Title of case study: Devising and implementing frameworks for Responsible Research and Innovation in emerging biotechnologies.

1.Summary of the impact (indicative maximum 100 words)

In the face of perceived public concerns about technological innovations, leading national and international bodies increasingly recognize the need for dialogue between policy makers, scientific researchers and social actors in order to develop the technologies to address the grand challenges facing our societies in a way that meets social needs and gains public trust. The Directorate-General for Research and Innovation of the EU, the UK Government and many funding bodies are addressing this issue by insisting on Responsible Research and Innovation (RRI) in the development of emerging technologies, yet the mechanisms for implementing RRI remain largely unspecified. Researchers in SSHM (Rose, Singh, Marris and colleagues) have established a Foresight and Responsible Research and Innovation Laboratory (FRRIL) that has devised and implemented the first detailed frameworks for applying the principles of RRI in the regulation of synthetic biology, novel neurotechnologies and cognitive enhancement; providing important, replicable models for translating the principles of RRI into policy and practice in emerging biotechnologies.

2.Underpinning research (indicative maximum 500 words)

Novel biomedical technologies (including synthetic biology; psychopharmaceuticals, brain stimulation technologies, neural stem cells and cognitive enhancers) are now moving from experimental development into clinical applications. UNESCO and FP7 now require Responsible Research and Innovation to be demonstrated in applications for technology research and development and are calling for comprehensive RRI frameworks to be developed for use in future initiatives such as Horizon 2020. Major European and UK funding bodies (FP7, EPSRC, BBSRC,TSB) are also insisting that researchers embody RRI in the design of their translation pathways to ensure that they are ethically acceptable, sustainable and focused on delivering societal benefits. Research by the FRRIL group has demonstrated weaknesses in previous models to ensure social responsibility, and proposed novel ways in which these RRI principles can be translated into governance of emerging technologies and into scientific practice itself. Rose has researched the democratic accountability of emerging technologies (Rose, 2012), and Rose and Marris published and edited a series of articles on public engagement and responsible research in the life sciences for PLoS Biology (Marris and Rose, 2012), further developed in a key report by Marris and Jefferson on RRI for the regulation of deliberate release of synthetic organisms (Marris and Jefferson, 2013). Rose and Marris were invited to participate in the first major EPSRC funded research programme on synthetic biology, enabling further research into the practical development of the RRI approach in a very early stage biotechnology which makes major claims about public and social benefit (Rose, 2012; Marris and Rose, 2012).

Rose's most recent research on the social implications of developments in the brain sciences (previously published in a number of highly cited articles on neuroscience) culminated in Neuro: The New Brain Sciences and the Management of the Mind (2013) which provides underpinnings for a new mode of critical friendship between social scientists and life scientists to facilitate the responsible translation process between laboratory research, clinical practice and policy in the real world. Singh took a different but complementary trajectory based on empirical research on ethical dilemmas on the use of 'cognitive enhancement drugs' which generated a pathbreaking model for linking technology development with everyday ethical experience based on empirical research into practical ethics in clinical settings. She has developed this sociological alternative to 'speculative ethics' in a number of research papers (Ragan, Bard & Singh, 2011; Singh et. al forthcoming).This underpinning research by members of FRRIL demonstrated a clear need to develop workable

frameworks for translating the principles of RRI (particularly collaborative evidence based policy making) into practice to meet domestic and international commitments to deliver social and ethical responsibility in biomedical research and innovation.

3. References to the research (indicative maximum of six references)

Where a DOI or URL is not given, a hard copy is available on request.

Rose, N, (2012) Democracy in the contemporary life sciences, *BioSocieties* 7 (4), 459-472. Doi: 10.1057/biosoc.2012.26

Marris, C. and Rose, N. (2012) Open engagement: exploring public participation in the biosciences, *PLoS biology* 8 (11), e1000549, doi:10.1371/journal.pbio.1000549

Rose, N. and Abi-Rached, J. (2013) *Neuro: The new brain sciences and the management of the mind*, Princeton: Princeton University Press.

Marris, C. and Jefferson, C. (2013) *Synthetic biology: containment and release of engineered micro-organisms*, SSHM Occasional Research Paper, London: SSHM

Singh, I. and Bard, I. (2012) Neuroscience: Help to survey the use of smart drugs. *Nature* 486, 473 (28 June 2012). Doi: 10.1038/486473b

Singh, I, Bard, I, Baker, L & Filipe, AM. (forthcoming). Neuroethics in the Clinic: ADHD Diagnosis and Treatment in a Global Context. *Current Psychiatry Reports*.

4. Details of the impact (indicative maximum 750 words)

Members of FRRIL have been responsible for developing the first detailed workable frameworks for translating the broad principles of RRI into practice by developing models for three key emerging biotechnologies: novel neurotechnologies, synthetic biology and cognitive enhancement, each of which are being taken up nationally and internationally in major programmes or technology development and governance.

Novel Neurotechnologies: Engagement with Rose's earlier research on the social implications of developments in the life sciences, biomedicine and neuroscience led to his appointment as a member of the Nuffield Council on Bioethics and his involvement as an internal reviewer of their Report on Emerging Biotechnologies in 2012. This, in turn, prompted the Council to initiate a report on the social and ethical implications of Novel Neurotechnologies. Rose was asked to steward production of this report which was published in June 2013. Rose researched and wrote the chapter on Economic Drivers of Innovation, and Rose and Singh (as invited expert) together developed an innovative applied framework for RRI in neurotechnology to guide those funding and undertaking such research. Singh also devised a detailed ethical framework for evaluating the impacts of novel neurotechnologies. The framework stresses the virtues of inventiveness, humility and responsibility, and proposes six elements as regulatory priorities for the RRI of novel neurotechnologies: Securing safety and efficacy; Generating robust evidence; Continuous reflexive evaluation; Coordinated interdisciplinary action; Effective and proportionate oversight; demonstrating how RRI can be operationalized in practice in this important emerging field of scientific development. Impact is at an early stage; however exemplars from earlier reports of the NCOB suggest that the framework will act as a key benchmark for future regulation of novel neurotechnologies, both in the UK and in Europe. In related work, Rose has been charged with responsibility for refining and applying the RRI models developed in FRRIL to governance of the Human Brain Project. Funded by the EU up to a level of 1 Billion Euros for ten years from October 2013 the HBP is addressing one of the greatest challenges of modern science: how to find rigorous ways to address the complexity of human brain function and neurological disease and mental disorder. As a key member of the Steering Committee of the Social and Ethical division of the HBP and leader of its Foresight Lab, Rose draws on FRRIL's research and models to develop, implement and evaluate mechanisms for fulfilling obligations to RRI in practice, providing one of

the first demonstrations of how this goal can be achieved in projects of this size.
Synthetic Biology: Rose and Marris' research in developing and implementing RRI in synthetic biology, carried out in the context of the EPSRC funded 'Flowers consortium' (King's, Imperial, Newcastle, Cambridge and Durham) led to their appointment to the Working Group developing the 'UK Roadmap for Synthetic Biology' (http://www.rcuk.ac.uk/documents/publications/SyntheticBiologyRoadmap.pdf). The RRI approach which they proposed was one of the "Key Themes" of the Roadmap: "It is crucial that this technology continues to be developed in a socially responsible fashion, and that relevant stakeholders, regulators and the public are engaged in research and innovation processes from the outset. Responsible research and innovation encompasses, but is not confined to, operating within an effective risk regulatory framework. The UK needs to be, and to be seen to be, leading the way in frameworks and methodologies for responsible innovation." The Roadmap led to the decision of the Department for Business, Innovation and Skills (BIS) to nominate synthetic biology as a key emerging technology for investment in the 2012 Autumn Statement. This led to further funding from TSB, and a major funding initiative by the EPSRC and BBSRC for multidisciplinary research centres in synthetic biology to "implement the Roadmap's recommendations and deliver on the investment from government …as part of a larger 'Synthetic Biology for Growth Programme'…accelerating the route to market for innovative synthetic biology research". It is intended that all UK funding in this area will, in future, be contingent upon recipients' demonstration of commitment to RRI. FRRIL is centrally embedded in UK's major consortia of universities funded to develop synthetic biology technologies in domains from health and medicine to green biofuels, who have undertaken to develop their next phases of R & D in accordance with these principles of RRI. The EPSRC explicitly cite the RRI chapter of the synthetic Biology Roadmap as a source for their "Responsible Innovation Framework", published in October 2013.
http://www.epsrc.ac.uk/research/framework/Pages/acknowledgementsandresources.aspx
Cognitive Enhancement: Singh's research on cognitive enhancement led to her invitation, in 2012, to join Professor David Nutt's Independent Scientific Committee on Drugs (ISCD) which is committed to generating evidence-based policy-making on drug use. Working with the ISCD, Singh developed the first national UK survey to evaluate the use of cognitive enhancers amongst university students. This research revealed that, contrary to speculation, use of cognitive enhancers amongst this group was actually low, strengthening the argument that responsible regulation must be evidence based. Preliminary results from the survey were discussed by Professor Nutt and Dr Nora Volkow (Director of the US National Institute of Drug Addiction - NIDA) in a podcast chaired by Dr Steven Hyman, former Director of the National Institutes of Mental Health (NIMH); the interview was subsequently published in Neuropsychopharmacology. Singh was also invited to present her findings at a rare UK Joint Academies meeting on responsible research and innovation in neuroenhancement (to which Rose also contributed). Emerging out of Singh's earlier work with ISCD, which demonstrated the need to employ empirical evidence as the basis of responsible policy-making on cognitive enhancement, she has recently secured €3.8 million of FP7 funding (from March 2013) to develop NERRI ('Neuroenhancement, Responsible Research and Innovation'), which mobilises stakeholder engagement around Europe to ensure that current and novel neurotechnologies are developed in the context of RRI values and objectives. The Italian Bioethics Commission (CNB) has recently developed recommendations on cognitive enhancement based on the framework developed by Ragan, Bard and Singh, as evidenced through CNB's extensive citation of that work. Whilst the opinions of the CNB are not legally binding they report directly to the Italian government and, according to specialists: "for all intents and purposes their opinion documents frame the issue". Singh is also mobilizing FRRIL objectives in talks on cognitive enhancement to international audiences of lay and professional adult stakeholders and to school

children; for example as part of the European Science Open Forum (ESOF) in 2014. Her earlier methodology for evidencing use of cognitive enhancers is now also informing the development of national surveys on cognitive enhancement in Australia (Hall, University of Queensland) in Montreal (Collins, University of Montreal) and by the Wellcome Trust's UK Monitor. These frameworks together provide much needed models through which to address the major funding bodies' new requirements to make RRI an integral part of technology development and governance and important exemplars of best practice models.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Synthetic biology:

Synthetic Biology Roadmap [confirms KCL contribution to the roadmap]: http://www.rcuk.ac.uk/documents/publications/SyntheticBiologyRoadmap.pdf Synthetic Biology

Flowers Consortium [details KCL contribution to Flowers Consortium]: http://www.kcl.ac.uk/sspp/departments/sshm/research/Research-Groups/bppp/Projects/An-infrastructure-for-platform-technology-in-synthetic-biology.aspx

Nuffield Council on Bioethics, Novel Neurotechnologies: Intervening in the Brain. London: Nuffield Council on Bioethics, 2013

Human Brain Project [sets out project and KCL role]: https://www.humanbrainproject.eu/en_GB/discover/the-project/strategic-objectives

The State of the Art Report [confirms scope of project]: https://www.humanbrainproject.eu/en_GB/discover/the-project/strategic-objectives https://www.humanbrainproject.eu/en_GB/ethics-and-society

Blog by the Director General, Research & Innovation, EC [confirms KCL contribution to the Human Brain project]: http://renevonschomberg.wordpress.com/2013/01/30/1-billion-euro-donated-human-brain-project-includes-a-responsible-innovation-approach/

Cognitive enhancement:

http://www.palazzochigi.it/bioetica/eng/opinions/Neuroscience_and_pharmacological_cognitive_enhancement_20130613.pdf

British Neuroscience Association Podcast (July 2012) on cognitive enhancement with Steven Hyman, David Nutt and Nora Volkow [refers to Singh's work]: http://www.bna.org.uk/news/view.php?permalink=YALHXTKTEC

Neuroenhancement, Responsible Research and Innovation (NERRI): http://www.nerri.eu/eng/home.aspx [confirms KCL's contribution to the NERRI project]

Factual Statements:

Letter from Director General, Research & Innovation, European Commission, confirms RRI and Foresight's part in the EC's view of the Human Brain Project, which received largest EU funding ever for a research project.

Letter from Global Strategic Programme Manager, Shell, confirms KCL team's input into the global impact of the Synthetic Biology Roadmap.

Letter from Head of Development, Technology Strategy Board, confirms Rose's contribution to the UK SB Roadmap Coordination Group, in particular on how to think about the potential societal and ethical impacts of the technology; confirms contribution to the Joint Academies' 2012 workshop on human enhancement; and confirms TSB consulted Rose when developing its own Framework.