# Biodiversity, Ecology and Evolutionary Processes Stream

**Projects 2014/2015**

(1) **The role of human generations in the development of prehistoric societies**
Prof. Christopher Ramsey (Archaeology)

How do the rates of human adaptation, migration and development, relate to the changeover of human generations? Using new methods for generating high-resolution chronologies we can start to answer questions about the way prehistoric societies develop, and capacity of humans to adapt to change due to migration, environmental change or population growth.

(2) **Do animals diffuse nutrients over large spatial and temporal gradients?**
Dr. Chris Doughty (Geography)

Recent modelling efforts suggest that large animals play an important role in the global distribution of nutrients. These models use a novel mathematical framework to analyse the lateral transport of nutrients as a diffusion-like process and large animals were shown to play a disproportionately large role in the horizontal transfer of nutrients across landscapes. For example, the extinction of the Amazonian megafauna may have led to a >98% reduction in the lateral transfer flux of the limiting nutrient phosphorus (P) with similar, though less extreme, decreases in all continents outside of Africa. However, these studies must be verified with field data. This D. Phil. project would focus on testing the predictions of this model and there are a number of ways to potentially test these predictions. Further, we would like to quantify this ecosystem service animals provide and apply it to the improvement of conservation efforts. Empty forests are becoming more common as forests are preserved but hunting decimates the animals within. We want to apply and test the model to put an economic value on the animals existing within intact forests.

(3) **Citizen cyber-science: mobilising recreational biodiversity data**
Dr. Paul Jepson (Geography)

The goal of this project is to design and develop a platform to mobilise and capture bird occurrence data present in bird-watcher trip reports so as to produce a global network of sites with longitudinal data on bird species population and assembly trends. The research questions relate to the interplay of citizen science with new technologies and the potential opportunities this offers for addressing data paucity in biodiversity science, specifically, What are the points of connection between the 'culture' of nature-based recreations (e.g. bird-watching, angling, hunting) and biodiversity data needs for science and decision making? How can new technologies and associated practices (e.g. computer gaming) be employed and assembled to mobilise these connections such that the recreation/pastime will be enhanced and useful biodiversity data will flow?

(4) **The functioning of intact and human-modified tropical forests**
Prof. Yadvinder Mahli (Geography)

There is much interest in how sensitive or resilient tropical forests are to climate change, and in particular drought. The student will be part of a research group that is conducting pioneering research on the functioning of both intact and human-modified tropical forests around the world. The details of any DPhil project would be defined in discussion with the student, but are likely to entail a significant ecological or ecophysiological component of fieldwork in one or more tropical sites, and could also involve computational modelling of tropical forest environments, airborne and satellite remote sensing, and laboratory or field experiments. Potential field areas include Peru, Brazil, Ghana, Gabon, Ethiopia and Malaysia.

(5) **Biodiversity and rapid evolution of virulence**
Kayla King (Zoology) and Mike Bonsall (Zoology)

Community ecology theory predicts that species-rich communities are more resistant to invasion than species-poor communities. For foreign pathogens invading a host with a diverse microbiota, this opposition may drive rapid evolution of virulence. The project will test this idea by manipulating species-richness within a host gut microbiome and assessing the relationship between species richness and virulence evolution in pathogenic bacteria. Using *Caenorhabditis elegans* nematodes as model hosts, this project will involve experimental infections of bacterial pathogens and experimental evolution, combined with mathematical modelling.

(6) **Experimental Evolution of Mutualistic Cooperation of gut bacteria**
Kayla King (Zoology) and Stu West (Zoology)

How is cooperation maintained when it could potentially be exploited by 'free-loaders' that avoid the cost of cooperating whilst still benefiting from the cooperative behaviour of others? This project will test how selection for mutualistic cooperation is influenced by the way in which gut bacteria are transmitted between hosts.

(7) **Environmental control of life history in a UK butterfly**
Prof. Peter Holland (Zoology)

The Comma butterfly has a remarkable interaction with its environment. As a larva, it senses day length and adjusts development accordingly, at least in the south of the UK. The project will use molecular methods to probe the internal mechanism of this switch. A second goal is to unravel whether the butterfly has changed its response as it moved further north in recent decades. This will involve breeding experiments and analysis of survey data.

(8) **The role of magentoreception in 3D animal navigation**
Theresa Burt de Perera (Zoology)

The ability to navigate is fundamental to the survival of animals, allowing them to find food, escape predators and find their way home. Animals can use a number of different environmental cues to help them find their way; one of the most remarkable abilities that many possess is sensing the Earth's magnetic field. Magnetic compass orientation in the horizontal dimension has been demonstrated in all classes of vertebrates as well as in some invertebrates (reviewed in Wiltschko and Wiltschko 2005; Muheim 2006). However, as the magnetic field contains both vertical and horizontal components we propose that it could also have a role in 3D orientation in animals that fly or swim. The aim of this project is to use behavioural paradigms that have been used extensively in my lab, to test whether the magnetic field can provide 3D directional information to fish.

(9) **Interactions between local subsistence and global market economies in a rapidly changing North**
Thomas F. Thornton (Geography) and Richard Powell (Geography)

What new relationships are emerging between local/subsistence and global market economies in rapidly changing circumpolar environments and to what degree are they adaptive? This project seeks to understand and model these emerging social-ecological systems using interdisciplinary methods to assess their (natural and social) assets, risk, vulnerability, resilience and sustainability.

(10) **Reconceptualising Arctic Coasts in relation to Ecosystem Services**
Thomas F. Thornton (Geography) and Richard Powell (Geography)

How can coastal zones, the most productive, inhabited, dynamic, and vulnerable areas in a changing arctic, be best conceptualised for managing the social and environmental changes they face under climate change? Indigenous peoples (e.g. Inuit) conceptualisations of coastal zones and systems are quite detailed and built up in cultural models that recognise complex relationships between coastal processes, ecosystem services, and other constituent factors that shape their viability as habitats homelands. Using cognitive, GIS, ecological, and ethnographic methods, this project examines indigenous conceptualisations of the coastal land-sea interface through aboriginal geographic nomenclature and participatory mapping, historical-ecological development, and contemporary livelihood and use patterns in coastal zones in order to assess how understanding and management of these critical environments can be improved to sustain key ecosystem services that underpin local and regional cultures, economies and social-ecological systems.

(11) **Conservation biogeography and macroecology of fragmented landscapes**
Prof. Robert J. Whittaker (Geography)

The project will use a combination of primary field research alongside macroecological analysis of secondary data to address the biodiversity implications of habitat loss and fragmentation in the context of other changes in the landscape (e.g. land use intensity, non-native species). The aims will include addressing the lag-times inherent in ecological responses (e.g. estimation of extinction debts) and the implications of non-random assembly for biodiversity changes at aggregated scales of analysis.

(12) **Development and evaluation of the General Dynamic Theory of Oceanic Island Biogeography**
Prof. Robert J. Whittaker (Geography)

The General Dynamic Theory of Oceanic Island Biogeography offers an integrated framework combining a simple model of island ontogeny with the fundamental processes of migration, extinction and speciation, and can account for emergent biodiversity properties of hotspot island archipelagos. This project will aim to develop and evaluate the GDM at multiple scales within islands and across archipelagos, extending the scope of the theory to encompass non-native species, functional traits and (potentially) interaction networks. The project will rely largely on existing data sets but will also involve the collection of original data based on either field (sub-island scale tests of the GDM) or laboratory study (trait data).

**(13) Density-dependence as an agent of selection**

Tim Coulson (Zoology) and David MacDonald (Zoology)

A change in limiting factor can have both ecological and evolutionary consequences, neither of which is well understood. For example, as large carnivores become extinct from an ecosystem, populations of prey frequently increase in numbers until resource availability limits their population numbers. However, the ecological and evolutionary responses to such environmental change differ between different species, currently in unpredictable ways.

The student will use detailed individual-based data from free-living and laboratory populations where density has changed dramatically, along with recently developed statistical and modelling techniques, to explore the ecological and phenotypic consequences of a change in density. The initial focus will be on the extensive badger dataset of Wytham Wood. There will be the opportunity for the student to participate in fieldwork.

**(14) The evolution of $C_4$ photosynthesis**

Steven Kelly (Plant Sciences)

My research group is focused on the evolution of gene expression regulation. In particular, we are interested in how systems have evolved to regulate the expression of genes and how we can exploit these systems to manifest changes in organism phenotype. Though we now know much about the gene content of many different species, we know little about how these genes act co-ordinately to bring about the expression of phenotype. My research group utilizes both computational and laboratory based techniques to study gene regulatory systems and evolution. We have two core focus areas 1) the evolution of $C_4$ photosynthesis 2) and using evolution to help design biological systems for synthetic biology.

***Background: $C_4$ Photosynthesis***

Most plants fix atmospheric carbon dioxide into a three-carbon compound and are thus referred to as $C_3$ plants. In contrast, $C_4$ plants have evolved an alternative pathway in which the first product of photosynthesis is a four-carbon compound. Although this difference may seem trivial, the evolution of $C_4$ photosynthesis from ancestral $C_3$ photosynthesis involved multiple discrete changes to biochemistry, subcellular compartmentalisation and leaf anatomy. Remarkably, $C_4$ photosynthesis has evolved independently in over 60 different plant lineages and thus represents one of the most widespread examples of convergent evolution on earth. Compared with ancestral $C_3$ photosynthesis, $C_4$ photosynthesis confers increased productivity and thus international efforts have been mustered to introduce advantageous $C_4$ traits into important $C_3$ crops (such as rice and wheat) to increase their yield. This ambitious goal will require a fundamental understanding of the regulatory systems which control expression of $C_4$ associated genes. Moreover, it will require an understanding of how these regulatory systems have evolved from their $C_3$ ancestors.

Brief description of project:

**I am offering one project on the evolution of $C_4$ photosynthesis this could include (but is not limited to) any of the following 5 areas**

1) Identification of convergent gene expression changes in $C_4$ species.
2) Identification of convergent/parallel sequences changes in $C_4$ species.
3) Identification of convergent evolutionary changes in co-expression networks.
4) Nested hierarchical models for differential gene expression testing.
5) Bayesian empirical models for differential gene evolution testing.

### (15) Evolution of the postcranial skeleton and adaptation to aquatic life on the crocodilian stem lineage

Dr Roger Benson (Earth Sciences)

Anatomical study of marine crocodylomorph fossils in the University Museum of Natural History and globally will be used to constrain phylogenetic hypotheses of evolution on the crocodilian stem lineage over 200 million years. Models of morphological evolution will be used to quantify the roles of convergence and adaptive radiation in crocodylomorphs.

These questions will be addressed:
(1) How does the inclusion of data on postcranial anatomy influence hypotheses of crocodilian evolutionary relationships and evolution?
(2) Is there evidence for adaptive radiation, entailing early, rapid rates of evolutionary change, in locomotory adaptation of Mesozoic crocodylomorphs?
(3) Do distinct 'attractors' exist in the evolution of crocodylomorph postcranial evolution driving convergent evolution of distinct body plans?

### (16) Biodiversity, adaptive radiation and global cooling – the evolution of sand dollars

Dr Roger Benson (Earth Sciences)

Patterns of morphological evolution, species diversification/extinction, and climate change have generally been estimated from data on living taxa, or observed from fossil data. However, a better approach would combine fossil and living data to fully understand the evolutionary history of a group, and the nature of adaptive radiation in general. Diverse modern clades of invertebrates, such as echinoids (sea urchins) are well suited to these kinds of analyses because they often have rich fossil records.
In this project, a phylogeny of the Cenozoic radiation of sand dollars, including fossil taxa, will be constructed using morphological data. This will be used to analyse patterns of lineage diversification through time, using models that account for varying preservation of rock and facies that drive the availability of fossils to address the following questions:

(1) How does variation in the rock depositional record influence hypotheses of the evolution of biodiversity?
(2) What is the pattern of species diversification during the major evolutionary radiation of sand dollars?
(3) How did Cenozoic global cooling affect pattern of echinoid biodiversity?

### (17) The early evolution of marine turtles based on exceptional British fossils

Dr Roger Benson (Earth Sciences)

Living and fossil sea turtle (chelonioid) anatomy will be studied using museum specimens and CT scanning. This will allow holistic study of phylogeny and evolution, and of sensory anatomy, and functional morphology.

These questions will be addressed:
(1) How does the inclusion of morphological data on extinct and extant chelonioids influence phylogenetic inference?
(2) What information does the diversity of Cambridge Greensand and London Clay turtles provide on the early chelonioid radiation, and its importance in Cretaceous and Cenozoic marine faunas?
(3) How was the unique underwater hearing anatomy of turtles assembled during their early evolution?

(18) **Drivers of local diversity in plant communities**

Lindsay Turnbull and Nicholas Harberd (Plant Sciences)

One key question in community ecology is how do many similar species coexist at small spatial scales? One commonly-cited hypothesis is that spatial variation in the physical environment is key to maintaining diversity, because different species specialise on different patch types, but it's very hard to quantify this effect and its implications for diversity in natural communities.

In this project we will use 'artificial' communities consisting of hundreds of genotypes of *Arabidopsis thaliana* to seed landscapes that differ in their spatial structure. Arabidopsis is 'rapid-cycling', meaning that in about 2 months an entire generation is complete, allowing us to conduct multi-generational community experiments comfortably within a PhD time-frame. A greenhouse setting will also allow us to manipulate dispersal distances and the patch structure of the environment.

We will investigate how 1) initial trait diversity, 2) landscape heterogeneity and 3) dispersal mode, influence final genetic and phenotypic diversity, shedding light on the relative contributions of these three factors to local diversity.