* Actual practical work will not be tested, however, candidates should have knowledge of practical work as they might have to draw on this knowledge to answer certain questions in the exam.

A. CORE SYLLABUS

1. Cellular Functions

Content

- Detailed structure of typical animal and plant cells, as seen under the electron microscope
- Outline functions of organelles in plant and animal cells
- The structure of carbohydrates, lipids and proteins and their roles in living organisms
- Mode of action of enzymes
- Replication and division of nuclei and cells
- Understanding of chromosome number and variation
- Effect of meiosis on chromosome number and variation

Learning Outcomes

Candidates should be able to:

(a) Describe and interpret drawings and photographs of typical animal and plant cells as seen under the electron microscope, recognising the following membrane systems and organelles: rough and smooth endoplasmic reticulum, Golgi body, mitochondria, ribosomes, lysosomes, chloroplasts, cell surface membrane, nuclear envelope, centrioles, nucleus and nucleolus.

(b) Outline the functions of the membrane systems and organelles listed in (a).

(c) Describe the formation and breakage of a glycosidic bond.
(d) Analyse the molecular structure of a triglyceride and a phospholipid, and relate these structures to their functions in living organisms.

(e) Describe the structure of an amino acid and the formation and breakage of a peptide bond.

(f) Explain the meaning of the terms primary structure, secondary structure, tertiary structure and quaternary structure of proteins, and describe the types of bonding (hydrogen, ionic, disulphide and hydrophobic interactions) which hold the molecule in shape.

(g) Analyse the molecular structure of a dimeric enzyme with a quaternary structure e.g. viral/HIV protease, as an example of a globular protein, and of collagen as an example of a fibrous protein, and relate these structures to their functions.

(h) Explain the mode of action of enzymes in terms of an active site, enzyme/substrate complex, lowering of activation energy and enzyme specificity.

(i) Follow the time course of an enzyme-catalysed reaction by measuring rates of formation of products (e.g. using catalase) or rate of disappearance of substrate (e.g. using amylase).

(j) Investigate and explain the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of enzyme catalysed reactions, and explain these effects.

(k) Explain the effects of competitive and non-competitive inhibitors on the rate of enzyme activity.

(l) Explain the importance of mitosis in growth, repair and asexual reproduction.

(m) Explain the need for the production of genetically identical cells and fine control of replication.

(n) Explain how uncontrolled cell division can result in cancer, and identify factors which can increase the chances of cancerous growth.

(o) Describe with the aid of diagrams, the behaviour of chromosomes during the mitotic cell cycle and the associated behaviour of the nuclear envelope, cell membrane and centrioles. (Names of the main stages are expected)

(p) Explain what is meant by homologous pairs of chromosomes.

(q) Describe, with the aid of diagrams, the behaviour of chromosomes during meiosis, and the associated behaviour of the nuclear envelope, cell membrane and centrioles. (Names of the main stages are expected, but not the sub-divisions of prophase)

*Use the knowledge gained in this section in new situations or to solve related problems.*
2 DNA and Genomics

Content

• DNA – structure and function
• Central Dogma – DNA to RNA, RNA to protein

Learning Outcomes

Candidates should be able to:

(a) Describe the structure and roles of DNA and RNA (tRNA, rRNA and mRNA).
(b) Describe the process of DNA replication and the experimental evidence for semi-conservative replication.
(c) Describe how the information on DNA is used to synthesise functional polypeptides.
(d) Explain how a change in the sequence of the DNA nucleotide (gene mutation) may affect the amino acid sequence in a protein, and hence the phenotype of the organism e.g. sickle cell anaemia.

Use the knowledge gained in this section in new situations or to solve related problems.

3 Genetics of Viruses and Bacteria

Content

• The Genetics of Viruses
• The Genetics of Bacteria

Learning outcomes

Candidates should be able to:

(a) Discuss whether viruses are living or non-living organisms and explain why viruses are obligate parasites.
(b) Describe the structural components of viruses.
(c) Describe the reproductive cycles of the following virus types:

i. bacteriophages, using T4 and lambda phages to illustrate the lytic and lysogenic cycles respectively;

ii. an enveloped virus e.g. influenza;

iii. retroviruses e.g. HIV.

(d) Explain how viral infections cause disease in animals e.g. mammals.

(e) Describe the structure of a bacterial chromosome including the arrangement of DNA within bacterial cells.

(f) Describe the process of binary fission, transformation, transduction and conjugation in bacteria and explain the role of F plasmids in bacterial conjugation.

(g) Distinguish between structural and regulatory genes, and between repressible and inducible enzymes.

(h) Describe the concept of a simple operon (using lac operon as an example).

Use the knowledge gained in this section in new situations or to solve related problems.

4 Organisation and Control of Prokaryotic and Eukaryotic Genome

Content

- The Structure of Eukaryotic Chromatin
- Genome Organisation at the DNA level
- The Control of Gene Expression
- The Molecular Biology of Cancer

Learning Outcomes

Candidates should be able to:

(a) Compare the structure and organisation of prokaryotic and eukaryotic genomes.

(b) Describe the structure and function of the portions of eukaryotic DNA that do not encode for protein or RNA.

(c) Describe the role of telomeres and centromeres.

(d) Describe the process and significance of gene amplification.
(e) Describe the eukaryotic processing of pre-mRNA.

(f) Define control elements and explain how they influence transcription.

(g) State the various ways in which gene expression may be controlled at translational and post translational level.

(h) Outline the differences between prokaryotic control of gene expression with the eukaryotic model.

(i) Describe how proto-oncogenes are converted into oncogenes including gain of function mutations in proto-oncogenes and loss of function mutations in tumour suppressor genes.

(j) Explain how mutations in tumour suppressor genes can contribute to cancer and describe the development of cancer as a multi-step process.

*Use the knowledge gained in this section in new situations or to solve related problems.*

5 Genetic Basis for Variation

Content

- The passage of information from parent to offspring
- Genotypes and phenotypes
- Dihybrid crosses
- Mutations
- The effect of genotype and environment on phenotype
- Interaction between loci
- Linkage and crossing-over

Learning Outcomes

Candidates should be able to:

(a) Explain the terms, *locus*, *allele*, *dominant*, *recessive*, *codominant*, *homozygous*, *heterozygous*, *phenotype* and *genotype*.

(b) Explain how genotype is linked to phenotype and how genes are inherited from one generation to the next via the germ cells or gametes.

(c) Explain, with examples, how the environment may affect the phenotype.
(d) Use genetic diagrams to solve problems in dihybrid crosses, including those involving sex linkages, codominance and multiple alleles (involving autosomal linkage or epistasis).

(e) Use genetic diagrams to solve problems involving test crosses.

(f) Explain the meaning of the terms linkage and crossing-over and explain the effect of linkage and crossing-over on the phenotypic ratios from dihybrid crosses.

(g) Explain, with examples, what is meant by the terms gene mutation and chromosome aberration.

(h) Describe the differences between continuous and discontinuous variation and explain the genetic basis of continuous (many, additive, genes control a characteristic) and discontinuous variation (one or few genes control a characteristic).

(i) Describe the causes of genetic variation in a population.

(j) Describe the interaction between loci (epistasis) and predict phenotypic ratios in problems involving epistasis.

(k) Use the chi square test to test the significance of differences between observed and expected results.

Use the knowledge gained in this section in new situations or to solve related problems.

6 Cellular Physiology and Biochemistry

Content

• The need for energy in living organisms
• Photosynthesis as an energy-trapping process
• Respiration as an energy-releasing process
• Aerobic respiration
• Anaerobic respiration
• The fluid mosaic model of membrane structure
• Homeostasis
• Electrical and chemical signalling
• Nervous and hormonal control
• An overview of cell signalling and communication
• Signal reception and the initiation of transduction
• Signal transduction pathways
• Cellular responses to signals

Learning Outcomes

Candidates should be able to:

(a) With reference to the chloroplast structure, explain the light dependent reactions of photosynthesis (no biochemical details are needed but will include the outline of cyclic and non-cyclic light dependent reactions, and the transfer of energy for the subsequent manufacturing of carbohydrates from carbon dioxide).

(b) Outline the three phases of the Calvin cycle: (i) CO₂ uptake (ii) carbon reduction and (iii) ribulose bisphosphate (RuBP) regeneration and indicate the roles of ATP and NADP in the process.

(c) Discuss limiting factors in photosynthesis and carry out investigations on the effects of limiting factors, such as light intensity, CO₂ concentration and temperature, on the rate of photosynthesis.

(d) List and give an overview of the 4 stages of aerobic respiration and indicate where each stage takes place in an eukaryotic cell and mitochondria, and add up the energy captured (as ATP, reduced NAD and FAD) in each stage.

(e) Explain the production of a small yield of ATP from anaerobic respiration and the formation of ethanol in yeast and lactate in mammals.

(f) Compare the storage and structural forms of starch, glycogen and cellulose and their roles in plants/animals with reference to the starting and end points of photosynthesis/cellular respiration.

(g) Describe and explain the fluid mosaic model of membrane structure, including an outline of the roles of phospholipids, cholesterol, glycolipids, proteins and glycoproteins.

(h) Outline the roles and functions of membranes within cells and at the surface of cells.

(i) Recognise the need for control in organised systems and explain the principles of homeostasis in terms of receptors, effectors, and negative feedback.

(j) Recognise the need for communication systems within organisms.

(k) Describe and explain the transmission of an action potential along a myelinated neurone. (The importance of Na⁺ and K⁺ ions in the impulse transmission should be emphasised.)

(l) Describe the structure of a cholinergic synapse and explain how it functions, including the role of Ca²⁺ ions.
(m) Explain what is meant by an endocrine gland, with reference to the islets of Langerhans in the pancreas.

(n) Explain how the blood glucose concentration is regulated by insulin and glucagon.

(o) Describe the three main stages of cell signalling - ligand-receptor interaction, phosphorylation and signal transduction and signal amplification.

Use the knowledge gained in this section in new situations or to solve related problems.

7 Diversity and Evolution

Content

• Classification
• The concept of the species
• Variation, natural selection and evolution
• The neo-Darwinian revolution
• Evidence of evolution

Learning Outcomes

Candidates should be able to:

(a) Explain the binomial nomenclature of a species and hierarchical classification.

(b) Describe the classification of species into taxonomic groups (genus, family, order, class, phylum, kingdom) and appreciate the significance of the various concepts of the species.

(c) Explain the relationship between classification and phylogeny.

(d) Explain why variation is important in selection.

(e) Explain, with examples, how environmental factors act as forces of natural selection.

(f) Explain how natural selection may bring about evolution.

(g) Explain why the population is the smallest unit that can evolve.

(h) Explain how homology (anatomical, embryological and molecular) supports Darwin's theory of natural selection.
(i) Explain how biogeography and the fossil record support the evolutionary deductions based on homologies.

(j) State the advantages of molecular (nucleotide and amino acid sequences) methods in classifying organisms.

(k) Explain how genetic variation e.g. recessive alleles may be preserved in a natural population.

(l) Briefly describe the neutral theory of molecular evolution.

*Use the knowledge gained in this section in new situations or to solve related problems.*

### B. APPLICATIONS SYLLABUS

#### 8 Isolating, Cloning and Sequencing DNA

**Content**

- DNA Cloning (Genetic Engineering)
- DNA Analysis and Genomics
- Human genome project

**Learning Outcomes**

Candidates should be able to:

(a) Describe the natural function of restriction enzymes.

(b) Explain the formation of recombinant DNA molecule.

(c) Outline the procedures for cloning an eukaryotic gene in a bacterial plasmid and describe the properties of plasmids that allow them to be used as DNA cloning vectors.

(d) Explain how eukaryotic genes are cloned using *E. coli* cells to produce eukaryotic proteins to avoid the problems associated with introns.

(e) Distinguish between a genomic DNA and cDNA library.

(f) Outline 2 important proteins and other products that can be produced by genetic engineering technique (e.g. human growth hormone, anti-thrombin, etc).
(g) Describe the polymerase chain reaction (PCR) and explain the advantages and limitations of this procedure.

(h) Explain how gel electrophoresis is used to analyse nucleic acids and proteins and to distinguish between two alleles of a gene.

(i) Outline the process of nucleic acid hybridisation and explain how it can be used to detect and analyse restriction fragment length polymorphism (RFLP).

(j) Explain how RFLP analysis facilitated the process of genomic mapping, diseases detection, DNA fingerprinting, etc.

(k) Discuss the goals and implications of the human genome project, including the benefits and difficult ethical concerns.

Use the knowledge gained in this section in new situations or to solve related problems.

9 Applications of Molecular and Cell Biology

Content

• Stem cells
• The treatment of genetic diseases in human
• Gene therapy
• Cloning
• Genetic engineering and genetically modified organisms (GMOs)

Learning Outcomes

Candidates should be able to:

(a) Explain the unique features of stem cells.

(b) Explain the normal functions of stem cells in a living organism, using appropriate examples to illustrate.

(c) Describe two types of genetic diseases e.g. SCID (severe combined immunodeficiency) and cystic fibrosis, using viral and non-viral gene delivery systems, that can be treated with gene therapy.

(d) Explain what are the factors that keep gene therapy from becoming an effective treatment for genetic diseases.
(e) Discuss the social and ethical considerations for the use of gene therapy.

(f) Discuss cloning in plants.

(g) Explain the significance of genetic engineering in improving the quality and yield of crop plants and animals in solving the demand for food in the world.

(h) Discuss the ethical and social implications of genetically modified organisms.

Use the knowledge gained in this section in new situation or to solve related problems.
TEXTBOOKS AND REFERENCES

Teachers may find reference to the following books helpful.

CORE SYLLABUS

40. Tomkins, S (1989) *Hereditary and Human Diversity* (CUP)

The following may also be useful.
46. *Biological Sciences Review* Philip Allan Publishers Ltd, Market Place, Deddington, Oxfordshire, OX15 0SE, England (www.philipallan.co.uk)

List of readings for enrichment: books, landmark papers, journals

**Books e.g.:**

15. *The Second Creation* – Ian Wilmut
16. *Genethics* – David Suzuki
17. Life on Earth – David Attenborough
18. *Trials of Life* – David Attenborough
19. *The Living Planet* – David Attenborough
20. *The Private Life of Plants* – David Attenborough
21. *Origin of Species* – Charles Darwin
22. *The Silent Spring* – Rachel Carson

**Landmark Papers e.g.:**

1. *The Double Helix*
2. McClintock’s Jumping Genes
3. *Kary Mullis Thermus aquaticus*
4. *HGP in Nature*
5. *Celera’s Genome in Science*

**Journals e.g.:**

1. *Nature’s 50th anniversary of the DNA structure*
GLOSSARY OF TERMS USED IN SCIENCE PAPERS

It is hoped that the glossary (which is relevant only to science subjects) will prove helpful to candidates as a guide, i.e. it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. Define (the term(s))… is intended literally. Only a formal statement or equivalent paraphrase being required.

2. What do you understand by/What is meant by (the term(s))… normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

3. State implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained ‘by inspection’.

4. List requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should not be exceeded.

5. Explain may imply reasoning or some reference to theory, depending on the context.

6. Describe requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. In other contexts, describe and give an account of should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. Describe and explain may be coupled in a similar way to state and explain.

7. Discuss requires candidates to give a critical account of the points involved in the topic.

8. Outline implies brevity, i.e. restricting the answer to giving essentials.

9. Predict implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an early part of the question.

10. Deduce is used in a similar way as predict except that some supporting statement is required, e.g. reference to a law/principle, or the necessary reasoning is to be included in the answer.

11. Comment is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.
12. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in chemistry, two or more substances may satisfy the given conditions describing an ‘unknown’), or to imply that candidates are expected to apply their general knowledge to a ‘novel’ situation, one that may be formally ‘not in the syllabus’.

13. *Find* is a general term that may variously be interpreted as calculate, measure, determine etc.

14. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

15. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

16. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, e.g. relative molecular mass.

17. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.

18. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value. In diagrams, sketch implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important details.

19. *Compare* requires candidates to provide both the similarities and differences between things or concepts.

20. *Recognise* is often used to identify facts, characteristics or concepts that are critical (relevant/appropriate) to the understanding of a situation, event, process or phenomenon.

21. *Classify* requires candidates to group things based on common characteristics.

**SPECIAL NOTE**

**Units, significant figures.** Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.