

ADVANCED HIGHER BIOLOGY

Learning Outcomes

Unit 1: Cell and Molecular Biology

CONTENT	NOTES
a) Structure, function and growth of prokaryotic and eukaryotic cells	
i Comparison of features and ultrastructure of prokaryotic and eukaryotic cells.	<p>Prokaryotes: single circular DNA molecule, nucleoid, ribosomes, cell wall with peptidoglycan, capsule, pili, flagella, plasmids.</p> <p>Eukaryotes: Plant cells: cell walls with cellulose, plasmodesmata, middle lamella, vacuole, nucleus, nuclear membrane (envelope), endoplasmic reticulum, ribosomes, Golgi apparatus, chloroplasts, mitochondria, lysosomes.</p> <p>Animal cells: nucleus, nucleosomes, Golgi apparatus, endoplasmic reticulum, mitochondria, microvilli, centrioles, endomembranes, microbodies, lysosomes, cytoskeleton.</p>
ii Cell growth and the cell cycle.	
Interphase: G1, S and G2 phases (G: growth, S: synthesis).	Between divisions cells are at interphase (period of growth and metabolism). The cells grow throughout interphase but DNA is replicated only during the S phase.
Mitosis: the M phase.	Prophase, metaphase, anaphase and telophase – describe what happens at each stage. Role of spindle fibres in the movement of chromosomes, alignment of chromosomes on metaphase plate, separation of sister chromatids and formation of daughter nuclei. Cytokinesis.
Control of the cell cycle. Abnormal cell division: cancer cells.	Position and purpose of checkpoints in relation to cell size. Mitosis promoting factor (MPF): protein complex controlling entry of cells into mitosis. Proliferation genes encode proteins that promote cell division. Mutations cause excessive cell growth, resulting in tumour formation. Normal proliferation genes are known as proto-oncogenes which may give rise by mutation to oncogenes. Antiproliferation genes (tumour-suppressor genes) help to restrict cell division at cell checkpoints.
iii Differentiation of cells into tissues and organs.	

Cells undergo differentiation to become specialised cells that are organised into tissues and organs.

Cellular differentiation depends on changes in gene expression resulting in genes being switched on and off.

iv Cell and tissue culture.

State that stem cells are used because they are able to differentiate, unlike specialised cells.

Mammalian cell culture.

Requirement of aseptic conditions, solid surface, growth factors and nutrients in complex growth media.

Bacterial and fungal cultures.

The addition of animal serum such as fetal bovine serum (FBS) to promote cell proliferation and antibiotics to prevent bacterial growth.

Cells adhere to the surface, spread out and divide until a monolayer is formed and the cells are confluent. Difficulty in maintaining cultures of mammalian cells due to cells dying after a finite number of divisions in culture.

Cell lines prepared from cells which undergo a genetic change that makes them immortal or from cancer cells.

The advantages of the simpler growth media requirements and culture conditions for bacteria and fungi compared to mammalian cells.

v Plant tissue culture.

Growth of explants on suitable media to produce a callus. The use of growth regulators such as auxins and cytokinins to cause tissue differentiation.

Production of pathogen-free plantlets and plants, generation of new varieties of plants and use in plant propagation.

Know the meaning of the terms protoplast and totipotent.

b) Structure and function of cell components

i Carbohydrates.

Glucose as a building block of carbohydrate macromolecules.

Structure of the monomer glucose.

Dehydration (condensation) to form 1-4 linkages between alpha and beta forms.

Disaccharides joined by glycosidic bonds.

Polysaccharide structure.

Comparison of structures of starch, cellulose and glycogen (in relation to linkage of glucose monomers and degree of branching).

Functions of carbohydrates: role in energy budget, storage, cell structures.

ii Lipids.

Structure of glycerol, saturated and unsaturated fatty acids. Functions of lipids: structural, storage, hormones.

Dehydration (condensation) of glycerol and fatty acids to form ester linkages in fats.

Triglyceride and phospholipid structure.

Comparison of structure in terms of hydrophobic and hydrophilic nature. Natural tendency for phospholipids to form bilayer.

Structure of steroids.

Steroids have a common four ring structure. Different steroids vary in their side chains attached to the rings as illustrated by cholesterol and testosterone.

iii Proteins.

Structure of amino acids.
Dehydration (condensation) synthesis and peptide bonds.

Identification of main classes: polar, non-polar, acidic, basic, i.e. by functional groups. State that a very strong covalent peptide bond links amino acid residues.

Primary, secondary, tertiary and quaternary structure.

Amino acid sequence in primary structure. α -helix, β -sheet arrangements (parallel and antiparallel) in secondary structure; covalent disulphide bond in tertiary structure; subunits in quaternary structure.

Functions of proteins. Examples to include catalytic, structural, messenger, carriers.

iv Nucleic acids.

Structure of DNA and RNA. Functions of the enzymes polymerase and ligase.

Pairing (A-T by 2 hydrogen bonds, G-C by three hydrogen bonds). Understand the terms purine (double-ring structure) and pyrimidine (single-ring structure).

Polymerase enzymes involved in DNA replication and transcription. DNA ligase forms phosphodiester bonds to join DNA molecules together.

v Membranes

Membrane composition and organisation.

Fluid mosaic model of membrane structure: proteins immersed in a lipid bilayer, held together by hydrophobic interactions.

Types of membrane proteins.
Functions of membrane proteins.

Integral (intrinsic) and peripheral (extrinsic) proteins. Attachment to cytoskeleton and extracellular matrix, intercellular junctions, transport, enzymes, receptors sites. Importance of glycoproteins in cell-cell recognition.

vi Cytoskeleton.
Composed of fibres as illustrated by microtubules. Function.

Microtubules are straight, hollow rods made of globular proteins called tubulins. Microtubules are found in all eukaryotic cells and radiate from a centrosome which is located near the nucleus.

The cytoskeleton gives mechanical support and shape to cells. It extends throughout the cytoplasm and governs the location of membrane-bound organelles.

c) Molecular interactions in cell events
i Catalysis.

Functions of proteases, nucleases, ATPases, kinases. Synthesis (anabolic) and degradation (catabolic) reactions involving condensation and hydrolysis.

Specificity of enzyme activity related to induced fit.

Change in shape of the active site when correct substrate binds.

Control of enzyme activity by competitive and non-competitive inhibitors, enzyme modulators and covalent modifications.
Role of end-product inhibition in the control of metabolic pathways.

Binding of inhibitor to active site prevents the substrate binding in competitive inhibition. Inhibitor binds to a second site which results in a change in shape of enzyme in non-competitive inhibition.

Positive modulators (activators) and negative modulators (inhibitors) bind to a second site on allosteric enzymes and result in shape changes. Covalent modifications including phosphorylation and dephosphorylation, and conversion of inactive enzyme to active enzyme as exemplified by trypsinogen and trypsin.

End-product binds to first enzyme in pathway to control the whole pathway as the supply of intermediates is restricted. This is a form of negative feedback.

ii The sodium-potassium pump (a specific case of active transport).

Ions pumped against a steep concentration gradient. The transport protein pumps sodium ions out of the cell as potassium ions are pumped into the cell.

ATP powers the pump by transferring a phosphate group to the protein (i.e. the transport protein is phosphorylated) resulting in a change in conformation (shape) of the protein.

iii Cell Signalling

Extracellular hydrophobic signalling molecules.

As illustrated by steroid hormones e.g. testosterone. These diffuse across the plasma membrane of the target cell and activate gene regulatory proteins which regulate the transcription of specific genes.

Extracellular hydrophilic signalling molecules.

As illustrated by peptide hormones e.g. insulin and neurotransmitters e.g. noradrenalin and acetylcholine. These activate receptor proteins on the surface of the target cell.

The receptors act as transducers, converting the extracellular binding event into intracellular signals which alter the behaviour of the target cell.

d) Applications of DNA technology

i The Human Genome Project.

Genetic linkage mapping.

Location of genetic markers to allow testing of genetic linkage to known markers.

Physical mapping.

Determination of order of genes on each chromosome.

Techniques used include: using a nucleic acid probe to identify a cloned gene; isolation of overlapping DNA segments obtained by cutting two samples of the original DNA with restriction endonuclease enzymes; amplification of DNA by the PCR (polymerase chain reaction).

DNA Sequencing.

Determining the order of nucleotide pairs of each chromosome.

PCR involves DNA heated to 95°C, DNA is denatured, primer (short length of DNA) binds (anneals) to template strands, complementary DNA strands form.

Advances in automation and electronic technology have greatly enhanced the speed of the project.

Detecting genetic disorders.

DNA probes and hybridisation used to locate specific sequences, genes and gene mutations.

Gene therapy: the replacement of a faulty gene with a normal gene; the insertion of an extra gene with the intention that the gene product will play a therapeutic role.

Difficulty of gene therapy in practical terms.

iii Forensic and agricultural uses.

DNA profiling: relies on repetitive, hypervariable DNA and not genes per se.

Stages involved: DNA isolation, restriction enzyme digestion, gel electrophoresis, blotting DNA onto a filter, hybridisation with a probe. Use of single locus probe.

Transgenic plants.

Transgenic plants are engineered by using a plasmid from *Agrobacterium*. Foreign DNA carrying genes for the desired characteristics inserted into bacterial plasmid. Plant cell protoplasts incubated with bacteria containing genetically engineered plasmid in medium which allows only those plant cells which have taken up the foreign DNA to grow.

Production of bovine somatotrophin (BST) by genetic engineering and its use in cattle.

Gene for BST cloned into a bacterial system. Product purified and administered to cattle by injection or in feed. BST increases milk production.

Unit 2: Environmental Biology

CONTENT	NOTES
a) Circulation in ecosystems	
i Energy fixation.	<p>The fixation of energy in autotrophs by photosynthesis.</p> <p>Primary productivity measured by rate of accumulation of biomass in the ecosystem.</p> <p>Gross primary productivity (GPP) as total yield of organic matter from photosynthesis.</p> <p>Net primary productivity (NPP) as biomass remaining after energy consumption in producer respiration.</p>
ii Energy flow.	<p>Roles of producers (autotrophs), consumers (heterotrophs) and decomposers (saprotrophs) in the flow of energy.</p> <p>Primary consumers/herbivores; secondary and tertiary consumers/carnivores; omnivores; detritivores.</p>
Increasing complexity of energy flow in food webs.	<p>Transfer of energy between trophic levels. Ecological efficiency as percentage of energy transferred from one trophic level to the next.</p>
Ultimate loss of energy as heat in respiration.	<p>Pyramids of numbers and biomass and their limitations. Pyramids of productivity.</p>
iii Decomposition.	<p>The importance of the soil organisms in the decomposition of organic matter. The role of invertebrate detritivores in the production of humus.</p> <p>Decomposer respiration as the ultimate releaser of energy and carbon dioxide fixed in photosynthesis. Available nitrogen as limiting factor in decomposition.</p>
iv Nutrient cycling.	<p>The importance of nutrient cycling in ecosystems.</p>
The nitrogen cycle.	<p>Chemical transformations in the nitrogen cycle: nitrogen fixation in free living cyanobacteria and mutualistic Rhizobium in root nodules in legumes, functions of nitrogenase and leghaemoglobin, decomposition of proteins to produce ammonium (ammonification), roles of nitrifying bacteria Nitrosomonas and Nitrobacter in nitrification to produce available nitrate, assimilation of nitrate and ammonia into proteins and nucleic acids, loss by leaching and free-living denitrifying bacteria including Pseudomonas. The influence of water saturation and anaerobic conditions on the cycling of nitrogen in ecosystems.</p> <p>Low solubility of phosphate as a limiting factor in the productivity of aquatic ecosystems. Problems of phosphate enrichment.</p>
The phosphorus cycle.	

b) Interactions in ecosystems

Biotic interactions

Distinction between biotic and abiotic components of ecosystem; density-dependent and density-independent factors. Interspecific and intraspecific interactions.

i Predation.

Predator/prey population cycles.

The role of predators in maintaining diversity in ecosystems by reducing the population density of prey species allowing weaker competitors to survive.

Defences against predation; camouflage (crypsis and disruptive coloration); warning (aposematic) coloration. Batesian and Mullerian mimicry.

ii Grazing.

The effect of grazing on plant communities: effects on diversity and the dominance of grasses and other plants with basal meristems.

iii Competition.

The damaging effects of exotic species.

The importance of survival of weaker competitors and their potential for growth in changing conditions.

Symbiotic Relationships

i Parasitism.

Parasitism as a biotic interaction beneficial to one species (parasite) and detrimental to the other (host). Obligate and facultative parasites.

ii Commensalism.

Commensalism as a biotic interaction beneficial to one species (commensal), leaving the other (host) unaffected.

iii Mutualism.

Mutualism as a biotic interaction beneficial to both species. The exchange of metabolites and complementarity of structures and behaviours found between symbionts in mutualism.

iv Interactions with the environment.

Two major types of responses of organisms to variation in environmental conditions are conformation and regulation. Conformation as exemplified by osmoconformers and poikilotherms. Restricted habitat occupation of conformers. The ability of regulators to occupy a wide range of habitats. Energy costs of homeostasis.

Dormancy as a means of resisting or tolerating environmental adversity. Predictive and consequential dormancy. Forms of dormancy: resting spores, diapause, hibernation, aestivation.

c) Human impact on the environment

i Changes in complexity.

Succession (primary and secondary). The increase in complexity of ecosystems from pioneer through to climax communities. Increase in complexity shown by increase in: diversity of species, variety of

habitats and niches, complexity of food webs.

Loss of complexity through human activity as illustrated by monoculture, eutrophication (algal bloom and its consequences), toxic pollution, and habitat destruction.

ii Effects of intensive food production.

Monoculture and its effect on soil condition, field size, shelter and habitats. Environmental impact of increased use of pesticides and chemical fertilisers in relation to species diversity and loss of stability.

iii Effects of increased energy production.

Fossil fuels as finite energy resources. Need for conservation and use of alternative sources of energy. Air pollution from fossil fuels: acidic gases (sulphur dioxide, nitrous oxide, and carbon dioxide) and greenhouse gases (carbon dioxide and water) produced.

Other greenhouse gases include methane and CFCs. Enhanced greenhouse effect and effects of global warming on abundance and distribution of species as exemplified by zooxanthellae and 'coral bleaching'.

iv Pollution.

Biodegradable organic pollutants and changes in biochemical oxygen demand (BOD).

Major types of toxic pollutants and their sources as exemplified by DDT and heavy metals. Bioaccumulation. Consequences of biological magnification in food chains. Biotransformation. Toxicity and persistent/non-biodegradable nature of DDT.

Unit 3: Physiology, Health and Exercise

CONTENT	NOTES
a) Exercise and the cardiovascular system	
i Structure and function of the cardiovascular system (CVS).	Components of the CVS. Normal values for blood pressure, heart rate, stroke volume and cardiac output.
ii Pathology of cardiovascular disease.	Pathophysiology of atherosclerosis, thrombosis, angina pectoris, myocardial infarction (heart attack), hypertension, stroke. Incidence in UK and other countries
iii Role of exercise in prevention and treatment of cardiovascular disease.	.
Risk factors and prevention of cardiovascular disease.	Modifiable: diet, smoking, activity, obesity. Non-modifiable: age, gender, heredity, race.
Effect of exercise on the CVS.	Effect on heart rate, systolic and diastolic blood pressure, cardiac output and recovery time. Distribution of blood to tissues during exercise.
The 'athletic heart'.	Cardiac hypertrophy as a fundamental adaptation to increased workload imposed by exercise training. Endurance training increases left ventricle mass. A significantly larger stroke volume allows an endurance athlete to pump more blood from the heart than an untrained individual. Improves maximal heart rate and cardiac output. Reduces heart rate at rest and recovery time.
The protective effects of exercise.	Improving myocardial circulation to protect heart from lack of oxygen; enhancing contractile properties of myocardium; improving blood lipid profile i.e. increasing High Density Lipoproteins (HDLs) and decreasing Low Density Lipoproteins (LDLs); lowering heart rate and blood pressure so that work of heart is reduced at rest and during exercise; decreasing body fat.
Principles of exercise testing.	Use of maximal and sub-maximal tests. Maximal oxygen uptake ($VO_{2\max}$) as a measure of the maximum amount of oxygen that a person can use which is used to measure fitness. Exercise stress testing and cardiac patient rehabilitation.
b) Exercise and metabolism	
i Energy. The need for energy. Energy balance.	Gain energy from carbohydrates, lipids and proteins. Energy used to synthesise ATP. Measured in kilojoules (kJ). Energy in –energy out = change in energy stores.

<p>Dietary recommendations for health. Energy expenditure and its measurement.</p>	<p>Link between diet, coronary heart disease and obesity.</p> <p>Basal metabolic rate (BMR) and its measurement, physical activity, dietary-induced thermogenesis, factors affecting total energy expenditure to include: body size and composition, age, sex, nutritional status, pregnancy and lactation, activity and climate.</p> <p>Measurement: direct calorimetry, indirect calorimetry, heart rate recording.</p>
<p>ii Body composition and weight control.</p>	<p>Methods to include: densitometry, skinfold thicknesses, bioelectrical impedance analysis, body mass index (BMI), waist/hip ratio, mid-upper arm circumference. Limitations of methods.</p>
<p>Measurement of body composition.</p>	<p>Importance of differentiating between ‘overweight’ related to large muscle mass or bone mass and that due to excess fat.</p>
<p>Weight control and obesity.</p>	<p>The place of exercise in increased energy expenditure as part of weight-control programmes. Exercise increases energy output relative to input, increases fat loss, preserves lean tissue and helps prevent obesity.</p>
<p>Effect of exercise on body composition and weight control.</p>	<p>Bone density increases from late adolescence and peaks at age 30 then decreases with age. Osteoporosis is caused by loss of minerals such as calcium from the bones, making them porous and brittle and liable to fracture.</p> <p>Affects men, women and children but is most common in post-menopausal women.</p>
<p>iii Osteoporosis. Osteoporosis and bone growth.</p>	<p>Regular weight-bearing exercise of moderate intensity can maintain bone mass and increase bone strength. Individuals who maintain physically active lifestyles have significantly greater bone mass than their counterparts. Women should maximise bone density before age related loss.</p>
<p>Effect of exercise.</p>	<p>Role of insulin and glucagon.</p> <p>Role of pancreas. Effect of changes in blood glucose levels. Non-insulin dependent diabetes mellitus (NIDDM) is generally associated with obesity. Plasma insulin levels are normal but cells have become less sensitive to insulin, resulting in a reduced uptake of glucose into the cells. This is thought to be due to a decrease in the number of insulin receptors on the cell membrane.</p>
<p>iv Diabetes mellitus. Control of blood glucose levels.</p>	

Effect of exercise on diabetes mellitus.

Exercise improves uptake of glucose in subjects with NIDDM and this is thought to be due to an increase in the sensitivity of the receptors and an increase in the actual number of functionally active insulin receptors.

Exercise increases blood flow to skeletal muscle and an increase in enzyme activity associated with glucose storage.