Institution: University of Liverpool and Liverpool School of Tropical Medicine

Unit of Assessment: 1 – Clinical Medicine

a. Overview

This submission presents the research activity from the majority of the staff (174.5 FTE) within four University research institutes in the Faculty of Health and Life Sciences and the Liverpool School of Tropical Medicine (LSTM) including basic scientists and clinicians. The institutes and LSTM are organised into departments. Those returning staff here are indicated in bold:

- **Institute of Translational Medicine** (Head: **Park**): Departments of Biostatistics; **Cellular and Molecular Physiology; Gastroenterology; Molecular and Clinical Cancer Medicine; Molecular and Clinical Pharmacology; Women's and Children's Health.**
- **Institute of Integrative Biology** (Head: Cossins): Departments of **Biochemistry and Cell Biology; Structural and Chemical Biology; Functional and Comparative Genomics**; Ecology, Evolution and Behaviour; Plant Sciences.
- **Liverpool School of Tropical Medicine** (Head: **Hemingway**): Departments of **Clinical Sciences; Parasitology; Vector Biology,** International Public Health**.**
- **Institute of Infection and Global Health** (Head: **Solomon**): Departments of **Clinical Infection, Microbiology and Immunology;** Infection Biology; Epidemiology and Population Health
- **Institute of Ageing and Chronic Disease** (Head: **Jackson**): Departments of **Eye and Vision Sciences; Obesity and Endocrinology Research; Musculoskeletal Biology**

The Faculty has established a **Technology Directorate** (Head: Beynon) that is managed separately from the institutes to facilitate access to state-of-the-art facilities and technologies for all researchers (see section D).

The return also includes research activity deriving from externally funded research Centres and other Centres recognised by the Faculty as Centres of Excellence and embedded within the institutes:

- Centre for Genomic Research (MRC, NERC)
- MRC-Arthritis Research UK Centre for Integrated Research into Musculoskeletal Ageing
- MRC Centre for Drug Safety Science
- MRC Hub for Regenerative Medicine
- MRC Trials Methodology Hub
- National Consortium for Zoonosis Research
- NIHR Biomedical Research Unit in Pancreatic disease
- NIHR Medicine for Children Research Network
- Wellcome Trust-Liverpool-Glasgow Centre for Global Health Research
- Wolfson Centre for Personalised Medicine

Veterinary and agricultural researchers within Ageing and Chronic Disease, Infection and Global Health, and Integrative Biology are returned to UoA6; Ecology, Evolution and Behaviour research from Integrative Biology is submitted to UoA5; health services research within Translational Medicine is submitted to UoA2; and Public Health researchers from LSTM are returned to UoA2 with the University of Warwick.

b. Research strategy

The University has identified seven cross-Faculty Research Themes linked to national and international priorities, and staff in this UoA lead the *Global Health* and *Personalised Health* themes. Each of these is aligned with research priorities within LSTM. The two themes have been, and continue to be, areas for development and investment as we respond to changing research needs arising from national and international health priorities.

Within LSTM, overall strategic planning is handled by the Management team, and within the University it occurs at Faculty level with detailed planning at institute level. In general terms we

seek to:

- Build on areas of international excellence and expand research in emerging areas of strength to develop programmes into new externally-funded Centres
- Invest in existing externally-recognised Research Centres to ensure their viability and growth and to support their renewal
- Invest in new technological and methodological advance and develop existing facilities and technological capacity for the University and LSTM
- Retain our high-quality researchers and recruit internationally-recognised researchers to develop areas of excellence and to support underpinning methodologies
- Provide a supportive environment for PGR students and support the development of early career researchers (ECRs)
- Establish local and wider external partnerships

Two areas of international excellence that connect the four research institutes and LSTM are *Global Health* and *Personalised Health*. *Infection and Global Health* includes major joint working through the Wellcome Trust Major Overseas Programme in Malawi (MLW Programme-Director, **Heyderman**) and the Wellcome Trust-Liverpool-Glasgow Centre for Global Health Research, which are partnerships involving LSTM and the institutes of Infection and Global Health, Integrative Biology and Translational Medicine. This activity is supported by excellent technology platforms for experimental medicine, pharmacology and product development within this UoA. Its success is also due to its location within a larger research community in Liverpool covering a range of research across high-technology basic science, medicinal chemistry, clinical trials and evidence-based implementation. This diverse community supports delivery and impact in this research area, and is expanding to include new research priorities such as the 'One Health' agenda.

We have developed a critical mass of expertise in *Personalised Health* that allows us to translate research from bench-to-bedside and bedside-to-application. By leveraging expertise in basic and clinical science and technology platforms we are able to optimise biomarker discovery, and take these discoveries into man through focused experimental medicine and innovative clinical trial designs, with the later translational gaps filled through health services expertise. This is driven by staff in UoA1 working through several externally-funded Centres including the MRC Centre for Drug Safety Science, Wolfson Centre for Personalised Medicine, MRC Centre for Genomic Research and MRC Trials Methodology Hub. Our strategy involves close collaboration with NHS partners to improve health, and with industrial partners to increase knowledge exchange and create wealth (demonstrated by joint TSB, Wellcome Trust and NIHR funded projects with industrial partners). The recent formation of Liverpool Health Partners (LHP) will impact in this area by facilitating access to patients and adoption of innovative technologies. LHP involves the University, LSTM and seven partner NHS Trusts. It has tripartite aims of research, clinical care and education, and has identified four internationally excellent Clinical Academic Programmes in Drugs, Musculoskeletal Disorders, Infection and Cancer. The academic strengths of the Faculty and LSTM, coupled with large and well-defined stable patient cohorts served by the Liverpool NHS Trusts and the regional and supra-regional services delivered by these Trusts, provide an ideal environment in which to pursue clinical research. This consortium played a crucial leadership role in the recent (August 2013) award of £9M from NIHR to establish a North West Coast Collaboration for Leadership in Applied Health Research and Care (CLAHRC).

Significant changes during the assessment period

To develop our focus on areas of excellence, research in the Faculty of Health and Life Sciences has been substantially reorganised during this REF period. This activity was originally split between the three separate Faculties of Medicine, Veterinary Sciences and Science (Schools of Biological Sciences and Psychology). In September 2009 a new Faculty of Health and Life Sciences was formed, bringing all related activity under one structure. By organising institutes and Departments around recognised areas of research strength, rather than simply maintaining staff associations based on traditional disciplines, we achieved critical mass in key areas and provide increased capacity for translation, as well as strengthening links with LSTM. This led to the establishment in 2010 of five research institutes (Ageing and Chronic Disease; Infection and Global Health; Integrative Biology; Psychology, Health and Society; Translational Medicine) and an

Institute of Learning and Teaching. In each institute, critical masses of clinical and basic scientists interact around a common basic-translational theme, adding substantial value to each other's science and offering an outstanding research training environment. For the Faculty, the new structure brings full clinical and scientific coverage, spanning Biosciences, Clinical Medicine, Health Sciences, Dentistry, Veterinary Science and Global Health and offers unparalleled opportunities for the development of interdisciplinary research collaborations.

This REF period has covered two strategy periods for LSTM; one ending in 2012 that delivered a new 8,500m^2 laboratory research building (Centre for Tropical and Infectious Disease) and new programmes in Neglected Tropical Diseases and Maternal and Newborn Health, doubling research awards from £122M (October 2008) to £257M (October 2013). The new research strategy from 2012 to 2017 has already delivered the award of HEI status to enable LSTM to operate efficiently in a changed research governance landscape and has three main aims; product development, policy into practice, and capacity strengthening. Expansion of research in these areas is underway, with particular emphasis on Applied Health Research and Delivery and Experimental Medicine.

Achievements against strategy during the REF period

The University and LSTM strategies have been accompanied by substantial recruitment of new staff and promotion of existing staff including, 14 and 19 positions at Chair level in LSTM and the University research institutes respectively. These have been prioritised on the basis of our understanding of existing research strengths, and our identification of the need for new developments in strategically important areas.

Examples of the success of our strategies include:

1. Grant income: Gross external research expenditure over the REF period has been ~£320M (equating to ~£1.8M/FTE) with the award of 430 doctoral degrees. Within this period, our relative performance in award of response-mode grants from research councils has improved substantially:

- MRC - 39th in the UK in 09/10 to 9th in both 11/12 (£11.2M) and 12/13 (£13.4M)
- BBSRC - 24th in UK in 09/10 to 9th in 11/12 (£5.4M) and 13th in 12/13 (£4.2M)

2. Outputs: Outputs in leading journals include ten papers in *New England Journal of Medicin*e, seven in *Nature,* seven in *Science,* 17 in *PNAS,* 19 in *Lancet* and 33 in *Nature Genetics* over the REF period.

3. Postgraduate Research students: The growth in Faculty PGR numbers over the REF period has been underpinned by the recent five year renewal (£4.2M) of our Wellcome Trust four year PhD programme in Cellular and Molecular Physiology (the first ever Wellcome Trust programme, started in Liverpool in 1994), a BBSRC DTP (commenced in 2012, held jointly with Newcastle and Durham Universities and superseding previous BBSRC DTGs, Liverpool award £1.3M), a BBSRC Systems Biology DTG (2009-2013), a MRC DTG including an MRC Capacity Building in Imaging DTG (£325K), a five year renewal of our Wellcome Trust Clinical PhD programme in Global Health (~£7M) and the North West England MRC Fellowship scheme in Clinical Pharmacology and Therapeutics (£3M). There is also increased internationalisation of PGR activities, with expansion of existing training through the Malawi-Liverpool-Wellcome Trust (MLW) programme (£14.7M) to include Bangalore and Ecuador and establishing other new joint programmes (see section C).

Research groupings, activities and achievements

Within the overarching strategy defined by the Faculty of Health and Life Sciences and LSTM Research Committees, the delivery of research is devolved to the University research institutes and LSTM:

1. **Institute of Translational Medicine** (ITM) is the largest research institute at the University with 74.5 FTE academic staff returned here, 323 current PGR students and £80M current external funding.

Rationale: The institute was formed to provide an effective translational pipeline, enabling basic

and clinical researchers to work jointly to improve the efficacy and safety of therapeutic strategies.

People, Centres and Facilities: The institute is organised into six departments containing several centres of research excellence including: the MRC Centre for Drug Safety Science; MRC North West Hub for Trials Methodology Research; Wolfson Centre for Personalised Medicine, Centre for Women's Health research, NIHR Pancreas Biomedical Research Unit; Liverpool Cancer Research Centre; Cancer Clinical Trials Unit; NIHR Medicines for Children Research Network Coordinating Centre and Clinical Trials Unit; and most recently the NIHR funded Pediatric Clinical Research Facility. To create an effective environment for translational research, there has been significant investment in staff recruitment, research infrastructure and enabling technologies. Recruitment of 14 new basic research posts and seven related clinical appointments have significantly increased critical mass in basic and clinical aspects of drug safety, personalised medicine, cancer research and neurobiology. Two new chairs in Statistical Genetics (**Muller-Myhsok**, **Morris**), a chair in Systems Pharmacology (to be appointed 2014) and a senior lecturer in mathematical modelling will provide leading expertise to enhance design of clinical trials, discovery of genetic profiles relating to disease susceptibility, drug efficacy and the prediction of improved stratified therapies. Two new chairs in Cancer Pharmacology; two in Medical Oncology and one in Radiation oncology enhance our ability to undertake both early and late phase cancer trials. A £7M redevelopment plan has been initiated to improve infrastructure and accommodate increased research activity linked to: renewal of the MRC Centre for Drug Safety Science (£3.2M: 2014-2019); a joint research council Regenerative Medicine Platform (RMP) award (£4.5M) to establish a Stem Cell Safety & Efficacy Hub (joint initiative with Integrative Biology and Chemistry; Director, **Park**); a recent £3.2M MRC-funded Centre for Preclinical Imaging (see section D).

Responsiveness to national and international priorities: Key areas of research within ITM are directly aligned with global priorities. These include improving strategies for personalised medicine, increasing the safety of drug and stem cell based therapies, improving diagnosis and treatment of poor prognosis cancers (lung, pancreas, head and neck and leukemia) and improving child health. Targeted appointments have created strong cohorts of basic researchers, clinicians, biostatisticians and computational biologists to provide an effective translational system, evolving to address new challenges. New appointments in neurobiology and inflammation also enable us to work with other institutes and LSTM to address other priority areas such as neuro-regeneration, tissue regeneration and age-related neuropathies.

Examples of significant findings:

- TPL2 kinase, previously considered as an oncogene, shown to have tumour suppressor function and highly deregulated in lung cancer (**Liloglou**, output #1).
- First effective patient stratification using p53 genetic status in any cancer (**Pettitt** outputs #1&2).
- Tumour hENTI levels shown to accurately predict response to Gemcitabine, a key chemotherapeutic in pancreatic ductal adenocarcinoma (**Greenhalf** output #1).
- First evidence for the role of circulating galectins in promoting metastasis and high mortality rates (**Yu** outputs #1&4).
- Providing fundamental insight into organisation and function of the human ubiquitome (**Clague** output #2, **Sanderson** output #2&3) including that the nucleolus acts as a novel stress sensor with therapeutic potential (**Boyd** output #1), enabling Clague and **Urbe** to establish international academic/industrial pipeline to identify DUB based therapeutic targets (Dub alliance 2013).
- Disproved established dogma that calorie restriction increases lifespan by activating Sir2 (**A. Morgan** output #2).
- A genome-wide study revealed a link between HLA-A*3101 and carbamazepine-induced hypersensitivity reactions in Europeans (**Pirmohamed** output #1). HLA-B*5701 genotype identified as a major determinant of drug-induced liver injury due to flucloxacillin (**Pirmohamed** output #3), followed by the first demonstration of how CD8+ T cells are involved in flucloxacillin-induced liver injury (**Naisbitt** output #1).
- Demonstration that genotype-guided dosing of warfarin can improve the time within therapeutic range compared with standard clinical care (**Pirmohamed** output #2).
- Mir122 identified as a potential marker of human drug-induced liver injury (**Park** output #4).

Future strategy:

- Delivering outputs and impact from our existing major programmes: RMP on stem cell safety and regenerative medicine, pancreatic disease, pre-clinical models of liver toxicity and drug re-purposing. Build on recent imaging investments to establish new programmes investigating molecular mechanisms of disease through integration of cell, tissue and whole-animal imaging.
- Extend statistical genetics through new appointments and develop network/systems based approaches to facilitate interpretation and translation of complex genetic and 'omic' data. This will consolidate strengths in stratified medicine, be linked to the Centre for Computational Biology and Modelling and to development of a bioinnovation hub that allows for integrated working with industry.
- Develop an efficient pipeline for translation of basic findings into clinical application. This will be facilitated by new infrastructure including the MRC methodology Trials Hub and NIHR-accredited clinical trials units (to optimise design and delivery of early and late phase trials); the MHRA-accredited academic clinical research facility for early phase studies, the NIHR-funded paediatric clinical research facility, partnership with the Northern e-Health Research Centre, and close working with the NHS Trusts (through Liverpool Health Partners).

2. **Institute of Integrative Biology** has 22 FTE academic staff returned here, 144 current PGR students and £33.2M current external funding.

Rationale: The institute provides the interdisciplinary research environment, spanning structural biology to community ecology, necessary to tackle fundamental questions in biology and underpin high quality biomedical and translational research.

People, Centres and Facilities: The research programmes of staff returned here bring critical mass to the fundamental science underpinning the basic and translational research of the other institutes and LSTM and ensuring excellence underpins large translational initiatives, e.g., NIHR, PBRU (**Fernig**), MRC Regenerative Medicine Safety Hub (**Levy**), and large basic science programmes, e.g. three BBSRC LoLAs with Manchester (**C Eyers**) and one with Ecology and Evolutionary Biology (**Lian**). Institute staff have a further role in leading flagship Shared Research Facilities (see section D) and Research Centres such as the Centre for Biological NMR, the Protein Function Group, Centre for Genome Research (CGR), Centre for Cell Imaging (CCI), the Centre for Computational Biology and Modelling (CCBM), the Barkla X-ray Laboratory and the Robotic Crystallisation facility. Institute staff also bring strong collaborations with Science and Engineering, particularly Chemistry, Physics and Mathematics.

The institute has benefitted from important strategic investments, including the recruitment of 9 new academic staff returned here. These are X-ray crystallographers (**Hasnain, Antonyuk** and **Strange**) and a physicist (**Lévy**) to add critical mass to bionanotechnology, microscope and probe development (including single molecule photothermal imaging); a molecular imager (**Sée**), protein kinase biochemist (**P Eyers**) and appointments in post-translational modification proteomics (**C Eyers**) and muscle stem cell biology (**Pisconti**) enable a full systems approach to biochemical signalling; a leader for the Centre for Computational Biology (**Falciani**) and a molecular microbiologist (**Hinton**).

Responsiveness to national and international priorities: Basic biosciences underpinning health is a key research priority of RCUK, major UK biomedical charities and international funding organisations. The institute's bioscience research focuses on specific aspects of this priority.

Examples of significant findings:

- A concerted dissection of mechanisms of cell motility: from molecular mechanism of stabilisation of integrin activation by talin's N-terminal head (**Barsukov** output #1&2) to a mechanistic model for talins's mediation of adhesion assembly-disassembly via molecules such as RIAM and vinculin (**Barsukov** output #3); motility promoted by the S100A4 and AGR2 proteins that drive metastasis (**Lian** output #1; **Barsukov** output #4); control of cell movement *in vivo* by the orthologue of RIAN, PICO, in a *Drosophila* model (**Bennett** output #2&4).

- The structural basis for mechanosignaling by titin, with important implications for skeletal and cardiac muscle disease (**Mayans** output1 #1&2).
- A predictive model for biochemical signalling by NFκB transcription using single cell measurements for the first dissection of its time-encoded signalling (**Sée** output #1).
- A bionanotechnology programme that changed understanding of nanomaterial-cell interactions (**Sée** output #3, Lévy output #4), demonstrating cellular capacity to metabolise nanomaterials, highlighted in Nano Today (**Lévy** output #4) and delivered novel insights, such as mechanisms of morphogen/growth factor transport through extracellular matrix (**Fernig** output #1).
- New molecular insights into microorganism pathogenicity. Mechanisms of electron transport in Cu nitrite reductases in opportunistic pathogens such as *Ralstonia pickettii*. (**Antonyuk** output #3), the first next-generation "deep" sequencing in *S. typhimurium* identified novel sRNAs bound to Hfq (**Hinton** output #4) allowing the first mechanistic analysis of *Salmonella* gene expression (**Hinton** output #1).

Future strategy:

- Integrate genomic and proteomic analytical and bioinformatics capacity with new expertise in the Centre for Computational Biology and Modelling to enable comprehensive systems-level dissection of the mechanisms of biochemical signalling in health and disease.
- Expand the basic science focused bionanotechnology programme with Chemistry into nanomedicine, particularly in preclinical imaging to exploit the MHRA-accredited academic clinical research facility for early phase studies in the Royal Liverpool University Hospital.
- Capitalise on the emerging cross-Faculty synthetic biology research programmes, e.g. US DOE award ($3M) for crassulacean acid metabolism CO_2 fixation, existing strong links with the University' Stephenson Institute for Energy (SIRE), and Micro Bio-Refinery and Materials Innovation Factory, to develop a cross-Faculty Liverpool Synthetic Biology institute.
- Deploy the institute's specialist facilities and research Centres to increase leverage of large cross-Faculty platform grants in the areas of disease mechanisms and drug development.
- Build on the mechanobiology/mechanosignaling and extracellular matrix/glycobiology community across several institutes to elucidate the structural basis of the cellular signals generated by the cell microenvironment in oncology and regenerative medicine

3. **Liverpool School of Tropical Medicine** with 31 FTE staff returned here, 77 postgraduate students and £257M current external funding.

Rationale: LSTM is a globally-recognised leader in Tropical Diseases research and capacity strengthening. It includes laboratory science, clinical studies and applied health research, working in partnership with governments, international organisations and other stakeholders to shape the global research agenda and create environments in which evidence–based research outputs can be used to impact on health.

People, Centres and Facilities: LSTM is a translational research centre with activity in *Product Discovery and Development, Translational of Knowledge into Practice* and *Capacity Strengthening*. LSTM's Centre for Tropical Infectious Diseases (CTID), a £26 million development completed in 2009, hosts most laboratory activities and develops new interventions for Tropical Medicine. It facilitates engagement with Product Development Partnerships (PDPs), which stimulate the discovery and development of tools for use against a broad range of infectious diseases, and allow industry to share the risk associated with product development with public or philanthropic capital. LSTM hosts one virtual PDP (The Innovative Vector Control Consortium: Head, **Hemingway**), operates a filariasis drug development PDP (Anti-Wolbachia Consortium: Head, **Taylor**) and accesses funding from other externally-hosted PDPs such as the Medicines for Malaria Venture. LSTM activities range from basic discovery research, funded by Wellcome Trust, MRC, BBSRC, BMGF, NIH and EU, to a strong portfolio in translational science, with work funded by the Seeding Drug Discovery programmes of the Wellcome Trust and MRC (**Ward, Biagini, Paine**) and a recent MRC/TSB initiative, the Biomedical Catalyst (**Ward, Biagini**). For Translation of Knowledge into Policy and Practice, LSTM has major programmes for the implementation of effective interventions for neglected tropical diseases (NTDs; Head, **Bockarie**), Maternal and Child Health (Head, **van**

den Broek), Respiratory (Head, **S. Gordon**) and Vector Borne Diseases (Head, **Ranson**). There is a substantial portfolio of clinical studies and trials, facilitated greatly through our involvement in the Wellcome Major Overseas Programme in Malawi, health services research (evidence synthesis and monitoring & evaluation studies) and operational delivery research funded by DfID, BMGF and EU. Strengthening health systems capacity is essential to improving health of individuals in low-income countries. LSTM is involved in several major programmes with strong capacity development themes, including the Wellcome Trust-funded Malaria Capacity Development Consortium (**Craig**) and DfID funded programmes on NTDs (**Bockarie, Bates**) and Child, Infant & Reproductive Health (**van den Broek, Bates**).

Responsiveness to national and international priorities: The application of LSTM's findings to product development and policy implementation to support improvements in health in low and middle income countries is key to the production of impact from research. This is delivered through partnerships with other academic institutions, governmental and non-governmental organisations and commercial companies, using product development partnerships, membership of national and international committees, as well as more traditional collaborations.

Examples of significant findings:

- Development of novel antimalarials targeting the *Plasmodium falciparum* mitochondrial respiratory chain with the University of Liverpool's Chemistry Department (**Ward**, output #1)
- Identification of cytochrome P450 alleles driving the spread of pyrethroid resistance in the major malaria vector *Anopheles funestus* (**Wondji** output #3)
- Identification of the pathway regulating dendritic cell homeostasis and adaptive immunity during Plasmodium infection (**Urban** output #4)
- A new pathway for pathology in cerebral malaria based on loss of endothelial protein C receptors links coagulation and inflammation to parasite sequestration (**Moxon** output #1)
- Investigation of the use of insecticidal bed nets as part of an elimination programme for filariasis in Papua New Guinea (**Reimer** output #2)
- Molecular epidemiology using whole genome sequencing of epidemic multiple drug-resistant Salmonella Typhimurium causing invasive disease in sub-Saharan Africa (**Heyderman** output #2)
- A randomized controlled trial showing macrofilaricidal activity after Doxycycline treatment for Onchocerca volvulus (**Taylor** output #3)
- A randomized controlled trial showing improved antifungal therapy for cryptococcal meningitis (**Lalloo** output #4)
- Large multi-centre trial in Malawi testing the efficacy and safety of intermittent preventive therapy post-discharge (IPTpd) in children (**ter Kuile** output #1)
- Impact of pyrethroid resistance on effective vector control as part of an elimination agenda (**Hemingway** output #2).
- A Multi-Country Non-Inferiority Cluster Randomized Trial of Frontloaded Smear Microscopy for the Diagnosis of Pulmonary Tuberculosis showing good sensitivity and specificity (**Squire** output #4).

Future Strategy:

- Producing new basic research outcomes to contribute to, or build, new product pipelines; where appropriate leading efforts in partnership with industry to develop new diagnostics, drugs and public health pesticides.
- To develop Monitoring and Evaluation methodologies and systems to measure Impact.
- To operate as a Centre of Excellence for Evidence-based Research Synthesis across a range of disciplines.
- To assist Disease Endemic Country partners to optimise intervention strategies and implementation.
- To selectively advocate in key areas of LSTM strength, such as Maternal and Child Health, Neglected Tropical and Other Vector Borne Diseases.
- To provide leadership in defining methodologies to monitor and evaluate the effectiveness of external and internal Capacity Strengthening programmes.

- To contribute to policies of influential agencies including research funders and government departments, on Capacity Strengthening issues

4. **Institute of Infection and Global Health** with 18 FTE academic staff returned here, 101 PGR students and £36M current external funding.

Rationale: The institute's mission is to improve the health of humans and animals by tackling key infectious diseases in both a UK and global context. It integrates medical and veterinary research to enhance exchange of knowledge and skills, thereby developing the 'One Health' agenda.

People, Centres and Facilities: 12 new senior academic staff have been appointed to build on areas of strength. These have been in brain infections (**Ng**), gastrointestinal infections (O'Brien [returned in UoA6], **Iturriza-Gomara**), respiratory infections (**French**, **Kadioglu**, Hiscox [returned in UoA6]), HIV (**Geretti, Van de Wijgert, Paxton**), and infection pharmacology (**Davies**). Diggle (biostatistics) and Fevre (emerging infections & zoonoses) work across the institute and are returned in UoA6. The institute is a major partner in the Wellcome Trust-Liverpool-Glasgow Centre for Global Health Research and the MLW Major Overseas Programme with LSTM. The institute hosts the National Consortium for Zoonosis Research (Director, O'Brien), and leads (through **French**) the Infection theme of Liverpool Health Partners. In December 2011, the institute opened a purpose-built £22M world-class infection research facility, the Ronald Ross Building, including CL3 Laboratories.

Responsiveness to national and international priorities: The institute investigates major infectious diseases of adults and children, including emerging and zoonotic infections. The institute's work is multidisciplinary, facilitating a development 'pipeline' through which basic research translates into benefit for patients and the public through the development and deployment of new diagnostics, therapeutics and vaccines.

Examples of significant findings:

- Human rotavirus vaccine significantly reduced the incidence of severe rotavirus gastroenteritis among African infants. This first trial of a modern rotavirus vaccine in Africa led to a global recommendation of vaccine use by WHO (**Cunliffe** output #1).
- A pneumococcal conjugate vaccine protected HIV-infected Malawian adults from recurrent pneumococcal disease. Results informed national and international recommendations for vaccine use in immunocompromised adults. (**French** output #1).
- Drug-resistant variants present at low frequency in plasma of HIV-infected patients negatively impact on responses to antiretroviral therapy. These data informed national and international guidelines on HIV management. (**Geretti** output #3).
- Vitamin D supplementation was shown not to accelerate elimination of tuberculosis organisms during treatment. (**Davies** output #1).
- Only 60% of patients with encephalitis in the UK had a confirmed aetiology. In 20%, encephalitis was caused by an immune mediated process. If identified promptly these patients respond to immunosuppressive treatment. (**Solomon** output #1).
- Elucidation of the first genome sequence of a cystic fibrosis epidemic strain of *Pseudomonas aeruginosa* implicated prophage regions as major pathogenicity determinants promoting human spread. (**Winstanley** output #3).
- Circulating histones mediate trauma-induced lung injury and represent viable therapeutic targets. (**Toh** output #4).

Future strategy:

- Build on the established 'One Health' approach to address major human and animal infectious diseases including gastrointestinal, brain, respiratory and emerging infections.
- Investigate basic mechanistic processes underpinning the pathogenesis of globally important infections (e.g. *Streptococcus pneumonia*e, viral encephalitis and HIV).
- Develop and test novel diagnostics for severe bacterial infection (e.g. use of biomarkers).
- Explore novel treatment approaches for severe bacterial infections (e.g. peptide therapy) and

drug-resistant infections (e.g. tuberculosis, hepatitis).
- Evaluate vaccines against major global causes of morbidity and mortality (rotavirus, pneumococcus, Influenza, Japanese encephalitis, Group B Streptococcus).
- Build upon existing national (e.g. Public Health England), and international partnerships (e.g. Malawi, Bangalore and Ecuador through the Wellcome Trust-Liverpool-Glasgow Tropical Centre for Global Health Research).

5. **Institute of Ageing and Chronic Disease** with 29 FTE academic staff returned here, 91 postgraduate students and £24M current external funding).

Rationale: The institute brings a critical mass of basic scientists, clinical and veterinary staff with common research expertise and interests in ageing and long term conditions to address major age-related challenges for both human and animal health.

People, Centres and Facilities: The institute leads the newly awarded MRC-Arthritis Research UK Centre for Integrated Research into Musculoskeletal Ageing (CIMA, Director, **Jackson**) a joint development with Universities of Newcastle and Sheffield to build on our expertise in this area and expands our access to specialist state-of-the-art facilities for musculoskeletal assessment. These include recent funding (August, 2013) from the MRC Centre Capital Panel (£660K) to establish a joint Bi-planar x-ray system (first in the UK for use in human subjects) in Liverpool. The institute has also invested in 14 new posts (including new Chairs in Eye and Vision Sciences (**Willoughby**), Matrix Biology (**Bou-Gharios**), Bone and Joint Biology (**Van't Hof**), and Rheumatology (**Cooper**) to significantly increase critical mass. Significant capital investment in specialist facilities and laboratory refurbishment has also underpinned an expansion of basic and translational research capacity. Eye and Vision Sciences (Head, **Harding**) undertake basic, applied, clinical and translational research and has a state-of-the-art *Clinical Eye Research Centre* and the *Liverpool Research Grading Centre* for both diabetic retinopathy and age-related macular degeneration. Obesity and Endocrinology Research (Head, **Wilding**) has basic science and clinical research programmes with novel studies of appetite control and adipose tissue function in obesity based in the excellent clinical research facilities in University Hospital Aintree. The large Department of Musculoskeletal Biology (Head, **McArdle**), hosts the *Muscle Pathophysiology Group* that utilises state-of-the-art electron paramagnetic resonance, confocal and single fibre muscle mechanics systems and undertakes *in vivo* studies of musculoskeletal structure, function and metabolism including whole-body composition analysis, MRS studies of muscle bioenergetics and structural and functional MRI though the *Magnetic Resonance and Image Analysis Centre* (MARIARC; Head, **Kemp**), the *Comparative Musculoskeletal Sciences Research Group* laboratory that investigates the mechanobiology of cells and tissues with cell loading and mechanical testing systems and the *Biomechanics Group* that undertakes full body dynamic modelling and finite elements analysis of musculoskeletal mechanics.

Responsiveness to national and international priorities: The problems of an ageing society and lifelong health and wellbeing are key UK and international research priorities emphasised by UK research councils, NIHR and major funding bodies. The institute addresses key aspects of these priorities and also contributes to the "One Health" agenda in musculoskeletal disorders.

Examples of significant findings:
- Identification of macrophage inhibitory cytokine-1 (MIC-1) as a novel adipokine which stimulates adiponectin production by human adipocytes (**Bing** output #1)
- Demonstration that overexpression of the mitochondrial heat shock protein 10 prevents age-related loss of skeletal muscle in experimental models (**McArdle** output #3) and identification that mice lacking copper, zinc superoxide dismutase provide a mechanistic model of accelerated age-related loss of skeletal muscle (**McArdle** outputs #1&4; **Jackson** output #1)
- Demonstration of the effectiveness of an inhibitor of homogentisic acid synthesis in reducing pathology in a mouse model of alkaptonuria (**Gallagher** output #1)
- Use of the novel SGLT2 inhibitor dapagliflozin as an adjunct to insulin treatment in patients with type 2 diabetes (**Wilding** output #1)
- Demonstration that phosphodiestase-4 inhibitors prevent disease exacerbations in COPD

(**Calverley** output #1)
- Optimisation of anti-VEGF therapy in age-related macular degeneration (**Harding** output #2).

Future strategy:
- Undertake innovative cross-species studies in musculoskeletal disorders through close working between veterinary, clinical and basic researchers and develop a facility for experimental interventions in large animal models to capitalise on excellent clinical veterinary facilities.
- Identification and trial of novel interventions based on exercise, nutrition or anabolic agents to reduce the risk of age-related musculoskeletal disorders through the MRC-Arthritis Research UK Centre for Integrated research into Musculoskeletal Ageing (current funding 2012-2017).
- Develop and expand the range and expertise in clinical musculoskeletal disorders as one of 4 key themes in Liverpool Health Partners
- Identify mechanisms by which hormones from the gut, adipose tissue and muscle regulate appetite and body composition during ageing and in obesity & related conditions and exploit large, well characterised patient cohorts to undertake innovative interventions
- Exploit new therapeutic targets identified through basic research in Eye and Vision Sciences (e.g. actin networks in the trabecular meshwork in glaucoma) for the treatment of eye diseases.

c. People, including:

i. Staffing strategy and staff development

The Faculty of Health and Life Sciences and LSTM have recruited extensively to build on recognised areas of research excellence and establish critical mass to enable delivery of strategic objectives. This has resulted in 118 new academic appointments in the four research institutes (28 at Professor/Reader level) and 26 in LSTM at Professor/Reader level.

These new appointments at senior and junior level have been made across the Faculty of Health and Life Sciences in the REF period and are planned to continue beyond 2013. Many have been in specific research areas to support and enhance identified research strengths. A major part of our strategy has been to support the development and renewal of externally recognised Centres. We have increasingly aimed to develop joint projects and funding applications with colleagues in the University's Faculty of Science and Engineering through cross-Faculty meetings and workshops. Recent success has included the MRC Regenerative Medicine Safety Hub and linked major capital bid for preclinical imaging with colleagues in Chemistry and Physics. Regenerative Medicine will be a major area for investment beyond 2013. Another major planned area for future development will be a new cross-Faculty translational Centre for Research and Innovation in Biomedical Science and Engineering with colleagues in the School of Engineering.

Other appointments have been made to address areas of need and to provide underpinning support in generic areas and methodologies that are relevant across all of UoA1. In particular new Chair appointments with accompanying junior posts have been made in computational biology (**Falciani**), Biostatistics (Diggle returned to UoA6), Statistical Genetics (**Muller-Myhsok** and **Morris** - will start January 2014), Systems Pharmacology (new appointment in 2014). In collaboration with the Department of Maths, a new cross-Faculty network in Bioinformatics, Biostatistics and Computational Biology was established in 2013 to initiate workshops to allow increased access to all researchers of expertise in quantitative techniques. To address the shortage of trained biostaticians, a new biostatistics fellowship and associated masters-level training programme will commence in 2014. As part of the Faculty succession planning **C. Eyers** was appointed to extend capacity to post-translational modification in proteomics and ensure long-term sustainability of the proteomics facility (Section D).

Promotions are awarded on the basis of defined criteria on a non-quota basis and are key to the retention of high-quality staff. All staff are included in the University's Professional Development Review process, which provides members of staff with an opportunity to discuss their personal and professional development on an annual basis, including the balance of research and other duties. Training courses and workshops are available for staff through the University's Centre for Lifelong Learning, covering many different skills and areas of development.

Strategy for support of ECRs and continuing career development: There is an active policy of

supporting all ECRs through mentoring, prioritisation for internal Research Development Awards and internal review of research grant applications that has enabled us to return 39 ECRs in this UoA. Individual institutes run bespoke programmes of seminars and training workshops in areas such as grant writing and publication strategy specifically for early career researchers (part supported by the Wellcome Trust ISSF), such as the *Fostering Liverpool and IGH Talent* (FLIGHT) initiative, which has supported 19 fellowship applications since 2010, with 10 awards, so far (five pending). Specific examples of where this has been successful are apparent at all levels: **Tew** was appointed as lecturer in Ageing and Chronic Disease and supported with pump-priming funding and a PhD studentship leading to securing a BBSRC Young Investigator project grant; **Biagini** started in Translational Medicine, transferred to LSTM into a Tenure-Track scheme with 50% institutional support to become a PI on several major grants and was recently promoted to Reader. **Solomon** was supported through Wellcome Trust Intermediate and MRC Senior Fellowships in Liverpool and is now Professor and Head of the Institute of Infection and Global Health. Clinical lecturers receive specific support through protected academic time and association with a successful research group. The University has developed a joint strategy with the Mersey Deanery focusing on academic foundation training, clinical academic training fellows and clinical lecturers (who must already hold a PhD) that is overseen by an Integrated Clinical Academic Training Committee (Chair, **Pritchard**).

Use of the Wellcome ISSF for support of ECRs: Wellcome Trust awarded £750K p.a. to the University and £500K p.a. to LSTM, as an Institutional Strategic Support Fund (ISSF) to support our Biomedical Research strategy. This has been used to support ECRs, and addressed differing issues for clinical, veterinary and basic scientists by proposing a flexible scheme for approval by the Trust. For clinicians, we addressed the need for research training of clinical lecturers to allow them to prepare for external funding applications by the award of short-term fellowships (six-12 months). Veterinarians involved in clinical teaching have the opportunity of a period of dedicated research through two-year research leave fellowships. With regard to non-clinical researchers, we wanted to address the difficulties that arise in the transition to an independent researcher after taking up an academic lectureship post. We observed that this can be a difficult transitional period, moving from being a full-time researcher to the challenge of establishing independent research projects needing external grant funding whilst at the same time taking on the new teaching and administrative duties expected of a lecturer. This we addressed by the establishment of 3-5-year tenure-track fellowships leading on to established posts. The key aspects of the tenure-track fellowship were that we defined a maximum level of teaching in the first three years so that we have a formal commitment to protect time for the establishment of independent research projects. We also defined what fellows could expect in terms of mentoring and support. We provide financial support from the ISSF for research in years 1-3, with an expectation that the fellows would by then have obtained external funding to pursue their research projects. Other aspects of the use of the ISSF have included the provision of bridging funding for post-doctoral fellows between external grants and we have sponsored a Faculty-wide Fellows network and Faculty workshops on how to apply for external fellowship funding. By the end of our second year of ISSF funding in September 2013, the Funding to the University had supported 25 ECRs and LSTM had supported 10. A second round of fellowships for clinical lecturers and for veterinarians is planned for 2014, and we are moving to convert all new lectureship posts to this tenure-track model.

Externally Funded Fellowships: Both the University and LSTM have supported young investigators in applications for externally funded Fellowships and created proleptic appointments to researchers holding such substantive fellowships (**Feasey, Gordon, Kearns, Lévy, Sée** and **Vasilaki** were recruited in this way). In the REF period 100 Fellowships have been obtained and the funding sources are indicated below:

Funding agency	Number of Fellowships
UK Research Councils	9
Wellcome Trust	45
Other charities	16
NIHR and NHS sources	5
Other sources (including EU and Industrial)	25

Human Resources: The University and LSTM share an approach to staff development, including the Professional Development Review (PDR) in which each researcher and academic member of staff participates at least annually. PDR is undertaken by the Heads of Department. PDRs are underpinned by a Portfolio of Activity which is completed by all research and academic staff to record the full range of their activity and which informs discussions about workload and development. The process is supported by a range of equality policies and action plans. All staff complete mandatory training in diversity and equality, and training in diversity and equality specifically for managers is also mandatory. **Reward and Recognition:** All research and academic staff have access to promotion through an annual review process. The University has introduced an Outstanding ECR Award as part of its 'Celebrating Success Awards'. Dr Laura Benjamin (Infection and Global Health) received a commendation in this category. The Postdoctoral and Early Career Research Staff Programme offers personal and professional development opportunities to ECRs including core research skills, personal and professional skills, specialist skills, teaching for researcher (HEA-accredited course) and career support.

Fixed term contracts: Whilst the nature of research work makes the use of fixed term contracts appropriate, during the period of their contracts all fixed-term staff have access to the same support and development as permanent staff and we proactively seek redeployment opportunities for fixed-term staff. The University and LSTM are signatories to the Concordat to Support the Career Development of Researchers and have an on-going commitment to the principles of the Concordat. The Wellcome ISSF funding is used to provide bridging funding for post-doctoral fellows between external grants (previously this was undertaken using Wellcome VIP funding). We have several examples where this funding has retained an individual and allowed them to develop their career and eventually secure a tenured academic position, including **Lévy** (Integrative Biology) who was supported for 12 months on Wellcome bridging funding to obtain a BBSRC David Philips Fellowship with subsequent appointment as Lecturer.

Athena SWAN: Bronze awards are held by the University (2010) and Ageing and Chronic Disease (2013). All institutes and LSTM have recently, or will shortly, apply for an award. Wray (Translational Medicine) is Institution and Faculty academic lead and champions are identified in all our institutes and LSTM.

ii. Research students

During the REF period, all LSTM students were registered with the University of Liverpool and hence training followed the same model. The University pioneered the 1+3 model of research training with the first Wellcome Trust four-year PhD programme in Cellular and Molecular Physiology in 1994 (the success of this programme with a 98% on time completion rate was recognised with four renewals including in 2013, with new intakes fully funded up to 2018). This now forms the basis of four-year (MRes/PhD) programmes across the Faculty. The large MRes programme in Biomedical Sciences and Translational Medicine is used as the first year of the programme. The use of rotation research projects in the MRes year with students embedded in active research groups has been extended as a general model across UoA1. Entry into MRes is now spread across all institutes as the standard approach for recruitment and training of research students. This model now underpins our other externally funded programmes including a BBSRC DTP (held jointly with Newcastle and Durham Universities that commenced in 2012, superseding previous BBSRC DTGs) and an MRC DTG. This model also ensures that research students are trained in well-funded laboratories with access to the full range of high quality core facilities.

The model is the basis of specialised training provided to increase research capacity in areas of strategic need including a BBSRC Systems Biology DTG (2009-2013), an MRC Capacity Building in Imaging DTG and Cell Biology DTG (LSTM with Warwick University), a Wellcome Trust Clinical PhD programme, the North West England MRC Fellowship scheme in Clinical Pharmacology and Therapeutics and the CIMA (MRC-Arthritis Research UK Centre for Integrated Research in Musculoskeletal Ageing) joint MRes and PhD programme with Newcastle and Sheffield.

High-quality supervision of PGR students is an expectation of staff in the UoA and discussed during the annual PDR process. In addition to academic staff, the UoA involves accredited

honorary staff in supervision (e.g. NHS staff), to ensure that students have the most appropriate guidance for their research. For doctorates included in REF4a, 287 individuals contributed to supervision of the students. The quality of the approach is demonstrated by completion times, with 93% full time students submitting their thesis within four years (average 3.6 years). 180 of the doctorates were awarded to part-time students; their average submission time was 5.3 years.

Substantial Faculty and LSTM investment (£440K 2011-2012, £826K 2012-2013 and >£900K 2013-2014 and continuing at that level) has enabled all institutes and LSTM to expand their PGR training. This internal funding has been used to lever matched funding has from NHS Trust partners, MRC, BBSRC, industry and other local sources. Within the REF period, the UoA has secured 47 CASE studentships from 33 different partners with a £1.2M contribution. Partners have included AstraZeneca (six awards), Roche (five), Biocomposites Ltd (three), Novartis (three), Unilever (three). In addition, from 2012, the Faculty has provided funding to boost international PhD recruitment and has established programmes with key partners. 19 students in the UoA1 area are now registered for dual or joint PhD programmes with:

- Chulalongkorn University, Bangkok, Thailand
- The College of Medicine, University of Malawi, Blantyre, Malawi
- A*Star, the Agency for Science, Technology and Research, Singapore
- RIKEN, Japan
- Mahidol University, Bangkok, Thailand
- CIC bioGUNE/ CIC biomaGUNE (Center for Cooperative Research in Biosciences, Bizkaia/Center for Cooperative Research in Biomaterials, Gipuzkoa, Spain

International students also travel to Liverpool for PhD study under formal arrangements with:
- University of Health Sciences, Lahore Pakistan
- Science without Borders, Brazil

Other international partnerships for PhD provision are currently in development.

The University's **Skills Programme** is compulsory for all research students and provides approximately six weeks of developmental activity over three years. The programme has an interdisciplinary approach to professional development. The University and LSTM have Poster Days for second year students and a range of career skills activities covering enterprise and business awareness, career management, teaching skills and work and volunteer experience. An online equivalent programme caters for part–time and students abroad. A personal development planning tool (the PGR Toolbox) is allied to a supervisor meetings record and provides up to date information on training and development opportunities. The University provides professional development and five-yearly supervisor 'refresher' courses. Each institute delivers subject-specific training including training in Public Engagement (Infection and Global Health and Ageing and Chronic Disease students organised public engagement days with World Museum Liverpool) and encourages students to act as STEM ambassadors, interacting with local schools and colleges.

d. Income, infrastructure and facilities

Income

For the University research institutes, total awards for the last six years have been £175M (increased from £106M in the previous 6 year period). This has included particular success in:

- Research Council awards (from £24.6M to £36.7M), including major awards in drug safety and stratified medicine (Centre for Drug Safety Science and cancer biomarkers from MRC), ageing (Centre for Integrated Research In Musculoskeletal Ageing from MRC with additional awards from BBSRC), stem cell tracking and nanomedicines awards (EPSRC), pancreas biology (BBSRC and MRC), bone biology and infection (BBSRC).
- UK Charity awards (from £40.9M to £66.6M)
- UK Industry awards (from £11.4M to £16.5M), with major collaborative projects with GlaxoSmithKline and NAPP Pharmaceuticals (CLL therapy), AstraZeneca (Drug Safety and pancreatic cancer therapy), Pfizer (training scheme in paediatric clinical pharmacology).

For LSTM research income has increased substantially compared with the RAE2008 period:

- Research Council awards have increased from £2.4M to £4.5M.
- UK Charity awards have increased from £20.9M to £31.7M.
- UK Government and health agency funding has increased from £18.2M to £50.1M
- Non-EU charity funding has increased from £12.4M to £54.6M.

Infrastructure and facilities

Provision of core research facilities: A major development in this REF period has been the increased investment in core research facilities. Following the recommendations of the Wakeham Review (June 2010) the Faculty established a Technology Directorate, to ensure efficient utilisation of core technologies, maintain a technological lead and drive academic excellence. The Directorate is managed independently of the research institutes and is led by Beynon (UoA6 return). The Technology Directorate gives an integrated approach to the development and delivery of enabling technologies to all members of the Faculty, including newly appointed ECRs. In addition, a Faculty-wide perspective ensures that we do not replicate capacity with lower grade instrumentation than could have been established centrally. We are well placed to engage with other Universities and other stakeholders in the sharing of facilities. Access to the shared research facilities operate at different levels, including a Technology Directorate Voucher scheme to provide subsidized routes to access for new academic appointments, ECRs, including research fellows. In the first nine months of operation, the TD has awarded 25 such vouchers, totaling £193K and obtaining £98K in matched funding from other sources.

The Technology Directorate oversees all Shared Research Facilities, of current capital value over £18M, including genomics (lead Hall, UoA6), proteomics (leads Beynon UoA6 and **C Eyers**), light microscopy (leads **Bennett** and **Sée**), NMR for structural biology/metabolomics (lead **Lian**), and magnetic resonance imaging (lead **Kemp**). The growth of the Directorate is progressive, with other shared research facilities, e.g. biomedical electron microscopy (lead **Prior**), robotic protein crystallisation (lead **Mayans**) developing compliant access, business and sustainability plans. The success of this model is evidenced by: (i) £931K MRC NextGen Optical Microscopy grant to Cell Imaging (2012); (ii) a successful MRC application to provide £3.2M to establish a new Centre for Preclinical Imaging (CPI), which will house small animal imaging systems, including a 9.4T MR scanner, a photoacoustic imager and a whole animal fluorescence/luminescence imaging system; (iii) four BBSRC Advanced Life Sciences Research Technology Initiative (ALERT 13) awards of competitive funding (light sheet microscopy, single molecule sequencing, mass imaging and 3-D electron microscopy). The total value of these latter developments is £2.4M and acquisition was supported by University matched funding of £0.6M.

LSTM has invested in the new Centre for Tropical Infectious Diseases (CTID), a £26M development completed in 2009. This hosts the majority of the School's laboratory activities, housing the largest collection of Cat III culturing laboratories in the UK, specialized Cat III insectaries for infected vectors as well as facilities for bioanalytical and biodiscovery research that complement core facilities in the University. Research facilities in older buildings have been refurbished during the REF period and a £7M re-build is due for completion in October 2014 to provide new accommodation for the Centre for Applied Health Research and Delivery (CAHRD).

The University recently completed the £22M Ronald Ross Building that provides purpose-built laboratories, including containment level II and III facilities, for the Institute of Infection and Global Health in addition to a state-of-the-art Biomedical Services Unit for all of the research institutes. An £11M refurbishment of the grade II listed Waterhouse Buildings, blocks A & B, has created a new research Centre for Personalised Medicine. A £4M refurbishment of the grade II listed Waterhouse Building Block F will provide a Clinical Trials Research Centre - a Centre of Excellence in clinical trial design, management and analysis, and one of only a small number of units in the UK awarded Full Clinical Research Collaboration registration status. At the Liverpool Women's' Hospital, £2.5M has been invested to provide a Centre for Women's Health Research covering a broad range of translational research themes including: Uterine muscle physiology, Research synthesis (Cochrane Pregnancy and Childbirth Group), International Maternal and Child Health (Sanyu Unit), Preterm labour and birth, Pathophysiology of endometriosis and Perinatal pharmacology.

The Faculty has substantial plans to ensure the sustainability of our existing strategic research facilities and to increase these through:

- Investment in a new purpose built, state-of-the art 10,000 m^2 laboratory building to be jointly occupied by industrial partners and the Institute of Ageing and Chronic Disease to replace outdated accommodation in the Royal Liverpool University Hospital. This accommodation will house a new biobank facility for the Faculty (£42M investment from the University with building work due to start in December 2013).
- Refurbishment of a substantial part of the Sherrington Building to provide a modern hub for laboratory-based facilities to exploit translational studies (University investment £7M)
- Development of a new integrated space in the Institute of Integrative Biology to house the expanding computational biology and bioinformatics groups.
- Refurbishment of existing laboratory space and provision of additional equipment resource (to supplement MRC funding) and establish the new Centre for Preclinical Imaging.

Collaborative use of infrastructure: Staff in UoA1 engage with partners across the N8 Universities in an asset sharing project in which all equipment and facilities over £100K is listed on a shared database with contact details for interested users. This also involves commitment to joint equipment initiatives and includes ResoN8 (**Lian,** Liverpool lead) that is planning future NMR resource requirements from 2014 across the N8 for which the University has ear-marked an initial £194K, Regener8 that co-ordinates stem cell research across the N8 and is boosted by the recent award of the Stem Cell Safety Hub and the Antimicrobial Hub (lead Raval returned to UoA8) that was originally N8, but now an externally funded collaboration with N8 Universities and NHS Trusts. The Centre for Genomics Research has been nominated as a trial N8 core facility and the Centre for Cell Imaging a designated Euro-Bioimaging node.

***Library and Research Computing Infrastructure*:** The University continues to invest in its libraries such that we subscribe to *all* of the national NESLi2 "big deal" site licences for journals, In 2009 the University undertook a five year investment (~ £5M) in its data network. The University works closely with Net North West which manages our wide area network connections and our high speed resilient links to JANET. These links operate at 10Gbps with an upgrade to 20Gbps due shortly. This will provide our researchers and partners with excellent bandwidth.

Research Governance: A Research Governance Working Group (RGWG) was formed in 2009 to integrate relevant research governance policies from around the University. The RGF Toolkit (implemented in July 2011) facilitates the research governance approval process for staff by streamlining processes via a simple step-by-step process, directing researchers to relevant departments and policies. RGWG also established the first University Research Governance Committee (RGC), chaired by an academic lead (Kinderman, UoA4).

Research Ethics: The University Committee on Research Ethics (CORE) comprise two new Sub-Committees and work closely with NHS. The Sub-Committee for Human Embryonic Stem Cells is Chaired by **Lian**; the International Online Research Ethics Committee (IOREC) considers Online *Laureate* research projects. IOREC is a virtual Sub-Committee of CORE and is Chaired by a member of staff from Walden University, USA. LSTM runs its own Ethics Committee specializing in research in low and middle income countries (one of only three in the UK) and has developed guidelines for overseas clinical studies. All relevant research is overseen by the Governance Oversight Committee, which reports directly to the Management Committee.

***Joint Research Office with NHS partners*:** Liverpool Health Partners (LHP) has launched a Joint Research Office (JRO) to streamline the research development process across Merseyside including seven NHS Trusts, LSTM and the University of Liverpool. This office provides advice, support and guidance to clinicians and academics to facilitate all aspects of clinical research with particular emphasis on supporting the establishment of clinical trials quickly and efficiently.

e. Collaboration and contribution to the discipline or research base

The Faculty has established a number of key strategic alliances to further its research and training strategies at both national and international levels. In postgraduate training, we have several joint doctoral training programmes (described in section C) and key national research collaborations

underpin the MRC-Arthritis Research UK Centre for Integrated Research into Musculoskeletal Ageing (CIMA; with Newcastle and Sheffield Universities) and the MRC Hub for Regenerative Medicine, which is held jointly with the University of Manchester and UCL.

Internationally there are numerous collaborations with key overseas partners including formal links with the national US Centers for Disease Control (CDC) in Atlanta, Georgia Tech, the University of Malawi College of Medicine, and Washington University, St Louis in Infectious Diseases; Universities of Michigan and Texas at San Antonio in NIH-funded studies of muscle ageing; CPMOH, University of Bordeaux in imaging with Human Science Frontier funding. Staff make major contributions to international research consortia, such as the International Pseudomonas Consortium (**Winstanley**), Pneumococcal African Genomics Consortium (**Everett**), EU Myonet (**Cooper**), and the European Childhood Life threatening Infectious disease consortium (**Carrol**). Liverpool leads the International Consortium in Drug Hypersensitivity involving 50 UK and 12 international centres (including US, China, Brazil and EU countries). In personalised medicine, collaborations include the US FDA (**Ning**), Institute of Pharmacology in Stuttgart (**Schwab**) and Adelaide University (**Somogyi**). The MRC Centre for Drug Safety Science (CDSS) is formally partnered with Manchester and links with Edinburgh and Leeds Universities to develop clinical networks. The CDSS also leads a major European programme (MIP-DILI) funded by the Innovative Medicines Initiative (IMI) that includes eight academic institutes, six SMEs and 11 pharmaceutical companies. CDSS is involved in two other IMI projects and is a partner in a new FP7 programme (COUNTERSTROKE). **Davies** is the academic lead of PreDiCT-TB, the largest public-private partnership in Europe devoted to improving the methodology of TB drug development through a €15.4m IMI project. LSTM is the largest recipient of Bill and Melinda Gates Foundation funding in Europe, leading four major programmes in vector control (IVCC), treatment for filariasis (A-WOL), malaria in pregnancy (MiP) and Visceral Leishmaniasis, as well as creating the first Centre for Neglected Tropical Diseases, with >£30M from DFID.

Major links with UK and international industrial partners have been established including the Materials Innovation Factory, a £35M development in collaboration with (i) *Unilever,* (ii) *Polyphotonics* in novel light therapies (Williams) and (iii) GSK (£2M) to evaluate a neonatally-administered malaria vaccine in Malawian infants (see REF3 for further examples).

Staff returned in this UoA also contribute extensively to setting the research agenda at national and international levels thorough their involvement in activities including funding bodies, advisory bodies, and editorial boards. This also provides increased opportunity for research intelligence allowing the Faculty and LSTM to be responsive to changing priorities. Whilst many of these roles are undertaken by senior staff, we actively seek opportunities to involve junior staff by supporting their involvement in professional activities of this kind.

Funding Body Membership (Research Committees): Agence Nationale de la Recherche, France (**Fernig**); Arthritis Research UK Fellowships committee (**Moots**); BBSRC: Committee A (**McArdle**), Committee C (**Hunt**), Committee D (**Turnbull, Eyres**), CR-UK Clinical Trials Committee (**Pettitt**); CR-UK Science strategy advisory Group (**Neoptolemos**); Cystic Fibrosis Trust (**Winstanley**); EPSRC (Chair, engineering prioritisation panel: **Williams**); EU FPVII committee member (**Hunt**); Fight for Sight (**Harding**); French National Cancer Institute (**Neoptolemos**); Lifelong Health and Wellbeing Board (**Jackson**); Medicine for Malaria Venture (**Ward**); MRC: Global Health Group (**Lalloo**); Infections and Immunity Board (**Lalloo, Ranson**); Population and Systems Medicine Board (**Jackson**), Stem Cell Panel (Chair: Greer, EPVC for Faculty of HLS; UoA2), Training and Careers Panel (**Solomon**); NC3R (**Wray**); Stratified Medicine Panel (**Pirmohamed**); NIH Intestinal Stem Cell review panel (**Pritchard**); NIH-NSF,USA (**Fernig)**; NIHR Health Innovation Challenge Fund (**Neoptolemos**); NIHR Research for Patient Benefit committee (**Wilding**); NIHR Efficacy and Mechanisms Evaluation Panel (**Pirmohamed**); Norwegian Research Council (**Wray**); Royal Society Travel Grants Committee (**Dockray**); Science Foundation Ireland (**Turnbull**); TSB: Stratified Medicine Innovation Platform (**Pirmohamed**), Wellcome Trust: ERG Pathogen Biology (**Hemingway**); WHO advisory panels (**Bates, Bokarie, Donnelly, Kroeger, Lalloo, Ranson. Stothard, ter Kuile**).

Membership of Prestigious Academic Research Based Bodies: Fellows, Academy of Medical Sciences (**Burgoyne; Dockray; Greer; Hemingway; Neoptolemos; Park; Pirmohamed; Wray**); Fellows, Royal Society (**Dockray; Hemingway**); National Academy of Science, USA (**Hemingway**); NIHR Senior Investigators (**Neoptolemos; Pirmohamed**); RAEng/Leverhulme Trust Senior Fellow (**Williams**).

Editorial Boards: Editors-in-Chief: Medical and Veterinary Entomology (**Ranson**); Physiological Reports (**Wray**); Rheumatology (**Moots**); **Editorial Board members:** Aging Cell (**Jackson**); American Journal of Physiology, Comparative (**McArdle**); American Journal of Physiology, GI and Liver (**Pritchard**); Autonomic Neuroscience (**Dockray**); Biochemical Journal (**Morgan**); BMC Infectious Diseases (**Carol**); British Journal of Pharmacology (**Owen**); Clinical Science (**Kemp**); Diabetic Medicine (**Wilding**); FEMS Microbiology Letters (**Winstanley**); Free Radical Biology & Medicine (**McArdle**); Genome Medicine (**Pirmohamed**), Glycobiology (**Turnbull**); Gut (**Pritchard**); Insect Molecular Biology (**Ranson**); International Journal of Obesity (**Wilding**); Journal of Medical Virology (**Cunliffe**); Journal of Infection (**Lalloo**); Longevity & Healthspan (**Jackson**); Malaria Journal (**Donnelly, Ranson**); Muscle, Ligaments & Tendons Journal (**Pisconti**); Nanomedicine (**Owen**); Pharmacogenetics and Genomics (**Pirmohamed**), Pharmacogenomics (**Pirmohamed**), OMICS (**Rigden**); Oncology Letters (**Yu**); Parasites & Vectors (**Taylor**); Parasitology (**Stothard**); Physiology (**Dockray**); PLoS NTD (**Lalloo, Lehane**); PLoS One (**Craig, Yu**); Regulatory Peptides (**Dockray**); Stem Cell Translational Medicine (**Ahmad**); Therapeutic Advances in Gastroenterology (**Pritchard**); Toxicon (**Harrison**).

Major Research Prizes: British Society of Gastroenterology Sir Francis Avery Jones Research Medal, (**Pritchard**, 2008); British Pharmacological Society Novartis Prize (**Naisbitt**); CA Wright Memorial Medal, British Society of Parasitology (**Taylor**, 2012); Chemical Research in Toxicology Young Investigator Award, American Chemical Society (**Naisbitt**, 2013); CR-UK Postdoc of the Year Award, 2012 (**Lake**); European Pancreas Club Lifetime Achievement Award (**Neoptolemos**); Eurotox HESI prize (**Park**, 2009); IPIT Award for Public Service, University of North Carolina (Pirmohamed, 2011); Malcolm Cambell Memorial Award, Royal Society of Chemistry (**Park**, 2011); Prix de l'Innovation (**Pleass**, 2013); Royal Society Wolfson Research Merit Award (**Ranson**, 2013); The Armourers and Brasiers' Materials Science Venture Prize (**Williams**); The Bayliss-Starling Prize lecture, Physiological Society (**Dockray**); Thompson Medal, Royal Society for Chemistry (**Ward**, 2011); William Withering Medal, Royal College of Physicians and British Pharmacological Society (**Pirmohamed**, 2010).

Competitive Fellowships to Young Investigators: Alzheimer's Research and British Heart Foundation (**Madine**); Fight For Sight Early Career Investigator Fellowship (**Kearns**); Fight for Sight Early Career Investigator Fellowship (**Lake**), Leverhulme Trust Early Career Fellowship (**Fothergill**). Marie Curie Intra-European Fellowship (**Pisconti**); NC3Rs David Sainsbury Fellowship (Patabendige); Research into Ageing Postdoctoral Fellowship (**Vasilaki**).

Individual Contributions to Major Advisory Bodies: Bill and Melinda Gates Foundation Malaria Strategy Group (**Hemingway**); Commission on Human Medicines (**Park, Pirmohamed**); Dept of Health, Advisory Group on Hepatitis (**Geretti**); Department of Work and Pensions Scrutiny Group on long term fluctuating conditions (**Moots**); Dutch AIDS Foundation (**van der Wijgert**); Google Foundation Emerging Infectious Diseases Strategy Group (**Hemingway**); MHRA Pharmacovigilance Expert Advisory Group (Chair: **Pirmohamed**); MRC Expert Group on ME/Chronic fatigue syndrome (**Jackson**); National Cancer Research Institute, Haematological Clinical Studies Group (Chair, **Pettitt**); Pan African Tsetse and Trypanosomiasis Eradication Campaign Steering Committee (**Lehane**); UK CLL Forum (Chair, **Pettitt**); UK DoH Antivenom Advisory Panel (Harrison; **Lalloo**); UK National Blood Service Advisory Committee on Transfusion Transmitted Infections (**Bates**); Scottish National Blood Transfusion Service (**Ahmad**).