Institution: Royal Holloway, University of London

Unit of Assessment: A5 Biological Sciences

a. Context

Research in the unit is organised in 3 research centres:

a. Biomedical Sciences (CBMS). Research themes: Neuroscience, Gene Therapy, Microbiology, Infection & Immunity. Main impact is on health, welfare and commerce.

b. Ecology, Evolution and Behaviour (CEEB). Research themes: Community, Evolutionary and Behavioural Ecology, Pollinator Biology, Conservation and Modelling. Main impact is on public policy and the environment.

c. Plant Molecular Biology (CPMB). Research themes: Genetic Engineering, Crop Improvement, Seed Biology, Plant Growth & Development and Stress Tolerance. Main impact is on commerce, production and international development.

Beneficiaries, audiences and users of the research:

Impact on health and welfare beneficiaries are individuals whose quality of life is enhanced through the development of therapies and treatment. Examples of impact include the development of gene therapies for muscular dystrophies, which are currently undergoing clinical trials (Dickson, see case study 1), work on the development of treatments of epilepsy using amoeba for screening (Williams) and the development of needle-free oral vaccines (Cutting).

Impact on commerce beneficiaries are industry and companies. For examples, research on GM technology (Bramley-Fraser, see case study 2) resulted from interaction with, and investment by Zeneca (now Syngenta). Cutting's research on vaccine development has led to the creation of a spin-off company (Holloway Immunology) and external investment. Research income from industry over the REF period exceeds £1.3M. Licensing royalties and money paid for IPR rights is approx. £350k. Our staff have worked with, and provided scientific support for: GSK, Boehringer, Probiotics International Ltd (Cutting, vaccines, probiotics), Buhler AG and KWS Saat AG (Leubner, seed treatment), Benitec Ltd (Dickson, gene therapy) and Vitaflo (Williams, epilepsy).

Impact on international development beneficiaries are overseas agencies and communities. Examples are the development of Golden Rice (see case study 2), which ultimately allowed the International Rice Research Institute to carry out field trials and prepare to release the crop to farmers, and the licensing of production of *Bacillus subtilis* strains HU58 and HU36 as probiotics to companies Viridis biopharma (India) and Anabio (Vietnam).

Impact on the environment beneficiaries are the natural environment and organisations working for the benefit of the environment. For example, research done for the People's Trust for Endangered Species (PTES), in monitoring programmes of the stag beetle and the hazel dormouse, has led to biodiversity action plans and changes in the management of the habitat of these species (e.g. case study 3). Research on insect parasites by Brown enabled the quarantine procedure needed for the reintroduction to the UK of an extinct species of bumblebee, *Bombus subterraneus*. Morritt has developed a monitoring scheme, with the Environment Agency and Marine Management Organisation, for both the invasive Chinese mitten crab and the declining eel populations in the UK.

Impact on public policy: beneficiaries include government, EU, charities and the public sector. For example, Raine informed the parliamentary environmental audit committee on the effect of pesticides on bees. Bogre's research has informed European funding policies through his membership of the executive committee of the EU Cooperation in Science and Technology committee. William's research on the development of novel model systems, which reduce or avoid the need for animal testing, has informed UK and European Parliament and UK Home Office.

Impact on production: beneficiaries include consumers, agricultural producers, agricultural industries and agribusiness. Examples: through contributions to the development of novel varieties of high antioxidant crops and foods (see case study 2) and for plant biofuels (Fraser). Research, supported by local companies Humber and Symbio, has led to the development of a methodology

to assess antioxidant levels in food.

Impact on society. Beneficiaries include individuals and organisations, for example, analysis of measles outbreaks by Jansen, influenced the debate on MMR vaccination. Research on species' phenology which found changes in the timing of ecological events, was widely covered in the media and informed the debate on climate change. The impact of Gange's stag beetle research on public understanding is detailed in case study 3.

Impact on practitioners and services: Benefits school teachers and their pupils. The topic of Golden Rice is included in GCSE and A level specifications so that tens of thousands of pupils learn about the development of genetically-modified foods. The stag beetle research resulted in teaching materials for KS2 and KS3 (see case studies 2 and 3).

b. Approach to impact

The generation of impact is an integral part of our research agenda. When appointing new staff, the potential for impact is an important consideration. Workshops aimed at improving staff's abilities to engage with impact are provided by the Staff Development Office. Impact is considered in staff workload models, it is a criterion for promotion, and in professorial pay banding. Awareness of impact, and realising the potential impact of research, is an element of our postgraduate training programme.

In order for impact to be maximised, we encourage it to be considered in the planning stage of projects. Where possible, contacts with stakeholders and beneficiaries are made at an early stage of the project, typically prior to the funding stage, where contacts may be either realised or planned. A common route is to seek funding which includes beneficiaries and stakeholders as partners in the research programme. For example, the grants funded by the Insect Pollinators Initiative had the companies Beeologics and Hymettus and the Ulster Beekeeping Association as partners.

Impact generation is facilitated through Royal Holloway's Research Strategy Fund, which offers seed funding to develop proof of principle; The Gateway Fund, which supports the exploration of new ideas to meet a social or market need and The Park Fund, which enables the identification of routes to market from intellectual property derived from recent research, and which funded a patent application for the use of dietary fatty acids to prevent seizure related disorders. Over the period of assessment we have actively increased the number of large grants which include stakeholders in industry, government and charitable organisations, and increased our involvement in EU-funded consortia, all of which have industrial partners. Some of these have delivered impact (like COLORSPORE, which researched natural food additives, and in which new food supplements were discovered, see case study 2). We anticipate others will follow in the near future, e.g., METAPRO (coordinated by Fraser) and CD-VAX (coordinated by Cutting). The institution employs a Major Grant Set-Up Manager who works with PIs to coordinate with Finance, HR, IP and Contracts, Communications and Estates in order to facilitate consortia.

An important vehicle to generate research leading to impact is through joint PhD studentships with stakeholders either as CASE studentships, or institutionally funded studentships. Over the period of assessment 10 CASE studentships were awarded with various partners (e.g. the James Hutton Institute, Boehringer, Syngenta, and the Forestry Commission). The institution provides matched funded studentships which provide up to 50% of the full costs of the studentship. The joint studentship schemes with the Animal Health and Veterinary Laboratories Agency (AHVLA) allowed the transfer of expertise and sharing of facilities. Links with stakeholders were further developed through the placement of students, in institutions such as RHS Wisley, RBG Kew, CABI and AHVLA.

In case the impact was not foreseen, we identify and realise the impact as soon it arises. An important step is to identify whether there are intellectual property rights associated with the research, after which partners can be sought to realise impact. The institution's Research and Enterprise Department provides legal and financial advice during the preparation of agreements and partnerships with external agencies, commercialisation, setting up of spin-out companies, patents, licenses and IPR. For example, the theoretical research of Bryden on structure in populations has led to a patent for uncovering structure in social media. Licensing of the patent and the development of a spin out company with Parity Ltd are at an advanced state. Currently, 16 patents are active and 4 have proceeded to grant. A further 2 patents have been filed, not yet granted and are assigned to AHVLA and MRC Technology. A spin out company, Holloway

Immunology, has been established with £200K external investment.

A further avenue to realise impact is through dissemination of our science to the general public. This involves public outreach as well as informing policy makers, etc. Communication and public engagement activities allow us to generate impact through informing a wide audience through the media (e.g. "The Silence of the Bees", an opera composed by Kelvin Thomson, is based on research by Brown). Research of potential wider interest is communicated to the Media Office, and is used for general dissemination. We release approximately 30 press releases per year, which are frequently taken up by the national and international media.

c. Strategy and plans

Our approach to impact, outlined above, is based on our strategy to optimise the potential for funding, in conjunction with the appropriate stakeholder community. Results of the research are communicated to the stakeholders, and further developed, commercialised or scaled up. A core part of our strategy is to develop a portfolio of research that will deliver sustained, significant and far reaching impact, in particular in areas coinciding with the institutional research themes of health, behaviour, security and sustainability. At present, the best examples are the development of therapeutics and vaccines and the application of molecular biology and ecology to food security.

For the next 5 years our goals are (1): to increase the awareness that all research can lead to impact. To achieve this we will provide training to staff and students. The unit has appointed an Impact Officer whose task it is to identify and maximise the potential for impact of our research. (2): to ensure the impact is realised. This will be achieved through identifying and facilitating impact and through assessing realised impact in appraisals, promotion and banding. (3): to monitor and publish the impact that is generated. A research information system (PURE) records research projects and links these to impact, outputs and activities, and publishes these on our website.

Impact training is provided through the "On Track "programme for staff and is also taught in our postgraduate programme. We encourage and stimulate engagement with impact amongst postgraduates, for instance, through partaking in a yearly competition to develop their business ideas. Royal Holloway is part of a BBSRC Doctoral Training Programme (DTP), with ICL, and a NERC DTP with a consortium of London institutions led by UCL. The DTPs provide impact training, and they include placement opportunities for students to gain experience in working with stakeholders in non-research related activities, which increases impact awareness.

Recently, Royal Holloway has launched five major research themes, which will facilitate the generation of impact. Particularly important for this unit are the themes of Health, the Human Body and Behaviour (championed by Dickson), and Security and Sustainability. Our strategy is to further develop and concentrate strengths in these areas. This will include an increased emphasis on crops in our plant research, extending the range of crops to include barley, cassava, banana, sweet potato and yam, via transnational funding. This also includes a concentration of research on pollinators and pollination biology, in which we have particular strength. Within our biomedical sciences research, we plan a further concentration on translational and regenerative medicine, with the aim of building a centre for research in translational gene therapy as a component in a broader ranging innovation centre under development by the university with support from the local enterprise partnership and enterprise hub.

d. Relationship to case studies

The case studies detail impact generated through:

1. the development of genetic therapies for Duchenne muscular dystrophy;
2. the development of foods with enhanced carotenoid content;
3. the conservation of the stag beetle *Lucanus cervus*.

These studies all resulted from funded research that gave stakeholders and researchers a common goal, either through inclusion of stakeholders in the funding networks, or direct charitable funding. For case studies 1 and 2 the research was supported by research officers and equipment funded by this institution. For case study 3 impact was facilitated by institutional provision of a PhD studentship to Gange. Sustaining and managing this support enables the research groups to develop the impact potential of their research. The case studies represent types of impact through research of a very different nature, and demonstrate the success of our strategy.