NST IA BIOLOGY OF CELLS: COURSE OUTLINES

Michaelmas Term

The Living Cell: Dr Helen Skaer (4 lectures)

The aim of these lectures is to introduce you to cells and their internal structure through the functions that they perform.

- **The concept of the cell:** Cell types and sizes; unicellular vs multicelluair; prokaryotic and eukaryotic cells.
- **Essential cell activities and the structures required for them:** maintaining integrity; the storage and flow of information and energy in cells; synthesis and delivery of materials; cell architecture and movement; dividing cells; interactions between cells and with the environment.
- **Ways of looking at cells:** light, fluorescence and electron microscopy; imaging techniques; genomics, proteomics and metabolomics.
- **Evolution of cells:** initial life forms and endosymbiotic theory.

Macromolecules in the Cell: Dr Helen Mott (5 lectures)

- **Macromolecules:** What are the major macromolecules in the cell and how can we understand their function?
- **Polysaccharides:** Introduction to stereochemistry. Common mono- di- and polysaccharides. Function of polysaccharides.
- **Nucleic Acids:** Building blocks of DNA and RNA. Structure of nucleic acids
- **Proteins:** Amino acids and the chemistry of the peptide bond. Primary structure of proteins. Methods of studying structure. Secondary structure of proteins. Three dimensional structure of globular proteins. Quaternary structure of proteins. Covalent bonds and non-covalent forces. Protein folding, misfolding and disease.
- **Proteins as enzymes:** The concept of catalysis. The basis for enzyme specificity. Classification of enzymes. Enzyme cofactors. Experimental determination of enzyme kinetics. How do enzymes work? Enzyme inhibition. Regulation and control of enzyme activity.

Membranes: Molecular Superstructures: Dr Julia Davies (5 lectures)

- **Membrane structure:** lipid bilayer. Phospholipids, glycolipids and sterols. Proteins: integral and peripheral.
- **Membrane function:** Barriers and compartmentation. Thermodynamics of transport processes. Translipid versus protein catalysed transport. Passive versus active transport. Primary active and solute-coupled transport. Introduction to membrane signalling.

The Chemistry of Life: Dr D Hanke and Dr Jules Griffin (10 lectures)

These lectures will deal with how cells extract energy from their environment, firstly by considering autotrophic growth, in particular photosynthesis, and then by the oxidation of foodstuffs.

The Chemistry of Life I: Dr David Hanke

- **Metabolic strategies:** where cells obtain their energy, and their carbon. The principles of redox potentials, and the transfer electrons from one compound to another compound with a higher affinity for the electrons.
- **Photosynthesis**: the mechanism of light absorption, and Photosystems. The transduction of light energy into ATP and NADPH via the photosynthetic electron transfer chain. Electron and hydrogen carriers. Arrangement in the thylakoid membrane. Formation of proton gradient.

- **Assimilation of carbon:** The fixation of carbon dioxide into sugars via the Calvin cycle, formation of starch and sucrose. Rubisco and photorespiration.

The Chemistry of Life II : Dr Jules Griffin

- **Thermodynamics:** An introduction to the basic concepts of thermodynamics and how this dictates the direction of a metabolic pathway in terms of changes in Gibbs free energy. A description of how cells couple a series of reactions together to get an energetically unfavourable process ‘to go’, for example during the synthesis of macromolecules.
- **Pathways responsible for the oxidation of foodstuffs:** The breakdown of polysaccharides via glycolysis, leads ultimately to the production of acetyl CoA. The breakdown of fats and proteins also results in acetyl CoA. This is oxidised completely to CO2 in the Citric Acid Cycle.
- **The Kinetics of food oxidation:** What is a metabolic pathway and how can we describe quantitatively the control of flux through a pathway; the regulation of pathways with special reference to the control of flux in glycolysis and the Citric acid cycle.

The Chemistry of Life III: Dr David Hanke

- **Amino acid biosynthesis:** the assimilation of inorganic nitrogen into organic combination. Formation of NADPH. Source of carbon skeletons for each of the amino acids.
- **Mitochondrial electron transfer chain:** Respiratory protein complexes. Arrangement in mitochondrial inner membrane and formation of proton gradient. Comparison to chloroplast photosynthetic electron transfer chain.
- **Synthesis of ATP:** How ATP is made in both chloroplasts and mitochondria from the proton gradient. Principles of Chemiosmosis, and evidence to support the theory. Universal nature of Chemiosmosis.

Lent Term

Hunting the Gene: Dr David Summers (7 lectures)

- **Early theories of inheritance:** from myth and magic through Ancient Greek philosophy to the mediaeval synthesis of science and theology.
- **Gregor Mendel's** experiments established the foundations of modern genetics. One factor and two-factor crosses: Mendel's conclusions. The chromosome theory of inheritance.
- **Challenging Mendel:** genetic linkage, sex linkage and variable dominance require modification and extension of the hypothesis. The development of genetic mapping. Linkage groups. Cytoplasmic inheritance: a new pattern of inheritance for genes in the mitochondria and chloroplasts.
- **Genetics of Prokaryotes.** Fine structure gene mapping: Benzer's analysis of the rII region in 'phage T4. Complementation testing and counting genes. Mechanisms of gene exchange in prokaryotes: transduction, conjugation and transformation. Restriction-modification systems: bacterial self-defence. The advent of gene cloning. Cloning vectors: uses of plasmid and phage vectors.

Genes in Action: Dr Martin Welch (6 lectures)

- **Nucleic acids.** Chemical structure of nucleic acids and the structure of chromatin. The mechanism of DNA replication in prokaryotes and eukaryotes. Mechanisms of DNA repair in prokaryotes and eukaryotes.

- **RNA replication**.
- **Mechanism of transcription and translation in prokaryotes.** Evidence for the nature of the genetic code.
- **Transcription and translation in eukaryotes.** Models for control of gene expression in prokaryotes and eukaryotes.

The Genetic Revolution: Dr Steve Russell (6 lectures)

- **Genomes, Gene Cloning & DNA Sequencing:** genome size & complexity, cloning & characterisation of dna, restriction mapping, nucleic acid hybridisation, pcr amplification, dna sequencing.
- **Genome sequencing & the Human Genome Project:** Sequencing genomes, microorganism genomes, model eukaryotes, human genome, annotating genome sequence, comparative genomics.
- **Chromosomes & Chromosome Biology:** Functional elements of chromosomes, repetitive DNA, DNA fingerprinting, gene families, unique sequence DNA, gene content.
- **The Genetics of Human Disease**: Meiotic defects and disease, the X-chromosome, autosomal genetics - Huntington's disease & sickle cell anaemia, mapping genes, RFLPs, SNPs.
- **Molecular Basis of Human Disease**: Tracing the defective gene - cystic fibrosis, subtractive cloning - muscular dystrophy, haplotypes, complex traits, linkage & association studies.
- **Genomic, Proteomics & Systems Biology:** Measuring gene expression, northern blotting, DNA microarrays, genomics and cancer, microarrays for DNA analysis, proteomics, identifying proteins, mass spectrometry, protein complexes, systems biology.

Cell Proliferation: Prof. Ron Laskey (5 lectures)

- **Cell proliferation:** Cell proliferation is the means of reproduction of unicellular organisms and the basis of growth and differentiation of multicellular organisms. It is also the basis of tissue renewal by an equilibrium between cell death and replacement. This course starts by surveying the patterns of cell proliferation in a wide range of organisms. It proceeds to examine how cells divide and the molecular controls of the cell division cycle.
- **Viruses:** One lecture considers the proliferation of the simplest organisms, viruses, and how viruses subvert the controls which govern host cell proliferation

- **The molecular biology of cancer:** Cell proliferation is tightly controlled. This is essential to establish the complex structures of animals and plants, and it is also essential for the maintenance of these structures once established. The occasional failure of control systems that regulate cell proliferation in animals and plants can result in unrestricted proliferation of the aberrant cell leading to cancer. In particular it considers the roles of genes called 'oncogenes' and 'tumour suppressor genes' which are directly involved in regulating cell proliferation.
- **Growth and duplication of cellular organelles** is considered in the final lecture.

Easter Term

Development: Professor Mike Bate (6 lectures)

- **Introduction, cleavage and fate maps:** The lectures begin by asking what species should one study in attempting to understand early embryonic development. They go on to describe how the egg divides to form a multicellular embryo, and how we can discover what the different cells eventually go on to form.
- **Determinants and induction:** The two most important ways in which cells in the embryo become different are through cytoplasmic determinants and embryonic induction. This lecture illustrates both mechanisms, using examples from the fruit fly *Drosophila* and the frog *Xenopus*.

- **Cloning and gene regulation:** Our ability to 'clone' animals reveals that genetic information is not lost from cells in the course of normal development. This lecture discusses the mechanisms by which different genes are activated in different cells, so that some might become muscle and others nerve.
- **Positional information and limb development:** There is a special kind of inductive interaction in which cells are provided with information about their position within the embryo, and then use this information to decide how to differentiate. This phenomenon is illustrated by referring to the development of the chick limb.
- **Homeosis and axis formation:** This lecture begins by discussing some remarkable mutations in *Drosophila*, in which one organ, such as the antenna, is transformed into another, such as the leg. The genes involved in these transformations are members of a complex, which is responsible for establishing the head-to-tail axis in both *Drosophila* and vertebrates.
- **Making patterns in plants:** Plant and animal embryos face similar problems in assembling themselves. In this lecture we see how genetic and cellular methods can begin to reveal the mechanisms underlying the patterning of plants.

Cell Signalling: Dr Alex Webb (6 lectures)

- **Classification and spatial organisation of cell communication mechanisms:** Introduction to cell communication. The types and range of signal molecules.
- **Signal reception and signal processing pathways**: Major components of signal transduction pathways and concepts of signal processing. The five major signalling pathways - steroid hormones, ion-channel linked receptors, cAMP pathway, phosphoinositide pathway and tyrosine kinase linked receptors.
- **Plant cell responses to light:** Plant cell processes influenced by light. Photoreceptors including phytochrome, cryptochrome and known elements of their signalling pathways.
- **Examples of cell communication pathways:** Bacterial chemotaxis, pheromones, hormones, neurotransmitters, cell surface molecules and intercellular messengers.