



THE ROLE OF BBSRC IN BIODIVERSITY RESEARCH

INTRODUCTION

The aim of this document is to explain the role of biodiversity research in the delivery of the BBSRC mission, and thereby to provide guidance to the scientific community on the areas of biodiversity research that are appropriate for funding by BBSRC.

The Convention on Biological Diversity, to which the UK is a signatory, defines biological diversity as “the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”.

All biodiversity is connected through common ancestry of species (phylogeny). This provides a framework for studying the patterns of diversity and for comparative analyses at various hierarchical levels of biological organisation. Because genes interact with other genes and with the environment, it is important to develop an understanding of biodiversity in terms of complex adaptive systems, both within and between different levels of organisation (e.g. molecule, gene, individual, and habitat). In particular, it is important to identify any generic properties, mechanisms or constraints involved in the maintenance, evolution, generation or loss of biodiversity.

The option for preserving biodiversity has passed with the mounting evidence that human activity is impacting on ecosystems at the global scale. Therefore, research must operate in the context of managing biodiversity (as defined above) towards prescribed goals relating to current and future values. Management of biological diversity towards a set of goals requires an understanding of the processes that sustain the vitality of ecosystems and give rise to function. Goals might relate to the discovery and exploitation of biological resources, but they must also relate to the management of biological diversity to promote as yet undefined future options. The goals are unlikely to be mutually consistent, so compromise based on a clear set of principles will be required. Many of the challenges lie clearly within the remit of BBSRC and these are outlined below. However, many of the most important questions require the integration of research at the interface between BBSRC, NERC, ESRC and DEFRA. In the research areas outlined below we provide examples that relate to the missions at the interface between BBSRC and other research councils. We strongly encourage the scientific community to exploit the opportunities of research at the interfaces, and to enter into dialogue with the appropriate programme managers to facilitate this goal.

In addition to fundamental studies on biodiversity aimed at improving basic knowledge of mechanisms and processes, research is needed to identify, characterise and harness biodiversity with the objective of enhancing the exploitable potential of organisms with commercial relevance, or impact, on the health of crops, animals and humans. There is

also substantial public interest in biodiversity, for example in gardening, conservation and natural history, and this can be used as a conduit to convey appreciation of how research on biodiversity can impact on everyday lives of the population.

Diversity and functionality emerge as a consequence of processes operating across different levels of organisation from pathways in cells to the interaction between ecosystems. Research on biodiversity is about understanding the dynamics of complex adaptive systems, and the examples provided below emphasise the need to focus on interactions and the emergence of behaviour across levels of organisation from genes to ecosystems.

Although biodiversity exists in the continuous spectrum from variation in molecules and genes to diversity of species within ecosystems, it is easiest to identify BBSRC's role in biodiversity research in the context of different 'levels', whilst at the same time recognising that boundaries between levels are not discrete and that overlap occurs. The role of BBSRC in supporting biodiversity research is outlined below for four different levels of diversity: molecular diversity, gene and genome diversity, organism diversity and habitat and ecosystem diversity. It is recognised that effective data and information handling capabilities are required throughout these levels, and specific requirements are discussed as a separate topic.

MOLECULAR DIVERSITY

Molecular diversity can be viewed as the diversity present among the primary and secondary products of genes. This encompasses variation in the chemical composition of cells and tissues with respect to their transcriptional and translational products and/or secondary compounds. BBSRC's interests in molecular diversity fall in the following areas:

Changes in molecular diversity

- Understanding the basic mechanisms and processes resulting in molecular diversity
- Understanding how molecular variation is related to functional and physiological diversity
- Improving our understanding and manipulation of key pathways
- Comparative studies of key pathways in different organisms, including pathogens (viruses, bacteria, parasites), to elucidate common and unique pathways that could be exploited

Exploitation of molecular diversity

- Identification and characterisation of diverse products that play a role in interactions with, and protection against, environmental challenges
- Identification of untapped sources of new and potentially exploitable metabolic and physiological pathways and natural products
- The significance of variation in cell products for the food chain
- Investigating variation in the protective and interactive roles of metabolites

Conservation of molecular diversity

- Identification and characterisation of biotypes with molecular diversity of agro-ecological significance

Tools and techniques for studying molecular diversity

- Development of high throughput or novel screening methods for the identification of products that have commercially exploitable potential
- Enhancement of molecular diversity (e.g. by exploiting mechanisms of recombination, shuffling and forced / directed evolution)
- Metabolomics studies in the context of food safety

GENE AND GENOME DIVERSITY

Genomes vary in gene organisation and structure, in the composition and organisation of non-transcribed regions (e.g. hypervariable regions, repetitive DNA, retroelements), in ploidy level and in karyotypic variation. Gene diversity is the allelic variation that can be found in structural and regulatory genes. Comparative genomics is based on the study and comparison of genes and genomes of different organisms, and is important for understanding evolutionary relationships between organisms in gene organisation and function. BBSRC's interests in gene and genome diversity fall in the following areas:

Changes in gene and genome diversity

- Biodiversity genomics, including the evolutionary mechanisms of genome organisation and genome change
- Understanding the molecular mechanisms and processes of genome change

- Understanding recombination, mutation and rates of evolution and how these are controlled
- Investigating different mechanisms resulting in genetic exchange and understanding how genetic information moves around within and between organisms
- Investigating the role of different genetic elements in genome change, genetic instability and phenotypic plasticity
- Investigating the evolution and generation of diversity in the genomes of organelles and other extra-chromosomal genomes
- Investigating the role of gene/environment interactions with respect to differential responses in ageing, nutrition and stress
- Understanding genes under selection during domestication
- The role of human genetic diversity in response to nutritional input, anti-oxidants and signalling molecules and their impacts on human health

Exploitation of gene and genome diversity

- Understanding and exploiting the genetic basis of diversity in form and function in animals, plants and microbes
- Elucidating how genome organisation, gene expression and allelic diversity are related to functional diversity
- Understanding the genetic basis of quantitative variation
- Characterisation and evaluation of gene diversity in germplasm, where this has strategic or applied context
- Development of approaches using linkage disequilibrium and association studies to relate specific gene functions and traits
- Investigating the consequences of contrasting adaptive selection pressures in domesticated versus wild germplasm
- Influence of genome organisation on inheritance/exploitation of genetic variation

Conservation of gene and genome diversity

- Development of models and approaches for the sustainable use of biodiversity
- Identifying and preserving genetic diversity of industrially and medically relevant microbes, farm animals and crop species to maintain potentially useful traits for breeding purposes

Tools and techniques for studying gene and genome diversity

- Efficient tools and techniques for detecting, characterising and analysing biodiversity
- Development of generic approaches that facilitate high-throughput analysis
- Development of improved statistical procedures for analysing diversity, for studying evolutionary change and for detecting the influences of selection
- Novel/high-throughput approaches to trait analysis or crop improvement
- Generic methodologies for characterisation or (high-throughput) analysis of large datasets
- Development of 'pharmacogenomic' techniques for identifying differences between genotypes
- Developing methods for the identification of rare alleles
- Development of tools for comparing large or complete nuclear and/or organellar sequences

ORGANISMAL DIVERSITY (INDIVIDUALS, POPULATIONS, SPECIES)

Species diversity is the number and kind of species in an ecosystem. Within species, diversity may be present among individuals within a population and among different populations. BBSRC's interests in population and species diversity fall in the following areas:

Changes in organismal diversity

- Systematic (including taxonomic) studies, where there is an intrinsic reason why improved systematic understanding is needed in order to deliver a hypothesis-driven objective, or a generic tool or technology for systematics research
- Understanding the genetic and epigenetic underpinnings of major phenotypic shifts in lineages; the origin and diversification of major clades
- Phylogenetic and phylogeographic approaches to understand the temporal and environmental context of evolutionary divergence
- Understanding processes leading to population divergence and speciation
- Investigating the evolution of breeding systems
- Understanding the behaviour of genes in populations
- Investigating spatial and temporal dynamics of interacting species
- Understanding mechanisms of co-evolution
- Investigating changes in species or population diversity in some natural environments of exploitable value or importance to crop, animal or human health and in artificial (i.e. man-made and man-managed) habitats such as fermenters and bioreactors
- Understanding the invasiveness and impacts of the release of introduced or GM organisms on biodiversity

Exploitation of organismal diversity

- Investigating natural variation where this leads to potential exploitation (e.g. for dealing with pollutants and toxins or bioremediation)
- Studies of extremophiles and their mechanisms for dealing with extreme environments, when these can yield exploitable traits or establish fundamental mechanisms of adaptation
- Identification of novel variation in natural populations of plants and animals that can be exploited in crop and farm animal genetic improvement
- Investigating population dynamics to increase understanding of fundamental processes
- Understanding the genetic basis of organismal adaptation to different environments

Conservation of organismal diversity

- Identification of microbial assemblages that have a key role in sustainable agriculture
- Conservation and management of soil biodiversity
- Supporting collections of strategic and/or exploitable value
- Investigating the maintenance and dispersal of adaptive genes in population networks
- Selection of new characters in relation to novel types of niche occupancy

Tools and techniques for studying organismal diversity

- Development of tools (e.g. databases) and bioinformatics approaches for managing and analysing information on biodiversity at the individual, population or species level
- Development of new approaches for inference of population genetic or evolutionary parameters
- Methods for rapid species identification and diagnostics including DNA barcoding approaches
- Using individual-based modelling to improve fundamental understanding of processes involved in the generation or dynamics of diversity

HABITAT AND ECOSYSTEM DIVERSITY

Habitat and ecosystem diversity is the variation in species within and between different habitats and ecosystems. BBSRC's interests in habitat and ecosystem diversity fall in the following areas:

Changes in habitat and ecosystem diversity

- Improving our mechanistic understanding of species diversity and distribution in managed and semi-natural habitats (e.g. agro-ecosystems)
- Understanding how climate change affects ecosystems, where these studies increase basic biological understanding or potential for exploitation. This includes the effect of climate change on artificial ecosystems such as agriculture
- Impact of global climate change on animal and plant health, and the changes in geographical ranges in which pathogens can survive
- The role of gene flow and horizontal gene transfer
- Evolutionary ecology of soil

Exploitation of habitat and ecosystem diversity

- Improving our understanding of how management affects the evolution of diversity as a component of ecosystem functioning in the context of production systems, including agriculture
- Exploiting the value of functional biodiversity in sustainable agricultural context
- Understanding the ecological significance of intra-specific variation and inter-relationships between inter- and intra-specific variation
- Investigating biodiversity processes in relation to different land-use patterns and different agricultural systems

Conservation of habitat and ecosystem diversity

- Identification of the mechanisms that promote coexistence of managed and natural/semi-natural communities, and the conservation of associated habitats and species
- Understanding the role of genetic diversity in habitat/ecosystem resilience
- Improving our understanding of the impact of nitrogen pollution on the biodiversity of ecosystems

Tools and techniques for studying habitat and ecosystem diversity

- Development of predictive models capable of relating ecosystem structure to dynamics and function

- Development of new tools to relate diversity to function (e.g. molecular biological approaches to characterising functional diversity)

BIODIVERSITY INFORMATICS AND E-SCIENCE

Improved access to biodiversity information underpins the delivery of many of the above objectives. Key to this is the development of technologies for the digitisation of large datasets and collections, and for the integrative interoperability of heterogeneous datasets. This latter objective is particularly dependent on the development of an electronic catalogue of species names, as the means by which all biological data can be related within a coherent framework. Modern e-science technologies (e.g. GRID systems) offer considerable promise for biodiversity informatics.

The BBSRC has a research priority, delivered through its Genes and Developmental Biology Committee (see Annex 1), to support the development of new techniques in this area. Other areas in which BBSRC's interests lie include:

- Methods that link diversity information on metabolomes, transcriptomes and proteomes
- Development of systems using a common language and common data standards
- Developing effective methods of data storage

CONCLUDING REMARKS

This document describes the aspects of biodiversity-related research relevant to the BBSRC mission and particularly to the delivery of its 10-year Vision and its Strategic Plan (q.v.). BBSRC's biodiversity research portfolio is complementary to, and developed and delivered in cooperation with, other Research Councils (particularly NERC) and key government stakeholders (particularly DEFRA). These organisations have their own missions and priorities, which also contribute to the overall UK effort in biodiversity research.

BIODIVERSITY INFORMATICS

The BBSRC, together with NERC, the Natural History Museum, Kew Gardens and DEFRA, contributes to the UK subscription to the Global Biodiversity Information Facility (GBIF): www.gbif.org. Applications which will contribute to the delivery of the GBIF programmes DADI (data access and database interoperability) and ECAT (the electronic catalogue of the names of known organisms) are particularly welcomed.

Taxonomically 'intelligent' systems (also systems for evolutionary data)

Information held in databases may be difficult to compare and use effectively because of differences in taxonomy or nomenclature. Intelligent systems can compare the nomenclature used in each database (species names, synonyms, common names, etc) to identify data that relates to one species, even when represented by different names in different databases. Applications are sought which develop intelligent systems for dealing with taxonomic and evolutionary data.

Synthesising Biodiversity knowledge from distributed systems

Because biodiversity is researched worldwide, information about a species is held in various databases in numerous locations. Knowledge can be gained by combining the information from these different sources, but this requires interoperable systems that are capable of identifying and managing relevant data from different sources. Studies that aim to improve interoperability between databases are encouraged.