Module L1 - Plant genomes and synthetic biology

**Coordinators:** Prof Sir David Baulcombe and Dr Ian Henderson

**Contact details:** irh25@cam.ac.uk

**Teaching Staff:** David Baulcombe, Ian Henderson, Jim Haseloff and Krys Kelly

Dobzhansky said in 1973 that “nothing in biology makes sense except in the light of evolution”. In 2015 he might have gone on to point out that “genomes reflect evolution and so we can make sense of biology by studying genomes”. He would be able to make this point because, from next generation sequencing and other powerful new methods, we now appreciate that nuclear genomes are much more than a linear array of coding sequence genes. They are a complex array of structural and regulatory components interspersed with genes for both coding and non-coding RNAs. Genomes are not linear: they are assembled into chromatin with several layers of organization in three dimensions and they are highly dynamic due to frequent whole genome duplications and more localized rearrangements. Superimposed on these genetic features there are heritable “epigenetic” effects that are independent of DNA sequence.

The aim of this module is to introduce recent progress in the understanding of plant biology in the context of their genomes and to provide hands-on experience with next generation sequence analysis. In the lectures you will hear about:

- how the dynamic nature of plant genomes has permitted the extraordinary diversity of flowering plants (Darwin’s abominable mystery)
- how genome integrity is protected against the effects of mobile “selfish” DNA
- how the genome can retain memory of its previous environment and whether there may be some truth in Lamarckianism
- why hybrids can be more vigorous than their parents
- asexual reproduction and why it frustrated Mendel
- how new genes evolve
- emerging genomic technology, including genome editing and epigenetic modification and whether or not these methods are GM
- intercellular movement of RNA that affects gene silencing at the RNA and chromatin levels
- the evolution of crops and modern plant breeding
- recombination of plant genomes and the influence of sequence motifs and chromatin states on crossover hotspots.
- functional genomics – assigning function to each of the 30,000 genes in a typical higher plant genome
- synthetic biology and what it means for plants and microbes

Recent articles and reviews will be used to illustrate concepts and principles in lectures and you will critically assess key papers in journal club supervisions. In addition, through a series of three computational workshops you will get hands-on experience of assembling genomes, analyzing differential RNA expression and phylogenetic analysis using next-generation sequencing data. The module content illustrates why (plant) biology is being transformed through the understanding of (plant) genomes. It is suitable for those interested in research and technology development related to crops, industrial biotechnology of plants or the societal impact of plant biology as well as those with a basic science interest in plants and plant evolution.
Module L2 - Responses to global change

Coordinator: Dr Edmund Tanner

Contact details: evt1@cam.ac.uk

Teaching Staff: Edmund Tanner, Peter Carey, Andrew Friend, Mike Harfoot, James Pearce-Higgins, Howard Griffiths, and Andrew Tanentzap.

This is an interdepartmental module also available to Part II Zoology students

Temperatures are rising, rainfall patterns are changing, nitrogen, phosphorus and salinity are all increasing – in short, we have never seen such changes in the history of humans.

Understanding what is happening, and why, will allow us to respond to these changes, potentially making a huge difference to what survives and how we humans live. This course explores changes in birds, plants, their physical environment, and then shows modelling approaches to predict the future. A range of experts with different perspectives deliver the course: James Pearce-Higgins, who works at the British Trust for Ornithology; Peter Carey, an environment consultant with much experience in evaluating biodiversity and assessing the impact of climate change; Ed Tanner (tropical forest dynamics); Howard Griffiths (impact of climatic extremes and drought tolerance); Andrew Tanentzap (global limits to growth and change), Mike Harfoot (biodiversity models) and Andrew Friend (earth-atmosphere dynamics models).
Module L3 - Frontiers in plant metabolism: A focus on food and fuel security

Coordinator: Prof Julian Hibberd

Contact details: jmh65@cam.ac.uk

Teaching Staff: Julian Hibberd, Alison Smith, Paul Dupree, Johnathan Napier (Rothamsted Research) and others

This is a joint module with Part II Biochemistry

Understanding plant metabolism informs our production of food, fuel and many high-value products. Modifying these metabolic pathways therefore provides the opportunity to contribute to more productive and sustainable societies. However, the complexity of metabolic systems leads to major intellectual challenges, both in terms of understanding but also in manipulating each system. We will address:

- Sustainable biofuels - the metabolism underpinning lipid, carbohydrate and plant cell wall components for biofuel production along with prospects for manipulating these pathways will be presented.

- Food for the future: C₄ photosynthesis allows ~50% increase in productivity. Despite being highly complex, it has multiple evolutionary origins. Mechanisms that control induction of the C₄ pathway will be discussed.

- Herbicides and high-value secondary products. The biosynthesis of high-value products including vitamins, aromatic compounds and isoprenoids from sustainable platforms will be covered.

In all cases, evidence from studies of gene expression, regulation of metabolism and compartmentation within cells will be integrated. As part of this module we run a workshop in which answers to past examination questions are marked, discussed and critically compared. The aim is for this process to improve your ability to generate high quality answers in the examinations.

Efforts to grow algae on a large scale for high value products such as β-carotene, or biomass for fuel production, require understanding of the biosynthetic pathway's involved.