Module PLL1 - Plant genomes and synthetic biology

Organisers: Dr. Ian Henderson

Contact details: irh25@cam.ac.uk

Teaching Staff: *David Baulcombe, Ian Henderson, Jim Haseloff, Sebastian Andreuzza, Sarah Lopez-Gomollon and Cristobal Uauy, Claudia Martinho.*

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 PLL2 - Responses to global change

Organiser: Prof. Howard Griffiths

Contact details: hg230@cam.ac.uk

Teaching Staff: *Howard Griffiths, Wanne Kromdijk, Mike Harfoot, James Pearce-Higgins, Nik Cunniffe, Andrew Tanentzap and Lynn Dicks.*

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

Global temperature is on the increase, extreme climatic events are increasing, and the sustainability of agricultural land use and vegetation cover is being challenged; pest and pathogen impacts are exacerbated in a warming world and their spread accelerated by human interactions. The scientific challenges underpinning these dramatic changes, and our collective response, will shape your future, and that of a growing global population. The module provides a generic background to climate change adaptation and mitigation, before considering a succession of timely issues in depth.

- Global limits to growth: planetary boundary layers and their impacts in key areas of water resources, ecosystem fertilisation and greenhouse gas emissions (Andrew Tanentzap)
- Impacts of seasonality and phenological mismatch on bird population dynamics in a changing world and development of appropriate conservation practices (James Pearce-Higgins, British Trust for Ornithology)
- Forests on the edge: combined impacts drought, fire and pestilence threaten carbon sequestration whilst sustainable water use is required for crop growth around the world (Howard Griffiths)
- Use of modelling to scale physiological limitations on plant growth from leaf, via canopy, to ecosystem (Wanne Kromdijk)
- Modelling epidemiology and plant pathogen distribution in a changing world (Nik Cunniffe)
- The “Madingley Model” of ecosystems and biodiversity: development of policy from projections of biodiversity change under different scenarios of human development (Mike Harfoot, UNEP-WCMC)
- Evidence-based analyses of insect declines and invasive species: how should society respond to the need for sustainability in the face of climate change? (Lynn Dicks)



Module PLL3 - Exploiting Plant Metabolism

Organiser: 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: Enhancing photosynthesis can increase yield and therefore contribute to food security. Ways that this can be achieved will be discussed, with an emphasis on C4 photosynthesis, which allows ~50% increase in productivity.

- High-value products. The biosynthesis of high-value products including vitamins, aromatic compounds, and isoprenoids from sustainable platforms will be covered, as well as approaches to metabolic engineering.

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 pathways involved.