC is being increasingly recognised as a centre of excellence and is starting to generate new external funding (CRUK Programme Grant & Pioneer Award (**Royle**), CRUK Interdisciplinary Award (**Levi/Dallman**/Rand).

1.2.6 Achievements: External Strategic Awards

- ***Wellcome-Warwick Quantitative Biomedicine Programme (QBP)***: Established by **Balasubramanian** in 2014 to build biomedical research through Wellcome Trust's Institutional Strategic Support Fund (ISSF). The initial £600K award (and an equivalent match from Warwick) supported two ECRs (one is now a Wellcome/Royal Society Sir Henry Dale Fellow) and internal seed grants (one of which led to a Wellcome Investigator Award, **Straube**). This success led to a second expanded award of £1M (and an equivalent match from Warwick) in 2016 (led by **Balasubramanian & McAinsh**) to support recruitment of five new QBP Assistant/Associate Professors (three to expand capacity in the CMCB (**Koester,**

Smutny & Ratheesh) and two to Infection/Epidemiology (**James**, BMS) and (Gorsich, Life Sciences). QBP also supports a thriving public engagement programme led by a dedicated Public Engagement coordinator, organises annual international symposia and provides seed grants to develop further quantitative biomedicine projects across the University.

- ***Wolfson Foundation award - Tissue Mechanobiology and Human Disease Laboratory:*** This £750K award enables the expansion of the CMCB into tissue mechanobiology research within the new Interdisciplinary Biomedical Research Building (IBRB).

- ***Microbial Bioinformatics***: Following the formation of a microbiology and infection programme in 2013 our researchers have established a world-leading microbial bioinformatics cluster including the £8.4M MRC-funded Cloud Infrastructure for Microbial Bioinformatics (CLIMB, *CLIMB2 Big Data*) facilities and BBSRC-funded Enterobase genome database. The latter (led by **Achtman**), provides a globally unique resource: ~250,000 genomes from multiple genera that were assembled from publicly available short read archives, creating an invaluable public resource for investigating the history of associations between pathogens and their hosts. International government laboratories have used Enterobase to supplement outbreak investigations including Public Health England, Public Health Agency of Sweden, Centre for Infectious Diseases and Microbiology - Public Health (NSW, Australia) as evidence in one of our impact case studies.

- ***Tommy's National Centre for Miscarriage Research***: Led by **Quenby** and **Brosens** (at Warwick), this £2.5M award established the Tommy's National Early Centre for Miscarriage Research in a partnership with Birmingham, and Imperial. The three sites run specialist clinics enabling 24,000 women per year to access treatment and support and participate in research studies. The Centre is dedicated to improving the lives of women and couples experiencing miscarriage and aims to serve 24,000 local couples every year; to advocate for access to recurrent miscarriage care and increase therapeutic options; to lead on national and international guidelines.

- ***Wellcome-Warwick Translational Partnership (W-WTP)***: The W-WTP was established in 2019 by a £600K award from Wellcome and £180K from the University to develop a translational ecosystem (REF5a-2.7). The long-term vision is to deliver essential resources, people and support to maximise the translation of our discovery science into new diagnostic tools, treatments and patient benefits using a multidisciplinary highly collaborative approach. To achieve this we have established: **(i) Translational Fellows programme**, aimed at existing researchers (PDRAs, ECRs) who have expertise and well-defined plans to drive forward translational research. Awarded fellows are developing non-invasive oxygen monitoring in neonates, endometrial organoids for drug discovery and cryopreservation for CAR-T therapy. **(ii) Translation and Innovation Grants** to overcome specific barriers and provide access to external expertise.

- ***MRC Proximity-to-Discovery:*** This fund supports opportunities to increase engagement with industrial and/or clinical partners, or to provide our researchers with opportunities to develop their skills and confidence to cultivate translational research ideas within MRC strategic priorities. This award is managed in conjunction with the University's innovation group which also holds a budget (£310K p.a.) used predominantly for supporting patent costs and is a node for the Research England funded Midlands Innovation Commercialisation of Research Accelerator (MICRA) and the Midlands Hub for Innovate UK

funded Innovation to Commercialisation of University Research (ICURe) programme. Our researchers are encouraged and supported to apply for internal funds to facilitate impact from research (REF5a-2.7). A number of researchers (**Waterfield,** Gibson) have received HEIF and UKRI IAA impact awards.

- ***Innovation*** (1) **Waterfield** (NanoSyrinx) - nanosyringes for drug delivery supported by Warwick Innovations impact development funds, BBSRC pathfinder grant, an iCURE (Innovate UK) 3-month fellowship, and secured an initial round of investment from Merck Ventures and BioCity; (2) **Gibson** (CryoLogyx) – awarded £300K from Innovate UK to develop innovate cryopreservation agents with applications in the diagnostic, medicines discovery and cell-based therapy markets; (3) UHCW is the lead partner on the £15.7m PathLAKE Innovate UK with **Snead** and Rajpoot (Department of Computer Science) leading the development, validation and implementation of AI in histopathology in the NHS to improve cancer diagnosis; this is further supported by specialist imaging and AI SMEs; (4) **Imray** (UHCW, Honorary Professor) is co-applicant on the 2014 NIHR i4i project led by Dale (Life Sciences/Sarissa Biomedical) to develop SMARTChip, the world's first point-of-care test for purines in whole bloodSMARTchip is progressing through clinical trials.

1.3 Future Development

WMS has undertaken a renewal of its 10-year strategy and will recruit 16 new posts, of whom 9 will be UoA A1-facing. The major focus will be on expansion of **"Discovery-to-early translation"** thereby bridging to our well-established Clinical Trails portfolio (returned in UoA A2). The recently established Warwick-Wellcome Translational Partnership was specifically designed to support this early stage translation and we will work to expand this in due course with the University's Health GRP providing an institution -wide framework. Our approach will initially focus on building three translational research themes (**Fig. 1**):

1. ***Translational Mechanobiology***: We will expand on our proven success in molecular and cellular mechanobiology (see CMCB, section **1.2.5**) and our new recruitments in tissue-scale mechanobiology (**Saunders**) to initiate a research programme in clinical mechanobiology. Building on our technological expertise in microscopy, image analysis and the measurement of forces, we aim to create technologies to probe and manipulate biomechanics - a key theme will be to evaluate the association between load and tissue damage and how nerves, tendons, and muscle respond to damage at both the cellular and tissue level. We will create new opportunities for interdisciplinary collaborative work with our Institute of Digital Health's Health Care Technologies and Biomedical Engineering group. A second theme will investigate how cellular and tissue level mechanochemical defects manifest into human disease, such as tendonopathies and myopathies and ageing processes; this work will be supported by new clinical academic appointments.

2. ***Reproductive Medicine***: Already a major strength with substantial outputs and impacts. We will aim to extend work using patient-derived organoids and organ-on-a-chip approaches to dissect diseases with a reproductive origin. We see a significant opportunity to develop new programmes at the interface of CMCB and CfEL, where the role of mechanical processes in reproduction and disease etiology will be explored.

3. ***Precision Diagnostics:*** We will build on our strengths in Infection biology and digital pathology with an initial focus on staphylococcal, mycobacterial and viral infections, and

digital pathology signatures in cancer diagnosis. We will strengthen these areas with new clinical academic appointments and use these to enhance the translational development of our molecular and cellular pathology programmes. The Centre will work closely with the Institute of Precision Diagnostics and Translational Medicine at UHCW which will provide the vehicle for the more applied aspects of the research, working with clinicians and industry to fast track key areas of innovation (*e.g.* digital pathology, biomarker development). Key industry partners will include Philips Healthcare and Siemens.

A key objective will be to develop national capacity for training clinical academics in the related clinical discipline areas that are less well represented nationally and establish Clinical PhD programmes in partnership with UHCW. At the same time, we will use resources to ensure the continued growth and sustainability of our thriving Discovery Science programmes.

2. People

2.1 Staffing strategy and staff development

2.1.1 Staffing strategy overview

The Division of Biomedical Sciences has a total of 198.9 FTE staff and students, with a REF-eligible research active staff complement of 33.1 FTE. The remaining staff constitute postdoctoral researchers/fellows (39), clinical lecturers (16 in WMS), technicians (13), administrators (12.1) along with PGR students (95) and teaching fellows (4). To build a positive and inclusive culture, all staff are invited to regular staff meetings (on-line for last year), and receive a weekly news bulletin to highlight successes and communicate key notices. Given we are co-located with SLS, we established a joint “return to research group” to ensure coordinated and consistent laboratory working during the COVID19 pandemic.

Our strategy has been one of sustained growth underpinned by external research grant income (see Section 3) and the launch in 2020 of our two new undergraduate UG courses **1.** A pioneering research-led MSci (Integrated Sciences) and **2.** A Health and Medical Sciences BSc, which provide opportunities for the recruitment of new junior faculty. Since REF2014 we have recruited eight new PIs (25% of total) including three QBP Assistant Professors (co-funded by Wellcome), three university-funded assistant professors (**Greaves**, MRC career development award; **Dean**, former Henry Wellcome fellow and **Robb**, Dorothy Hodgkin Royal Society Fellow) and two Associate Professors (**James,** former Henry Dale fellow and **Saunders**, National Research Foundation Fellow, Singapore).

The next step in our strategy is to complete recruitment of three additional PIs who will be accommodated in the new £54M research facility, the **Interdisciplinary Biomedical Research Building (IBRB)**. Our search will focus on infectious diseases and immunity researchers, who will help generate a critical mass in this area. The second step will involve recruitment of 7 translational researchers. Thus, the recruitment process will target translational clinical researchers in our key areas (Early Life, Translational Mechanobiology, Precision Diagnostics, **Fig. 1**) who are attracted to our multidisciplinary environment. In parallel we are seeking to attract outstanding early career researchers who we will sponsor to win career development fellowships. We offer attractive start-up packages (>£130K), alongside underwriting of access to equipment, facilities and staff/students to fully support career progression and success as first external awards are sought.

2.1.2 Awards/International Recognition

The excellence of our staff at all levels is demonstrated by awards and international recognition as described in more detail in Sections **2.2** and **4**, the most prestigious including:

1 Fellow of The Royal Society (FRS) [**Achtman**]
1 Pettenkofer Prize 2018 [**Achtman**]
1 Fellow of The Medical Academy of Sciences [**Young**]
2 Hooke Medals, British Society of Cell Biology [**McAinsh, Royle**]
1 Lister Prize Fellow [**Straube]**
2 Wolfson Royal Society Research Merit Awards [**Balasubramanian, McAinsh**]
7 Wellcome Investigators [**McAinsh/Achtman/Cross/Straube/Balasubramanian/Brosens/Ott**]
8. **Quenby** and **Brosens** both named in the top 100 Nation's Lifesavers.

2.1.3 Academic Development

Continued development of all our academics, irrespective of career stages, is a key aim with multiple programmes now in place to build a positive research culture (see below and REF5a-3.3). We are signatories to DORA (San Francisco Declaration for Research Assessment).

1. We established an Internal Review Committee (IRC) to ensure thorough internal peer review, monitor PI response to review and provides constructive feedback. All grants now flow through this system.

2. Alongside a vibrant external seminar series, we established an internal-facing programme in order that PIs can share their research discoveries with colleagues. This has proved to be extremely valuable in building collegiality. There are also regular subject-specific seminars in *Microbiology & Infection* and *Stem cells & Development* that are jointly run with the School of Life Sciences. Centre-focused seminar programmes provide additional opportunities for research discussion, critical feedback and the identification of collaborative opportunities.

3. Annual review: either the official University Personal Development Review (PDR) or an informal one-to-one discussion with Head of Division is now mandatory to ensure that we can provide appropriate support for the development all academics. All Assistant Professors are also subject to a 5 year probation period with close mentorship - a positive outcome leads to promotion (to Associate Professor) and is based on performance across four key areas of academic activity: Research & Scholarship, Teaching & Learning, Impact, Outreach & Engagement and Collegiality, Leadership & Management. Annual meetings are held with Dean/ Head of Division to monitor progress and provide support and guidance.

4. For academics with leadership potential we have encouraged participation in the University's Leadership Programme; in the REF period 7 academics have benefited, 4 of whom have gone on to leadership roles (*i.e.* **Millar** and then, **McAinsh** to Head of Division; **Straube** to Deputy Director PGR in WMS).

5. All new staff have induction meetings with our Research & Impact Services (R&IS) who provide guidance on eligibility, remit and budgets for funding schemes (REF5a-1.7). Training events and funder visits are organised on a regular basis, such as visits by the Wellcome Trust (Sep 2016, Sep 2018), BBSRC (March 2019) and MRC (July 2019) as

well as sessions on grant writing, where early career researchers can learn about funding schemes including Fellowship schemes and develop their grant writing skills. Further, R&IS members advise researchers on an individual basis on planned research grant or fellowship applications where required and support the Division of Biomedical Sciences in their peer review (see IRC above).

6. We are proud to hold an Athena SWAN Silver Award with the effectiveness of our equality and diversity strategy demonstrated by our excellent gender balance at all levels (see section **2.4.1**).

Successful promotions all academic career transitions
McAinsh - Associate Professor to Professor (2014)
Straube - to Associate Professor (2014), and Professor (2020)
Royle - Associate Professor to Reader (2016), and Professor (2019)
Bastie - to Associate Professor (2016, now teaching focused)
Sampath - Associate Professor to Professor (2018)
Unnikrishnan - Assistant Professor to Associate Professor (2018)
Dallmann - Assistant Professor to Associate Professor (2020)

2.2 Early career researchers (ECRs)

Our ECRs are valued members of research groups, taking a full and active role, and are essential to our current research success as well as the future of research. We have a specific academic development programme for ECRs, who are also encouraged to have a senior academic mentor, with this obligatory for probationary staff. Our commitment to ECR development is exemplified by both Wellcome-Warwick QBP and TP strategic awards directly supporting the recruitment of independent fellows (2), Assistant Professors (4) and Translational fellows (3). In total we have 52.9 ECRs that includes postdoctoral researchers, research associates, research fellows, senior research fellows, assistant professors, teaching fellows, senior teaching fellows, academic clinical fellows and academic clinical lecturers. WMS established an Academic Staff Development Network to focus support on these staff. The group meets quarterly, hosts multiple events/workshop. We share responsibility for 1) representing staff at the WMS Welfare Strategy Group and other relevant committees. 2) Provide signposting and information 3) Raise concerns and issues on behalf of staff to the senior management, 4) Provide networking opportunities for members.

Additional support mechanisms have been developed for the following groups:

2.2.1 Postdoctoral Research Fellows (PDRFs)
We keenly support our researchers in building successful careers both in academia and industry. We ensure that there are opportunities to meet with funders and discuss their plans in one-to-one meetings. We also support and encourage the writing of grants for pilot work that can lead to fellowships, e.*g.* supported Dr. Emma Watkins (*nee* Lucas) in a successful application to Medical Life Science Research Fund to acquire preliminary data for a RCUK fellowship application.

Examples of success:
Vladimirou - PDRF to Independent Group Leader, UCL Cancer Center (2016)
Auckland – PDRF to Independent Group Leader, Randal Institute, KCL (2021)

Drummond – PDRF to Full Professor, Kyushu University, Japan (2014)
Watkins - Promoted to Senior Research Fellow (2019)
Koester – PDRF to Assistant Professor, Warwick (2018)
Booth – PDRF to Independent Group Leader, Nottingham (2019)
Tchoupa – PDRF to Humbolt fellowship (2019)
Louise-Davies – PDRF to Lectureship, UCL (2017)
Leazza – PDRF to lecturer, University of Potenza (2019)
Healey – PDRF to CEO of the spin-out Nanosyrinx
Palani – PDRF to Assistant Professor, Indian Institute of Science, Bangalore, India (2020)
Hatano – PDRF to Deputy Director, Chitose Taberumo Corporation, Japan (2020)

2.2.2 Clinical Lecturers/Fellows

Within WMS we have hosted Integrated Academic Training posts within a programme that has expanded to include 9 specialties and attracts high calibre candidates across all levels of the programme. In 2018, Warwick was joint second in the country amongst medical schools whose students have been the most successful in applying to join the Academic Foundation Programme with 67% of our students who applied receiving an offer. Since 2014, WMS has had 16 CLs in post of which 14 have gone on to continue their academic careers through multiple channels (taking posts such as Associate Professors and other academic positions).
While building ACF and CLs into our UoA A1-based researchers is at an earlier stage, there are already notable successes all with substantive posts:

- **Dr Hsu Chong** (14/16), now NHS Consultant, Addenbrookes, Cambridge.
- **Dr Shreeya Tewary** (18/20) - shortlisted for the GSK Star Researcher award for her precision medicine early phase trial, now in sub-speciality training, Addenbrookes, Cambridge.
- **Dr Lauren Lacy** (17/21), novel diagnostics for pre-term labour, Seed award from Warwick-Wellcome Translational Partnership.
- **Dr Hasan Kahal** (17) now a Consultant endocrinologist, Bristol.
- **Dr Bassel Al-Wattar** (17/21) currently sub-specialty training at UCL.

2.2.3. Assistant Professor/Independent Fellowship holders

In 2018 we established Advisory committees for all new Assistant Professors and Clinical Associate Professors. In this scheme, assistant professors organize a 3-member committee, that mentors them with respect to 1. Grant writing 2. Laboratory management 3. PhD student training 4. Teaching 5. Conflict resolution, and 6. Budget management. The committees meet on a yearly basis but have an informal flavour. ECRs are guided to focus on strategic issues, and not use time reporting data. They also benefit from informal interactions over the years with their committee members. This scheme goes above and beyond the standard University scheme which involves a single academic mentor who they meet annually (this individual now acts as the chair of the advisory committee). Assistant Professors also benefit from our internal grant review system to maximise their research potential and are invited to senior committees to provide input and gain experience (**Koester** is member of WMS Research Committee).

Examples of success:

Bowman - QBP fellow, now a Wellcome/Royal Society Sir Henry Dale Fellow.
Smutny – Assistant Prof. since 2019 - awarded BBSRC new investigator award.
Ratheesh - Assistant Prof. since 2019 – led successful infrastructure bid to BBSRC ALERT19.

2.3 Training and supervision of postgraduate research (PGR) students

The 95 postgraduate research students in Biomedical Sciences are supported through multiple funding streams including University/WMS Scholarships, research grants from CRUK, Leverhulme Trust or British Heart Foundation, and via multiple University-wide doctoral training Centers (REF5a-3.9).

Our PGR training is organized around four key programmes:

2.3.1 MRC Doctoral Training partnership (DTP) in Interdisciplinary Biomedical Research

This flagship DTP (Directed by **Millar**) was renewed for a second 5 year period in 2016, ranking highly in a UK wide competition. The programme (56 students) delivers a class-leading interdisciplinary training programme comprised of a 1 year MSc and a 3 year PhD – students following projects with supervisors from distinct disciplines. There is a strong focus on quantitative imaging, microbial genomics, bioinformatics, polymer chemistry and chemical biology. In the first MSc year students gain core quantitative skills in mathematics, programming, statistics, mathematical and molecular modelling, chemistry and frontier techniques in biomedical research, such as genome engineering, before embarking on a 3-year PhD jointly supervised across departments and disciplines. Such training is particularly suitable for bridging the skills gap to the biotechnology and pharmaceutical sectors as identified by the MRC. To recruit an excellent and diverse cohort applicants are shortlisted and interviewed by a diverse gender-balanced panel of 4 academics with at least two female and two male members and at least one representative from another department. Cohort building is at the heart of this programme – ensuring students benefit from peer-to-peer support throughout the training year and beyond. In monthly DTP meetings, students present their research to the cohort, receive skills training and career advice. All students are mentored by the DTP management team and meet an advisory committee once per year.

2.3.2 MRC Industrial Collaborative Awards in Science and Engineering (iCASE)

Following national competitions, 12 industry linked iCASE studentships from the MRC and 6 studentships from the National Productivity Investment Fund (NPIF) were secured. This enabled the DTP to expand its scientific remit to include projects in applied biomedical technologies including health informatics, digital pathology, point-of-care diagnostics, biomedical engineering, biosensors, nano-biotechnology, small animal *in vivo* and clinical imaging. This takes advantage of particular strengths of UoW and hospital partners and the establishment of an industry focused Medicines Discovery Catapult for tackling the threat of antimicrobial resistance (AMR). A further 3 industry linked studentships from through the National Productivity Investment Fund (NPIF), expand the remit to Artificial Intelligence (AI) for the analysis of big data. DTP industry partners currently include both large pharmaceutical firms such as AstraZeneca, Boehringer Ingleheim, Roche, LifeArc and Sosei Heptares Ltd and small and medium enterprises (SMEs) and Warwick spin off companies such as Bicycle Therapeutics PLC, Sarissa Biomedical and Neurosolutions Ltd. Industry partners provide bespoke training opportunities to all DTP students including drug discovery, intellectual property and patent law.

2.3.3 Warwick-Singapore A*STAR institute ARAP program

Launched in 2018, this 4-year programme (Directed by **Sampath**) enables students to conduct a research project with time spent in both an A*STAR institute in Singapore (2 yrs) and WMS or WMG (2 yrs). There are already 13 students on this programme and projects are in the field of

molecular cell biology or microbiology. The success has now led to renewal of this programme for another 4 years with 5 students per year.

2.3.4 PGR Academy

Inspired by our MRC DTP, this brings all the School's Biomedical PhD students from diverse funding streams into a single cohort for advanced training, peer-to-peer support, networking, career guidance and research symposia (Directed by **Straube, Blanks**). This initiative will also streamline the administration to ensure high quality support for students and a common recruitment process to ensure that only the highest quality students join the division. All PGR students have two supervisors and are mentored by their divisional academic PGR lead. Progress is formally assessed after 9 months and 21 months of full-time study by a review panel. Pastoral care is provided by the postgraduate tutor who supports all our students with a range of personal problems and mental health issues. In 2021 we established a new PhD programme that is supported through the newly founded Institute for Global Pandemic Planning.

Awards and Recognition

Cerys Currie – Young Cell Biologist of the Year Award, British Society of Cell Biology, 2018.
Jonathan Fenn – International Journal of Molecular Sciences Poster Prize, 2018.
Thomas Rawlings – President's Presenter Award, Society for Reproductive Investigation, 2019.
Katie Smart – MRC Festival Open Award, 2019.
Karen Dhillon – secured a Royal Society Policy internship, 2020.

2.4 Equality and diversity

We are proud to have Equality and Diversity embedded in all of our decision-making processes, with a 2019 departmental Athena Swan Silver award building on our previous Bronze award. Our processes support all our researchers in achieving their full potential and ensure that this is recognised and rewarded (see Section 2.1 and 4).

UoW has been implementing the principles of the Concordat agreement between funders and employers of researchers in the UK 2009 (REF5a-3.3). The UoW has recently been awarded the HR Excellence in Research Award. Equality and diversity is a key part of our strategy (REF5a-3.4). The UoW Single Equality Scheme and associated Equality Objectives explicitly cover all research full-time, part-time and fixed term staff. The UoW maintain an institutional Athena SWAN Silver Award, achieved in 2013 and has established a University-level committee to oversee a forward-thinking research culture agenda (postdoc representative from our staff).

The Warwick self-assessment team, and the WMS Welfare Strategy Group (WSG, co-Chaired by two females, an academic and Chief Operating Officer), embraces the wider departmental working, environment and culture of the School. Members derive from all areas of WMS bringing together a wealth of differing staff and student welfare experiences. The co-chair of the University-wide Athena SWAN Group sits on the group to advise on University and national matters. WSG endeavors to take a strategic, pro-active approach to establishing and embedding fair working practices across WMS. The WSG initiatives and AS Action plan are progressed and implemented by 'Task and Finish Groups' with the WSG membership leading groups comprised of the wider department and Gibbet Hill community. WMS organises/is involved in a number of Health and Wellbeing activities, such as regular Wellbeing Days with a number of activities on offer for staff to try out, including yoga sessions, the Gibbet Hill Walking group etc.

The Warwick Learning and Development Centre (LDC) has a programme of workshops and on-line courses on Diversity and Inclusion, for example Dignity and Respect at Warwick, Disability Awareness, Mental Health Awareness, Types of Discrimination and Understanding Unconscious Bias.

Beyond these School and University-wide endeavors we support ***Ambassadors for Better Research Culture***, a grass roots initiative (2018) that has held lauded day long events focused on Women in Science and Bullying & Harassment. The recent Wellcome findings into how we can reimagine how research is conducted have set our agenda for how we can ensure creativity, inclusivity and honesty at the heart of what we do.

2.4.1 Gender Equality

We are actively supporting women ECRs reach research independence and be positioned to win personal fellowships and become successful academics; we have assembled a gender-balanced leadership team for BMS and have ensured gender balance on all shortlisting, search and interview panels for academic posts. We also ensure the same for PGR students. Currently, 53% of research staff and 28% of academics are female. In the REF period academic promotions are 7:4 (Female:Male) with 2:2 becoming full Professor. Our four recent academic appointments have been 2 Female and 2 Male clearly demonstrating how we have created an inclusive and positive environment.

3. Income, infrastructure and facilities

3.1 Research income

Our annual research grant income for UoA1 during the REF period is ~£6M (median) with an overall increase of 50% since 2013/14. While the number of FTEs remains similar the income per FTE increased from £120K (REF2014) to £181K. During this time UKRI (BBSRC/MRC) income has remained stable while UK-based charity income (largely Wellcome and CRUK) increased from £842K to £2.5M p.a.. Major funding also comes from European Research Council, NIHR and Leverhulme Trust. Below are the major awards >£500K which involve contributions from one third of our PIs, of which 20% are Wellcome Investigators (~£10M).

1. Pallen: MRC CLIMB; 2013/14: £7.7M
2. Millar: MRC Programme Grant; £1.83M 2014-2019
3. McAinsh: Wellcome Collaborative Award; 2018/19: £2.6M
4. Quenby: Tommy's National Centre for Miscarriage Research; 2015/16: £2.5M;
5. Balasubramanian: H2020 ERC Advanced Grant; 2014/15: £2.5M
6. Balasubramanian: Wellcome Senior Investigator Award; 2013/14: £2.4M
7. Balasubramanian: Wellcome ISSF Warwick QBP 2014/2015: £ 0.6M
8. Quenby: NIHR HTA The Big Baby trial; 2017/18: £2.27M
9. Achtman: Wellcome Investigator Award; 2016/17: £2.2M
10. Quenby: NIHR EME CERM trial; 2018/19: £1M
11. Royle: CRUK Programme grant; 2018/19: £1.54M;
12. McAinsh: Wellcome Senior Investigator Award; 2014/15: £1.3M
13. Brosens and Ott: Wellcome Joint investigator Award; 2018/19: £1.28M
14. Cross: Wellcome Senior Investigator Award; 2013/14: £1.2M
15. McAinsh: BBSRC; 2017/18: £1.1M
16. Achtman: BBSRC EnteroBase; 2013/14: £1M

17. Balasubramanian: Wellcome ISSF Warwick QBP; 2016/17: £1.2M
18. Straube: Wellcome Investigator Award; 2015/16; £947K
19. Bowman: Wellcome Sir Henry Dale Fellowship; 2017/18: £922K
20. McAinsh: Wellcome Multi-User Equipment award; 2017/18: £822K
21. Royle: CRUK Senior Cancer Research Fellowship (yrs4-6); 2015/16: £707K
22. De Piccoli: CRUK Career Development Fellowship (yr4-6); 2016/17: 614K
23. Balasubramanian: BBSRC; 2018/19: £507K
24. Sampath: BBSRC; 2014/17: £680K

Our current and future strategies to generate research income revolve around a healthy mix of individual PI driven research (responsive mode, investigatorships, and fellowships) and collaborative-research with appropriate UK (including within Warwick) and international partners with complementary skills to develop impactful research that is more than the sum of the parts. We also anticipate that our world-leading groups linked through a research theme will seek "research centre" status from UKRI or AMRC charities, including via the establishment of an NIHR BRC. Finally, in keeping with our recent strategy of translational medicine, we will work with industry where appropriate. The Universities Research and Impact Services (R&IS) has a strong presence embedded within WMS and this team provides expert help in crafting research proposals helping our current and future research strategies.

3.2 Infrastructure and facilities

Research groups are located in laboratories on the University's Gibbet Hill (GH) campus or University Hospital Coventry & Warwickshire site, with several sharing time on both sites providing a continuum of research activity. The existing state-of-the-art infrastructure and facilities (see below) are now part of a long-term master plan to expand and renew buildings (home to the sister schools of Life Science and Medicine) into a world-class physical and intellectual environment for biomedical and translational research.

A major step is the £54M UoW/Wolfson-funded ***Interdisciplinary Biomedical Research Building* (IBRB):** (opening April 2021) as a joint endeavour between the SLS and WMS and will enable expansion of biomedical research at Warwick providing a home to 300 scientists (REF5a-4.2). One floor is a dedicated Tissue Mechanobiology & Human Disease Laboratory. A second floor houses our Microbiology & Infection programmes – of which there is a focus on AMR and established links with industry, while the third floor is dedicated to neurobiology (largely part of School of Life Sciences). IBRB provides expanded microscopy, animal procedure, zebrafish holding facilities alongside multiple collaboration spaces, a 400-seater lecture theatre and exhibition space.

3.2.1 Existing Physical Spaces

- ***Mechanochemical Cell Biology Building (MCBB):*** Opened in 2012 and supported through a £1M award from the Wolfson Foundation, Advantage West Midlands and the University, this state-of-the-art laboratory incorporates both primary and secondary wet labs, extensive temperature-clamped vibration-free microscope spaces and computing workstations for data analysis. Home to twelve research groups.
- ***Mechanochemical Cell Biology Building extension:*** Opening in 2015, this £4M investment from UoW followed successful growth of the Centre and provides space for expanding research groups and three new Assistant Professors.

- ***Biomedical Research Building****:* This laboratory space is shared with SLS and home to nine of our research groups including our growing translational research programmes.
- ***Clinical Sciences Research Laboratories (CSRL):*** This laboratory block is positioned adjacent to UHCW and is currently home to eight research groups. These laboratories provide a focus for our translational research activities and provide regular opportunities for engagement with NHS staff. CSRL will facilitate our future developments (section **1.3**) in providing space for our main translational themes along with key infrastructure (*e.g.* human tissue bank, access to digital pathology).

3.2.2 Facilities

- **Computational and Advanced Microscopy Development Unit** is home to state-of-the-art light microscopy including Wellcome lattice light sheet (LLSM) facility (Wellcome Equipment Grant) and two-photon microscope (BBSRC ALERT19). An LLSM visitor programme enables access for other UK scientists. Instrument maintenance, development, user training and oversight is provided by two full time imaging specialists. Data storage is fully supported through a University-funded Petabyte server with a full time Systems Administrator.
- **Cell Sorting facilities** have been established to provide essential capacity for genome editing with a user base from both Medical School and Life Sciences; with the location at CSRL labs key to facilitate new clinical-facing research using human tissue.
- **Next Generation Sequencing** technologies including MiSeq/Next-Seq/Hi-Seq, Single cell sequencing (Drop-Seq) and ATAC-Seq.
- **MRC-funded Cloud Infrastructure for Microbial Bioinformatics** (MRC CLIMB, CLIMB2 Big Data plus the BBSRC-funded Enterobase). Composed of over 7,500 CPU cores of processing power make this the largest single system dedicated to Microbial Bioinformatics research, anywhere in the world.
- **MRC-funded Titan Krios cryo-electron microscopy facility** established to provide a Midlands hub (with Leicester, Nottingham).
- **MRC/Tommy's Reproductive Health Biobank.** (led from WMS with Institute of Digital Health, Edinburgh, KCL, Manchester, Imperial) – Provides a platform for personalised medicine by facilitating data linkage (clinical phenotyping via genomics/proteomics), between the human samples and multiple disparate research and NHS databases containing couple's clinical history. The development of a searchable database of samples and metadata is linked with Tommy's Net, the existing data linkage system created for the Tommy's National Centre for Miscarriage Research.
- **Research Technology Platforms (RTP) (REF5a-4.3)**. Our research community (and also external partners from academia and industry) have access to a series of world-class platform technologies that have been established by the University, (i) Proteomics (Orbitrap Fusion, Quantiva triple-quad and Xevo TQ) expanded through BBSRC ALERT19, (ii) Advanced Bioimaging (Electron microscopy focus) established with BBSRC ALERT14 funding, (iii) Bioinformatics – downstream analysis of genomic, proteomic and metabolomic datasets and (iv) Scientific Computing and (v) Biomedical Services Unit that provides facilities for animal models, including a Zebrafish [Wellcome Trust £583K]

Key facilities embedded in UHCW including Human Metabolism Research Unit, Centre for Reproductive Medicine and NIHR Clinical Research facility.

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

4.1 Collaboration

The success of our mission for WMS to be a leading medical school in the UK, internationally renowned for the excellence and significance of our research is built on effective collaborations achieved through partnership with clinicians, the wider biomedical research community, policy makers, service providers, commercial organisations, patients, carers and the public.

4.1.1 Collaborative Research

We collaborate extensively with other groups within the University and other HEIs both in the UK and overseas as an important way to strengthen our research outputs and impact. Nearly 40% of the outputs submitted involve collaborators within the University or from outside of Warwick and 25% of our grants are held as collaborative projects. In addition to numerous collaborations within the UK, including with almost all Russell Group universities, particularly notable international links are outlined in **4.1.4**.

4.1.2 Interdisciplinary Research

Interdisciplinarity is a key feature of our research. UoW has always maintained a culture of 'low walls' and this ethos is reflected in the research interactions between the formal Divisions within WMS (returned in UoA A2) as well as those with the other departments across campus (REF5a-2.9). This approach is enhanced by WMS being part of the Faculty of Science & Medicine, further endorsing our major strategic aim to develop STEM at Warwick (REF5a-1.6,2.3,4.2). Interdisciplinary research is encouraged through seed funding available for new collaborations between different departments within the university through various programmes (*i.e*. QBP, Health GRP, W-WTP) which also engage with clinical research at UHCW. The success of this approach is evidenced by:

1. Four joint appointments with other Science departments:
    - Gibson (25% WMS, returned to UoA B8) and Perrier (25% WMS, returned to UoA B8).
    - Physics – Polin (30% WMS, returned to panel UoA B9) and Kantsler 30% WMS, returned to UoA B9).

2. Multiple cross-departmental grant awards including:
    - McAinsh/Burroughs (Maths) - BBSRC/Wellcome awards.
    - McAinsh/Bretschneider (Computer Science) - BBSRC award.
    - Brosens/Ott (Computer Science, now WMS) - Wellcome collaborative award.
    - Straube/Cross/Polin (Physics) - Leverhulme Trust.
    - Levi/Rand/Perrier (Maths/Chemistry) - CRUK interdisciplinary award.
    - Dallmann/Rand (Maths) - CRUK Interdisciplinary Award (2020)

3. Led the establishment of multiple interdisciplinary University-wide research centres (see section **1.2.5** and REF5a-2.9.4). The majority of PIs are members of these, or others including Institute of Digital Healthcare, Warwick Antimicrobial Interdisciplinary Centre, Centre for Soft Matter, Warwick Synthetic Biology Centre and the Zeeman Institute – Systems Biology & Infectious Disease Research.

4.1.3 University Hospital Coventry and Warwickshire (UHCW)

Our strategy is well aligned with UHCW (**Fig. 1**), with our partnership overseen by a joint UHCW R&D/WMS strategy group. There is already ~£37.5M of collaborative/joint research awards, with highlights from UoA1 staff including:

- £3.6M Tommy's National Miscarriage Centre and MRC/Tommy's Biobank
- £2.6M Wellcome Collaborative Award – Understanding the origins of aneuploidy in human embryos (McAinsh/Hartshorne).
- £10M PathLAKE (Pathology image data Lake for Analytics, Knowledge and Education) - consortium aims to meet the *Data to Early Diagnosis* and *Precision Medicine Challenge*.
- £7M in NIHR-funded trials involving UoA1 along with colleague returned in UoA2.
- Involvement (Young, Grammatopoulos) in developing the UHCW Centre of Precision diagnostics and Translational Medicine.

4.1.4 Examples of International Partnerships

- A*STAR relationship, Singapore. A*STAR Singapore is the major funding body in Singapore with whom we have established a PhD program (ARAP- described in **2.3.3**) with ~£2M invested from Warwick and an equivalent amount from A*STAR Singapore
- Columbia University, New York (Blanks, National Institutes of Health).
- Monash University (Perrier, Australian Research Council grant)
- Monash University (Brosens, National Health and Medical Research Council, Australia grant)
- Harvard University, Uppsala University, University of Stockholm (Balasubramanian, Wellcome Collaborative Grant)
- China – Hong Kong Baptist University and Sun Yat-sen University [HK and Chinese agencies]
- Indonesia – Universitas Gadjah Mada [GCRF Accelerator Award]

4.2 Contribution to the research base, economy and society

Our research makes a substantial contribution to the research base, economy and society across all four of the strategic priority areas described in Section **1.1**. Particularly notable contributions in each area are highlighted below.

4.2.1 Notable contributions to the research base

PIs participate in organization of national and international meetings, including:

i. The British Society for Cell Biology Annual "Dynamic Cell" meetings ('14, '18 and '20) over the last 5 years; UK Microtubule Meeting; Annual Meeting of Microbiology Society '17 and '18, UK Cellular Microbiology Meeting, Staphylococcus Great Britain and Ireland. Our Quantitative Biomedicine Programme (QBP) also runs an annual symposium open to all researchers worldwide and invites ~10 external speakers including from North America, Asia, and Europe.

ii. Members of the division also have/had served on editorial boards of esteemed journals, e.g.
   - eLife, Cytoskeleton (Balasubramanian).
     Seminars in Cell & Developmental Biology (Millar, Straube).
   - Pathogens Journal, J. Invertebrate Pathology (Waterfield).

- J. Cell Science Advisory Committee Member, Affiliate for BioRxiv and ASAP Ambassador (Royle).
- Founding editor-in-chief, Pathogens (Young)
- J Lipid Res and Prog Lipid Res (Zammit)

and external grant, institute Review panels and research organisations,

- Wellcome Expert Review Group (Cross, McAinsh).
- BBSRC Committee D, Pool of Experts (Royle).
  MRC Industrial CASE studentship panel (Millar).
- Quinquennial Review of CRUK Paterson Institute (Millar).
  Worldwide Cancer Research panel (McAinsh).
- L'Agence Nationale de la Recherche National (Straube, Royle).
- British Council Biomedical and Medical Science Panel (Young)
- Guts UK Research Awards Committee (Young, Chair 2010-2019)
- Advisory Board, Wellcome Trust (Edinburgh) and MRC (Oxford) PhD programmes (McAinsh).
  Meetings Secretary, British Society of Cell Biology (Straube, Royle).
- Board member, Prokaryote Division, Microbiology Society (Unnikrishnan).
- Scientific Committee, North West Cancer Research (Royle).
  Director & Trustee, Company of Biologists (Royle).
- Expert Review Panel CRUK Programme Awards (Royle).
- Yorkshire Cancer Research Scientific Advisory Committee (Young)
- Evaluation committee of CRBM (Straube) and IGDR (McAinsh) institutes, France.
- Wellcome Trust India Alliance (Balasubramanian)

4.2.2 Collaborations with industry

Researchers are encouraged to develop successful research collaborations with industrial partners, and these include: (i) large pharmaceutical companies - Glaxo SmithKline (Blanks, Greaves). Astra Zeneca (Barber); (ii) technology companies such as Philips Healthcare (Levi, Snead) and Abingdon Health (Young); and (iii) smaller biotechnology and drug development companies – Viracta Therapeutics Inc (Young), Stabilitech Biopharma Ltd.

Our MRC DTP is also driving a new generation of academic-industry projects through iCASE studentships and investment from the National Productivity Investment Fund (NPIF; see section **2.3.2** for detail). Both institutional funds, the MRC P2D and the Wellcome-Warwick Translational Partnership all make it possible to pump prime relationships and projects with stakeholders and for industry-based researchers/entrepreneurs to spend time in Warwick.

Warwick Innovations (the Technology Transfer arm of Warwick – REF5a-2.8) also plays a key role in fostering collaborations with the industry as well as establishment of spin out companies. Our major spin out, Neurosolutions (**Spanswick**) goes from strength-to-strength (our third impact case study), Sarissa Biomedical (Dale, Life Sciences) is now developing further clinical applications in partnership with WMS/UHCW (Imray) and a new generation of spin-outs are coming into view *i.e.* NanoSyrinx (**Waterfield**) and Cytoswim (Kantsler, WMS/Physics). These activities promote a culture facilitating industrial engagement.

4.2.3 Informing Policy

Our researchers work with international public health organisations and professional societies such as the European Society of Human Reproduction and Embryology, Royal College of Obstetricians and Gynaecologists and Royal College of Pathologists to shape research, share findings and inform professional training and guidance.

4.2.4 Open Science

We advocate the open-access publishing (at least green, preferably gold OA) and the use of pre-print servers (BioRxiv, ArXiv) to ensure the widest possible dissemination of our research discoveries (REF5a-2.10). Our scientists develop software for image analysis and other tools and make them open source, *e.g.* CMCB GitHub. The Warwick Open Source Microscope (WOSM) is our major open source hardware development project. We support sharing of scientific imaging data through our OMERO database, managed by CAMDU.

4.3 Public Engagement

UoW and WMS have over the last 5 years embarked on a strategic goal of embedding Public Engagement for research (PER) within the academic community and research lifecycle. A central Public Engagement Team has been created, initially funded by RCUK, and provides support via training, activity funding, an engagement network, and international, national and local festival/event participation. PER is now part of promotion criteria and both UoW and the Wellcome QBP provide seed funding to kick-start projects. Exemplar events as follows:

1. **Community-based events**: (i) Science on the Hill: programme of public science evenings jointly hosted by the School of Life Sciences and Warwick Medical School (co-located on Gibbet Hill), (ii) 'Ideas Cafes', Café Scientifique and the U3A invited talks which bring a wide range of people together; (iii) Pint of Science – three nights in local pub venues across Coventry and Warwickshire and (iv) Photography competition (Cellfie Gallery) voted on by the public online and displayed at UHCW as an alternative method to engage the public's interest in our research.

2. **National profile**: (i) Our stand at New Scientist Live at the Excel in London promoted CMCB research to a huge audience (>39,500 visitors attended over the 4-day event) with a series of interactive exhibits and opportunities for the public to engage with our staff and students. (ii) **Young**, **Quenby** and **McAinsh** all presented on the main programme of the British Science Festival held at the University of Warwick in 2019 to audiences of 50-100+ people. A Warwick run Family Day at the end of the festival also had our staff and students presenting more hands-on displays of our research aimed at engaging and inspiring the younger members of our community. (iii) **Quenby**, **Brosens**, have been nationally recognised for the impact their research has had on everyday lives (#misCOURAGE) and have been named as part of Universities UK's MadeAtUni campaign.