

WRITTEN EVIDENCE FROM RESEARCH COUNCILS UK (RCUK) IN RESPONSE TO THE HOUSE OF LORDS SCIENCE AND TECHNOLOGY COMMITTEE INQUIRY INTO GENOMIC MEDICINE

1. The MRC works closely with the National Institute for Health Research (NIHR) and the UK Health Departments to give a high priority to the translation of underpinning research in genomics and genetics into improved healthcare, products and services. MRC thus is a key player in the area of genomic medicine.
2. The ESRC plays a major role in funding research addressing the implications of ethical, political, legal and social dimensions for the application of genomics in healthcare settings.
3. The BBSRC's role is to support basic, strategic and applied research, training and knowledge transfer in the non-medical biological sciences. One of BBSRC's roles is to underpin developments in human healthcare and as a consequence of this underpinning role, BBSRC is not a major stakeholder in the implementation of genomic medicine.
4. Research Councils UK is a strategic partnership set up to champion the research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more effectively to enhance the overall impact and effectiveness of their research, training and innovation activities, contributing to the delivery of the Government's objectives for science and innovation. Further details are available at www.rcuk.ac.uk
5. This evidence is submitted by RCUK on behalf of the three Research Councils listed below and represents their independent views. It does not include or necessarily reflect the views of the Science and Research Group in the Department for Innovation, Universities and Skills. It is structured around answers to the specific questions posed in the call for evidence. In addition, the AHRC will submit a separate response to this Inquiry.

Biotechnology and Biological Sciences Research Council (BBSRC)
 Economic and Social Research Council (ESRC)
 Medical Research Council (MRC)

6. The RCUK Office in Washington DC has provided detailed information about the situation in the United States in [Annex 1](#).

Key Points:

7. The Research Councils have invested heavily in genetics and genomics research and infrastructure over many years, including cross -Council programmes with ring-fenced funding. £110 M was allocated to Research Councils in SR2000 for genomics and £136 M was allocated in SR2002 for post-genomic, proteomic and systems biology research.
8. The framework for the support of innovation in genomic medicine in the UK is effective compared with many other European countries, although the situation in the US is much more favourable (see Annex 1). However, given the speed of scientific development, regulatory gaps sometimes do appear and may inhibit translation from basic research to

patient benefit. There is a need for a review of the role of policy and regulation in promoting innovation and optimising translation.

9. Genomic science is in a healthy state and is developing very fast. This is an area in which international collaboration is extensive and effective. UK work is internationally competitive, thanks to a high level of investment by the Research Councils and other funders over many years. This high level of investment will need to be maintained to ensure that the developing understanding feeds through into benefits for clinical care and public health.
10. There are significant and increasing opportunities for translation of genomic information into improved therapies, via the identification of new molecular targets for treatment and the ability to target treatments more precisely at those most likely to benefit. Improved understanding of disease mechanisms will also lead to new diagnostic or prognostic indicators with clinical application.
11. Storage and interpretation of very large and increasing volumes of data are major issues in genomics. There are already many large databases for common use, and the European Bioinformatics Institute in Cambridge plays a key role in curating and annotating these, and in developing the bioinformatics methodology to enable optimal exploitation of the data. Promoting interoperability of related databases via common standards will be important, but the Research Councils do not think a single common public database of genomic information is realistic.
12. The research capacity programme of the NHS Connecting for Health initiative will be very important in ensuring that medical information can be used optimally to interpret genomic information.
13. The use of genomics and gene expression platforms at the level of the entire genome offers unique opportunities for biomarker research and its translation to patient benefit in terms of tailoring treatments for optimal efficacy and safety according to an individual's genetic make-up.

Biobanks such as the UK Biobank and Generation Scotland will build on current advances in genomics to develop the knowledge of genetic and environmental influences involved in health and disease to underpin discovery of new ways to prevent and treat different conditions.

15. Genetic information has already had a significant impact on the diagnostic classification of single gene diseases, and increasingly will allow tailoring of treatments. As the use of genomic information becomes more widespread in the prevention and treatment of more common complex diseases, patients will have to be informed much more clearly of the meaning and consequences of any genotyping, and a much wider spread of practitioners will need to be trained to offer advice based on genomic information.

Definition

16. For the purposes of this response, we have taken genomic medicine to mean the application of scientific understanding emerging from research carried out at the level of the genome to medicine and public health, including increased understanding of disease aetiology as well as applications in diagnosis, treatment and prevention of disease.

Policy Framework

Who is in charge of setting and reviewing policy in this area?

17. A large variety of bodies, of differing status, are involved in setting and reviewing policy relevant to different aspects of genomic medicine. These include the Health Departments, statutory bodies such as the Human Fertilisation and Embryology Authority, Government advisory bodies such as the Human Genetics Commission and the UK National Screening Committee, Special Health Authorities and Agencies such as the National Institute for Clinical Excellence (NICE) and the Medicines and Healthcare products Regulatory Agency (MHRA), and non-government bodies such as the Nuffield Council on Bioethics, the Research Councils, the Wellcome Trust and other funding bodies. Learned societies (including the Academy of Medical Sciences) and, internationally, the Human Genome Organisation (HUGO), also play a major role. As the area of policy-making is very wide, this variety of input is probably a strength. Review and input is usually on an issue-specific level¹, and this is perhaps the most sensible approach, given that the issues in different fields and different disease settings are liable to be very different.

Who provides scientific advice on policy development? Who monitors and anticipates potential scientific developments and their relevance to future policy? How effective are these mechanisms?

18. The Department of Health's Policy Research Programme funds research to inform policy development. Learned societies, Research Councils and the large funding bodies like the Wellcome Trust provide scientific advice and play a major role in monitoring and anticipating potential scientific developments and their relevance to future policy. The mechanisms for monitoring are usually *ad hoc* and are related to the peer review system and the expert panels managed by grant-awarding bodies, although major Foresight exercises have also played a role. The mechanisms work reasonably well, and are sufficiently flexible to respond quickly to new scientific advances. Where issues are of sufficient importance to merit changes in law (e.g. the current discussion of stem cell issues or the use of human tissues), the same bodies are also active in providing scientific advice and input to government consultations.

Does the existing regulatory and advisory framework provide for optimal development and translation of new technologies? Are there any regulatory gaps?

19. Genomics-related technologies have been predicted since the 1980s to be a basis for revolutionising clinical practice but so far, despite long-term investment of public and commercial funding, they have failed to live up to expectations. Policy support and, increasingly, public financial support have been provided for the more effective translation of fundamental scientific findings to therapeutic applications, and yet the timescales for emergence of effective novel treatments seem to be ever-lengthening.
20. In most industry sectors, the expectation is that small and medium-sized enterprises (SMEs) will be more innovative than large multinational companies, challenging existing innovation models and succeeding with new approaches. However, in the case of life science and genomics-related areas, the large multinational companies have an unassailable dominance of the translational processes for genomics-related technologies

¹ For example, the Nuffield Council on Bioethics report on Pharmacogenomics (2003)

and the role of regulatory systems in reinforcing this dominance is increasingly being recognised.

21. The life science industry sector, which includes genomics-related medical developments, has evolved over the past thirty years in a symbiotic relationship with regulators and regulatory systems: regulation to some extent constrains the companies it applies to, but as it becomes more onerous, it increasingly acts as a barrier to entry for new companies until only the incumbents, of ever-increasing size, are able to operate profitably. This situation mitigates against optimal development and translation of new technologies.
22. Given the pace of fundamental scientific developments relevant to genomic medicine, regulatory gaps appear frequently. Recent examples include pharmacogenetics and stem cell-based therapies. The technology in both these cases clearly requires regulation to ensure its safety, quality and efficacy – indeed regulation is required before private investors can be assured of a viable market for the medical developments in which they may choose to invest. The response of regulators is usually to seek precedents among existing instruments rather than to design a regulatory system *de novo*. However, the choice of instrument then locks the relevant technology into an innovation pathway that may not be optimal for its future contributions to medicine. In light of such limitations, there is a need for fundamental review of the role of policy and regulation in guiding and constraining innovation in genomics-related medicines. Regulatory systems to control the safety, quality and efficacy of products operate mainly at European level, with the European Medicines Agency (EMA) and the US FDA increasingly being the main locus of regulatory development and reform. Any fundamental review of regulation as applied to genomic medicine will therefore need to be undertaken at an international level.²

In what way is science and clinical policy decision-making informed by social, ethical and legal considerations?

23. Reviews of social, ethical and legal issues by bodies with a national remit such as the Human Genetics Commission and the Nuffield Council on Bioethics (funded in part by the MRC) have a significant influence on science and clinical policy decision-making. Research Councils contribute to such reviews, and have been actively promoting research into social, ethical and legal aspects of genomics for some time, the output of which informs national debate and policy setting. The MRC and ESRC both develop and promote ethical and legal guidance for researchers and MRC has an internal ethics, regulation and public involvement advisory committee. BBSRC Bioscience for Society Strategy Panel provided social and ethical guidance for researchers. The Research

² Contributions provided by the **ESRC Innogen Centre** (<http://www.genomicsnetwork.ac.uk/innogen/>) based on findings that have been published in Tait, J. (2007), "Systemic Interactions in Life Science Innovation", *Technology Analysis and Strategic Management*, 19/3:257-277; Tait, J. and Chataway, C. (2007) The Governance of Corporations, technological change and risk: Examining industrial perspectives on the development of genetically modified crops. *Environment and Planning – C: Government and Policy*, 25, 21-37; Tait, J., Chataway, J. and Wield, D. (2006) Governance, Policy and Industry Strategies: Agro-biotechnology and Pharmaceuticals. In eds. M. Mazzucato and G. Dosi, *Knowledge Accumulation and Industry Evolution*. Cambridge University Press, pp 378-401; Chataway, J., Tait, J. and Wield, D. (2006) The governance of agro- and pharmaceutical biotechnology innovation: public policy and industrial strategy. *Technology Analysis and Strategic Management*, 18(2), 1-17.

Councils also ensure that large scientific studies which raise particular issues have their own source of ethical advice; for example the UK Biobank has its own Ethics and Governance Council. NHS ethics committees have an important role in monitoring ethical acceptability of individual studies involving NHS patients or data relating to them.

How does the framework compare internationally?

24. The policy framework for the support of innovation in genomic medicine in the UK is effective compared with many other European countries, although Denmark and Sweden are claimed to be more effective than the UK. However, the situation in the US is very much more favourable than in Europe, including the UK, with an order of magnitude more investment, both public and private, in translation of new technologies. More detail on the US position is in the submission from the RCUK USA office at [Annex 1](#).

Research and Scientific Development

What is the state of the science? What new developments are there? What is the rate of change?

25. The state of science appears healthy, based on large-scale investment over many years by Research Councils and other major funders, particularly the Wellcome Trust, and the outputs of major international collaborative initiatives such as the Human Genome Project, the HapMap project and the SNP (Single Nucleotide Polymorphism) consortium. Following on from the completion of the Human Genome Sequence and the subsequent SNP discovery initiatives there is a large-scale research effort to identify genetic factors involved in common complex diseases. The success has been variable to date but large collaborative initiatives and funding (such as the Wellcome Trust Case Control Consortium and MRC funding for collections of DNA samples from large patient cohorts) have led to a rapid increase in the identification of potential genetic markers of complex disease risk from genome-wide association studies. From these, many more genuine genetic influences on disease risk or outcome are likely to be identified in the near- to medium-term. The need for European collaboration on disease specific cohorts has become increasingly important as there are insufficient patients in the UK and the speed of DNA collections will need to be accelerated. High throughput genotyping and sequencing are the main technology platforms required to identify and screen for variations in the genome which may give rise to disease or influence treatment outcome. Both platforms are now readily available, although costs are still rather high. Significant developments in high throughput sequencing technology are rapidly reducing the cost of large-scale sequencing and genotyping, and it is likely that widespread genotyping or sequencing of individual genomes will become feasible at reasonable cost in the medium term. This raises the issue of how best to make high throughput sequencing accessible to the scientific community and whether this should be centralised as opposed to being distributed. In the field of cancer research, genetic and genomic research has made significant progress and it is generally accepted that we are on the cusp of a new era of medicine that will be driven by genomic medicine (e.g. the tailoring of therapy to particular genetic lesions in tumours).
26. Large-scale efforts to understand the function of all mammalian genes and their relevance to human disease are underway, using a range of model systems, and the rate of research developments is very fast. Significant advances are also being made in understanding the

role of epigenetic modification and other regulatory mechanisms in controlling gene expression and function, and genetic discoveries will increasingly lead into a systems biology approach to understanding human biological function and disease aetiology. The importance of genes in microbes is also now becoming recognised: about 90% of the cells in the human body are in fact resident microbes, which are essential for human functioning.. The human microbiome project is now beginning the project of cataloguing these genes.

27. Many of the high-throughput experimental techniques in genomics became available for the first time in the mid-1990s, but they were expensive to acquire and operate and in the UK were therefore limited to the major pharmaceutical companies. However, the techniques were available to other well-funded laboratories around the world and the UK academic sector needed to acquire and use these techniques to understand a wide range of biological and biomedical problems at the genomic level. Visits made by BBSRC staff to the United States confirmed that the UK research community was in danger of becoming less internationally competitive without access to facilities for these techniques.
28. In 1998 the Research Councils received a generous allocation of funds from the Office of Science and Technology which permitted the first large scale co-ordinated investment in genomic research. BBSRC funded a series of special initiatives starting in 1997, the main focus of which was to provide the capital funding necessary to acquire the new technologies (largely transcriptomics) as quickly as possible for those communities most relevant to the BBSRC mission to ensure their continued competitiveness. This was achieved through competitive funding of consortia built around model organisms of interest to BBSRC in the Investigating Gene Function Initiative. Funded consortia were based around model plants (*Arabidopsis*, cereals) bacteria (*E. coli*, *Streptomyces*) and animals (*Drosophila*, farm animals). The role of the consortia was to acquire, use and develop the new technology and to provide a source of expertise and advice to the scientific community about these new techniques and to assist in their widespread implementation.
29. To ensure co-ordination of investments with other research councils (who also received additional funding to support genomics research starting in 1998/1999), a cross-Council genomics co-ordinating committee was established involving representatives from BBSRC, CCLRC, ESRC, EPSRC, MRC and PPARC together with a representative from DTI. The role of this group was to exchange information about intended investments and future strategies, encourage co-funding of research proposals and establish an evaluation plan for the investments being made in genomics.
30. In addition to the direct support of the acquisition and use of genomic technology, funding was also provided by BBSRC to support the further development of the techniques and to improve the analysis of data through the support of bioinformatic research.
31. Further initiatives were supported by BBSRC through funding provided under spending reviews in 2000 and 2002 to support exploitation of the new technology, some of which were relevant to genomic medicine. These include the Exploiting Genomics Initiative and the Applied Genomics LINK programme, co-sponsored with MRC and DTI, in which BBSRC supported 13 projects sharing 50% of the costs of each project in collaboration

with the private sector³. A report on the outcome of this LINK programme has been published recently as a cross-council case study for economic impact⁴.

32. Between 1997-2007 BBSRC has spent approximately £102M on 352 grants through 12 separate initiatives that acquire, support and exploit genomics research. In addition to the special initiatives supported by BBSRC, an increasing number of grant proposals involving genomic level investigations was funded through the responsive mode. BBSRC spent £141M between 2003-2007 on research in responsive mode that acquired, supported or exploited genomics research. Both studentships and fellowships that feature genomic approaches have been supported to ensure the next generation of researchers are well trained in genomic techniques. Some of these are likely to enter genomic medicine. BBSRC spent £12.5M on studentships in the area of genomics between 2003-2007. BBSRC spends close to a quarter of its annual investment in research on projects that acquire, support or exploit genomics research.
- The ESRC used its spending review allocation of £10 million to invest in research into the implications for society of advances in genomics technologies. This funding, together with subsequent further investment from the Council's baseline, has established the ESRC Genomics Network⁵. This consists of three Research Centres and a Genomics Forum:
 - Cesagen – ESRC Centre for Economic and Social Aspects of Genomics, a collaboration between Cardiff University and Lancaster University. The focus of Cesagen's work is on the social, policy, economic, ethical and legal aspects of genomics and associated developments.
 - Egenis – ESRC Centre for Genomics in Society based at the University of Exeter. Egenis researches developments in the field of genomics (and more broadly bioscience and biotechnologies), and the social implications of these developments from a social science, philosophical and biological stance.
 - Innogen – ESRC Centre for Social and Economic Research on Innovation in Genomics, a collaboration between the University of Edinburgh and the Open University. Innogen's research has a strong focus on innovation, globalisation and stakeholder engagement with regards to genomics and the life-sciences.
 - ESRC Genomics Policy and Research Forum. The Genomics Forum has the remit to identify and exploit synergies between the Genomics Centres, and promote work between natural and social scientists. The Forum aims to actively engage policy audiences, business, the media and the public more widely with genomic science and technology debates.
33. By virtue of the investments made by Research Councils and other funders, genomic research has become commonplace over the last decade and has been fully integrated into both experimental and theoretical approaches to studying biology and applications to research involving disease aetiology, diagnosis and development of therapeutics for the clinic.

Who is taking the lead in the consideration and co-ordination of research and the development of new technologies?

³ <http://www.appgen.org.uk/projects.htm>

⁴ <http://www.rcuk.ac.uk/innovation/impact/default.htm>

⁵ <http://www.genomicsnetwork.ac.uk/>

34. Funding bodies take the lead in co-ordination of research in the UK, and of the large international initiatives. The Human Genome Organisation, the US National Institutes of Health (NIH) and Genome Canada play a significant role in co-ordination of international initiatives. European consortia funded under the EU Framework Programmes play an important role in co-ordination of research in Europe. Considerable benefits have been gained from cross-Research Council initiatives on research in genomics over more than a decade, ensuring for example the co-ordination of research in human and animal model systems, with research into ethical, social and legal issues being linked to, and informed by, biological and biomedical advances. The commercial sector plays a very significant role in the development of new laboratory and medical technologies, often initially based on spin-out companies from academic research.

How effective is the policy and investment framework in supporting research in this area?

35. The framework for academic research appears to be effective in maintaining the internationally competitive position for UK research (see below). The Research Councils have historically worked together to ensure complementarity of approach and economies of scale where possible and will continue to do so in future.

How does research in the UK compare internationally? How much collaboration is there?

36. The direct outcome of the investments in genomics over the last ten or more years has been the continued competitiveness of UK research in the biological and biomedical sciences. The performance of the UK scientific community in these areas has been second only to the United States in international terms⁶. International visibility, as demonstrated by invited speakers to international conferences, is however decreasing compared with 10-15 years ago and the recent high levels of investment in Asian countries is starting to feed through into increased international impact. A continued high level of investment will be required to maintain the UK's competitive position.

37. Several UK initiatives have the potential to give the UK an advantage in the area of genomic medicine. The UK Biobank initiative⁷ is world leading, and has the potential to facilitate research into identifying gene-environment interactions for a range of common diseases in the population at large. The investment of the Research Councils and the Wellcome Trust in supporting large-scale genotyping and sequencing projects in centres of excellence within the UK are all positive factors. The NHS "Connecting for Health" initiative is important in enabling better use of clinical information held throughout the NHS for research, and ensuring that the UK can utilise the advantages for health research that stem from a universal publicly-funded health care system.

38. The US Food and Drug Administration has been very proactive in encouraging the submission of genetic data from clinical trials under a voluntary scheme which takes account of the fact that much of the science is at the exploratory stage at present. Their activities, supported by the US Government, have placed the USA at the forefront in progressing research towards translation into medical practice. Europe and the UK are

⁶ www.evidence.co.uk/downloads/OSIPSAATargetMetrics070326.pdf

⁷ www.ukbiobank.ac.uk

currently following the USA lead in the area.

What are the current research priorities?

39. An important research priority for MRC is to ensure that findings from genome wide association studies of common complex diseases showing possible genetic influences on disease risk are translated into useful information for health care or disease prevention, for instance by improved understanding of disease aetiology or mechanism, or the development of diagnostic or prognostic biomarkers.
40. The widespread availability of genomic and related data arising from high throughput techniques, together with investments in bioinformatics and computational approaches has allowed the development of computational models to explain experimental observations and predict alternative possible outcomes. This integration of mathematical modelling and direct experiment is known as systems biology, and is currently one of the most rapidly developing scientific areas. The UK has a significant international lead in systems biology largely as a result of Research Council investments through the spending review settlements of 2002 and 2004. The BBSRC strategy panels for Integrative and Systems Biology, Tools and Technologies, the Healthy Organism, and Studentships and Fellowships are able to develop and maintain an overview of the resources, facilities, tools, technologies, and training required to sustain the UK's lead in systems biology. Following the Comprehensive Spending Review 2007 settlement, BBSRC is embedding a systems approach to all areas of its remit, and this will underpin advancements in systems approaches to medicine.
41. It seems that the rate of change in pure scientific development terms might be faster than associated governance, ethical and legal frameworks, and we therefore stress the benefits of continuing to fund work on these alongside pure biomedical research. Current research priorities for ESRC include:
 - The need to explore more fully the relationship between a range of biological influences, including genetics, and societal factors when understanding the precursors and motivations involved in individual behaviour and make-up (ESRC strategic plan p 14⁸).
 - Collection of biomedical and genetic data alongside large scale longitudinal social science data collection as part of the UK Household Longitudinal Study (UKHLS) in order to better understand the interaction and influence of each over the life course.

What is the role of industry? How much cross-sector collaboration takes place?

42. The pharmaceutical industry is currently examining the potential of pharmacogenetics (i.e. the role of genetic factors in a patient's response to therapy) to impact on the field of personalised medicine. There are already a number of cancer treatments that are only effective in certain genetically-defined tumour subtypes, and the pharmaceutical industry will play an important role in the development of genetic testing to improve treatment efficacy or avoid adverse reactions in other diseases. For this reason, they have been acquiring DNA from individuals participating in clinical trials on a large scale. These samples will represent worldwide populations, the UK being a fairly minor component,

⁸ www.esrcsocietytoday.ac.uk/ESRCInfoCentre/Images/Strategic_Plan_2005-10_tcm6-12995.pdf

and there may be an opportunity to use these collections to look for genetic factors involved in disease. There is good cross-sector and industrial collaboration, but there is always room for improvement here, as most major pharmaceutical companies have only bought into this idea relatively recently.

43. The diagnostics industry will play an increasingly important role in the translation of laboratory based research into practical and cost-effective tests for clinically relevant genetic variations. There is active collaboration between Biopharma sector and academic scientists at the level of pre-competitive discovery research, and between academic researchers and the biotechnology sector in relation to technology development^{3,4}.

DATA USE AND INTERPRETATION

Is genomic information published, annotated and presented in a useful way? Should there be a common, public database? If so, who should fund, and have responsibility for, such an initiative?

44. Relative to conventional biological research, genomic research data are generated in large volumes and are often complex, involving many inter-related genes and/ or proteins. The European Bioinformatics Institute (EBI), an outstation of the European Molecular Biology Laboratory, located near Cambridge, holds large-scale databases of this nature, and has been instrumental in setting the international standards through which such experiments are conducted and results are annotated. It provides bioinformatic research and technological solutions to the methods of curating and making available data generated through genomic investigations. This has ensured that results from large sections of the community involved in genomic research are made available in a format that is consistent with other laboratories world-wide and available for anyone to access for research purposes. This has been further encouraged through the expansion and development of data-sharing policies by several Research Councils. Recent expansion of the EBI to provide a new building to house larger numbers of staff involved in service provision and research has been funded by BBSRC, MRC and the Wellcome Trust. Further plans are currently being drawn up for increased activity of biological data provision in Europe through EBI using a collaborative funding approach from European member states.
45. Any common public database would need to be very complex to deal with the different types of platform and data (e.g. nucleotide sequence vs array data vs single nucleotide polymorphisms (SNPs) vs methylation vs proteome etc). Information in genomic databases is of optimal use for research only when collected alongside other information (genotypic, phenotypic, social, economic data etc). The more detailed this information is, the more useful it becomes for research purposes, but the practical, ethical and legal issues increase (eg. the cost of keeping such resources, the potential for disclosure of participants' personal data, the potential for use of the resource beyond what was originally envisaged, and associated decisions about access to the resource). Decisions about storage and the governance arrangements for such studies are therefore critical.
46. On the face of it, it seems entirely logical that there should be a standard depository for all information, as it should cross-fertilise. However, capturing a wide range of information (including social and economic) in relation/ addition to the genetics in a single database would probably be impossible, and a single database probably cannot answer all the

potential research questions. For this reason, the continuance of collection of genetic data in a variety of databases will be important, as will the promotion of common standards and practices to facilitate data-sharing.

Who should provide the framework for optimal evaluation of data and translational opportunities? What policy and funding mechanisms are in place for recognising and utilising potential opportunities?

47. Currently the MRC and MRC Technology play a major role in the evaluation of data and translational opportunities, alongside other major funding bodies (eg Cancer Research UK and the Wellcome Trust), university technology transfer offices and patent agencies. There is effectively a “market economy” which operates reasonably efficiently. The problems of a gap in funding for translational research in the UK, as identified in the Cooksey Report⁹, exist in this field as in other areas of applied medical research. The MRC and NIHR are providing new investment and new funding mechanisms for translational research, with additional resources provided in the recent Comprehensive Spending Review, to help bridge this gap.

Is other medical information recorded in a suitable format to allow optimal interpretation of genomic data? How should genomic data be brought together with other health information?

48. The increasing use of electronic storage for health records has the potential for significantly increasing the utility of medical information in genomic studies, and the NHS Connecting for Health initiative is very important in this regard. Standardisation of the way medical data and other phenotype information is recorded remains a challenge.

49. The ESRC, Wellcome Trust, EPSRC and MRC, wish to stimulate and support the use of electronic databases for health research. Electronic patient records and longitudinal cohort databases provide a rich data source with the potential to answer key questions in biomedical, clinical and public health research across the full range of infectious and non-communicable diseases, as well as other medical conditions. As a result, the four funding bodies are commissioning a range of research projects and activities to encourage the use of health data for research purposes¹⁰. Research is due to begin in Autumn 2008 and will last between one and five years. Support will be provided across three main areas:

- Health research using electronic patient records and major longitudinal cohort databases;
- Training programmes and workshops;
- Public engagement activities.

50. It is recognised that the utility of the biological and genetic data is enhanced by the wealth of social and economic data. Indeed, a key aim is to allow the genotype to be studied with the phenotype - bringing together economists, sociologists, psychologists, epidemiologists, genetic scientists, to work together in ways that combine all their skills and expertise in the study of specific medical and psychological conditions.

⁹ “A review of health research funding” Sir David Cooksey Dec. 2006 http://www.hm-treasury.gov.uk/independent_reviews/cooksey_review/cookseyreview_index.cfm,

¹⁰ See www.wellcome.ac.uk/Funding/Biomedical-science/Grants/Other-initiatives/WTD028245.htm

51. The MRC and ESRC have been working with Wellcome Trust to assist with the collection of biomarkers and genetic material from a number of pre-existing national birth cohort studies which contain a wealth of medical, social and economic data. These include the 1958 Birth Cohort (National Child Development Study, NCDS) and the 2000/2001 Birth Cohort (Millennium Cohort Study). Plans, led by the ESRC, are being developed with MRC and Wellcome Trust to co-ordinate some existing studies with other cohorts (ALSPAC – 1990/91 Birth cohort, English Longitudinal Study of Ageing (ELSA), 1970 and 1946 cohorts), and to launch a new cohort study in 2012. Cooperation among funders in relation to the governance of cohort data is particularly important and an appropriate governance structure for this particular set of longitudinal studies is currently being developed. The UK Household Longitudinal Study (UKHLS) is a major new longitudinal study, commissioned by the ESRC, of 40,000 households from across the UK¹¹. It will provide high quality, longitudinal social survey data for academic and policy research and will also support the collection of a wide range of biomarkers and health indicators, thereby opening up prospects for advances at the interface between social science and biomedical research.

What are the implications of the generation and storage of genome data on personal data security and privacy, and on its potential use or abuse in employment and insurance? How should these be addressed?

52. The generation and storage of genome data for research and medical practice will require systems to be established to ensure personal data security and privacy, as there are clear concerns on this issue among the general public and government. The potential use or abuse of information in both employment and insurance are issues which should be addressed via both public consultation and by discussion with relevant professional or trade associations. However, we should also consider the possible negative ‘alarmist’ impact of identifying disease associations for which there is no current therapy, especially where there is a high penetrance for a given allele in the population that actually has a low relative risk. The ongoing Research Capability Programme within the “NHS Connecting Patients for Health” initiative and the systems put in place by the UK Biobank will address the above concerns to some extent.

53. In terms of data storage and access, safeguarding anonymity is a key issue and we suggest that genetic information and phenotypic information should always be stored in physically separate locations, with the key to data matching, and data matching capacity, held by a third and neutral party and for particular safeguards to be set up for accessing sensitive data (e.g. the ESRC is commissioning a ‘Secure Data Service’¹², which could be of use in holding information related to health). Governance arrangements should specify how linkage approval should be made, for what purpose, and should ensure that the anonymity of linked records is preserved.

TRANSLATION

What opportunities are there for diagnostics, therapeutics and prognostics – now and in the future?

¹¹ See <http://www.iser.essex.ac.uk/ukhls/>

¹² www.esrcsocietytoday.ac.uk/ESRCInfoCentre/opportunities/current_funding_opportunities/ads_sds.aspx

54. The opportunities for diagnostics, therapeutics and prognostics are clear and exciting. Improved understanding of disease mechanisms and aetiology will lead to new prognostic, diagnostic or therapeutic biomarkers and new therapeutic targets, although many will take some time to materialise. The UK has been at the forefront of academic research in genomics this field, and it is important that this position is maintained and translated into patient care. Diagnostics in relation to tumour markers is already well-established and will continue to develop, allowing more appropriate therapies to be used, especially where there is only a narrow therapeutic window. There is considerable concentration of effort, especially by large pharmaceutical companies, into relatively few areas. The higher risk areas of research are still undertaken in the public/charity sector. A further encouragement or small Biopharma ‘roll out’ from the public sector would certainly be welcome.
55. However, the practical returns on the identification of specific genetic risk in common complex diseases are less clear, in view of the relatively low penetrance of most susceptibility genes, the confounding aspects of environment and lifestyle, and the resulting difficulties in drawing useful lessons or identifying useful interventions¹³. It is possible that improved genomic understanding of the mechanisms of disease aetiology may in time lead to novel forms of therapy, but such gains may be piecemeal and unpredictable.
56. Developments in the field of pharmacogenetics, including the identification of genes associated with positive or adverse drug responses, are likely to follow a similar pattern to the identification of disease susceptibility genes. In other words, a number of relatively rare single-gene responses will be identified that may prove useful in practice. However, genetic explanation of more common variations in drug response, and the development of effective tests, will likewise be confounded in practice by factors including low penetrance and other sources of personal variation. There is thus a likelihood of significant but highly localised pharmacogenetic gains in the efficiency and efficacy of drug use, but a revolutionary shift towards so-called “personalised medicine” is far less likely⁴.

Who is responsible for translation to clinical practice?

57. Progress in this area tends to be driven by small Biopharma, although both large Biopharma and charity/Research Councils are also playing an important role. In addition, the NHS and the Medical Royal Colleges (eg in their role of providing continuing professional development) have a role.

Given the pace of technological advance, how ‘future-proof’ is healthcare investment in this area? How does the UK compare to other countries and what lessons can be learnt?

58. We have not addressed these questions, which are somewhat outside our remit.

How meaningful are genetic tests which use genome variation data? What progress has been made in the regulation of such tests?

59. Genetic tests related to single gene disorders and high penetrance genes such as BRCA1 are clearly meaningful, and already play an important role in clinical practice and for affected families and individuals. However, the meaning of tests relating to more complex

¹³ Contributions provided by the ESRC genomics forum: <http://www.genomicsforum.ac.uk/>

disorders still requires very careful evaluation. There are many publicly available genetic tests. For example, genetic testing for psychiatric disorders is becoming commercially available with venture capitalists and scientists seeking to establish niche markets by selling 'direct-to-consumer' testing. Psynomics (www.psynomics.com) has developed a test that helps diagnose people with bipolar disorder (Couzin, 2008). Companies such as SureGene (www.suregene.net/home.aspx), are developing tests for other psychiatric disorders while NeuroMark (www.neuromark.com) is marketing a test for pharmacogenetic responses to anti-depressant treatment. The success of the business model in driving these developments is likely to encourage further biotech companies to circumvent existing psychiatric healthcare models in favour of selling direct to the customer¹⁴.

60. In the UK, recent media coverage¹⁵ has raised public awareness and expectations of these scientific developments as well as fears and concern about the commercial availability of predictive and diagnostic testing. Psychiatrists and other doctors have warned that the proliferation of such direct-to-consumer testing will mislead and confuse consumers¹⁶. Providing individuals with an estimate of the risk of developing psychiatric disorders is far from straightforward, and may not account for the complex interaction of genetic and environmental factors. There seem to be two critical potential difficulties: 1) the correct interpretation of the test, which is a particular concern given the generally poor grasp of scientific method by practitioners, counsellors and public, and 2) statistics and the validity of the test, and public perception of that validity. Both of these problems are compounded by the limited value in delivering a test/genetic predisposition if there is no suitable course of action for the individual to take. However, these considerations have implications for how the utility of new genetic and genomic techniques should be evaluated. Any assessment of utility must take account of the complex meanings that attach to genetic testing, and the ethical and social consequences that follow from the application of such tests. This would be best achieved by adopting some of the newer developments in health technology assessment which pay explicit attention to the context of use, and which draw on new methods of user engagement -- including both practitioners and patients/consumers -- to ensure that new technologies meet genuine needs.
61. Annex 1 provides details on the US Government legislation, in particular the Food and Drug Administration (FDA) which has responsibility for assessing the safety and effectiveness of genetic tests used for diagnosis or prediction of disease.

BIOMARKERS AND EPIDEMIOLOGY

*In what way do genome-wide association studies contribute to the identification of biomarkers?
How is the study of genetic factors and biomarkers integrated for translational purposes?*

¹⁴ Contributions provided by the ESRC Cesagen Centre: <http://www.genomicsnetwork.ac.uk/cesagen/>

¹⁵ (*Observer*, 03/02/08; *The Daily Telegraph*, 4/02/08; *The Express*, 5/02/08; *The Times*, 10/03/08)

¹⁶ (*Observer*, 03/02/08; *BBC News*, 11/03/08)

62. Biomarkers¹⁷ are characteristics that are objectively measured and evaluated as indicators of normal biological processes, pathogenic processes or pharmacological responses to a therapeutic intervention¹⁸. They play a key role in understanding the aetiology and progression of disease, as well as understanding the mechanism of action of therapeutic agents and investigating the response of individual patients to treatment. Biomarkers are an essential part of the drug discovery process, being used at every stage from target identification to patient stratification.
63. Genome-wide association studies provide a comprehensive approach to identification of common genetic variants (one type of “biomarker”) across a population which are either directly associated with the risk of disease (e.g. cancer risk) or influence the inheritance of commonly measured quantitative traits, (another kind of biomarker, eg plasma concentrations of cholesterol as a risk factor for cardiovascular disease). These studies will lead to the discovery of new genetic factors and disease causing molecular pathways that will in turn lead to the development of further biomarkers and open up new therapeutic avenues.
64. Genome-wide association scans will also help screen for biomarkers associated with the clinical response to treatment and may lead to the identification of SNPs and differentially expressed genes that are related to, and are predictive of, the responder status. The use of genomics and gene expression platforms at the level of the entire genome therefore offers unique opportunities for biomarker research and its translation to patient benefit in terms of tailoring treatments for optimal efficacy and safety according to an individual’s genetic make-up.

What impact will genomic data have on data emerging from projects such as UK Biobank, Generation Scotland and other biobanks?

65. UK Biobank is developing a prospective resource of 500,000 people aged 40-69 from around the UK, involving extensive baseline information, physical measures, biological samples and medical information. Generation Scotland (like many other studies) is complementary to UK Biobank and will help to develop the knowledge of genes which contribute to health or ill-health. Such studies aim to help researchers better understand the causes of disease and to find new ways to prevent and treat different conditions. Understanding the genetic basis of disease is one component of building a full picture of health processes. UK Biobank and other biobanks provide the opportunity to investigate how genetic factors combine with lifestyle and other factors to cause disease.

¹⁷ Descriptors: Biomarker: A characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes or pharmacological responses to a therapeutic intervention.

Clinical biomarker: A biomarker that associates a treatment to a patient subpopulation that has historically showed a differential and substantial clinical response. These can be based on genotypes, proteins, metabonomic patterns, histology, imaging, physician clinical observations or even self-reported patient surveys.

¹⁸ Trusheim, Berndt and Douglas (2007). *Stratified medicine: strategic and economic implications of combining drugs and clinical biomarkers* Nature Reviews Drug Discovery 6 287-293

66. The population-based, prospective approach is complementary to other genomic research approaches. UK Biobank will build on existing genomic information arising from genome-wide association studies and other approaches, provide further opportunities for genomic investigation and discovery, and, importantly, become increasingly valuable (and cost-effective) to researchers to extend studies into the assessment of the complex interplay between the effects of different factors (e.g. genetic and environmental) in the development of, and recovery from, disease. The suite of samples stored will support study of a wide range of biomolecules and will allow many types of assays (e.g. proteomic and metabolomic) to be undertaken in addition to genetic analyses. Studies of the scale and complexity of UK Biobank will be unique in having the power to address these research questions which build on the outputs of genomic research data.

USE OF GENOMIC INFORMATION IN A HEALTHCARE SETTING

What impact will genomic information have on the classification of disease? How will it affect disease aetiology and diagnostic labels?

67. Genetic information has already had a significant impact on the diagnostic classification of a number of single-gene disorders. However, even in single-gene diseases such as cystic fibrosis, genetic techniques have been assimilated into existing clinical methods of diagnosis and treatment, resulting in modification rather than straightforward replacement of established disease categories¹⁹. The incorporation of genetic and genomic information and techniques into clinical practice, and the reformulation in practice of disease categories, depend as much on how that information comes to be used in the clinic as on basic scientific ideas of aetiology.
68. At the moment there is relatively little genetic data that is clinically useful in relation to more complex disorders. However, this is clearly going to change over the next two decades with the likely integration of symptomatology-based classification with classification related to the molecular basis of disease, which may also lead to differentiation of disease into sub-categories. For example, genetic epidemiology has already proved influential in shaping the nosography of psychiatry and developments in molecular genetics are beginning to provide evidence to challenge the traditional classifications. This makes it increasingly difficult for psychiatrists unambiguously to assign patients to distinct categories of major psychosis.
69. The situation is far more complicated when dealing with the much larger and epidemiologically more important class of common complex diseases. In most such cases, however, susceptibility genes confer only a relatively small increase in the risk of developing symptomatic disease, while a wide range of environmental, social and lifestyle factors may contribute to the development of disease in the presence or absence of any genetic predisposition. Consequently, the impact of such information on the clinical classification and diagnosis of disease will depend upon a wide range of variables,

¹⁹ Kerr, A (2007), "(Re)constructing Genetic Disease: The Clinical Continuum Between Cystic Fibrosis and Male Infertility." *Social Studies of Science* 30: 847–94; Hedgecoe, A,M (2003), "Expansion and Uncertainty: Cystic Fibrosis, Classification and Genetics." *Sociology of Health & Illness*, 25, 50–70; Latimer, J et al. (2006), "Rebirthing the Clinic: The Interaction of Clinical Judgment and Genetic Technology in the Production of Medical Science." *Science, Technology & Human Values* 31.5: 599–630.

including the size of the genetic contribution to risk and the availability of effective preventive or therapeutic interventions. The context of use, and the meaning and utility of genetic and genomic information in that context, will be a key factor in determining how such information will be incorporated into clinical practice and health care delivery.

How useful will genomic information be as part of individualised medical advice? What provisions are there for ensuring that the individual will be able to understand and manage genomic information, uncertainty and risk?

70. From the patient's point of view, genomic information may be interpreted in a number of ways. In some cases, knowledge of a genetic predisposition may relieve feelings of guilt or responsibility for an illness. In other cases, however, identification of a genetic risk may entail an additional burden of responsibility on the patient, not just directly for themselves, but for their families and reproductive choices. Indeed, the language in which medical and policy discussions are couched commonly tends to suppose that patients have a duty to take appropriate preventive or prophylactic action. But such action is not always in the patient's best interest²⁰. There is also evidence that patients are less inclined to follow the advice of healthcare professionals on changes to life style and behaviour than to seek specific medical interventions²¹. Increased testing for susceptibility genes may consequently lead to a corresponding increase in the demand for medical monitoring and support²². Any such increase will obviously have resource implications for the health services.
71. The language in which preventive advice is offered may play an important role in the failure to effect behavioural change among those deemed to be at increased genetic risk. Patients often have a complex multi-causal understanding of inherited risk and prevention that draws on knowledge of their own family history and the health of relatives²³. While lay ideas of kinship commonly differ significantly from genetic accounts of relatedness, knowledge of family history nonetheless provides a useful medium of communication between health care advisors and patients. In this respect, overly rigorous insistence on a strictly genetic understanding of relatedness may inadvertently lead to a failure of

²⁰ Hallowell, N (1999), "Doing the Right Thing: Genetic Risk and Responsibility." *Sociology of Health and Illness* 21.5 : 597–621; Hallowell, N (2006), "Varieties of Suffering: Living with the Risk of Ovarian Cancer." *Health, Risk & Society* 8: 9–26;

²¹ Saukko, P, Richards, S., Shepherd, M. and John Campbel, J.(2006), "Are Genetic Tests Exceptional? Lessons from a Qualitative Study on Thrombophilia." *Social Science and Medicine* 63.7: 1947–59.

²² Bharadwaj, A., Lindsey, P., Atkinson, P. and Clarke, A (2006), "Genetic Iceberg: Risk and Uncertainty in Cancer Genetics and Haemochromatosis." *Innovative Health Technologies: Meaning, Context and Change*. Andrew Webster. Palgrave Macmillan; Lock, M., et al. (2007), "Susceptibility Genes and the Question of Embodied Identity." *Medical Anthropology Quarterly* 21.3: 256–76.

²³ Lock, M., Prest, J and Lloyd, S. (2006), "Genetic Susceptibility and Alzheimer's Disease: The Penetrance and Uptake of Genetic Knowledge." *Thinking About Dementia: Culture, Loss, and the Anthropology of Senility*. Ed. Annette Leibing and Laurence Cohen. New Jersey: Rutgers UP, 123–56.

communication and foreclose on a valuable channel for offering meaningful advice on risk and prevention²⁴ .

Should there be a regulatory code (mandatory or voluntary) covering the provision of this advice?

72. It is clearly important to ensure the quality of advice based on genetic and genomic information, and effective training of those giving advice is essential (see below) but we do not have a view on whether this might best be achieved via a regulatory code.

What are the implications of developments in genomic technologies for the training of medical specialists and other health professionals? Are there any gaps that need addressing? What is the assessment and planning for future needs in capacity?

73. Until recently, responsibility for providing genetic health care and advice has largely devolved to genetic medicine specialists and genetic counsellors. With increased knowledge of the genetic dimensions of common complex diseases, however, a much wider spread of practitioners are likely to find themselves called on to offer advice on genetic matters. There will therefore be a need not only to increase provision of specialist training, but also to integrate appropriate training in providing genetic health care into the core medical and nursing curriculum. The meaning and utility of this additional information in a healthcare setting is not determined solely by the possibility of estimating the extent of the genetic risk that patients face. The training of healthcare professionals (for example, via Continuous Professional Development courses.) should not be confined to a scientific appreciation of disease genetics. It should also emphasise the value of family history as an effective means of structuring communication with patients, and should stress the importance of understanding that history from the patient's perspective as well as from a strictly genetic point of view. In other words, the utility of information on genetic factors also depends upon the practitioner's ability to relate the risk of disease to the patient's life and circumstances, including the social and moral complexities of family life. A recent Academy of Medical Sciences Report²⁵ has highlighted similar issues relating to the identification of environmental causes of disease and this could be an excellent starting point.
74. New exploratory research is needed in order to assess the likely consequences of these developments for individuals and family members, for medical practitioners, genetic specialists and health professionals, and the potential demands on healthcare services. For example, the ongoing collaboration between Cesagen, Psychological Medicine, Medical Genetics, Social Sciences, and the Wales Gene Park at Cardiff University will provide an evidence based assessment of the likely personal and professional consequences of new

²⁴ Hall, R. et al.(2007), "Assessing Family History of Heart Disease in Primary Care Consultations: A Qualitative Study." *Family Practice* 24: 435–42.

²⁵ An Academy of Medical Sciences working group report chaired by Sir Michael Rutter, November 2007 – "Identifying the environmental causes of disease: how should we decide what to believe and when to take action?"

genetically-based diagnostic criteria and risk information. It will also inform the ethical debate concerning the consequences of risk evaluation for psychiatric conditions.

75. Overall, prognostic and diagnostic testing will become increasingly important and medical practice will move towards preventative treatment or lifestyle management.

ANNEX 1

RCUK USA OFFICE INPUT ON US POLICY FRAMEWORK ON GENOMIC MEDICINE

76. The US government has powers to regulate the commercial development of genetic technologies. These include the laws governing the ability to patent gene sequences, laws regulating clinical laboratory quality, and laws regulating the safety and effectiveness of genetic diagnostics. In particular the Food and Drug Administration (FDA) has responsibility for assessing the safety and effectiveness of genetic tests used for diagnosis or prediction of disease. In recent years, several bills have been introduced into Congress to prohibit genetic discrimination although have yet been enacted into law. State legislatures also have broad powers to legislate to protect the health, safety, and welfare of their citizens, and these powers have begun to be exercised in the context of genetic technologies.
77. The US Genetics and Public Policy Centre has produced a good summary briefing on the law and genetics in the US at: <http://www.dnapolicy.org/policy.law.php>

Food and Drug Administration (FDA)

78. The FDA takes a leading role in working with the academic community and business to ensure that regulatory science and regulations are developed at a pace which responds to scientific and technological advances, particularly in relation to pharmacogenomics and the implications this has for personalized medicine.
79. To date the FDA has cleared a number of genotyping tests to enable doctors to determine whether patients have genetic mutations which could influence their ability to metabolise certain drugs.
80. The FDA's 2004 white paper "Stagnation or Innovation? Challenge and Opportunity on the Critical Path to New Medical Products" looks at the possible opportunities from genomic medicine and the challenges of developing these medical products as part of a wider study of the lag between discovery and product development. FDA also produced a good, plain English summary on the opportunities and challenges of genomics and personalized medicine in 2005.
81. White paper is at:
<http://www.fda.gov/oc/initiatives/criticalpath/whitepaper.html>
82. Consumer briefing is at:
http://www.fda.gov/fdac/features/2005/605_genomics.html
83. The FDA has also produced guidance on the use of pharmacogenomics for regulatory decision making, and participates in a number of research projects to support and promote the translation of pharmacogenomics from basic research, drug discovery and development into clinical practice, focused on responsible use to protect public health.

National Institutes for Health (NIH)

84. The NIH funds the National Human Genome Research Institute (NHGRI), whose activities are focused on understanding the structure and function of the human genome and its role in health and disease. NHGRI supports the development of resources and technology that will accelerate genome research and its application to human health. A critical part of the NHGRI mission is the study of the ethical, legal and social implications of genome research, as well as the training of investigators and the dissemination of genome information to the public and to health professionals.
85. On the policy side, NHGRI runs a policy and legislation database which contains federal and state laws, statutes, policies and other material covering: privacy of genetic information/ confidentiality; informed consent; insurance and employment discrimination; genetic testing and counseling; and commercialization and patenting. NHGRI also provides comprehensive policy briefings on its website, addressing current research, policy issues and legislation (including listings of significant research, policy reports and recommendations). Recent highlights include:
- Director NHGRI's address to the President's Council of Science Advisors on S&T on the science and policy of personal medicine (Sept 2007)
 - Genomic medicine: a revolution in medical practice in the 21st century (presentation to Annual World Health Care Congress April 2006)
 - The future of genomic medicine: policy implications for research and medicine (roundtable conference, 2006)

All documents can be accessed at: <http://www.genome.gov/PolicyEthics/>

National Academies

86. In 2005, NIH funded the US National Academies to undertake a study on IP issues related to genomic and proteomic research. The report "Reaping the Benefits of Genomic and Proteomic Research: Intellectual Property Rights, Innovation and Public Health", reviewed US patenting practice in relation to genes and gene function and their use to diagnose and treat disease, and the implications and restrictions this could place of future research. It recommended that policy makers, courts and health patent officials should take steps to prevent increasingly complex IP protection hindering future breakthroughs in genomics and proteomics research for health. For example it recommended that NIH should continue to encourage researchers to freely exchange materials and data, and place their data in free public databases. Report is at:

<http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=11487>

Non-governmental organisations

87. One of the leading US non-governmental organisations working in this area is the Genetics and Public Policy Centre. The Centre is supported by the Pew Charitable Trusts, with research funding from the NHGRI and the U.S. Department of Veterans Affairs.
88. The Centre works with policy leaders, decision makers, and the public to help all parties better understand the evolving field of human genetics and its application to healthcare. Specifically the Centre produces reports, issues briefs and holds policy seminars on range of issues, including genomic medicine. All reports and briefs can be accessed at the Centres website (<http://www.dnapolicy.org/>). Recent topics of relevance include: IP and

the human genome; pharmacogenetics; the impact of genetic discrimination; and FDA regulation of genetic tests.

89. The Centre also undertakes surveys public attitudes about genetics issues, conducts analyses of the existing regulatory landscape, monitors the transition of genetic applications into clinical practice, and posits options and likely outcomes of key genetics policies.

US research on genomic medicine

National Advisory Council for Human Genome Research

90. The US Government has established the National Advisory Council for Human Genome Research (NACHGR) to advise the Department of Health and Human Services, NIH and NHGRI on genetics, genomic research, training and programs related to the human genome initiative. NACHGR performs second-level peer review for grant applications, and determines the program priorities for NHGRI and the goals for the US efforts in the International Human Genome Project. The Council is appointed by the Secretary for Health and Human Services. As well as the Directors of NIH, NHGRI, the Chief Medical Director of the Department for Veterans Affairs and the Assistant Secretary of Defence for Health Affairs, the Council includes 12 scientists from a range of disciplines (including information and social sciences) and 6 members from the legal profession, health policy sector and economic sector (<http://www.genome.gov/10000905>).

National Human Genome Research Institute

91. The NIH funded National Human Genome Research Institute (NHGRI) led the participation of NIH in the International Human Genome and now funds research on the genome's structure, function, and role in health and disease and supports studies on the ethical, legal and social implications of genome research. NHGRI's total budget in FY2008 is \$487M.
92. NHGRI funds research via extramural and intramural programmes and also coordinates related research activities across NIH's other institutes as well as maintaining an overview of international developments. The intramural programme (\$100M) consists of laboratory based and clinical research to translate genome research into a greater understanding of human genetic disease (<http://www.genome.gov/10001634>). Research includes work medical genetics (focused on disorders of human development), genome technology and social and behavioural research focused on communication of genetic risks, best practice in genetic counseling and integrating genetics into primary care (<http://www.genome.gov/10000010>). The clinical programme includes work to identify disease causing genes as well as studies aimed at examining the psychosocial, ethical and policy implications of genetics research (<http://www.genome.gov/10000331>).
93. The extramural research programme (\$362M for grants and contracts) includes a number of strands including large-scale genome sequencing activities, informatics and computational biology and legal, ethical and social research (<http://www.genome.gov/10001092>).

94. NHGRI also funds postgraduate training and fellowship awards (\$7M), and provides information on genetics diseases and genetic research to improve health for the general public (see: <http://www.genome.gov/Health/>)

US-UK research collaboration on genomic medicine

95. The US (NJGRI) and the UK are partners in the International HapMap Project, which also includes scientists and funding agencies from Canada, China, Japan and Nigeria. The project aims to identify and catalog genetic similarities and differences in human beings. Using the information in the HapMap, researchers will be able to find genes that affect health, disease, and individual responses to medications and environmental factors. All of the information generated by the Project will be released into the public domain. The UK partners in the project are:

- the Wellcome Trust Sanger Institute
- the University of Oxford (funded by the Wellcome Trust, NIH, and the SNP Consortium which comprises of a number of pharmaceutical companies, the Wellcome Trust, the Sanger Institute and a number of US universities)

96. The NHGRI extramural programme also directly funds some relevant research in the UK. Current awards include:

UK institution	Award	Value
Wellcome Trust Sanger Institute	Detecting human functional sequences with mircoarrays	\$272k
UCL	Human genome nomenclature	\$464k
European Bioinformatics Institute, Cambridge	The UniProt protein sequence and function knowledge base	\$5,872k
European Bioinformatics Institute, Cambridge	The nomenclature of human genes	\$340k

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