BYU11101: From Molecules to Cells I

Semester 1, 10 credits

Module Coordinator: Kevin Mitchell Email: kevin.mitchell@tcd.ie

Module Learning Aims

This module aims to introduce students to molecular and cellular biology, including key topics in Cell Biology, Biochemistry, Genetics and Microbiology. A description of the possible origin of life, from the abiotic world to single-celled and multicellular organisms is given, and the ultrastructure of the prokaryotic and eukaryotic cells is covered in detail. The properties and functions of the major classes of biochemicals found in living systems (carbohydrates, lipids, proteins and nucleic acids) are described, the structure and function of membranes and organelles, and the chemical basis of metabolism and energy transfer in the cell.

Students are introduced to basic concepts in Genetics, how the information contained in DNA (genes) is expressed, replicated and inherited. Finally, the sheer diversity of life forms, from viruses to prokaryotic and eukaryotic microorganisms, to more complex plant and animal life forms is described. Students also study cell and virus structure, cell growth and viral replication, agents of infectious diseases, and host immunity.

Learning Outcomes

On successful completion of the module, students will be able to:

- Provide an account of the cellular basis of life: from its origins in the abiotic world, to the evolution of unicellular and multicellular organisms.

- Describe the diversity of life forms: including viruses, prokaryotes (bacteria), archaea, and eukaryotes (unicellular organisms, animals and plants).

- Provide an account of the chemical basis of life and the biochemistry on which living systems depend: the properties and functions of the major classes of biomolecules, the structure and function of membranes and organelles, and the chemical basis of metabolism and energy transfer.

- Describe how the information contained in DNA (genes) directs the construction and growth of an organism, and how this information is replicated and transmitted from one generation to the next (inheritance; genetics).

- Employ a range of laboratory techniques, demonstrating the development of practical scientific skills, knowledge of experimental design and the interpretation of results.

- Apply the scientific method as a fundamental approach to experiment-based investigations, critical analysis of data, and problem solving.

Methods of Teaching and Learning / Contact Hours

Lectures and practicals will be supplemented with information sessions and activities that provide guidance in the use of library resources, laboratory health and safety, writing techniques, help with avoiding plagiarism and examination techniques. The module will be supported by a range of learning resources provided through a virtual learning environment. Sixty-five hours contact time.

Module Content

Lecture Topic	**Lecturer**	**Practicals**
Introduction and Overview	Kevin Mitchell	
Section 1 Origin of Life – Cellular basis of life – Diversity of Life Forms		
1. Introduction	Luke O'Neill	The Diversity of Life Forms
2. Origins of Life	Luke O'Neill	
3. Cellular Basis of Life 1	Fred Sheedy	Liquid Handling
4. Cellular Basis of Life 2	Fred Sheedy	
5. Cellular Basis of Life 3	Fred Sheedy	
6. The Tree of Life	Alastair Fleming	
7. Bacteria	Alastair Fleming	Bacterial Growth & Survival
8. Fungi & Protists	Alastair Fleming	
9. The Archaea	Alastair Fleming	
10. Viruses	Kim Roberts	Essay Writing Skills
Section 2 The Chemistry of Life		
11. Introduction to Biochemistry	Luke O'Neill	
12. Nucleotides, Amino Acids & Peptides	Ken Mok	
13. Protein Structure	Ken Mok	Chromatography of Biomolecules
14. Protein Function	Ken Mok	
15. Enzymes 1	Vincent Kelly	
16. Enzymes 2	Vincent Kelly	
17. Lipids & Membranes	Vincent Kelly	
18. Metabolism 1	Vincent Kelly	Enzyme Kinetics
19. Metabolism 2	Vincent Kelly	
20. Mitochondria & Respiration	Vincent Kelly	
21. Chloroplasts & Photosynthesis	Vincent Kelly	
Section 3 Biological Information – Genetics, Heredity & DNA		
22. Introduction to Genetics	Matt Campbell	Mendelian Genetics
23. Mendelian Genetics	Matt Campbell	
24. Linkage & Recombination	Matt Campbell	
25. Identification of DNA as Hereditary Material	Matt Campbell	
26. Quantitative Genetics	Matt Campbell	
27. DNA – Structure & Function	Kevin Mitchell	

28. Information Flow – The Central Dogma 1	Kevin Mitchell	
29. Information Flow – The Central Dogma 2	Kevin Mitchell	
30. Mutation & the Consequences	Kevin Mitchell	
Module Overview	Kevin Mitchell	

Lecture Content:

- **Origin of Life:** What is Life? How did it arise? The Origin of Life from a chemical and cellular perspective; the abiotic world; the prebiotic world; Miller-Urey experiment; the first cell; photosynthesis and oxygen – mass extinction; origin of first eukaryotic cell; multicellular life; cell specialization.
- **Cellular basis of life:** Cell structure – prokaryotes, archaea, eukaryotes – animal and plant organelles & their prokaryotic origin – mitochondria, chloroplasts, mitosis and meiosis – cell division – regulation of cell division.
- **Diversity of Microbial Life:** The tree of life; bacteria, archaea, fungi & protists, cell structure, morphology, function and habitat; extremophiles; viruses.
- **Relationship between life forms**: The good, the bad and the ugly; concepts of symbiosis and parasites; plant and animal diseases.
- **Structural principles for small molecules:** Elements and chemical groups in life, bonds, bond energies, bond lengths; forces between biological molecules and chemical groups; asymmetry; four classes of biomolecules: amino acids, nucleotides, carbohydrates & lipids.
- **Nucleotides, Amino acids and peptides**: DNA, RNA, chromatin and chromosome structure, properties of amino acids, chemical features and physical properties of the R-groups; the peptide unit and peptide bond.
- **Proteins and protein structure:** The concept that shape dictates function; hierarchical organization of protein structure; concept of primary, secondary, tertiary and quaternary structure; introduction to forces that stabilize protein structure.
- **Protein function**: Functional classes of protein; introduction to bioinformatics; proteins and evolution; relationships between proteins; similarity and identity.
- **Enzymes:** Structure & function; reaction mechanisms; co-factors and vitamins; kinetics; regulation of enzyme activity.
- **Lipids and membranes:** Lipid structures, fatty acids, phospholipids; membranes, chemical and physical properties, membrane proteins; transport across membranes; concept of compartmentation and membrane traffic.
- **Metabolism & major metabolic pathways:** The starting point: introduction to carbohydrates and fatty acids; organization, energetic principles, key steps and links between the main metabolic pathways; glycolysis, TCA cycle, beta oxidation; outline of the reversing catabolic pathways, gluconeogenesis and fatty acids synthesis.
- **Mitochondria & Respiration:** Mitochondria, redox reactions and energy transduction; electron transport and the electron transport chain; oxidative phosphorylation; coupling of oxidation to phosphorylation; chemiosmotic view of energy transduction (in brief).
- **Chloroplasts and Photosynthesis:** Chloroplast, architecture and function, overview of the light and dark reactions of photosynthesis.

- **Introduction to Genetics:** An outline of some core concepts from classical Genetics to the present; a whistle stop tour of key discoveries in the history of Genetics.
- **Mendelian Genetics**: Mendel's laws, the 1st law of segregation and the 2nd law of independent assortment using monohybrid and dihybrid crosses; concepts relating to genetic analysis and the use of model systems; inheritance patterns for single gene disorders – pedigree analysis.
- **Linkage and recombination:** Meiosis and the role of 'crossing over' in gene mapping; a brief recap regarding Mendelian genetics – for example, highlighting that genetic linkage breaks Mendel's 2nd law of independent assortment; outline of key concepts underlying the generation of genetic maps; classical work by Sturtevant / Morgan.
- **Identification of DNA as hereditary material:** Key experiments establishing DNA as the genetic material; bacterial transformation and its significance (Griffith / Avery, McLeod & McCarthy / Hershey-Chase); the concept of horizontal gene transfer (mechanisms transformation, conjugation, transduction); differences in vertical and horizontal gene transfer.
- **Quantitative Genetics:** An overview of concepts relating to discrete variation versus continuous variation; experiments demonstrating that quantitative traits are inherited, examples of quantitative traits in humans; concepts regarding the use of GWAS to elucidate the genetics architecture of complex traits using an example of one or more disorders.
- **DNA, Structure and Function:** The double helix – discovery of the structure of DNA – DNA composition – DNA replication – semi-conservative replication, replication forks, leading and lagging strand synthesis, DNA polymerases; DNA replication in prokaryotes and eukaryotes.
- **Information flow in the cell – The Central Dogma:** Transcription, RNA polymerases in prokaryotes and eukaryotes; promoters, repressors, terminators – the *lac* operon; transcription factors, enhancers; decoding the information in mRNA, translation; ribosomes in prokaryotes and eukaryotes, tRNAs and aminoacyl tRNA synthetases, the genetic code; introduction to the regulation of gene expression – positive and negative regulation.
- **DNA –Mutation and its consequences:** Mechanisms by which mutations are generated – including errors in DNA replication; the action of chemical and physical mutagens; errors in chromosome construction and distribution; an outline of the different types of mutation (missense, nonsense, frameshift mutations) and their molecular consequences in relation to gene expression and protein function; mutations causing inherited diseases and cancer; DNA repair – mechanisms of DNA repair, repair deficiency and disease.

Recommended Textbook:
Biology: A Global Approach, 12th Edition (Published by Pearson (2020)

Assessment Details:

(A) **End of semester examination: 50% of module mark**

(B) **Coursework: 50% of module mark.** Coursework includes compulsory attendance at laboratory sessions, assignments associated with practicals, an in-course essay and in-course tests of lecture material.

Students must obtain an overall module mark of 40% to pass the module.
A student who fails to attend more than one-third (1/3) of the practical sessions cannot pass the module without completion of a supplementary practical session, or an alternative exercise in the event that a practical is not possible.

Contacts:

Module Coordinator: Kevin Mitchell	kevin.mitchell@tcd.ie
Biology Course Coordinator: Glynis Robinson	robinsog@tcd.ie Phone: 01 8962895
Laboratory Manager: Audrey Carroll	aucarrol@tcd.ie Phone: 01 8961049
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BYU11102: Organisms to Ecosystems I

Semester 2, 10 credits

Module Coordinator: Trevor Hodkinson hodkinst@tcd.ie

Module Learning Aims

This module aims to introduce students to the biology of individuals, species, populations and ecosystems, and explore how humans interact with other living organisms. It covers the developmental biology of organisms, their physiology, brain function and the evolutionary and ecological responses of organisms to their environment.

Topics incorporate the diversity of life and its biological development, interactions between organisms and their environment, the biological context of climate change, human impacts on the environment, future food sustainability, urban ecology, ecosystem services and the value and conservation of biodiversity.

Topics are arranged in three sections:

1. Multicellularity and Development, Physiology, Behaviour and Neuroscience.
2. Evolution: Adaptation, Populations and Biodiversity.
3. Ecology and Environment.

Learning Outcomes

On successful completion of this module, the student will be able to:

- Outline the major steps involved in how complex animal and plants are formed and be able to relate the morphological changes that occur to the molecular and cellular changes that underlie and drive embryo and organ development.

- Describe the concept of homeostasis at the cell, organ and organism level; give examples of the functional interrelationships that exist between cells, organs and systems; provide an account of how organisms can sense change in the environment.

- Describe the basic principles by which the brain functions and outline key experimental steps and informative clinical cases that have elucidated our current understanding of brain function.

- Recognise the diversity of life on earth and describe how it evolved over geological time scales.

- Describe the ecological relationships between individuals, populations, communities and ecosystems, and between organisms and their environment.

- Recognise how humans can positively and negatively influence other living organisms and their environment and understand the value of other living organisms for humans.

- Demonstrate practical, numerical and analytical skills.

- Collate, synthesise and present information in written reports.

Methods of Teaching and Learning / contact hours

A mixture of lectures, hands-on laboratory practicals and field work are used in the delivery of this module. The module is supported by a range of learning resources provided through a virtual learning environment. Essay writing skills will be developed.
Sixty hours contact time.

Module Content

Lecture Topic	Lecturer	Practicals
Introduction and overview	Trevor Hodkinson	
Section 1 Multicellularity and Development, Physiology, Behaviour and Neuroscience		
1. Multicellularity and Development	Rebecca Rolfe	Development and Floral Morphology
2. The first steps in building a new organism	Rebecca Rolfe	
3. Establishment of a body plan	Rebecca Rolfe	
4. Cellular differentiation, regulation of gene expression	Rebecca Rolfe	
5. Morphogenesis	Rebecca Rolfe	
6. Form and Function	Áine Kelly	Physiology
7. Homeostasis	Áine Kelly	
8. Physiological Regulation	Áine Kelly	
9. Pre-neuroscience History of Ideas of Mind & Brain	Tomás Ryan	
10. Fundamentals of Nervous System Structure and Function	Tomás Ryan	
11. Introduction to the Biology of Memory Storage	Tomás Ryan	
Section 2 Evolution: Adaptation, Populations and Biodiversity		
12. Short history of life	Trevor Hodkinson	First Life
13. Fossils, global change and extinctions	Trevor Hodkinson	
14. Selection/modern synthesis	Trevor Hodkinson	
15. Species	Trevor Hodkinson	Diversity of Life
16. Speciation	Trevor Hodkinson	
17. Phylogeny	Trevor Hodkinson	Evolution

18. Genetic Basis of Selection	Aoife McLysaght	
19. Genetic Basis of Evolution 1	Aoife McLysaght	Species Diversity Evolution & Modularity
20. Genetic Basis of Evolution 2	Aoife McLysaght	
21. Genetic Basis of Evolution 3	Aoife McLysaght	
22. Human Evolution	Aoife McLysaght	
23. Summary of key concepts: Q&A	Trevor Hodkinson	
Section 3 Ecology and Environment		
24. Species - Commonness, rarity and population	James Barnett	
25. Species – Conservation	James Barnett	Biodiversity & Ecosystems Services
26. Trophic Cascades and Rewilding	James Barnett	
27. Constructing Ecosystems and Conservation	James Barnett	
28. Urban ecology	James Barnett	
29. Ecosystem Services and Natural Capital	James Barnett	
30. Global Ecology and Climate Change	Richard Nair	
31. Impacts of Climate Change, Biological Niches	Richard Nair	
32. Biomes and Global Productivity	Richard Nair	
33. Biomes and Biogeochemical Cycles	Richard Nair	
34. Biodiversity Crisis	Richard Nair	Biological Responses to Climate Change
Module Overview	Trevor Hodkinson	

Lecture Content:

- **Introduction to development:** Core concepts, model organisms, analysis of development; morphology, genetic, biochemical.
- **Embryogenesis and morphogenesis:** Germ layers.
- **Intercellular communication:** Determination, potency, axis formation – anterior-posterior, dorsal-ventral.
- **Differential gene expression:** Temporal and spatial, master regulators.
- **Form and Function**: Functional characteristics of living things; specialisation of cells/tissues/organs to fulfil specific functions.
- **Homeostasis:** The concept of the internal environment; composition, temperature, pH etc. of body fluids; maintenance of homeostasis by cooperation of different physiological systems; feedback and feed-forward.

- **Physiological Regulation of Function**: Fundamentals of nervous and endocrine control of function and comparison of speed and modes of action: how an individual organism senses and responds to changes in the external and internal environments.
- **Pre-neuroscience history of mind/brain ideas**: Cartesian dualism and materialist and non-materialist explanations of mind; the brain as the substrate of mind; the effects of head trauma on behaviour and memory, anatomy of the human/mammalian brain, functions in behaviour and in homeostasis, overview of human brain regions and attribution of various regions to broad functions (evidence from lesions, imaging).
- **Fundamentals of nervous system structure and function**: Reticular vs. neuron theory, nervous system as electrically active, Helmholtz and excitable neurons, action potentials & synaptic transmission.
- **Introduction to the biology of memory storage**: Challenges of integrating neurobiology and brain function at multiple levels; reductionism and correlation vs. causation; the biology of memory storage.
- **Short history of life**: Timeline, major groups, diversity.
- **Selection/modern synthesis**: Adaptation.
- **Species**: Definitions, taxonomy, diversity, species rich groups.
- **Speciation:** Allopatric, sympatric, adaptation, radiations, key innovations.
- **Extinction**: Fossils, global change (climate, atmosphere, tectonic).
- **Phylogeny**: Homology, convergence, reversals, methods.
- **Genetic basis of selection**
- **Genetic basis of evolution**: Molecular variation, neutral theory, drift; molecular evolution of population genetic variation.
- **Human evolution**
- **Global ecology and climate change**: Future climate change – global challenges – projections; pest diseases, human physiology, how to predict; need to understand fundamentals of ecology to address these global challenges.
- **Biomes, niches**: Introduction to biomes, what shapes biome distribution? Climate change, climate niches / fundamental versus realized niche; challenge of predicting future ecological responses to climate change.
- **Commonness, rarity and population processes**: Extinction or persistence are processes that operate at the population level; introduction to concepts of abundance and rarity, competition, dispersal, demography and its application to conservation (endemism and invasions).
- **Conservation**: Applications of population biology at the species level, including prioritizing species for conservation management, assessing threat and red listing.
- **Trophic cascades and rewilding**: What is a community, energy flow, applications of community ecology to conservation and rewilding challenges; consumption, facilitation & predation.
- **Constructing ecosystems and conservation**: In the Anthropocene humans have constructed new ecosystems, what are they, where do we find them and what are their values? Contrast with "natural" ecosystems.
- **Urban ecology**: How have organisms adapted to living in urban environments? How can we better design our cities and buildings to gain more value from nature and support biodiversity?

- **Ecosystem services and natural capital**: Nature provides many valuable ecosystem services supported by natural capital; introduction to the concepts and controversies surrounding the ecosystem services and natural capital concepts.
- **Food**: Environmental impacts and ecological process: food security- ecological concepts- productivity- energy flows through ecological systems/basic concepts of biogeochemical cycles.
- **Future food and a changing planet**: Food security; ecological concepts, human population increase, projections for future productivity.
- **Biosphere feedbacks on climate system**: Introduction to biological feedbacks on the climate system; carbon sequestration/ transpiration/ water budget, within biomes; fire feedbacks/rain seeding; nature-based solutions to climate mitigation and adaptation; green and blue solutions – cities etc., 'The Martian' closed system.

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