

**IM SYLLABUS (2016)**

**BIOLOGY**

**IM 05**

***SYLLABUS***

<b>Biology Syllabus</b>	<b>IM 05</b>	(Available in September) 1 Paper (3 hours)
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**Introduction**

The intermediate level syllabus in biology is intended either for candidates who have studied biology at a lower level but who wish to widen their knowledge of the subject, or for those candidates who have never studied biology, but who still feel that a good understanding of the subject may be useful.

**Aims**

- To provide an insight in science and its relevance to the human condition particularly to candidates having an arts and humanities orientation.
- To develop an understanding of biological facts, principles and concepts.
- To appreciate that biological principles are applicable to everyday life experiences.
- To enable candidates to appreciate the impact of human activities on the environment.
- To help candidates develop a respect for all life forms and a respect for the uniqueness of individual organisms.
- To promote an interest in, and enjoyment of, the study of life processes and living organisms.

**Examination**

One three hour paper will be set consisting of two sections. Section A will be compulsory and will consist of short-answer questions, while section B will offer a choice of structured questions. Both sections carry equal marks.

**Syllabus**

The following sections of the syllabus are not meant to be treated separately and independently of each other. On the contrary, the teaching of biology should aim at the appreciation of unified biological principles. Where possible and appropriate, local examples should be used. The notes in italic are meant for general guidance only.

**TOPIC I CELLS AND THEIR FUNCTIONS****1.1 The basic nature of life****Cellular Respiration.**

Aerobic and anaerobic respiration as a means of ATP production: glycolysis as a common pathway to both aerobic and anaerobic respiration and involving the oxidation of glucose to pyruvate with a net gain in ATP and reduced NAD; anaerobic respiration involving the production of ethanol or lactate as by-products and the regeneration of NAD; aerobic respiration as a highly efficient process involving ATP production; Krebs cycle involving a series of oxidation steps that generate high energy reduced co-enzymes; oxidative phosphorylation leading to aerobic generation of ATP via a chain of electron carriers.

*Respiratory pathways are not required but the principles should be understood.*

ATP as the energy currency in the cell.

Simple outline of mitochondrial structure and function.

Metabolic rates: definition and factors which affect metabolic rate (e.g. temperature, hormones, gender).

**Photosynthesis.**

Structure of a mesophytic leaf and its adaptations for gas exchange and photosynthesis.

Simple outline of chloroplast structure and function.

Internal and external factors affecting photosynthetic rate.

Chlorophylls and accessory pigments.

Outline of light dependent and light independent reactions (*only definitions and functions required*).

*Details of pathways are not required but processes should be considered only in such detail as to show that the light dependent stage provides ATP and reducing power to drive the light independent reaction.*

### **1.2 Cell theory**

Basic cell structure. Definition of organelle. The relative sizes of molecules, cell membrane thickness, viruses, bacteria, organelles and cells, using appropriate SI units.

*Appreciation of relative size is required, such as molecules (1 nm), thickness of membranes (10 nm), viruses (100 nm), bacteria (1  $\mu\text{m}$ ), organelles (up to 10  $\mu\text{m}$ ), cells (up to 100  $\mu\text{m}$ ). The three dimensional nature/shape of cells should be emphasised.*

Explanation of the importance of the surface area to volume ratio as a factor limiting cell size.

### **1.3 Prokaryotic cell structure**

The structure of a generalised prokaryotic cell as exemplified by a bacterium.

*Classification of prokaryotes and the Gram stain are not required.*

One function for each of the following: ribosomes, slime capsule, cell wall, flagellum, cell surface membrane, plasmid and naked nucleic acid.

### **1.4 Eukaryotic cell structure**

The ultrastructure of a generalised animal and plant cell as seen in electron micrographs.

The structure and function of each of these: ribosome, rough endoplasmic reticulum (RER), lysosome, Golgi apparatus, mitochondrion, nucleus and chloroplast.

Similarities and differences between prokaryotic and eukaryotic cells.

Composition and function of the plant cell wall.

*The composition of the plant cell wall should be considered only in terms of cellulose microfibrils.*

### **1.5 Membranes**

Diagram showing the fluid mosaic model of a cell membrane including the phospholipid bilayer, cholesterol, glycoproteins and intrinsic and extrinsic proteins.

Characterisation of the outside of the cell membrane (outer face) and the links with the protruding proteins.

*Variations in composition related to type of membrane, and the functions of cholesterol and glycoproteins are not required.*

Explanation of how the hydrophobic and hydrophilic properties of phospholipids help to maintain the structure of cell membranes.

Definition of diffusion and osmosis as examples of passive transport.

Description of active transport across membranes including the roles of protein carriers, ATP and a concentration gradient.

## **TOPIC 2 THE CHEMISTRY OF LIFE**

### **2.1 Atoms, ions and molecules**

Awareness that the three commonest elements of life are carbon, hydrogen and oxygen and that a variety of other elements are needed by living organisms including nitrogen, sulphur, phosphorus, iron and potassium.

*The proportions of the elements are not required.*

Outline description of the difference between an atom and an ion.

*Ions only in terms of being charged particles.*

## 2.2 Water

The unique properties of water in biology including transparency, cohesion, surface tension, solvent properties and thermal properties, referring to the polarity of water molecules and hydrogen bonding where relevant.

The significance of water to organisms as a coolant, transport medium and habitat, in terms of its properties

*Quantitative details of bond angles, strength, or electronegativity are not required. Explanations should be limited to the O 'side' of the (H<sub>2</sub>O) molecule being slightly negative and the H 'side' being slightly positive.*

*One example to illustrate the importance of each property is sufficient.*

*No physical, chemical or quantitative details are required.*

## 2.3 Biomolecules

*Wherever molecular structures are required only 2-dimensional structural formulae need be used.*

The nature of organic compounds: That organic compounds are based on carbon and that most also contain hydrogen and oxygen. Covalent bonds

Proteins: Definition of proteins as polymers of amino acids.

.The basic structure of a generalised amino acid. Only a 2-dimensional structural formula is required without details of the R group.

The structure of a generalised dipeptide, showing the peptide linkage

*Neither the fact that the linkage is planar nor that it permits rotation about the C-N bond is required.*

Functions of proteins: reference to fibrous proteins such as muscle proteins (*Details of mode of operation are not required*), collagen, keratin and globular proteins such as haemoglobin and enzymes.

Carbohydrates: Definition of monosaccharides, disaccharides and polysaccharides. *No structural formulae are required.*

The ring structure of glucose.

One function of the following carbohydrates: glucose, fructose, sucrose, starch, glycogen and cellulose.

Lipids: The basic structure of glycerol and a generalised fatty acid. Functions of lipids as energy reserves and cell-membrane components.

Outline description of the role of condensation and hydrolysis in the relationships between monosaccharides and disaccharides; fatty acids, glycerol and triglycerides; amino acids, dipeptides and polypeptides.

Explanation of the relative solubility of carbohydrates, lipids and proteins in water. *Awareness that solubility tends to decrease with increasing molecular size.*

Comparison between the energy content of carbohydrates, lipids and proteins.

*Only qualitative comparisons are required.*

## 2.4 Enzymes

Definition of the terms: enzyme, denaturation and active site.

Description of the "lock-and-key" model.

The effects of temperature, pH, inhibition and substrate concentration on enzyme activity.

## 2.5 DNA structure

Description of the DNA nucleotide structure in terms of sugar (deoxyribose), base and phosphate.

*Chemical formulae and the purine/pyrimidine subdivision are not required. Simple shapes can be used to represent component parts. Only the spatial arrangement is required.*

The names of the four bases in DNA.

Outline description of how the DNA nucleotides are linked together by covalent bonds into a single strand.

*Only the spatial arrangement is required:* P-S--P--S-P



Explanation of how a DNA double helix is formed using complementary base pairing and hydrogen bonds.

Simple diagram of the molecular structure of DNA. *An extension of the diagram above is sufficient. A 'twisted ladder' arrangement to show the complementary base pairs of A - T and G - C held together by hydrogen bonds and the S-P backbone is sufficient. The number of H- bonds between pairs and details of purine/pyrimidines are not required.*

## TOPIC 3 GENETICS

### 3.1 Chromosomes, genes and alleles

Awareness that eukaryote chromosomes are made of DNA and protein.

*The names of the proteins are not required, nor is the structural relationship between the DNA and the proteins.*

Definition of the terms: chromosome, gene and allele.

### 3.2 Cell division

Awareness that cells arise from division of other cells.

Description of the cell cycle as consisting of three phases:

(1) nuclear division (mitosis or meiosis)

(2) cell division (cytokinesis)

(3) interphase as an active period in the life of a cell, where many biochemical reactions, DNA transcription and DNA replication occur.

Mitosis:

An understanding of the general principles of the process, the relationship between the DNA molecules, the changes observed in chromosomes and the final product of the process, i.e. two genetically identical diploid nuclei.

Outline description of how replicated DNA molecules (chromosomes) are moved to opposite ends of the cell by microtubules.

A simple series of diagrams could be used to illustrate this process. The terms of the various stages are not required.

The process of cytokinesis in animal and plant cells.

Awareness that tumours (cancers) are the result of uncontrolled cell division and that these can occur in any organ.

The significance of mitosis in growth and replacement of cells and asexual reproduction.

**Meiosis:**

Awareness that meiosis is a reduction division in terms of diploid and haploid numbers of chromosomes.

The significance of meiosis in production of animal gametes.

Outline description of the process of meiosis including pairing of chromosomes and crossing over followed by two divisions which result in four haploid cells. Use of the terms bivalents, tetrad, synapsis and chiasmata is not expected.

Explanation of how crossing over and independent assortment of chromosomes during meiosis can give rise to genetic variety in the resulting haploid cells.

Candidates should also appreciate the significance of random fertilization in generating diversity.

Candidates should be able to compare and contrast mitosis and meiosis.

### **3.3 DNA replication**

Awareness that DNA replication is semi-conservative.

Outline description of DNA replication in terms of unwinding the double helix and separation of the strands by helicase followed by formation of the new complementary strands by DNA polymerase.

*It is not necessary to mention the fact that there is more than one helicase and polymerase or that more enzymes are involved.*

Explanation of the significance of complementary base pairing in the conservation of the base sequence of DNA.

### **3.4 Protein synthesis**

Comparison of the structure of DNA and RNA. *To be limited to names of sugars, bases and number of strands.*

Explanation of the relationship between one gene and one polypeptide. Awareness of the fact that genes code for the production of enzymes and so genes can control cellular metabolism by controlling enzyme synthesis.

Awareness that the base sequence on DNA strands will determine the base sequence on RNA which, in turn, is translated into the sequence of amino acids in a protein. .

Outline DNA transcription in terms of the formation of an RNA strand complementary to the DNA. Students should be aware that DNA is so important for the cell that it cannot be allowed to move out from the nucleus with the risk of being damaged. However, copies of particular genes can be made and these will then leave the nucleus and become attached to ribosomes where protein synthesis occurs. Similarities and differences between transcription and DNA replication should be highlighted.

Description of the genetic code in terms of codons composed of triplets of bases as well as being degenerate, universal, punctuated and non-overlapping. *Details of base sequences not required.*

Definition of translation as a process occurring on ribosomes during which the nucleotide sequence of mRNA is used to produce an exact sequence of amino acids in a polypeptide.

### **3.5 Mutation**

Definitions of gene and chromosomal mutations.

*Some discussion could come in here about the overlap between the frequency of the sickle cell allele and the distribution of malaria. The terms 'point mutation' or 'frameshift mutation' will not be used.*

Explanation that non-disjunction can lead to changes in chromosome number, illustrated by reference to Down's Syndrome (trisomy 21).

*The recognition of Down's syndrome in a person is not required. Translocation of part of chromosome 21 possibly resulting in Down's syndrome is not required.*

Explanation of the consequence of a base substitution mutation in relation to the process of transcription and translation, using the example of sickle cell anaemia.

Awareness that mutation is central to the theme of evolution.

### **3.6 Gene Technology**

Recombinant DNA in the production of proteins: The production of recombinant DNA and its use in the production of human insulin. Consideration should be given to the isolation of the gene coding for the required protein; use of the enzymes restriction endonuclease and ligase (*outline only*); sticky ends – insertion of the gene into a vector and its subsequent introduction into host cells; plasmids and viruses as examples of vectors; multiplication of the host cells emphasizing the production of genetically identical bacteria.

Other uses of gene technology: treatment by gene therapy as exemplified by its application in the treatment of cystic fibrosis; Genetically Modified Organisms (GMOs) (*only definition and one example, such as the production of pest-resistant crops*); moral and ethical issues associated with recombinant DNA technology (*only for class discussion – not examinable*).

## **TOPIC 4 ECOLOGY**

### **4.1 Basic ecological concepts**

Definition of the terms: ecology, ecosystem, population, community, species, biosphere and habitat. Food chains, giving three examples, each with at least three linkages (four organisms).

Ecology in terms of the relationship between organisms, communities and ecosystems. *To include competition, predation and parasitism.*

*Food chains are best determined using real examples and real information based on local examples. A→B indicates that A is being 'eaten' by B.*

Definition of trophic level.

Describe what is meant by a food web.

*Candidates should be able to deduce the trophic level(s) of organisms in a food chain and a food web.*

Definition of the terms: autotroph (producer), heterotroph (consumer), detritivore, saprotroph (decomposer).

### **4.2 Energy relationships**

Explanation of biomass and energy transfer in a food chain in terms of growth, respiration, cell activities and waste. *Qualitative treatment only.*

Awareness that when energy transformations take place, including those in living organisms, the process is never 100% efficient, commonly being 10-20%.

*Reference to the Second Law of Thermodynamics is not expected.*

Pyramids of energy and reasons for their shape.

*Pyramids of numbers and biomass are the most problematical and so are not required.*

Explanation that energy enters and leaves an ecosystem, but nutrients must be recycled.

The carbon cycle to show the processes including photosynthesis, respiration, combustion and fossilisation.

*The details of the carbon cycle should involve the interaction of living organisms and the biosphere through the processes of photosynthesis, respiration, fossilisation and combustion. Recall of specific quantitative data is not required.*

The nitrogen cycle and the role of saprotrophs (decomposers) in returning elements to the environment in inorganic form.

*Names of decomposer organisms are not required*

#### **4.3 Populations**

Outline description of how population size can be affected by natality, immigration, mortality and emigration.

*A formula relating these is not required; simply that the first two increase population size whilst the latter two decrease it.*

Sigmoid (S-shaped) population growth curve.

Reasons for the exponential growth phase, the plateau phase and the transitional phase between these two phases.

*The emphasis should be placed upon the factors affecting population growth rate. The terms exponential growth phase, transitional phase and plateau phase will be used.*

Definition of carrying capacity.

Three factors which set limits to population increase.

#### **4.7 Human impact**

Use of available resources: energy, water, land and biotic resources. Effects of waste disposal, loss of biodiversity, environmental pollution (*to include discussion of the effect of greenhouse gases*) and agriculture. Environmental management as exemplified by reclamation and conservation.

Two examples of local or global issues of human impact causing damage to an ecosystem or the biosphere, one of which must be the increased greenhouse effect.

### **TOPIC 5 EVOLUTION AND DIVERSITY OF LIFE**

#### **5.1 Evolution and diversity of life**

*It is important that the concept of Evolution is placed firmly in the context of ecology and an understanding of natural selection is crucial.*

Awareness that the members of a species show variation

The importance for evolution in response to environmental change

Awareness that the consequences of the potential overproduction of offspring is a competition for survival.

Evolution by natural selection.

Explanation of how, by natural selection, the best adapted will survive to breed.

The five kingdoms of life and the main characteristics of each:

Prokaryota: exemplified by bacteria; to emphasize the absence of nucleus and membrane-bound organelles.

Protoctista: exemplified by an alga and a phagotrophic protozoan; to emphasize the lack of complex organ systems, their basically aquatic nature and their position at the base of eukaryote evolution, the other three kingdoms being rooted in the Protoctista.

Fungi: exemplified by a mushroom or a mould; to emphasize hyphal organisation and saprotrophic modes of nutrition.

Plantae: exemplified by an angiosperm; emphasizing basic terrestrial habit, presence of cell walls, photosynthetic mode of nutrition and vascularity in the majority.



Animalia: exemplified by an invertebrate and a vertebrate; to emphasize their fast response to stimuli, cells lacking cell walls and mobility.

## **TOPIC 6 HUMAN HEALTH AND PHYSIOLOGY**

### **6.1 Digestion and nutrition**

Explanation of why digestion of large food molecules is essential.

The need for enzymes in digestion.

*The need for increasing the rate of digestion is the important point.*

The source, substrate, products and optimum pH conditions for one amylase, one protease and one lipase.

*Any human enzymes belonging to the above-mentioned classes can be selected. Details of structure or mechanisms of action are not required.*

The digestive system to include mouth, oesophagus, stomach, small intestine, large intestine, anus, liver, pancreas, and gall bladder and the main function of each.

*Candidates should be able to label the features mentioned on a diagram but are not expected to reproduce it themselves.*

*The important points are the relative sizes, positions and order - not artistic accuracy.*

Structure of a villus in vertical section.

*Microscopic details of the structure of the intestinal wall are not required.*

Knowledge of absorption, transport and fate of digestion products.

The concept of a balanced diet with reference to: malnutrition, undernutrition and overnutrition in humans.

The general importance of vitamins and minerals.

*Lists of vitamins and minerals are not required, only an explanation of their general importance.*

### **6.2 The transport system**

The need for a transport system and its property of transporting materials in bulk.

Structure of the heart including all four chambers, associated blood vessels and valves.

The action of the heart in terms of collecting of blood, pumping of blood and opening and closing of valves.

*A basic understanding limited to the collection of blood by the atria which is then pumped out by the ventricles into the arteries. The direction of flow being controlled by atrio-ventricular and semilunar valves. All blood vessels connected directly to the heart including coronary vessels should be known.*

*It is important that the students understand that the heart beats 'of its own accord' and is made to speed up or slow down, under involuntary control, by means of nerves and hormones.*

The relationship between the structure and function of arteries, capillaries and veins. Tissue fluid as a medium for diffusion between blood and tissues.

*Formation and return of tissue fluid and details of the lymphatic system are not required.*

Awareness that blood is composed of plasma, erythrocytes, leucocytes and platelets.

*Detailed classification of leucocytes is not required.*

The role of blood in the transport of heat, nutrients, oxygen, carbon dioxide, hormones, antibodies, and waste products. *No chemical details are required.*

One health problem concerned with disorders of the transport system.

*An example could be chosen from coronary heart disease, heart pacemakers, haemophilia etc., according to needs/ wishes of teachers.*

### **6.3 Defence against infectious diseases**

Pathogens and disease with reference to a viral and a bacterial disease.

Explanation of how skin and mucous membranes act as borders against microbes.

*Reproduction of a diagram of a section of the skin is not required.*

Awareness that phagocytic leucocytes ingest disease causing organisms in the blood and in body tissues.

*Details of the sub-divisions and classification of phagocytes is not required.*

The difference between antigen and antibody. Antibody production.

Vaccines and antibiotics

The existence of B and T lymphocytes.

*B-lymphocytes in bone marrow produce, during development, clones of identical cells programmed to secrete a specific antibody when recognising one type of antigen (surface recognition sites, humoral immunity and memory cells should be mentioned). Details of cellular immunity NOT required.*

*Details of the structure of the antibody molecules is not required, beyond the existence of an antigen binding site.*

The effects of HIV on the immune system.

*AIDS, being a syndrome has very varied symptoms, being determined mostly by secondary infections, therefore knowledge of these is not required. The effects of AIDS should be limited to a reduction in T-cells, which lowers the communication between the cells of the immune system leading to infection by certain bacteria, fungi, protoctists and viruses.*

### **6.4 Gas exchange**

Four features of alveoli that allow them to carry out gas exchange efficiently.

The necessity for a ventilation system.

The structure of the gas exchange system to include trachea, bronchi, bronchioles and lungs and their principal functions.

The difference between breathing and cell respiration.

One health problem involving gas exchange. *Examples could be smoking and cancer, tuberculosis, asthma, emphysema etc.*

### **6.5 Homeostasis**

Definition of homeostasis.

The concept of homeostasis with reference to body temperature and levels of blood glucose.

Thermoregulation: monitoring of skin temperature (by thermoreceptors in the skin) and blood temperature (by thermoreceptors in heat centres in the hypothalamus. Heat gain and loss by active mechanisms, mostly under unconscious control, although conscious behavioural mechanisms are important. Warming up mechanisms (vasoconstriction, increased cell metabolism, shivering), cooling down mechanisms (vasodilatation, sweating - decreased metabolism). Conduction, convection and radiation, in outline only.

Glucose regulation: the monitoring of glucose by chemoreceptors in the pancreas. Rise of levels due to food intake or else from liver by demand, and falls due to respiration or conversion to other metabolites or storage as glycogen. Secretion of glucagon by the pancreas to stimulate liver cells to convert glycogen to glucose, and amino acids to glucose. Insulin secretion at high glucose levels to stimulate cell respiration, increased absorption of glucose by muscle cells, conversion of glucose to fat and to glycogen.

The concept of negative feedback.

Awareness that the endocrine system consists of glands which release hormones that are transported in the blood.

*The nature and action of hormones or direct comparisons between nerve and endocrine systems are NOT required. Structural details of endocrine glands other than the pancreas are NOT required.*

### **6.6 Response to the environment**

The general plan of the human nervous system: Central nervous system and peripheral nervous system.

*Only a labelled diagram outlining the organisation of the nervous system is required.*

The building blocks of the nervous system: The neurons: the three types of neurons – sensory, intermediate and motor and the structure and function of each.

The electrical properties of neurons: The resting potential; the generation and propagation of an action potential.

Synaptic transmission: Transmission of a nerve impulse across a synapse (*only a cholinergic synapse is required*); neurotransmitters (acetylcholine and noradrenaline); effects of drugs as exemplified by nicotine and amphetamines (*details of EPSPs and IPSPs are not required*).

The central nervous system: The brain: gross structure; location and one function of the medulla, cerebellum, hypothalamus and cerebral hemispheres including definition of sensory, association and motor areas. The spinal cord as seen in transverse section; a simple reflex arc; concept of receptors and effectors.

The autonomic nervous system: Autonomic control of the internal environment (with examples); an overview of the sympathetic and parasympathetic nervous systems (to include awareness that these systems are antagonistic to each other).

### **6.7 Reproduction**

Awareness that sexual reproduction promotes variation in a species.

Structure of the adult male and female urinogenital systems.

The role of hormones in the male and female reproductive systems and in the menstrual cycle (FSH, LH, oestrogen, testosterone and progesterone).

*Reference to the fact that in males LH is called ICSH and the involvement of the hypothalamus (releasing factors) in both sexes are not expected.*

*Graphs showing relative changes of hormone levels are not required.*

Secondary sexual characteristics in both sexes.

*Histological changes in the ovary, testis and mammary glands are not required.*

The difference between copulation and fertilisation.

Awareness that the foetus is supported and protected by the amniotic sac and amniotic fluid.

### **Suggested Texts.**

Audesirk, T. & Audesirk, G. - *Life on Earth*. Prentice Hall. [ISBN 0 13 5703751]\*

Starr, C. - *Biology - Concepts and Applications*. Wadsworth Publishing Ltd. [ISBN 0 534 17616 X]\*

Toole, G. & Toole, S. - *Understanding Biology for Advanced Level*. Stanley Thornes Ltd [ISBN 074870539 2]

Taylor, D. & Jones, M. – *Foundation Biology*. Cambridge University Press [ISBN 0-521-42199-3]

Jones, M. & Gregory, J. – *Central Concepts in Biology*. Cambridge University Press [ISBN 0-521-48501-0]

\* Can be accessed on the Internet.