

NST Part II Genetics

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What is Genetics?

Genetics is the most fundamental of the biological sciences – it underpins all of biology and all biomedical research. It is the core discipline for understanding that grandest of phenomena – evolution - and, as the famous evolutionist Dobzhansky once said, 'Nothing in biology makes sense except in the context of evolution'

Sydney Brenner, who was awarded a Nobel prize in 2002 for his work on *C.elegans*, predicted 'Genetics will disappear as a separate science because, in the 21st century, everything in biology will become gene-based, and every biologist will become a geneticist' [*Trends in Genetics* 9:104, 1993].

Modern genetics encompasses an enormous diversity of topics. These can be divided into two broad categories: function, how the genetic blueprint operates during the lifetime of an organism; and evolution, how the genetic systems we see today have come about.

Function can be studied at many levels. At the level of the genome, we are interested in how DNA is copied, transcribed and repaired, how genes work and how chromosomes are organised. During development, we would like to know how groups of genes work together to orchestrate cell division and differentiation. The end-product is an adult organism whose behaviour, physiology, morphology and ecology are determined by a complex interaction between the environment and the genes it carries. Disentangling the effects of genes and environment is a further area of interest.

All organisms are the product of **evolution**. To understand the overall biology of an organism we must appreciate both the evolutionary steps that shaped it and the forces that are acting to change or maintain it now.

Sydney Brenner's prediction has proved to be largely correct, with genetics one of the most important disciplines in both the basic and biomedical sciences today. Several other Part II courses cover some aspects of genetics, but we offer a broad grounding in the subject, which will equip you for a wide range of careers, both in and outside science.

'Genetics is the most exciting subject to study. It was so 40 years ago when I started, and it is even more so now, a time when the complete genomic sequences of organisms for bacteria to humans are being made available' *Professor Michael Ashburner FRS*

The Genetics Department and the Part II Class



As a Department, Genetics is small, friendly and has a much less formal atmosphere than many larger Departments. Final year students become integrated into the life and work of the Department and interact daily with the academic staff. Our Part II class has averaged about 30 students for the past few years - small enough for the entire class to know each other and the staff and large enough to make an impact on the Department. The familiar atmosphere of the Department gives students easy access to staff and arranging supervisions, or more informal meetings, is straightforward.

A large ground floor seminar room is set aside for the use of the Part II course, and our first floor library is shared among all members of the Department - although the majority of users at any one time are usually Part II students. The library has a wide range of books and journals, and computer links to the necessary e-resources. These facilities allow students to ensconce themselves in the Department during the day. The departmental tea room is shared by all members of the department, including of course Part II students, and this encourages a sense of belonging and familiarity.

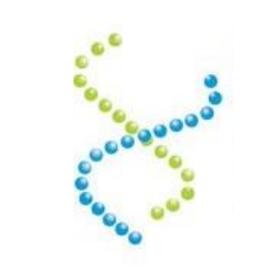
The Department houses a wide spectrum of interests, with a common theme being the application of genetic tools to the understanding of biological problems. Areas of interest include cell and chromosome biology, epigenetic inheritance, mammalian developmental biology, insect and worm development and neurobiology, plant development, microbial genetics, functional genomics and systems biology, and various aspects of evolution and population genetics. The breadth of interests of the Department means that it is possible to obtain tips and contacts in a wide range of research areas, which could help with your career planning. For more details, please see 'Research in the Department of Genetics' on page 19, or: <http://www.gen.cam.ac.uk/research-groups>

Part II teaching in Genetics during the COVID-19 pandemic

Due to the current pandemic, most in-person teaching has had to be suspended and sadly the 2020-21 Part II class, along with staff, have had only very limited access to the department. However, everyone involved in the course has worked hard to ensure that we continue to deliver first class teaching and support to our Part II students. Hopefully, normal life will resume in 2021-22.



Genetics Part II logo above designed by Luke Cahill (Part II 2011/12)



Students and staff enjoying previous summer events, dressing up, department outreach activities and Christmas party and Pantomime

Course aims and objectives

The Genetics Part II course aims to provide both a **broad overview** of the subject, and to give you an opportunity to study some selected areas **in depth**.

During the year, we aim to give you:

- A thorough grounding in the theoretical and practical foundations of basic genetics.
- An appreciation of the breadth of genetics; how genetics is applied in other disciplines.
- Detailed knowledge of selected areas.
- The chance to discuss and think about moral and ethical questions arising out of the applications of genetics to modern life, e.g. genetic counselling and CRISPR/Cas.
- Experience of research through a term-long project working within a research group.
- The ability to muster information about a topic, to critically assess it, and to communicate this information effectively in speech and writing.

What does the course entail?

The course is organised into **4 modules**, each being made up of ~24 lectures, accompanied by seminars or discussion sessions. These modules aim to cover the range of genetics from cellular to organism level, and will show how the latest developments in areas such as genome sequencing, functional and computational biology, and stem cells and organoid technology, are being applied to the problems of how genes in different species are organised, expressed and interact, to give the final phenotype.

There is no option system; instead you are encouraged to attend all the lectures, to ensure that you acquire the necessary breadth of background in the subject. Lectures generally take place at 9 am and 11 am, Monday to Friday, with 'extras' usually in the afternoons.

Teaching in the Department takes a variety of forms. Apart from lectures, we provide interactive seminars, examples and data handling classes, and journal clubs. We offer supervisions with teaching staff around the time of their lectures. You will also be assigned an Adviser within the Department, with whom you meet regularly, to support your progress during the year.

*Teaching in the
Department takes a
variety of forms*

In the Michaelmas term, you are offered sessions to help you make the transition to Part II, for example: sessions on essay writing, study skills, basic statistics and introductions to the online resources available via the UL and to bioinformatics [see page 12 – Extras]

You have an opportunity to show your individual worth through your research project, and the project oral presentation [see page 14]. You are also encouraged to submit regular essays or specimen answers throughout the year, on which you receive feedback. This practice is vital preparation for the exams.

NST Part II and Part II BBS

You can take Genetics as a single subject in Part II of the Natural Sciences Tripos. This route will automatically involve a research project. Alternatively, you can take Genetics as your major subject in Part II Biological and Biomedical Sciences, or you can take a single Genetics module as a Part II BBS minor subject:

Single subject Genetics in Part II NST (NST2GN)

You will do **all four modules** plus the module-linked problem solving and journal criticism sessions, and the SAG discussions. You will also undertake a **research project and linked literature review**.

Four paper subject in Part II BBS (414)

You **will take the four Genetics modules** (including module-linked journal and problem sessions), together with another one paper (your minor subject), and complete a **dissertation**. You can select your minor subject from the list of permissible options available. Students choosing the BBS route will have Genetics as their 'home' department, and have access to exactly the same facilities as single subject NST students.

One Genetics module taken as a Part II BBS Minor subject

Two of our modules are offered as Minor subjects to Part II BBS students who are not taking Major subject Genetics: **M2 Human Genetics, Genomics & Systems Biology** (120) and **M4 Evolutionary Genetics & Adaptation** (121). In addition to the lectures you will be expected to attend relevant journal and problem solving sessions for that module.

The Department also offers a stand-alone module in **Bioinformatics** (128) that is available as a minor subject to BBS students. More information about the Bioinformatics minor subject can be found here: <https://bioinfotraining.bio.cam.ac.uk/undergraduate>

BBS information can be found at : <http://www.biology.cam.ac.uk/undergrads/nst/bbs>

There is also a separate brochure for Part II BBS as a whole, from the Faculty of Biology.

MVST - Are you a Medic or a Vet?

In most years 20-50% of the class has comprised Medical and Veterinary students, so if you are concerned about your relative lack of subject background, there will be others in a similar situation. Access to appropriate Moodle Part I course sites is provided, and background reading suggestions are provided, prior to the course, to help you catch up.

See page 21 - 'Preparation and previous courses of study'.

Genetics in IA and IB

Lecturers from the Department of Genetics contribute to a variety of IA and IB courses, so you will probably have already encountered many of us at some stage in your degree course.

For example, in the following NST courses:

Biology of Cells (IA)

Lectures from: Dr David Summers (Hunting the Gene; Lent Term), Prof Steve Russell (The Genetic Revolution; Lent Term) and Dr Marisa Segal (Cell Proliferation; Lent Term).

Lent Term Practicals on fungal, bacterial and *Drosophila* genetics (introduced by Marco Geymonat).

Evolution & Behaviour (IA)

Lectures & practical from: Dr John Welch (Evolutionary Genetics & Adaptive Evolution in Populations; Michaelmas term)

Mathematical Biology (IA)

Lectures from: Dr Aylwyn Scally (Probability, genome sequencing and population genetics; Michaelmas Term).

Cell & Developmental Biology (IB)

Lectures from: Prof Eric Miska (Molecular biology of the nucleus; Michaelmas Term). Dr David Summers (Prokaryotic strategies; Michaelmas Term), Prof Alfonso Martinez Arias (Gene expression and cell decisions; Michaelmas Term), Dr Cahir O'Kane (Genome organisation and genomics; Michaelmas Term, plus Cell and organelle regulation, Lent Term), and Dr Marisa Segal (The eukaryotic cytoskeleton and mitotic cell division; Lent Term).

Practicals on stem cells (Martinez-Arias), on mobile elements in *Drosophila* from Dr O'Kane (both in the Michaelmas Term) and on the cytoskeleton from Dr Marisa Segal (Lent Term).

Evolution and Animal Diversity (IB)

Lectures from: Professor Frank Jiggins lectures (Genes, genomes and infectious disease; Lent term).

Or in the following MVST courses:

Molecules in Medical Science (MIMS) (IA)

Lectures from: Professor Eric Miska (Transcription, translation and control; Lent Term) and Professor Anne Ferguson-Smith (Genetics in human and animal medicine; Lent Term)

Human Reproduction (IB)

Lectures from: Dr Aylwyn Scally (Human genetics and whole genome association studies; Lent Term)

The Part II Modules

Michaelmas Term

- Module 1: Genomes, Chromosomes and the Cell Cycle
- Module 2: Human Genetics, Genomics & Systems Biology

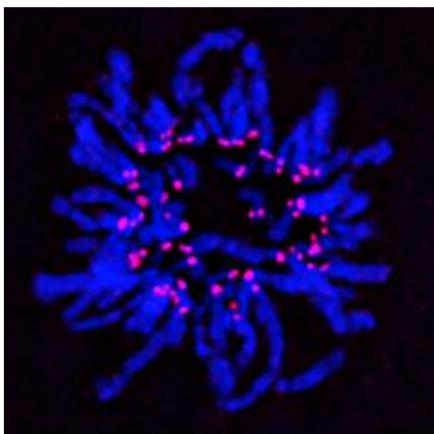
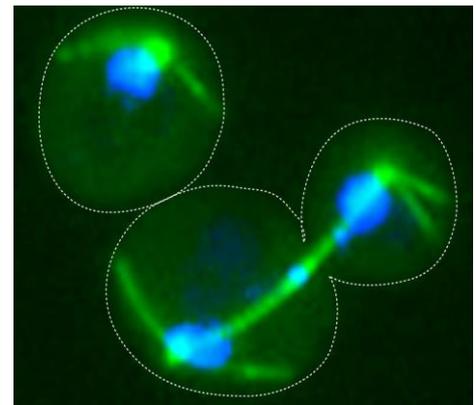
Lent Term

- Module 3: Developmental Genetics
- Module 4: Evolutionary Genetics & Adaptation

MODULE 1 – Genomes, Chromosomes and the Cell Cycle

This module will first focus on the control mechanisms that promote correct cell cycle progression and the accurate segregation of genes and chromosomes into daughter cells at cell division. We will also consider the special case of cells dividing asymmetrically and the molecular pathways accounting for spatial and temporal coupling.

Then we will explore how genomes are organised. We will examine histone modifications, chromatin structure and the organization of the eukaryotic chromosome in interphase. Topics discussed will include the contribution of liquid-liquid phase separation within the genome.



We will then examine the mechanisms for compaction in mitosis and two key functional elements: the centromere and telomere.

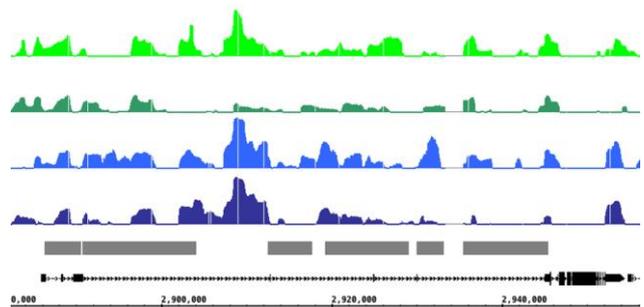
Finally, we will consider prokaryotic genomes and the “floating genome” of bacterial species (comprised of mobile elements including plasmids, transposable elements, integrons and conjugative transposons).

[Taught by: David Summers, Marco Geymonat, Marisa Segal, Christine Farr, Rosana Collepardo]

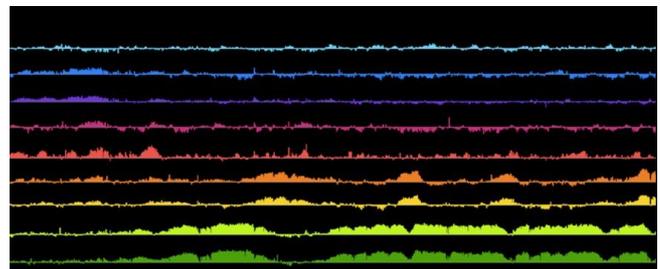
MODULE 2 - Human Genetics, Genomics & Systems Biology

This module will focus on human genetics, the genetic basis of human disease and the role genomics in tackling it. Although we can't experimentally modify the germline of humans in the same way as with model organisms, there is a long history of human genetics based both on the study of naturally occurring genetic variation, and on experiments in cells. Human genetics has always needed to exploit technology to obtain answers to the problems it poses. We will examine the sequencing technologies that underpin our ability to analyse genomes, the human genome and its organisation, and the role of repetitive DNA in the control of gene expression. We will explore how we deal with assembling genome sequence, sequence variation and rare disease genetics.

We will then move onto genetic approaches aimed at characterising other aspects of human variation, including genome-wide association studies, which lead to an understanding of the human genetic system. We will introduce the genomics approaches that underpin the functional analysis of genomes including the technologies for measuring gene expression, analysing transcription factor activity and chromatin states as well as an introduction to modern proteomics.



The module will also examine the role of imprinting in mammalian genetics and the increasingly important area of mitochondrial genetics. Finally, we will explore the application of gene therapy approaches to deal with human disease.



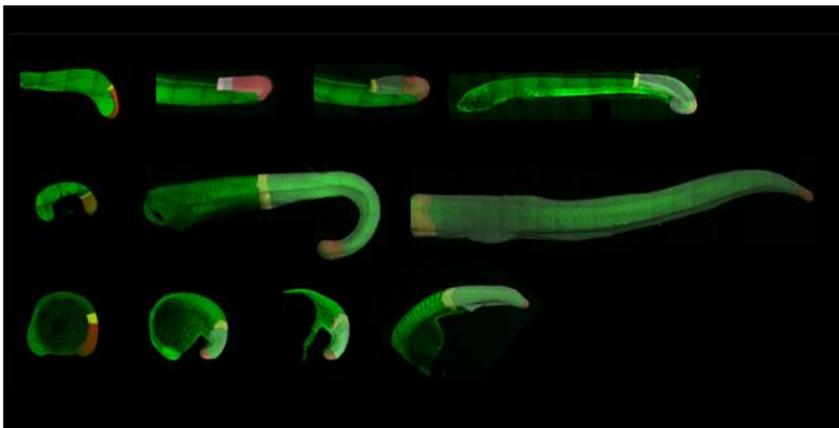
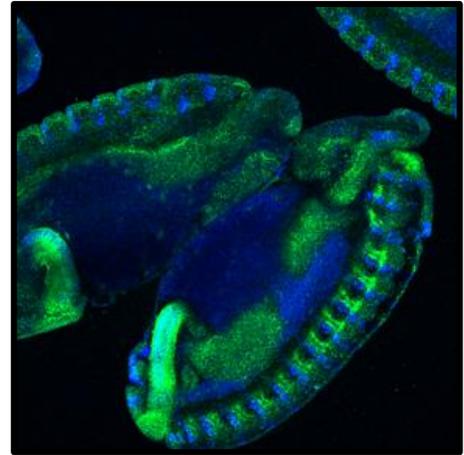
[Taught by: Steve Russell, Gos Micklem, Hansong Ma, Anne Ferguson-Smith, Michael Imbeault, Felix Day, Richard Durbin and Christine Farr]

MODULE 3 - Developmental Genetics

This module will cover the field of developmental genetics with an emphasis on how genetics is used to study cellular and molecular mechanisms of development and the genetic technologies used for addressing biological questions.

In the first part of the module the establishment of body axes and cell fate determination will be illustrated using *Drosophila* and *C.elegans*. Then the roles of small RNAs (such as miRNAs and the piRNA pathway), the development of the germ line, and the regulation of transposons will be examined.

Mouse development and the properties of stem cells and of organoids (advanced genetic tools allowing the study of mouse and human development) will be discussed.



Other topics covered will include the role of gene regulatory networks, transcriptional noise and cellular heterogeneity in development.

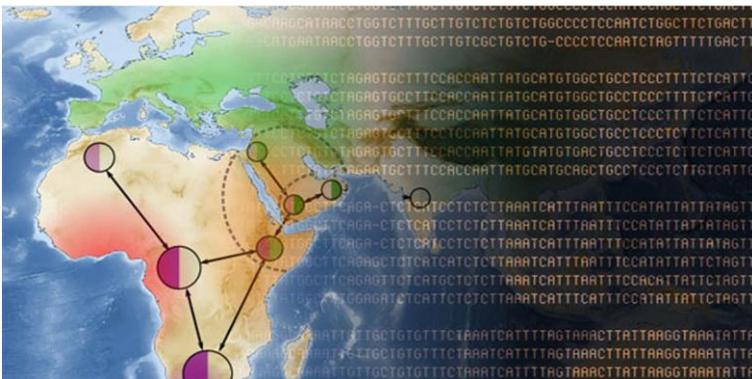
[Taught by: Julie Ahringer, Daniel St Johnston, Marta Shahbazi, Eric Miska, Ben Steventon, Felipe Karam-Teixeira]

MODULE 4 - Evolutionary Genetics & Adaptation

Modern evolutionary theory has its roots in the union of Mendelian genetics with Darwin's theory of evolution, two of the great unifying themes of biology. This course will consider the process of evolution from a genetic perspective, exploring the central topics of natural selection, adaptation and genetic drift, and combining a variety of empirical and theoretical approaches. Alongside this, the course will explore how genomes themselves are shaped by selection, drift and their evolutionary history.



The first half of the module will explore the genetic basis of adaptation. Do we expect evolutionary change to involve few or many genes, and how might we go about identifying the genes underlying a particular trait? What kinds of genes control evolutionary changes in morphological traits? We look at the genes underlying convergent evolution as a way of understanding the predictability of evolutionary change. Genomic data contain a wealth of information about the history of populations and natural selection, and population genetics provides a framework to reconstruct these processes. The final lectures in this section will show how mathematical models of population genetics can be used to describe and reconstruct the action of natural selection, genetic drift and mutation.



The second half of the module will look at the evolution of genomes and conflict within genomes. We will begin by considering one of the conundrums of evolutionary biology—why most species reproduce sexually—from a theoretical and empirical perspective. Sexual reproduction leads to conflicts between genes within the genomes, and we will explore its consequences for genome evolution. We will then examine the evolution of key features

of genomes—sex chromosomes, introns, repetitive DNA and gene expression. Finally, we will consider the evolution of quantitative traits that are controlled by many genes, and what constrains the evolution of these traits.

[This module is taught jointly by the Departments of Genetics (M4) & Zoology (ZL5): Frank Jiggins, Aylwyn Scally, John Welch, Chris Jiggins, Bill Amos, Nick Mundy, Emelia Santos, Lucy Weinert, Richard Durbin]

'Extras'

Social Aspects of Genetics (SAGs)

A series of interactive discussions, with invited speakers from the Sanger Institute, Addenbrooke's, and other sources. Topics include scientific fraud, "open research", medical ethics (e.g. issues surrounding gene therapy approaches and genome sequencing) and bioethics (e.g. genome editing technologies such as CRISPR), biofuels, antibiotic resistance, plant GMOs, and human diversity & race.

Michaelmas Term Information Sessions

Sessions will cover study skills (including essay writing workshops and information on plagiarism and how to avoid it). Introductions to bioinformatics and to statistics will be run, along with briefings on coursework preparation and the end-of-year examinations. In addition, there will be sessions outlining the PhD application process, and on careers in genetics.

Journal Sessions

Sessions are held for each Module, in which students learn to read, understand and criticise papers from the primary scientific literature.

Problem-solving/ Data-handling sessions

In these sessions, students work in groups solving genetics problems or interpreting experimental data. This forms vital practice for the exams, and indeed for any future career in a lab.



Computational practical sessions

In recognition of the need for more training in programming and bioinformatics, Module 2 will include an introduction to some of the computational approaches covered in the lectures.

Meetings with your Adviser

During the Michaelmas term you are encouraged to arrange weekly meetings with your assigned Adviser, who will answer any queries you have about the course and its organisation and will help sort out any problems that arise during the year.

Seminars

The Department runs two main seminar series, which Part IIs are encouraged to attend. One series is given by external speakers; and in the other series current Postgraduate students give a brief lunchtime presentation on their research.

Supervisions

Supervisions on the lecture material are provided by the lecturers themselves. Each lecturer will provide a list of times when they are available to give supervisions, together with possible essay titles and topics for discussion. We encourage you to submit essays to lecturers, who will provide you with feedback.

Revision Seminars

There is no formal teaching in the Easter Term, but revision seminars are organised for each Module, to allow you to ask questions about the aspects you don't feel you have understood, and to help with your preparation for the exams.

The Part II Examination

The examination for Genetics Part II (NST2GN) consists of five written papers, and a research project. There is also a brief oral examination, although this does not make a numerical contribution to the final mark.

Each module in the course will be examined by a separate 3 hr written paper in the final examination, so you can expect questions on Module 1 to be in Paper 1 and so on. Each paper will include both essay-based questions and questions designed to assess the skills acquired in the problem-solving component of the course and the journal sessions.

There is one additional paper, the Integrated Paper. This is a 2 hr paper and will contain a mix of broad-based questions designed to test your ability to integrate knowledge from across the course, as a whole.

If you are taking **NST Part II Genetics**, the current weightings of each part of the examination are:

Papers 1- 4 (16% each)	64%
Integrated Paper	10%
Research Project (a literature review, research project & report) <i>See the following pages for information about the project</i>	26%

If you are taking Genetics as **BBS Part II major subject** the current weightings of each part of the examination are:

Genetics Papers 1-4	64%
Minor Subject	16%
Dissertation <i>See page 17 for information about the dissertation</i>	20%

The Research Project

In the Lent Term each Part II Genetics student carries out an individual research project. This forms an important part of the course, and allows you to engage in your own research work within an established group in the Department. It gives you an opportunity to work alongside graduate students and post-doctoral scientists who are carrying out up-to-date work in the field, and to become familiar with the atmosphere of an experimental laboratory.



Each student selects a project from a list of options suggested by members of staff. Projects are chosen during October/November, which gives plenty of time to plan them before the beginning of Lent Term. Breeding experiments can be set up before the Christmas vacation if necessary, but no substantial commitment of time on the actual research is required before the New Year.

From mid-November and over the Christmas vacation you will be asked to write a review of the scientific literature in your chosen field.

Then your actual research will start at the beginning of the Lent term. Your findings are written up and the report handed in at the beginning of the Easter vacation.

As well as providing an exciting opportunity for you to demonstrate initiative and ability, the project gives you some idea of what research is really like.



Project Presentations

All students give a short oral presentation on their research project to the rest of the class, and a few of the lecturers. A chance to try to lecture better than the lecturers!

As well as providing an exciting opportunity for you to demonstrate initiative and ability, the project gives you some idea of what research is really like.

In the time available, exciting results can emerge: some projects have evolved into PhDs for the student concerned, and others have contributed to published scientific papers.

For example, Raag Agrawal [Part II 2018/19] contributed to :

Agrawal R, Prabakaran, S. : Big data in digital healthcare: lessons learnt and recommendations for general practice. **Heredity** (2020) 124(4) 525-534 doi: 10.1038/s41437-020-0303-2

... Mi Kieu Trinh [Part II 2018/19] contributed to :

Trinh MK, Wayland MT, Prabakaran S. : Behavioural analysis of single-celled asexual ciliate, *Stentor roeseli*, using machine learning approaches. **The Royal Society Interface** (2019) 16(161): 20190410. doi: 10.1098/rsif.2019.0410.

... Alistair Dunham [Part II 2015/16] contributed to :

Nene NR, **Dunham A**, Illingworth CJR : Inferring fitness effects from time-resolved sequence data with a delay-deterministic model. **Genetics** (2018) 209(1) 255-264. doi: 10.1534/genetics.118.300790.

... Tim Freeman [Part II 2014/5] contributed to :

Shaw C , Lonchamp J, Downing T, Imamura H, **Freeman T M**, Cotton J A, Sanders M, Blackburn G, Dujardin J C, Rijal S, Khanal B, Illingworth C J, Coombs G H, Carter K C. : In vitro selection of miltefosine resistance in promastigotes of *Leishmania donovani* from Nepal: Genomic and metabolomic characterization. **Molecular Microbiology** (2016) 99(6) 1134-48. doi: 10.1111/mmi.13291

... and Jessica Patel [Part II 2010/11; Part III 2011/12] contributed to :

Corrigan AM¹, Shrestha RL, Zulkipli I, Hiroi N, Liu Y, Tamura N, Yang B, **Patel J**, Funahashi A, Donald A, Draviam VM. : Automated tracking of mitotic spindle pole positions shows that LGN is required for spindle rotation but not orientation maintenance. **Cell Cycle** (2013) 12: 2643-2655

Examples of projects offered

- Deterministic and stochastic models for inferring fitness effects in viral populations
- A connectomics approach to study the role of novel neurons in sensory discrimination
- Bioinformatic identification and characterisation of KRAB-ZPPs transcripts and their isoforms in purified *ex vivo* mammalian cells
- Dissecting the C-terminal region of human Topoisomerase II α
- Determining the function of long non-coding NAs using Cas9/CRISPR genome editing
- Heat responsive transposon and its possible role in acclimation to heat stress
- Genomics of *Drosophila* Sox100B transcription factor
- Visualising single neurons that monitor activity in mushroom bodies (memory centre) of larval *Drosophila* – a Brainbow approach
- The role of Par-1 in polarising the cortex
- Genome reduction and pathogenicity in bacteria
- Indole signalling and antibiotic resistance
- Polarising the epithelial microtubule cytoskeleton
- Manipulating mother-daughter controls for asymmetric expression and age-sensitive protein mobility
- Comparing recombination maps in Pan genome sequence data
- Characterisation of cellular immune response in resistant and susceptible *Drosophila* lines to the parasitoid wasp *Leptopilina boulardi*
- Using micro-injection to down-regulate genes involving retro-element suppression in maize endosperm
- Viewing the axonal ER network in live *Drosophila* that are mutant for hereditary spastic paraplegia genes
- Optogenetic activation of modulatory neurons to test behavioural odour discrimination in *Drosophila* larvae
- Analysis of cell behaviour and gene expression during mouse ES cell differentiation
- Characterisation of Tem1 phosphorylation in the control of mitotic exit network and the spindle orientation checkpoint in yeast
- Investigating the molecular mechanism behind gene repression via a Retinoblastoma-like protein in *C. elegans*
- Identification of mammalian metastable epialleles

The COVID-19 pandemic has meant that opportunities for laboratory-based research are currently severely restricted for everyone. However, because research in Genetics is both laboratory-based and computational we have been able to offer an enormous range of "dry" research projects. This has allowed our 2020-21 Part IIs to gain experience in computational research skills that are in high demand and ensure that all project students complete exciting and highly rewarding research projects, despite current lockdown restrictions.

The BBS Dissertation

BBS students will have the chance to select a dissertation topic from a list circulated early in the Michaelmas term. All BBS students will have the chance to give a short oral presentation on their dissertation research to the rest of the Genetics class at the end of the Lent Term. Past topics have included:

- Bacterial persisters: molecular mechanisms and clinical management
- Can we assign a function to 80% of the DNA in the human genome?
- The biology of CRISPR/CAS systems and their uses in eukaryotic genome engineering
- How can genomic data be used to understand cancer evolution and to assist with cancer therapy?
- How does a cell make a decision to divide – or stop dividing?
- How have bdelloid rotifers avoided sex for so long?
- Discuss the concepts presented in C H Waddington's 1942 paper in *Nature* 'Canalisation of development and the inheritance of acquired characteristics'
- Transgenerational epigenetic inheritance in mammals - fact or fiction?
- Many human cancers are aneuploid. Yet aneuploidy has detrimental effects on human development and has been shown to reduce cellular fitness : Consider this conundrum
- Why do endosymbiotic bacteria have small genomes?
- Cell and gene therapy – the future of human monogenic disorders
- Have regulatory changes been more important for the evolution and divergence of species than changes in protein coding sequence?
- Discuss recent developments in the mechanistic understanding of cell size control

Social Aspects of Life in the Department

Research in Genetics Day

This one-day review of research in the Genetics Department takes place at the end of the Michaelmas Term. This informal meeting is an excellent way to appreciate who does what within the Department. Part II students are encouraged to attend.



The Christmas Party and Student Pantomime

At the end of the Michaelmas Term there is a Christmas Happy Hour, which traditionally includes a Panto, performed by the Part IIs. This could be your chance to not only demonstrate your thespian skills, but also to exact revenge on the academic staff who have tortured you in lectures! This Department can, shall we say, boast several members of staff who can easily be represented as compelling pantomime characters – and they love it! Old-timers maintain that the jibes have become

more barbed since exam scripts have become anonymous.

Happy Hour

On Friday evenings the Happy Hour Team invite everyone along for drinks and snacks.

The Garden Party

After the exam results are announced we hold a Garden Party; a chance to relax once the year's hard work is over, with champagne and strawberries.



Sadly, many of these events have had to be suspended, or moved online, for 2020-21. We hope that the social life of the department will be able to resume fully in the next academic year.

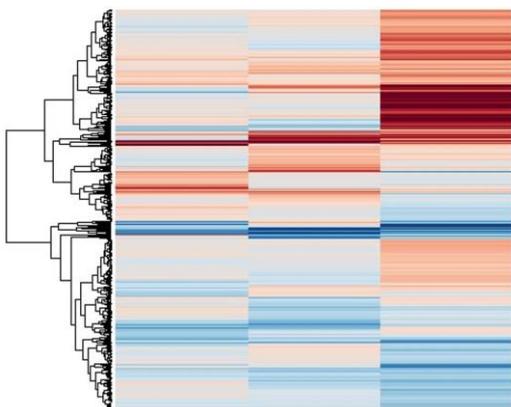
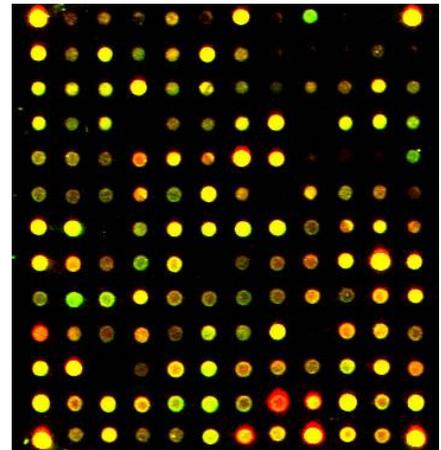
Research in the Department of Genetics

The range of research subjects in the Genetics Department is very broad, but it can be roughly divided into the 'themes' below. Of course, many Groups fit more than one 'theme'. This breadth benefits students in several ways. First, it means that the Department is well balanced between whole-organism and molecular approaches. Second, for those wishing to go on to research, there will almost certainly be someone with useful contacts, to help you get into almost any branch of genetic research. Each research group has its own web page, with more details about their work, accessed from: <http://www.gen.cam.ac.uk/research-groups>.

An * indicates a Group which is based outside the main Department building. Most are sited just across Tennis Court Road

Functional Genomics and Systems Biology

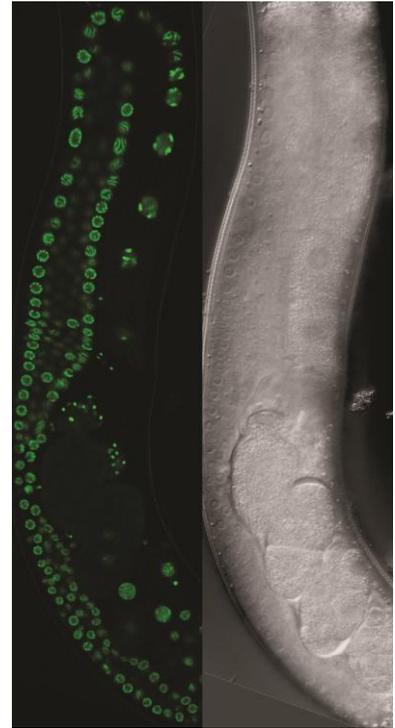
Professor Steve Russell. Steve's group is studying the function of the Sox family of transcriptional regulators during *Drosophila* embryonic development with a particular focus on the role the proteins play in the formation of the CNS. Along with classical genetics and developmental biology approaches, they are utilising modern functional genomics approaches such as microarray-based gene expression analysis and mapping of DNA-binding proteins.



Dr Gos Micklem. Gos is interested in using computational approaches to model biological systems, in particular using data from high throughput methods - such as gene expression microarrays - for functional and also comparative genomics. Wet lab work is directed towards generating data for building and testing models, together with development of technology to enrich mRNA from specific cell populations of interest within *Drosophila*.

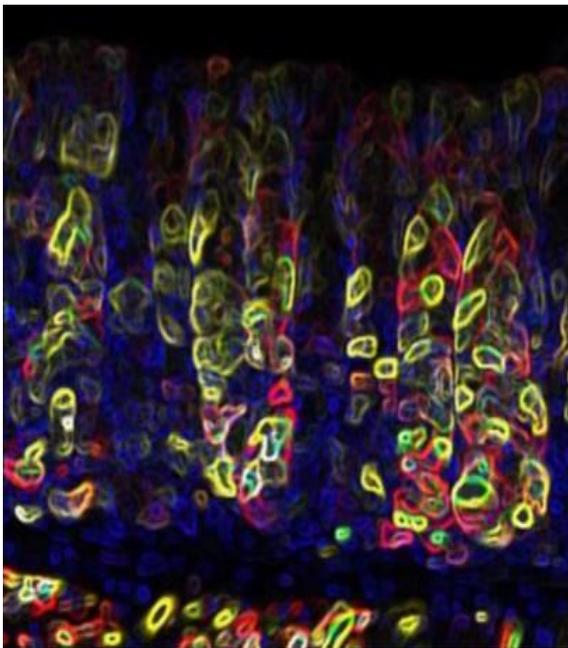
Developmental Biology

Professor Julie Ahringer *. Julie's group is interested in how the right type of cell forms in the right place in embryonic development, using the nematode *Caenorhabditis elegans* as a model system. Her group uses a wide range of techniques to study the genes involved (genetics, microscopy, molecular biology, transgenesis, RNAi etc) and is aided by the worm's short life cycle (3 days) and the availability of the complete genome sequence. Another reason that Julie and her colleagues study *C. elegans* is because it's beautiful!



Professor Daniel St Johnston FRS *. Daniel makes fruitfly larvae with no heads or no abdomens, or in some cases, two heads or two abdomens. He studies the mechanisms involved in localisation in the egg of maternal determinants such as bicoid RNA, which control embryonic pattern formation. He uses *Drosophila* as a model system to investigate intracellular transport and the origin of anterior-posterior polarity. Daniel himself has a normal complement of body parts.

Dr Ben Steventon. Ben's research interest is in comparative developmental dynamics. He is studying how self-renewal and differentiation, precisely balanced within stem cell populations, generates well-proportioned tissues during development and growth.

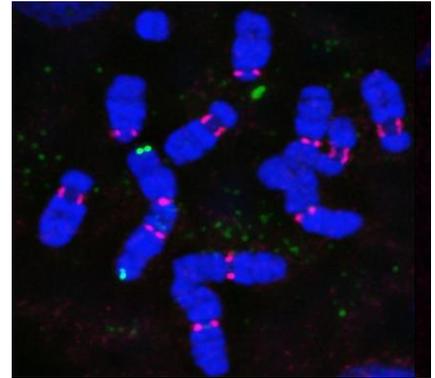


Dr Felipe Karam Teixeira. Felipe's interest is the development of the germline, the 'immortal' cell lineage that provides the continuity of life. In particular, he is interested in the genetic and molecular mechanisms controlling germline stem cell behavior and protecting totipotency, using the *Drosophila* ovary as a model system.

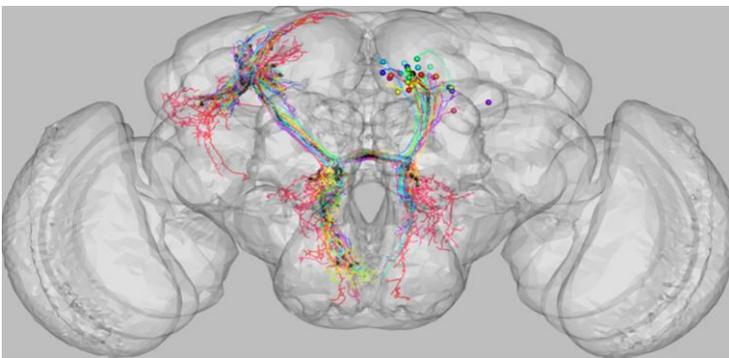
Dr Edwige Moyroud *. Edwige investigates the mechanisms of pattern formation on the petals of flowering plants. These patterns play crucial roles in both pollinator attraction and in pollen protection against UV damage. They also represent striking examples of evolutionary diversification by natural selection. Her group combines a range of genetics and developmental biology approaches with novel imaging, modelling and phylogenomic tools.

Chromosomes and Cell Biology

Dr Christine Farr. Christine's research focuses on centromeres and telomeres. Her lab has created vertebrate cell lines mutated for various chromosomally-associated proteins, as well as a series of human mini-chromosomes. These reagents are being used to study chromosome behaviour in mitosis.



Dr Rosana Colleparido. Rosana's research focuses on understanding DNA packaging inside cells using approaches that bridge genetics, theoretical chemistry and physics. She develops and applies multi-scale computational models to investigate the structure of the genome at the nanoscale level.



Dr Liria Masuda-Kakagawa. Liria is interested in brains and is using *Drosophila* to investigate the circuitry of odour discrimination and olfactory memory formation.

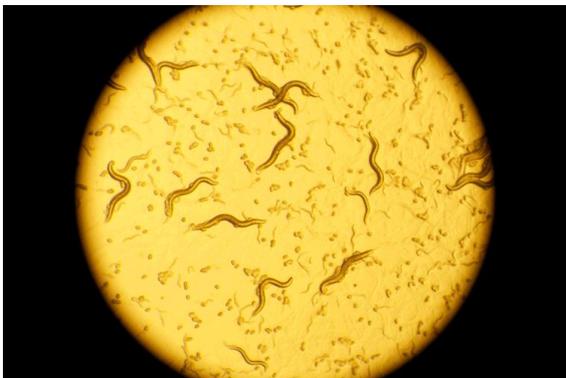
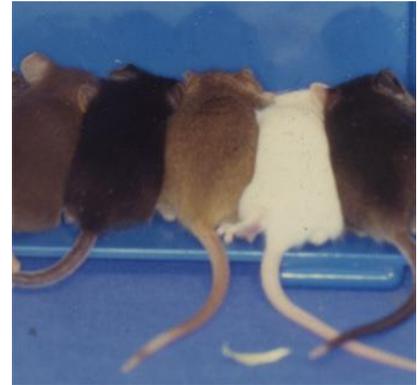
Dr Cahir O'Kane. Cahir studies how neurons work and how they go wrong during neurodegeneration in *Drosophila*.

Of particular interest are the processes that organise and traffic membranes, both pre-and post-synaptically. At this level, flies are about as smart as we are.

Dr Hansong Ma * Hansong is interested in that other genome – the one packed inside the mitochondrion. She is using *Drosophila* to study how mtDNA mutations are inherited and how different mutations contribute to longevity and fertility.

Epigenetic Inheritance

Professor Anne Ferguson-Smith FRS. Using mouse genetic models, the Ferguson-Smith lab studies the genetic and epigenetic control of developmental processes including stem cells, and the epigenetic control of genome function. The research combines both experimental and bioinformatics approaches to understand the link between genome and epigenome and the impact that this has on normal and abnormal development and physiology in tissues and in the whole organism.



Professor Eric Miska *. The Miska group studies microRNAs (miRNAs) and other short RNA species, using *C.elegans* as their model organism. Approximately 3% of all known human genes encode miRNAs and important functions in animal development and physiology are emerging, with some directly implicated in human disease.

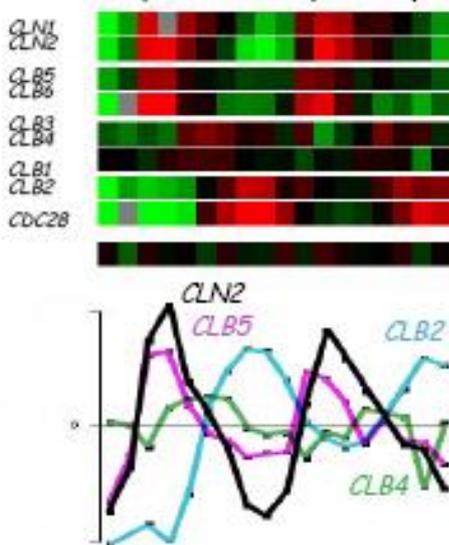
Dr Michael Imbeault. Michael is interested in the impact of transposable elements on mammalian genomes. Using a mix of bioinformatic and molecular biology approaches his group is delving into how TEs, and DNA binding proteins that interact with them, contribute to disease risk factors and other complex traits.

Microbial Genetics

Dr David Summers. Bacterial plasmids are sophisticated parasites. David's group studies two aspects of their life story: multimer resolution and bacterial cell cycle control. The lab discovered that ColE1 controls *E. coli* cell division so that the cell cannot divide until the plasmid is ready. It achieves this by stimulating production of a signalling molecule (indole) whose mechanism of action is the subject of current research. The group is also interested in the expression of foreign proteins and metabolites in bacterial cell factories and has developed a novel expression system where proteins are made in non-growing "quiescent" *E. coli*.



Dr Marisa Segal. Marisa's group uses the yeast *S. cerevisiae* to explore the mechanisms coupling mitotic spindle orientation with cell polarity, processes critical for the fidelity of chromosomal segregation and cell division. The principles emerging from these studies can be extended to learn how spindle orientation is controlled throughout metazoan development to generate cell diversity.



Dr Marco Geymonat. Marco is a big fan of yeast and is using genetics, biochemistry and microscopy in budding yeast to study the mitotic exit network.

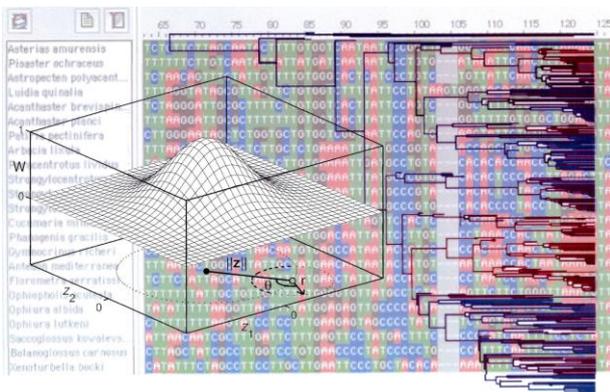
Dr John Archer *. A key challenge in understanding the genetic content and species composition of microbial habitats is the difficulty of culturing diverse fastidious microorganisms in pure culture in the laboratory. John is applying metagenomics to capture the microbial population DNA sequence content of given environments. Such approaches have applications in environmental, biotechnological and medical sciences.

Evolution and Population Genetics

Professor Frank Jiggins. Using insects as a model system, Frank's Lab is studying the evolution of hosts and parasites. A combination of population, quantitative and molecular genetics is being used to address the genes that cause variation in susceptibility to infection, the evolutionary processes that maintain this variation in populations and how coevolution with parasites has shaped the insect immune system.



Dr John Welch. John's research focuses on the processes that shape DNA sequence variation within and between populations. Ongoing research projects involve quantifying the contribution of natural selection to genomic change, inferring specific selection pressures that were faced by natural populations, and identifying the general conditions that promote or hinder an adaptive response.



Dr Aylwyn Scally. Aylwyn's research focuses on the evolution of populations and species, using computational analyses of large-scale genome sequence data. His particular interest is in human and primate evolution, but the methods and approaches involved in evolutionary genomics are applicable to organisms across the tree of life.

Professor Richard Durbin FRS. The focus of the Durbin group is sequence-based analysis of genetic variation and genome evolution. Their computational research projects encompass a broad range of organisms, including ancient and modern human DNA samples, induced pluripotent stem cells and cichlid fishes.

Dr Henrik Salje. Henrik's research is on applied public health research, especially with regards to the spread of infectious pathogens. His work sits at the interface of mathematical modelling, genetics, population biology, big data, public health and field-based epidemiology. His group has recently published findings highlighting the age-specific mortality and immunity patterns of SARS-CoV-2.

Beyond Part II

Part II Genetics offers a challenging, rewarding and socially enjoyable course, which combines whole organism biology and molecular studies effectively to provide a step towards a successful career.

Many in the Part II class will progress to PhD positions in Cambridge and elsewhere. This is normally the best option for an eventual career in either pure research (e.g. in a university or research institute), or industrial research (e.g. in a biotechnology or pharmaceutical company). There are prospects for research positions in both 'pure' areas such as cell biology, genome analysis, evolutionary and population biology, and more 'applied' areas such as agricultural and medical genetics, biotechnology, and genetic applications to environmental problems. Where funding is tight a background in genetics may give prospective candidates an edge. A PhD might for example lead on to a career in bench science, academic or industrial research, science administration and management, working in an advisory capacity, or publishing and disseminating scientific information.

Employment prospects are good for Cambridge graduates in general. Part II Genetics provides an excellent training also for those not wishing to continue in 'front-line' science. Many employers are realising that they require people with a good background knowledge of genetics and a broad scientific training, even for jobs that do not involve bench science. Therefore, there are Part II geneticists doing well in traditional publishing, in the City, in the law, even accountancy!

Genetics is a booming subject that offers a wider range of job opportunities than many other areas of biology

Former Part II and PhD students from this department now hold significant scientific positions in the UK and world-wide: Oxford, Cambridge, the USA (Yale, California), and the Pacific rim (Singapore and Papua New Guinea). They often work as research group leaders for companies such as Unilever, AstraZeneca, Novartis and GlaxoSmithKline. Some have joined Cambridge area 'Start Ups'. Other science-related destinations have included publishing (e.g. Benjamin Lewin, who founded the important journal, 'Cell') and venture capital consultancy.

Part III Systems Biology

For those interested in the Part III Systems Biology course, Part II Genetics offers an ideal platform by providing a comprehensive grounding in the basic methods underpinning genomics as well as an introduction to modelling approaches from a developmental biology perspective.

Feedback from former Part II students

Kane Toh [now in the Department, working on his PhD]

The Part II Genetics course gave me a thorough and critical knowledge of genetics. This is excellent as students of genetics are particularly well-equipped to enter different sub-disciplines in biology, since all fields in biology must intersect with the fundamental study of genetics. In terms of its atmosphere, the Genetics Department is really welcoming towards its small cohort of Part II students, and our unique pantomime tradition brings the class and the research community together. With the thorough syllabus, excellent teaching and vibrant atmosphere, I am proud to have chosen genetics as my Part II subject!

Katherine White

The small class size means that everyone knows each other and there's a feeling of belonging to a department that you don't get in Part I. The course itself is broad enough that you'll find something that you really love and goes into enough depth so that it's interesting. If that isn't enough for you then there's the fact that tea breaks are scheduled into the timetable and the fun of putting on a pantomime for Christmas!

Marianne Quigley

Part II Genetics definitely made my third year the most enjoyable of the three. The five modules divide up the different aspects of Genetics in a really comprehensive way ... We also had problem solving classes (useful for exams) and ethics classes, which helped put the information learnt in the course into a social context. The small class sizes really helped and meant that the lecturers could learn our names and faces and we felt like a valued group to the Department. The project in Lent term was definitely the highlight for me – it sounds a lot of work (and it is) but it allowed 'proper' scientific investigation with an active research group and the production of a report that could potentially be useful, in a small way, to scientific progress, which was really rewarding.

Sarah Jones

There is no denying that the Genetics course is extremely hectic, especially when you have to undertake a research project as well as keep up with all the lecture material, and it often feels as though there aren't enough hours in the day. However, due to the helpful atmosphere of the Department and the structure of the course, there is always enough support to help you through. Even if you do not want a career in science, the Genetics Department is a fantastic place to spend a year, and will hopefully provide you with some great memories!

Joe Laycock

Imagine yourself surrounded by desert with neither water nor sustenance. Hungry and thirsty you espy an oasis surrounded by a banquet of magnificent proportion. A mirage? Why no, this is Part II Genetics. An overflowing cornucopia awaits, ready to cater for every taste with a bounteous panoply of succour. Classical versus modern, genomics, cell cycle, development, evolution, plants; even the most ravenous of desires will be sated. Extended essays, projects and bio-informatics provide appetising introductions to some of the delicacies of modern genetics. Rich, succulent, alluring; come, eat, for none shall go hungry.

How to apply

All students are required to register their Departmental preferences on-line through CamSIS.

This booklet, together with our website (<https://www.gen.cam.ac.uk/undergraduate/genetics-for-pt1>) should provide the necessary background information about the Department of Genetics and our Part II course.

Students considering taking Part II Genetics are invited to join our live "Open Day" zoom session on **Thursday 18th March, 3:00 – 5 pm**, when there will be the opportunity to chat to teaching staff and current Part II students about the course:

<https://zoom.us/j/99552903119?pwd=VURKaFJZTDFPV0xQZUxVZ1ViK0VTdz09>

Meeting ID: 995 5290 3119 Passcode: CPd0KcDT6z

Information on the course will also be available in the Genetics folder on the **NST Part II Subjects Fair Moodle site**, which will be accessible from 1st March.

Preparation and previous courses of study

There are no compulsory prior courses or prerequisites for admission to Part II Genetics; we are looking above all for students with a genuine interest in genetics, who will get the most out of our stimulating course.

Part II Genetics students from the Natural Science Tripos will typically have taken courses such as Part IA Biology of Cells, IA Evolution & Behaviour, Part IB Cell & Developmental Biology, IB Ecology (now Evolution & Animal Diversity), or IB Biochemistry & Molecular Biology. Medical and veterinary students may also elect to take this course before proceeding to their clinical studies, and often form a significant proportion of the class. Students with a background in the physical sciences or mathematics have also done well in Part II Genetics in the past, and we welcome applications from such students.

For all incoming Part IIs who have not taken IA Biology of Cells, IA E&B and/or IB CDB, access is granted, during the long vacation, to the previous year's version of the Moodle sites for these courses, so that they can consult lecture notes and other posted material. The Department can also suggest material for directed reading prior to the course.

Vacation Research

Hands-on experience is an invaluable bonus when it comes to getting a foot in the door in research. The way that undergraduates, wanting to carry out summer vacation research in the UK, are funded has recently been reviewed and, while some support is available, opportunities are limited. Information on possible sources of funding and on how to apply can be found on our website at:

<http://www.gen.cam.ac.uk/undergraduate/vacation-research>

General bursaries – open to all students

- **Amgen Scholars' Programme**
<https://amgenscholars.bio.cam.ac.uk/>
- **Experience Postgrad Life Sciences**
<https://www.exppg.lifesci.cam.ac.uk/>
- **BBSRC Research Experience Placements**
<https://bbsrc.ukri.org/skills/investing-doctoral-training/research-experience-placements/>
- **Colleges:** Many colleges provide funds to support students wishing to broaden their experience by conducting research over the summer period.

Collated information about Undergrad funding can be found at :

<https://www.biology.cam.ac.uk/undergrads/InfoCurrentStudent/undergrad-fund>

Interested students should approach staff members directly to find out if they have vacation research opportunities and space available <http://www.gen.cam.ac.uk/research-groups>

The earlier you apply the better - some closing dates are as early as February.

For further information on the Part II Genetics Course:

- Visit our website : <https://www.gen.cam.ac.uk/undergraduate/genetics-for-pt1>
- Visit our folder on the NST2 Subjects Fair Moodle site
- Use the QR code below
- For general information about the course e-mail : undergrad.admin@gen.cam.ac.uk
- To contact the course organisers : ptIIorganisers@gen.cam.ac.uk



Several members of this Department lecture in IA and IB NST and MVST:

Prof Anne Ferguson-Smith, Prof Alfonso Martinez Arias, Prof Eric Miska, Dr Cahir O’Kane, Dr Aylwyn Scally, Dr Marisa Segal, Dr David Summers, Dr Marco Geymonat, Dr John Welch, Prof Steve Russell and Prof Frank Jiggins.

They can supply further information about the Department and the Part II course. All can be contacted by email at the generic address: first initial.surname@gen.cam.ac.uk (no spaces or apostrophes).