Institution: London School of Hygiene & Tropical Medicine (LSHTM)

Unit of Assessment: UoA1 – Clinical Medicine

a. Overview

LSHTM is one of the world's leading schools of public health, strongly focused on research for the prevention and control of high-burden diseases. In 2013 we topped the table of the world's leading research-focused graduate schools in the *Times Higher Education* World University Rankings. We are one of the UK's most research-intensive higher education institutions (HEIs): in 2012/2013 63% of our total income was for research; our research income per FTE (£125K pa) is the highest in the UK, almost twice that of the next placed HEI. We have one of the most extensive collaboration networks of any university globally and our clinical medicine citation rate tops the national table, and is markedly above those of the leading US schools of public health.

The School is renowned for its emphasis on cross-disciplinary working, bringing innovative and effective solutions to complex health problems. We are returning our fundamental research on the biology of hosts and pathogens, their interactions, treatment and control, within UoA1. Public health and policy research on infectious diseases is returned alongside our other public health research, in UoA2. Our 56.58 FTE UoA1 staff, significantly higher than the 30.80 submitted to RAE UoA3, are housed within the four departments of the Faculty of Infectious and Tropical Diseases. Departments are the 'home' of academic staff, where technical and administrative support is provided for research, research degree training and career development. This submission covers all the research in the Departments of Immunology & Infection and Pathogen Molecular Biology, approximately half of the research in the Clinical Research Department, and some in the Department of Disease Control. Over the REF period, our staff associated with UoA1 have raised £53.9m in research income (including transfers to collaborators) and published over 1454 peer-reviewed papers.

Multidisciplinary research is facilitated by 13 School Centres, 10 of which were formed during the assessment period. Centres foster internal and external collaboration, training and mentoring, dissemination and translation of research outputs, and communication with stakeholders. Of particular relevance to UoA1 are the Malaria Centre, the International Diagnostics Centre and the Centres for Tuberculosis (TB) and Mathematical Modelling of Infectious Diseases. External collaboration is also facilitated by Centres involving other Bloomsbury colleges including the Bloomsbury Wellcome Trust Centre for Global Health Research, the London International Development Centre and the Bloomsbury Centre for Genetic Epidemiology and Statistics.

Flexible and dynamic research groups develop and evolve over time in response to research priorities and opportunities and may span departments. Key UoA1-relevant groupings include human immunology and immunoepidemiology, experimental immunology, pathogen population genetics, protozoan biology, microbiology, parasite-vector interactions, anti-infective drug development, vaccine research and development, diagnostics and clinical trials.

b. Research strategy

Our research strategy reflects the essential interplay between discovery and development, innovation and implementation in public and global health. After appointing a new Director, Professor Peter Piot, in 2010, and a new Vice Director, Professor Anne Mills FRS, in 2011, we developed a new School Strategy for 2012–2017, combining staff insights with those from our international collaborators and external advice from a visiting committee of world-leading experts. The Strategy provides the framework for investment decisions and priority-setting. Implementation of the Strategy is monitored by the Senior Leadership Team and by Council, the School's

governing body.

Achievement of strategic aims during assessment period

The overarching aims set out in our RAE2008 submission included building on existing strengths, focusing on multidisciplinary working, and sustaining and developing strategic partnerships. In line with these objectives, the School signed a memorandum of understanding with University College London (UCL) in November 2011 to establish the Bloomsbury Research Institute (BRI). With over 250 researchers from the two HEIs working on pathogens, the diseases they cause, and new modes of treatment and control, BRI facilitates multidisciplinary working at the interface of biomedical science, epidemiology, experimental medicine, and drug, diagnostics and vaccine development. All 65 staff submitted within UoA1 are affiliated with BRI. A research facilities database has been developed and planning is well underway for joint MRes and PhD programmes. A feasibility study for a shared laboratory building at the School's Tavistock Place site has been undertaken, with high-level support from both directorates. The School/BRI has also strengthened partnerships with the nascent Crick Institute, the Wellcome Trust Sanger Institute (WTSI) and the Singapore Genome Institute via joint appointments (see Section c), joint funding applications and postgraduate training.

Below are some of our major achievements within the research themes identified in RAE2008.

Integrative biology of host-pathogen interactions

Our aim was to bring together bioscience, bioinformatics, statistics and epidemiology to model the impact of immunity, drug resistance and pathogen population structure on disease transmission and control. Establishing the Bloomsbury Centre for Genetic Epidemiology and Statistics (with UCL and Birkbeck) has contributed greatly to success in this area. Specific objectives included non-invasive *in vivo* imaging of infected animals, moving from genomic analysis to functional genomics and an increased focus on emerging infections. Key achievements since 2008 include:

- development of a high throughput forward genetic screen based on parallel sequencing of RNA interference targets in African trypanosomes (Alsford)
- development of highly sensitive *in vivo* imaging systems for trypanosomes and mycobacteria (Kelly, Croft, Ward)
- exploitation of inductive logic programming to reveal polysaccharide biosynthetic pathways in bacteria such *as Campylobacter jejuni* (Wren)
- identification of genetic associations and transcriptomic biomarkers of scarring trachoma (Holland, Burton, Mabey)
- recovery of infectious bluetongue virus from synthetic RNA transcripts (Roy)
- fine-resolution, genome-wide association study of severe malaria risk (TG Clark)
- whole genome sequencing of novel, drug-resistant influenza strains leading to changes in public health practices (Hibberd).

A translational research initiative in anti-parasitic drugs and diagnostics

Our aim was to translate our improved understanding of pathogen biology and host responses into the development of new drugs and diagnostics, with a focus on malaria and neglected tropical diseases. Accordingly, we have developed predictive *in vitro* and *in vivo* models for drug discovery for malaria, leishmaniasis, Chagas' disease and human African trypanosomiasis; established a high throughput screening platform to identify novel anti-infectives; and developed collaborations with major pharmaceutical companies including Celgene, GSK, Novartis and Pfizer. Key achievements include:

- image-based screening of >500,000 compounds against *Schistosoma mansoni* (Bickle)
- development of highly potent inhibitors of the *Plasmodium falciparum* cGMP-dependent protein

kinase (Baker)
- high throughput decoding of anti-trypanosomal drug efficacy and resistance (Alsford)
- field evaluation of new diagnostic assays for HIV-associated TB, leading to the commercial launch of a novel low-cost point-of-care assay (Lawn)
- development and implementation of cryptococcal antigen screening to prevent HIV-associated cryptococcal meningitis (Jarvis)
- founding of PathGEN Dx Pte Ltd, a small/medium-sized enterprise (SME) which is using genomic technology to detect more than 70,000 viruses and bacteria in a single reaction (Hibberd).

Research partnerships in Africa

High-quality research requires well trained and highly motivated research staff and appropriate research facilities. Our research- and capacity-strengthening activities are built around active participation in major research programmes within long-standing collaborations in Africa. Major initiatives since 2008 include: participation in six Wellcome Trust research capacity-building consortia for Africa; ongoing support for TB, HIV and non-communicable diseases research in Karonga, Malawi; participation in the National Institutes for Health (NIH) International Centres of Excellence for Malaria Research in Mali and Uganda; and establishment of an MRC-funded joint fellowship scheme linking our School with the MRC Unit in The Gambia. The quality of these research partnerships is evidenced by the following research achievements since 2008:

- developing and implementing tools to eliminate blinding trachoma (Mabey, Burton)
- demonstrating a causal association between maternal worm infection and reduced rates of infant eczema (Elliott)
- demonstrating (in a community study of >1m people in South Africa and Zambia) that a targeted household approach can reduce the burden of TB (Ayles)
- conducting the first clinical trial of human papillomavirus vaccine in sub-Saharan Africa (Watson-Jones)
- Conducting phase 2 and phase 3 clinical trials of the malaria vaccine, RTS, S/AS01, in Tanzania (Riley, Drakeley).

Research objectives and activities 2014–2020

Achieving our aims for excellence and impact in our research requires focusing on our strengths: recognising the areas where we have critical mass and an international reputation and where we can compete for funds and develop key partnerships. Within UoA1, our established strengths are in vector-borne diseases (especially malaria), respiratory diseases (TB, bacterial pneumonia), enteric infections, HIV and other sexually transmitted infections (STIs), and neglected tropical diseases (trachoma, leishmaniasis and the trypanosomiases). In the current REF period we have also established the School as a centre of excellence in emerging and re-emerging infections (including pathogens transmitted between animals and humans). Within these areas, we prioritise research that particularly benefits from our interdisciplinary ways of working, including pathogenesis, biomarkers/diagnostics, vaccinology, and drug discovery and development.

We work at the interface of basic laboratory science, clinical medicine and population health to deliver tangible public health benefits within the ever-changing landscape of infectious diseases. In the period to 2020 this will require access to rapidly evolving technologies, extending our skill base in bioinformatics and systems biology, strengthening our links to the pharmaceutical and biotechnology industries and further development of key collaborations. This underpins our strategic objectives in UoA1 for 2014–2020.

Establishing the BRI as a world-leading centre for infectious disease research

Over the next six years, in partnership with UCL, we will establish the BRI as a world-leading centre for research on pathogens, their interactions with their hosts, and novel tools and products

for their detection, control and elimination. Investment in new technologies (proteomics, sequencing, bioimaging) and maintaining thriving collaborations with key partners in the UK (e.g. the Crick Institute and WTSI) and overseas (see below) are integral to this strategy. Better understanding of pathogen biology underpins all our strategic objectives and BRI will build on strengths in biochemistry, cell and molecular biology, genomics and computational biology. We will further enhance our multidisciplinary working by, for example, supporting staff to acquire both wet lab and *in silico* skills and further developing integrative approaches.

Specific objectives include:

- comparative genomics for development of point-of-care diagnostics, biomarkers of clinical disease status and drug sensitivity monitoring for bacterial and viral pathogens
- decoding bacterial glycosylation systems to understand pathogenesis and to exploit them for glycoengineering
- exploiting pathogen signalling pathways as targets for drugs to both cure disease and block transmission.

Our pathogen handling facilities, particularly those requiring BCL3 biocontainment for small animals, are unrivalled in the UK university sector. Our ability to infect by clinically relevant routes (e.g. aerosol, vector) and monitor individual animals over time by *in vivo* bioimaging allows us to mimic the biology of human infections and their response to intervention. Our plans include:

- using existing models for TB, bacterial sepsis, leishmaniases, trypanosomiases and helminths for pharmacokinetics/pharmacodynamics, vaccine assessment and validation of traits emerging from human population genetic studies
- developing new infection models, including genetically manipulated mice, for globally important human viruses (e.g. HIV, HBV, HCV) and the malaria parasite *P. falciparum*
- evaluating novel imaging systems (TRUE and TROVE) for *in vivo* deep tissue imaging of pathogens and host responses.

Our involvement with large epidemiological cohort studies in the UK and overseas provides a unique resource for longitudinal studies of the relationship between life history, infection, immune function and long-term health outcomes. BRI will become a hub for human life course immunology. Specific objectives include:

- linking microbial colonisation and antigenic exposure with immune development and child health in the UK Life Study (joint Wellcome Trust strategic award to UCL and LSHTM)
- integrating life-course immunology into long-term demographic, anthropometric, genetic and clinical studies of village communities in The Gambia and Uganda.

Building partnerships with industry

Our expertise in pathogens, *in vitro* and *in vivo* models of disease, informatics and drug resistance, and our links to the clinic and the field, provide a route for discovery and development projects with links to real target product profiles. This expertise also underpins our plans to expand collaborations with the private sector. This will be done by increasing our work with:

- product development partnerships (e.g. Medicines for Malaria Venture, the Drugs for Neglected Diseases Initiative – DNDi, the Foundation for Innovative New Diagnostics – FIND) where our application of imaging technologies to disease models is enabling drug discovery and evaluation, and our access to clinical material is enabling diagnostic development
- the biotech sector, where we are developing projects with SMEs in the UK, Europe and India in vaccine, drug and diagnostic discovery and development
- large pharmaceutical companies (e.g. Roche, Boehringer Ingelheim, GSK, Novartis, Sanofi),

where we contribute expertise in pathogens and disease models in the discovery and development of vaccines, antimicrobials and anti-parasitic drugs, ideally by adopting open lab models

- major diagnostics companies (e.g. Alere, Abbott, Becton Dickinson, Standard Diagnostics).

In addition, through the BRI and in collaboration with UCL Department of Infection, we will:

- expand our research links for discovery of antiviral drugs (e.g. for HIV and dengue)
- establish a drug discovery laboratory within a bioincubator; we are currently exploring the potential of the Stevenage Bioincubator Centre at the GSK site.

These activities will be supported by our recently established Chariot Innovations Ltd and the commercialisation subcommittee of our planning and finance committee. We anticipate several commercialisations on biomarkers and diagnostics in the next two to five years.

Embedding research capacity for global health

Overseas programmes are a cornerstone of our infectious disease research and since 2008 a much more strategic approach to our international partnerships has both enhanced their effectiveness and increased genuinely collaborative working. Within UoA1, we will continue developing our key long-standing partnerships in The Gambia, South Africa, Tanzania, Uganda and Zambia while developing new partnerships in China, India, Japan and Singapore, by:

- training and mentoring outstanding overseas scientists
- seconding our academic and support staff overseas to nurture these programmes
- offering joint appointments at LSHTM to overseas colleagues to sustain them in post and to support their career development.

Specific avenues for this include:

- the Wellcome Trust Bloomsbury Centre for Global Health Research (funding 2013–2018)
- the Wellcome Trust African Institutions Initiative
- the Public Health Foundation of India Centre for Infectious Diseases
- the newly-established Institute of Global Health, University of Nagasaki, Japan
- training and research awards from MRC, the Wellcome Trust and EDCTP.

Specific research objectives include:

- completion of large-scale disease mapping projects for malaria, trachoma and soil-transmitted helminths to inform disease elimination programmes
- evaluation of the effect of universal test and treat with antiretroviral therapy on HIV incidence and burden of TB at the community level
- multicentre trials of tools to reduce malaria transmission as well as disease burden
- multicentre evaluations of new diagnostics for HIV/STIs and neglected tropical diseases.

Responsiveness to national and international policies and initiatives

We seek to achieve an appropriate balance between researcher-initiated discovery, from which innovative solutions to global health problems will emerge, and research that responds to emerging national and international health needs. School staff play major roles in setting UK and international research priorities. UoA1 staff currently sit on advisory bodies of the MRC, BBSRC, the Wellcome Trust, WHO-TDR and the Bill & Melinda Gates Foundation (Gates Foundation). School staff are also seconded to or have joint appointments with government agencies and international organisations (e.g. DFID, WHO, Public Health England – PHE, UNAIDS). Honorary academic staff associated with UoA1 occupy positions at, for example, the UN Foundation

(Carucci), the US Centers for Disease Control and Prevention (CDC) (de Cock), WTSI (Dougan, Parkhill) and PHE (Zambon, Drobniewski, Hewson).

We have efficient dissemination systems to alert scientists to funding calls and when necessary we establish panels for internal peer review of competing bids for the same call. Examples of success in responding to such calls during this assessment period include:

- Bloomsbury Wellcome Trust Centre for Global Health Research (Mabey)
- MRC Environmental and Social Ecology of Human Infectious Diseases (Drakeley)
- Wellcome Trust Capacity Building in Africa (four of the seven awarded, plus two other strategic awards for capacity development)
- Gates Foundation programme on determinants of healthy growth (Burr, Mabey).

Promoting a collaborative, sustainable research culture and research dissemination
Collaboration across disciplines and between academic departments is inherent to our way of working. Our unique focus and compact location help to create a lively and cohesive culture with numerous opportunities for academic interaction. Our School Centres bring together researchers with common interests across the School, including at annual retreats; for example discussions at a Malaria Centre retreat stimulated work which culminated in a forthcoming Nature paper. The internal structure of departments and faculties gives students and staff a sense of belonging and identity. Research strategies are reviewed and renewed at annual research retreats. A weekly electronic newsletter (*The Chariot*) and faculty publications advertise research meetings, funding opportunities, journal clubs, internal and external seminars, and social events. They also celebrate achievements including funding awards, fellowships, publications and research degrees. Our annual research symposium is designed to further enhance interaction among staff, including those based overseas.

The recently restructured central Research Operations Office disseminates information on funding opportunities and provides guidance on priorities and application processes of specific funders. This is supplemented by faculty-level funding workshops led by staff with experience serving on funders' advisory boards. Faculties also arrange sessions on publishing, drawing on staff with expertise as authors and journal editors. With the creation of an External Relations Department in 2011, we now provide greater support for interactions with the public, the media and politicians. The School is a hub for external medical science events (conferences and workshops, press conferences and book launches, Café Scientifique, London Molecular Parasitology Club, *Lancet* Global Health lectures, etc.). We participate in science fairs (e.g. the Cheltenham Science Festival) and in All Party Parliamentary Groups on malaria and other tropical and neglected diseases.

c. People, including:

i. Staffing strategy and staff development
Our staff recruitment is designed to sustain and complement our research strengths and key partnerships, deliver our research strategy and provide leadership of major research programmes. External recruitment directly to core-funded posts is usual for strategic appointments. In UoA1, since 2008, external recruitment has been used to fill Chairs in emerging infectious diseases (Hibberd, also Genome Institute of Singapore), molecular parasitology (Blackman, also National Institute for Medical Research/Crick Institute), bacterial genomics and evolution (Thomson, also WTSI) and the Directorship of the Malawi Epidemiology and Interventions Research Unit (Nyirenda); and to make appointments in genetic epidemiology and statistics (TG Clark), bacterial pathogenesis (S Baker) and immunology (Fletcher).

The School has a proactive policy to attract outstanding young scientists and clinicians seeking to advance through the external fellowship route to a permanent academic appointment, and to mentor such individuals through this process. The model for this was pioneered by the Wellcome

Trust Bloomsbury Centre for Global Health Research which has achieved a success rate of more than 60% for clinical fellowship applications at all levels over the past five years and currently supports 27 clinical fellows, based in 17 institutions in 13 low- and middle-income countries. Among our UoA1 submitted staff, successful applicants/renewals to the Trust since 2008 include Burton and Elliott (Wellcome Senior Clinical Fellows); Ferrand (Wellcome Clinical Intermediate Fellow); Lawn and Drakeley (Wellcome University Awards); Judkewitz (Sir Henry Wellcome Postdoctoral Fellowship); and S Baker (Wellcome Trust Sir Henry Dale fellowship).

We achieve similar success rates for other fellowship schemes, including: Rogers (BBSRC David Phillips Fellow); Hafalla (Royal Society University Research Fellow); Furnham (MRC Methodology Research Fellowship); Bousema (Netherlands Organisation for Scientific Research); and Stegmann and Valiente (EU Marie Curie Postdoctoral Fellowships). Since 2008, numerous externally-funded fellows have moved into permanent core-funded posts: to Chairs in immunology and infection (Drakeley), tropical medicine (Elliott) and pathogen biology (Conway), and to appointments in bacterial population biology (Stabler), molecular parasitology (Alsford), host, parasite and vector biology (Rogers), clinical infectious diseases (Lawn, Watson-Jones) and immunology (Hafalla).

Recognising the limited opportunities for early postdoctoral fellows to apply for their own funding, we instituted our own postdoctoral fellowship scheme (co-funded through the Wellcome Trust Institutional Strategic Support Initiative) for outstanding researchers coming to the end of their first or second postdoctoral appointment, allowing them to build a base for applications for external fellowships. UoA1 awardees include Alsford in 2012 and Dawson in 2013.

The Concordat to Support the Career Development of Researchers guides our staffing strategy and staff development programme. We operate a single academic staff promotion and progression policy, thereby actively supporting career progression of both core staff and those funded through research grants. A ‘career map’ for all academic staff, introduced in 2003 and most recently revised in 2011, provides guidance on balancing research, teaching and other activities at different career stages. Our annual appraisal system supports staff to assess their progress and provides advice on career progression, development needs and opportunities. The mentoring system for new lecturers and PhD supervisors is now being extended to mid-level academic staff. Our staff development programme includes technical, transferable skills, teaching, mentoring and management courses. Research staff can take courses in epidemiology, data analysis and statistics, mathematical modelling and bioinformatics to extend their quantitative skills and/or our modular MSc courses to gain or update their knowledge of specific aspects of biomedicine; they are encouraged to gain teaching experience and obtain a Certificate in Learning and Teaching.

The value of all these policies is reflected in the high success rates for fellowship applications and the fact that early-career researchers make up 25% of the UoA1 submission. We thus have an excellent balance of junior and senior researchers, and are successfully nurturing the career development of future research leaders. Staff with five or more years' continuous service whose salaries are funded from research grants or contracts have an explicit entitlement to a period of employment on School funds when other sources are not available, providing additional opportunities to secure further funding and ensure we retain expertise.

We provide flexible working arrangements, including encouraging co-location with our overseas partners. Currently, 10 of the 65 UoA1 staff are based overseas: Andreasen, Reyburn, Watson-Jones (Tanzania), S. Baker (Vietnam), Burr (Gambia), Elliott (Uganda), Ayles (Zambia), Ferrand (Zimbabwe), Nyirenda (Malawi), Judkewiz (USA) . Others have been based overseas during the period of assessment: Clarke (Uganda), Conway, Holland (both Gambia), Lawn (South Africa), Burton (Tanzania), Hibberd (Singapore). Since 2008, we have invested in additional support for overseas staff and projects including the appointment of a Special Advisor on Overseas Programmes (Dockrell), an overseas IT advisor and a post to enhance good laboratory practice

and management systems. We also recognise the value of paid study leave, both to support career development and as a means of strengthening the School's relationships with research partners; examples since 2008 include Wren (WTSI), Croft (Public Health Foundation India) and Dockrell (Jenner Institute).

Eleven UoA1 researchers hold clinical appointments, and 15 full-time NHS staff hold honorary appointments at the School within UoA1, collaborating in joint research activities. The School is a centre for academic clinical training in infectious diseases: we have been awarded NIHR Academic Clinical Lectureships and Academic Clinical Fellowships annually since 2008. In addition, Sutherland is funded 0.5 FTE by PHE to work with the Malaria Reference Laboratory and as Clinical Scientist in the Department of Clinical Parasitology at the Hospital for Tropical Diseases (HTD), where he has translated his academic research in molecular parasitology into novel diagnostic tools which are now used in the NHS.

The School's Equality & Diversity Strategy sets out our strong commitment to equality and diversity, encompassing characteristics protected by the Equality Act 2010. Implementation and monitoring of the Strategy are supported by a full-time manager and a dedicated committee. Policies and procedures cover gender, race, disability, fixed-term and part-time staff, equal pay, dignity at work and study, and family-friendly policies. Equality and diversity are integral to policies relating to recruitment, promotion, training and appraisal. All staff are required to undertake equality training and equality impact assessments are made when developing or revising policies. We have a Bronze Athena SWAN (Scientific Women's Academic Network) award and are working towards a Silver award. In 2012 we ranked second in the UK for the percentage of female professors (33%). The School is a certified user of the Two Ticks scheme and actively supports staff to declare disabilities.

ii. Research students

We are an exclusively postgraduate, research-led institution with exacting recruitment and selection procedures to register the highest quality research students from across the world; in keeping with our mission, 50% of the School's current research degree students are from outside the EU. An unusual feature of our PhD programme is the opportunity for students to gain field research experience working with our overseas partners. As part of our commitment to developing research capacity, staff employed by 18 of our overseas partner organisations can register for a PhD at LSHTM at subsidised rates (12 such students have been registered with UoA1 staff since 2008), and School staff co-supervise more than 40 students registered at partner universities in Africa, funded by the Wellcome Trust African capacity development consortia. Junior research staff are encouraged to register as part-time PhD students for a nominal fee; 28 staff have registered in the UoA1 remit since 2008.

We held doctoral training grants from BBSRC and MRC throughout the assessment period. In 2011, we were awarded an MRC doctoral degree programme in vaccine research (three new students per year for three years). The first intake of this highly multidisciplinary programme is working in cellular immunology, molecular biology and modelling of vaccine coverage. We held a BBSRC doctoral training award (four students over three years, including one CASE award) from 2009–2013 and are now one of the partner institutions (with UCL, King's College London and the Royal Veterinary College) in the BBSRC London Interdisciplinary Biosciences Doctoral Training partnership which recruits 18 students each year for three years. MRC, BBSRC, the Defence Science and Technology Laboratory, the Natural History Museum and PHE support research students through their UK research institutes (10 have been registered at the School since 2008). The School also offers scholarships from endowed funds and contributes to the Bloomsbury PhD scholarship programme which offers 12 studentships per year to encourage collaborative interdisciplinary projects with the Institute of Education, the Royal Veterinary College, SOAS and Birkbeck. Finally, the Bloomsbury Centre for Global Health Research provides a focus for PhD

training for clinicians, funded by *ad hominem* research training fellowships from MRC or the Wellcome Trust (12 students registered with UoA1 supervisors since 2008) or by the Wellcome Trust clinical PhD programme in international health (three clinical PhD fellows annually for six years).

Research students are fully integrated into research groups, sharing open plan offices and multi-user laboratories with research staff, and participating in research retreats, Centre activities, seminars and journal clubs. An annual PhD student Poster Day provides an opportunity for them to present their work, receive feedback and network with their peers and colleagues. Structured training and learning opportunities for research students include access to the School's extensive portfolio of masters-level modules and laboratory skills workshops including relevant health and safety matters. Generic, transferable and employment-related skills can be acquired via an in-house Transferable Skills Programme, the Bloomsbury Postgraduate Skills Network and the online research skills package 'Resources for Doctoral Researchers'. A significant milestone is the PhD Upgrading, a formal oral and written assessment, including a departmental seminar, towards the end of the first year of study, to determine whether the student may continue to a PhD.

Each student has a primary academic supervisor and is supported by an advisory committee with complementary skills and expertise. Students' individual development needs are identified early in their period of registration and regularly reviewed and updated thereafter. The online *Research Degrees Handbook* provides students and supervisors with a comprehensive guide to supervision, progress, monitoring and examination. Primary supervisors are expected to maintain regular email contact with students working away from the School and to visit those who are overseas for more than six months. Departments receive a financial allocation for each student which funds supervisor visits, conference attendance and computing resources.

First-time supervisors are required to attend a workshop on research degree supervision before taking on their first student, and will normally have a mentor. All supervisors are required to attend a refresher workshop at least once every five years. An experienced supervisor will not normally supervise more than three full-time research degree students at any one time. In 2012/2013, 64 research degree students were supervised by staff submitted in UoA1, and since 2008/9, 76 UoA1 students have completed their PhD. The 2012 QAA institutional review concluded that 'The School offers excellent opportunities for its research students.' In the 2012 Postgraduate Research Experience Survey, 86% of our respondents said they would recommend the School to a friend.

d. Income, infrastructure and facilities

The School's research activity has risen year on year since 2008/9 with total research income increasing from £60.9m to £79.3m. Within UoA1, net of payments to collaborators, 63% of research income is generated from UK sources, 17% from elsewhere within the EU (European Commission and industry) and 20% from other overseas sources (primarily the NIH and the Gates Foundation). For our UK income, 28% is from research councils (MRC and BBSRC), 60% from charities (primarily the Wellcome Trust) and 12% from the UK government and industry.

During the assessment period we made major capital investments in research facilities, including the completion in April 2009 of the £14m South Courtyard development within our Keppel St building. This has provided an additional 2,400m^2 of space including two floors of research offices, two lecture theatres, open plan areas and a suite of meeting rooms. We also purchased and refurbished our Tavistock Place building (£28m, 2,942m^2). Both developments are part of our strategy to improve the quality and sustainability of our working environment, consolidate our core activities from seven sites across Bloomsbury into two main buildings, and physically co-locate staff and students working in cognate areas of research. The priority for capital investment in 2014–2017 will be to establish a purpose-built facility for the BRI, with capacity for up to 200

researchers (approx. 5,200m^2 and £50m, shared between the School and UCL).

Research within UoA1 is housed on three floors of the Keppel St building or takes place with our partners overseas. Our extensive BCL3 facilities enable research on *Mycobacterium tuberculosis* and *Burkholderia pseudomallei*; on *Trypanosoma cruzi*, *Leishmania donovani* and *Plasmodium falciparum* and on their vectors (BCL3 insectaries allow pathogen transmission to and from mosquitoes and sandflies); and on animal pathogens regulated by the Department for Environment, Food and Rural Affairs (*Trypanosoma brucei,* bluetongue virus, *Trichinella spiralis*). We refurbished the animal facility (912m^2, £12 million) which reopened in October 2012, providing the largest BCL3 animal containment facility in London and the only such facility with BCL3 live imaging. The facility is already well used for collaborative projects with UCL, Imperial College, the Royal Veterinary College, NIMR and WTSI. We also benefit from the clinical research facilities at the HTD and from unparalleled access to clinical and field samples from the HTD, the LSHTM-based Malaria Reference Laboratory, the WHO Schistosomiasis Reference Centre and our many overseas collaborative field sites and projects.

Other major investments since 2008 include a high-throughput genome facility; multiparameter flow cytometry and cell sorting; and automated microscopy with high content screening. Access to other specialist equipment platforms is achieved via collaboration with UCL, Imperial College and WTSI. The opening of the Crick Institute (a short walk from the School) in 2015 will provide further opportunities for collaboration and equipment-sharing. Finally, we restructured and significantly strengthened our IT services in the assessment period, including expanding network storage to provide resilience, installing an 8gb fibre network, allocating a post specifically to support our laboratories and recruiting a head of IT security and compliance.

The Library, with its extensive collections in biomedicine, public and global health, is a valuable resource for staff, students and the public. The historical collections, together with rare book collections, form the basis of regular, publicly accessible exhibitions (recently including those on malaria, maternal health and blindness). Electronic resources, including journal subscriptions, databases and ebooks, can be accessed by staff and students anywhere in the world. Training on effective literature searching, text retrieval, open access publishing, etc. runs throughout the year. The Library & Archives Service maintains the School's publications repository (LSHTM Research Online) and provides support and guidance on research data management, freedom of information and data protection. A research data management policy has been developed and we expect to comply with EPSRC expectations by May 2015.

Research governance

Our Quality and Governance Manager (QGM) is responsible for ensuring that all our research is undertaken to the highest standards in accordance with UK law and the School's *Guidelines on Good Research Practice*. The *Guidelines* follow national guidance from Research Councils UK and the UK Research Integrity Office, and are supported by detailed policies for ethical review, health and safety, research management, confidentiality of data and records, intellectual property, working with the private sector and investigating allegations of misconduct. These policies are currently being reviewed to ensure conformity with the Concordat for Research Integrity.

During the assessment period the School revised its ethical review process, splitting the former ethics committee into one for observational studies and another for interventions. All research projects with human participants involving a School staff member or doctoral student must be reviewed by one of these committees, and most receive a first or final decision within four weeks. All overseas projects must also receive approval from the relevant overseas partner country ethics committee and, for clinical trials, from their FDA equivalent.

A clinical trials sub-committee was established in 2008 to ensure we meet our responsibilities and obligations as a sponsor of clinical trials, wherever they are undertaken. Procedures and templates

are available to help researchers develop high-quality protocols that comply with the current regulatory framework. Clinical trials and projects involving human tissue (including tissue storage facilities) are regularly audited by the QGM to ensure compliance with study protocols, the Human Tissue Act and other applicable regulations, good clinical practice, good clinical laboratory practice and our *Guidelines on Good Research Practice*. A 2013 inspection by the Medicines and Healthcare Products Regulatory Agency (MHRA) found examples of good practice and no critical issues. Animal research is overseen by the Animal Welfare and Ethical Review Board which reviews all project licence applications, interim and final reports, liaises with the UK Home Office and coordinates our participation in the Concordat on Openness in Animal Research.

e. Collaboration and contribution to the discipline or research base

Working with other researchers locally, nationally and internationally

Networking and collaboration are essential elements of our research. The extent of our collaborative approach is evidenced by the number of multicentre studies and research networks involving LSHTM; our engagement in public–private partnerships; and the high-profile publications emerging from these partnerships. Of our School papers, 92.5% are published in collaboration with other institutions, putting us first in the UK (seventh in the world) for this indicator in the Leiden biomedical and health sciences ranking; we also rank first in the UK (second in the world) for proportion of papers with international collaborators (71.8%). Over the assessment period we transferred £96 million to support our collaborative research programmes overseas (of which £7.8m was for UoA1 research).

UoA1 staff contribute to more than 25 EU consortia for development and implementation of drugs, vaccines and diagnostics for malaria, TB, leprosy, leishmaniasis and arboviruses. We participate in eight Gates Foundation funded consortia covering subjects as diverse as *in vivo* imaging to develop and evaluate drugs for neglected tropical diseases; multicentre trials of the RTS,S/AS01 malaria vaccine; and mass azithromycin treatment to reduce childhood mortality. Other major collaborative programmes include the ESRC/MRC Life Study, the HIV Prevention Trial Network, the Partnership for Rapid Elimination of Trachoma and the World Wide Antimalarial Resistance Network.

Our major academic collaborations in the UK are with UCL (18 current projects), Imperial College (14), WTSI (13), Oxford (11), Glasgow (8), Cambridge (6), NIMR (5) and Liverpool (5). Our major overseas collaborations are with the MRC Units in The Gambia and Uganda, Kilimanjaro Christian Medical College (KCMC), University of Cape Town and Johns Hopkins University.

Our strategic partnership with the MRC Unit in The Gambia continues to be highly productive. Current activities include trachoma elimination research (Mabey, Holland, Burr), immunology of TB (Dockrell) and vaccines (Riley), malaria elimination (Drakeley, Bousema) and pathogen population genetics and genomics (Conway, T Clark, Wren). The partnership has been further strengthened by the award of an MRC postdoctoral programme for collaborative research. The MRC Unit in Uganda is a long-standing partner: all the previous directors have been School staff; the current director (Kaleebu) is an honorary member of School staff; Elliott has led a large co-infection programme since 1997 and collaborates with Dockrell on an MRC-funded TB trial.

Our partnership with KCMC in Tanzania now includes clinical training (through the joint East African Diploma in Tropical Medicine and Hygiene, also involving Makerere University, Uganda) and PhD training (through the Wellcome Trust THRiVE and malaria capacity development consortia). Research activities have expanded from an initial focus on malaria (Drakeley, Bousema, Reyburn, Riley, Roper, Hafalla), to ground-breaking studies of trachoma (Holland, Mabey, Burton). Other examples of our thriving international collaborations include: the new centre for gastroenterology at the University of Zambia; the National University of Singapore's School of Public Health; the Genome Institute of Singapore (where Hibberd is Associate Director) and the

Wellcome Trust/Oxford University Unit in Vietnam (where S Baker is Head of Enteric Infections), along with partnering with the Public Health Foundation of India (where Croft will be Co-director of the Centre for Research in Infectious Diseases).

We have productive collaborations with the pharmaceutical, biotech and agrochemical sectors in the UK, the USA, Europe and India. We make major contributions to pharmaceutical R&D (e.g. Celgene, GSK, Intervet, Johnson & Johnson, Merck, Merial, Novartis, Pfizer, Pharmidex, Procter & Gamble, Roche, Serono) and to the development of diagnostics (e.g. CORIS, Delft Diagnostic Systems, IDVET, Illumina Inc., INGENESA Diagnostics, Sanofi Pasteur), vaccines (e.g. Boehringer Ingelheim, Deltamune, Gylcovaxyn, Mologen, Novovax, Redbiotec AG) and insecticides (returned in UoA2).

Our collaborations with UK government include the Department of Health, PHE (including NIBSC), the Defence Science and Technology Laboratory, and MRC Technology. Outside the UK our major non-academic collaborators are WHO and CDC (USA).

Indicators of wider influence and contribution to discipline or research base

Major scientific advisory board memberships include: BBSRC Bioscience for Health Strategy Advisory Panel (Riley); DNDi and Medicines for Malaria Venture (Croft); European Technology Platform for Global Animal Health (Roy); GAVI Alliance (Watson-Jones); PHE Respiratory Infections Programme Board (Wren); International Committee Taxonomy of Viruses (Gompels); Malaria Vaccine Initiative (Bousema, Drakeley); Novartis Institute for Tropical Disease, Singapore (Croft); Roche Translational Medicine (Hibberd); WHO-TDR Innovation and Technology (Croft); WHO HPV/HVAC (Watson-Jones); WHO Reproductive Health Scientific Advisory Group (Mabey); WHO Global Alliance for the Elimination of Blinding Trachoma (Burton, Mabey).

Honours and awards in the REF period include: Academy of Medical Sciences (Mabey, Roy); Wellcome Trust Senior Investigator Award (Roy); European Research Council Advanced Investigator award (Conway); General President's Gold Medal, Indian Science Congress (Roy); Finalist, BBSRC Innovator of the Year (Roy); Chalmers Medal, RSTMH (Lawn); RCP Weber-Parkes Medal (Grant); 2011 RSTMH George MacDonald Medal (Mabey); 2012 Ronald Ross Medal (Mabey).

Membership of major funding committees: Wellcome Trust (Croft, Dockrell, Kelly, Riley, Sutherland, Wren); MRC (Wren); BBSRC (Riley); NIAID/NIH (Riley, Gompels); Research Council Ireland (Roy); Research Council of the RFCID and HHSRC, Hong Kong (Roy); British Society for Antimicrobial Therapy (Sutherland); HIV Trust (Lawn); Public Health England (Dorrell); Science Foundation Ireland (Wren); Genome Canada (Wren); Singapore National Research Foundation (Hibberd), French ANR/SIDA (Mayaud).

Editors/associate editors/section editors of major journals: *BMC Infectious Diseases* (Drakeley, Lawn); *BMC Immunology* (Helmby); *BMC Public Health* (Clarke); *PLoS Pathogens* (Riley); *PLoS NTDs* (S Baker, Lockwood); *Current Opinion in Infectious Diseases* and *Parasitology* (Croft); *Journal of the International Statistical Institute* (T Clark); *Genome Medicine* (Hibberd), *Malaria Journal* (Bousema, Drakeley); *Science Translational Medicine* (Croft).

Editorial board memberships include: *BMC Immunology*, *Infection and Immunity*, *European Journal of Immunology*, *Pathogens and Global Health*, *International Journal of Biotechnology*, *Malaria Journal*, *Journal of General Virology*, *Clinical Infectious Diseases*, *Parasite Immunology*, *Parasitology*, *Journal of Infectious Diseases*, *Transactions Royal Society of Tropical Medicine & Hygiene*, *International Health*, *Current Opinion in Investigational Drugs*, *International Journal of Parasitology*, *Molecular and Biochemical Parasitology*, *Philosophical Transactions of the Royal Society: B*, *Quarterly Journal of Medicine*.