BIOLOGY SYLLABUS

Topic 1: Statistical analysis

1.1.1	State that error bars are a graphical representation of the variability of data.
1.1.2	Calculate the mean and standard deviation of a set of values.
1.1.3	State that the term standard deviation is used to summarize the spread of values around the mean, and that 68% of the values fall within one standard deviation of the mean.
1.1.4	Explain how the standard deviation is useful for comparing the means and the spread of data between two or more samples.
1.1.5	Deduce the significance of the difference between two sets of data using calculated values for t and the appropriate tables.
1.1.6	Explain that the existence of a correlation does not establish that there is a causal relationship between two variables.

2.1 Cell theory

2.1.1	Outline the cell theory.
2.1.2	Discuss the evidence for the cell theory.
2.1.3	State that unicellular organisms carry out all the functions of life.
2.1.4	Compare the relative sizes of molecules, cell membrane thickness, viruses, bacteria, organelles and cells, using the appropriate SI unit.
2.1.5	Calculate the linear magnification of drawings and the actual size of specimens in images of known magnification.
2.1.6	Explain the importance of the surface area to volume ratio as a factor limiting cell size.
2.1.7	State that multicellular organisms show emergent properties.
2.1.8	Explain that cells in multicellular organisms differentiate to carry out specialized functions by expressing some of their genes but not others.
2.1.9	State that stem cells retain the capacity to divide and have the ability to differentiate along different pathways.
2.1.10	Outline one therapeutic use of stem cells.

2.2 Prokaryotic cells

2.2.1	Draw and label a diagram of the ultrastructure of *Escherichia coli* (*E. coli*) as an example of a prokaryote.
2.2.2	Annotate the diagram from 2.2.1 with the functions of each named structure.
2.2.3	Identify structures from 2.2.1 in electron micrographs of *E. coli*.
2.2.4	State that prokaryotic cells divide by binary fission.

2.3 Eukaryotic cells

2.3.1	Draw and label a diagram of the ultrastructure of a liver cell as an example of an animal cell.
2.3.2	Annotate the diagram from 2.3.1 with the functions of each named structure.
2.3.3	Identify structures from 2.3.1 in electron micrographs of liver cells.

2.3.4	Compare prokaryotic and eukaryotic cells.
2.3.5	State three differences between plant and animal cells.
2.3.6	Outline two roles of extracellular components.

2.4 Membranes

2.4.1	Draw and label a diagram to show the structure of membranes.
2.4.2	Explain how the hydrophobic and hydrophilic properties of phospholipids help to maintain the structure of cell membranes.
2.4.3	List the functions of membrane proteins.
2.4.4	Define *diffusion* and *osmosis*.
2.4.5	Explain passive transport across membranes by simple diffusion and facilitated diffusion.
2.4.6	Explain the role of protein pumps and ATP in active transport across membranes.
2.4.7	Explain how vesicles are used to transport materials within a cell between the rough endoplasmic reticulum, Golgi apparatus and plasma membrane.
2.4.8	Describe how the fluidity of the membrane allows it to change shape, break and re-form during endocytosis and exocytosis.

2.5 Cell division

2.5.1	Outline the stages in the cell cycle, including interphase (G_1, S, G_2), mitosis and cytokinesis.
2.5.2	State that tumours (cancers) are the result of uncontrolled cell division and that these can occur in any organ or tissue.
2.5.3	State that interphase is an active period in the life of a cell when many metabolic reactions occur, including protein synthesis, DNA replication and an increase in the number of mitochondria and/or chloroplasts.
2.5.4	Describe the events that occur in the four phases of mitosis (prophase, metaphase, anaphase and telophase).
2.5.5	Explain how mitosis produces two genetically identical nuclei.
2.5.6	State that growth, embryonic development, tissue repair and asexual reproduction involve mitosis.

3.1 Chemical elements and water

3.1.1	State that the most frequently occurring chemical elements in living things are carbon, hydrogen, oxygen and nitrogen.
3.1.2	State that a variety of other elements are needed by living organisms, including sulfur, calcium, phosphorus, iron and sodium.
3.1.3	State one role for each of the elements mentioned in 3.1.2.
3.1.4	Draw and label a diagram showing the structure of water molecules to show their polarity and hydrogen bond formation.
3.1.5	Outline the thermal, cohesive and solvent properties of water.
3.1.6	Explain the relationship between the properties of water and its uses in living organisms as a coolant, medium for metabolic reactions and transport medium.

3.2 Carbohydrates, lipids and proteins

3.2.1	Distinguish between *organic* and *inorganic* compounds.
3.2.2	Identify amino acids, glucose, ribose and fatty acids from diagrams showing their structure.
3.2.3	List three examples each of monosaccharides, disaccharides and polysaccharides.
3.2.4	State one function of glucose, lactose and glycogen in animals, and of fructose, sucrose and cellulose in plants.
3.2.5	Outline the role of condensation and hydrolysis in the relationships between monosaccharides, disaccharides and polysaccharides; between fatty acids, glycerol and triglycerides; and between amino acids and polypeptides.
3.2.6	State three functions of lipids.
3.2.7	Compare the use of carbohydrates and lipids in energy storage.

3.3 DNA structure

3.3.1	Outline DNA nucleotide structure in terms of sugar (deoxyribose), base and phosphate.
3.3.2	State the names of the four bases in DNA.
3.3.3	Outline how DNA nucleotides are linked together by covalent bonds into a single strand.
3.3.4	Explain how a DNA double helix is formed using complementary base pairing and hydrogen bonds.
3.3.5	Draw and label a simple diagram of the molecular structure of DNA.

3.4 DNA replication

3.4.1	Explain 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.
3.4.2	Explain the significance of complementary base pairing in the conservation of the base sequence of DNA.
3.4.3	State that DNA replication is semi-conservative.

3.5 Transcription and translation

3.5.1	Compare the structure of RNA and DNA.
3.5.2	Outline DNA transcription in terms of the formation of an RNA strand complementary to the DNA strand by RNA polymerase.
3.5.3	Describe the genetic code in terms of codons composed of triplets of bases.
3.5.4	Explain the process of translation, leading to polypeptide formation.
3.5.5	Discuss the relationship between one gene and one polypeptide.

3.6 Enzymes

3.6.1	Define *enzyme* and *active site*.
3.6.2	Explain enzyme–substrate specificity.
3.6.3	Explain the effects of temperature, pH and substrate concentration on enzyme activity.
3.6.4	Define *denaturation*.
3.6.5	Explain the use of lactase in the production of lactose-free milk.

3.7 Cell respiration

3.7.1	Define *cell respiration*.
3.7.2	State that, in cell respiration, glucose in the cytoplasm is broken down by glycolysis into pyruvate, with a small yield of ATP.
3.7.3	Explain that, during anaerobic cell respiration, pyruvate can be converted in the cytoplasm into lactate, or ethanol and carbon dioxide, with no further yield of ATP.
3.7.4	Explain that, during aerobic cell respiration, pyruvate can be broken down in the mitochondrion into carbon dioxide and water with a large yield of ATP.

3.8 Photosynthesis

3.8.1	State that photosynthesis involves the conversion of light energy into chemical energy.
3.8.2	State that light from the Sun is composed of a range of wavelengths (colours).
3.8.3	State that chlorophyll is the main photosynthetic pigment.
3.8.4	Outline the differences in absorption of red, blue and green light by chlorophyll.
3.8.5	State that light energy is used to produce ATP, and to split water molecules (photolysis) to form oxygen and hydrogen.
3.8.6	State that ATP and hydrogen (derived from the photolysis of water) are used to fix carbon dioxide to make organic molecules.
3.8.7	Explain that the rate of photosynthesis can be measured directly by the production of oxygen or the uptake of carbon dioxide, or indirectly by an increase in biomass.
3.8.8	Outline the effects of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis.

4.1 Chromosomes, genes, alleles and mutations

4.1.1	State that eukaryote chromosomes are made of DNA and proteins.
4.1.2	Define *gene*, *allele* and *genome*.
4.1.3	Define *gene mutation*.
4.1.4	Explain the consequence of a base substitution mutation in relation to the processes of transcription and translation, using the example of sickle-cell anemia.

4.2 Meiosis

4.2.1	State that meiosis is a reduction division of a diploid nucleus to form haploid nuclei.
4.2.2	Define *homologous chromosomes*.
4.2.3	Outline the process of meiosis, including pairing of homologous chromosomes and crossing over, followed by two divisions, which results in four haploid cells.
4.2.4	Explain that non-disjunction can lead to changes in chromosome number, illustrated by reference to Down syndrome (trisomy 21).
4.2.5	State that, in karyotyping, chromosomes are arranged in pairs according to their size and structure.
4.2.6	State that karyotyping is performed using cells collected by chorionic villus sampling or amniocentesis, for pre-natal diagnosis of chromosome abnormalities.

4.2.7	Analyse a human karyotype to determine gender and whether non-disjunction has occurred.

4.3 Theoretical genetics

4.3.1	Define *genotype*, *phenotype*, *dominant allele*, *recessive allele*, *codominant alleles*, *locus*, *homozygous*, *heterozygous*, *carrier* and *test cross*.
4.3.2	Determine the genotypes and phenotypes of the offspring of a monohybrid cross using a Punnett grid.
4.3.3	State that some genes have more than two alleles (multiple alleles).
4.3.4	Describe ABO blood groups as an example of codominance and multiple alleles.
4.3.5	Explain how the sex chromosomes control gender by referring to the inheritance of X and Y chromosomes in humans.
4.3.6	State that some genes are present on the X chromosome and absent from the shorter Y chromosome in humans.
4.3.7	Define *sex linkage*.
4.3.8	Describe the inheritance of colour blindness and hemophilia as examples of sex linkage.
4.3.9	State that a human female can be homozygous or heterozygous with respect to sex-linked genes.
4.3.10	Explain that female carriers are heterozygous for X-linked recessive alleles.
4.3.11	Predict the genotypic and phenotypic ratios of offspring of monohybrid crosses involving any of the above patterns of inheritance.
4.3.12	Deduce the genotypes and phenotypes of individuals in pedigree charts.

4.4 Genetic engineering and biotechnology

4.4.1	Outline the use of polymerase chain reaction (PCR) to copy and amplify minute quantities of DNA.
4.4.2	State that, in gel electrophoresis, fragments of DNA move in an electric field and are separated according to their size.
4.4.3	State that gel electrophoresis of DNA is used in DNA profiling.
4.4.4	Describe the application of DNA profiling to determine paternity and also in forensic investigations.
4.4.5	Analyse DNA profiles to draw conclusions about paternity or forensic investigations.
4.4.6	Outline three outcomes of the sequencing of the complete human genome.
4.4.7	State that, when genes are transferred between species, the amino acid sequence of polypeptides translated from them is unchanged because the genetic code is universal.
4.4.8	Outline a basic technique used for gene transfer involving plasmids, a host cell (bacterium, yeast or other cell), restriction enzymes (endonucleases) and DNA ligase.
4.4.9	State two examples of the current uses of genetically modified crops or animals.
4.4.10	Discuss the potential benefits and possible harmful effects of one example of genetic modification.
4.4.11	Define *clone*.
4.4.12	Outline a technique for cloning using differentiated animal cells.
4.4.13	Discuss the ethical issues of therapeutic cloning in humans.

5.1Communities and ecosystems

5.1.1	Define *species*, *habitat*, *population*, *community*, *ecosystem* and *ecology*.
5.1.2	Distinguish between *autotroph* and *heterotroph*.
5.1.3	Distinguish between *consumers*, *detritivores* and *saprotrophs*.
5.1.4	Describe what is meant by a food chain, giving three examples, each with at least three linkages (four organisms).
5.1.5	Describe what is meant by a food web.
5.1.6	Define *trophic level*.
5.1.7	Deduce the trophic level of organisms in a food chain and a food web.
5.1.8	Construct a food web containing up to 10 organisms, using appropriate information.
5.1.9	State that light is the initial energy source for almost all communities.
5.1.10	Explain the energy flow in a food chain.
5.1.11	State that energy transformations are never 100% efficient.
5.1.12	Explain reasons for the shape of pyramids of energy.
5.1.13	Explain that energy enters and leaves ecosystems, but nutrients must be recycled.
5.1.14	State that saprotrophic bacteria and fungi (decomposers) recycle nutrients.

5.2 The greenhouse effect

5.2.1	Draw and label a diagram of the carbon cycle to show the processes involved.
5.2.2	Analyse the changes in concentration of atmospheric carbon dioxide using historical records.
5.2.3	Explain the relationship between rises in concentrations of atmospheric carbon dioxide, methane and oxides of nitrogen and the enhanced greenhouse effect.
5.2.4	Outline the precautionary principle.
5.2.5	Evaluate the precautionary principle as a justification for strong action in response to the threats posed by the enhanced greenhouse effect.
5.2.6	Outline the consequences of a global temperature rise on arctic ecosystems.

5.3 Populations

5.3.1	Outline how population size is affected by natality, immigration, mortality and emigration.
5.3.2	Draw and label a graph showing a sigmoid (S-shaped) population growth curve.
5.3.3	Explain the reasons for the exponential growth phase, the plateau phase and the transitional phase between these two phases.
5.3.4	List three factors that set limits to population increase.

5.4 Evolution

5.4.1	Define *evolution*.
5.4.2	Outline the evidence for evolution provided by the fossil record, selective breeding of domesticated animals and homologous structures.

5.4.3	State that populations tend to produce more offspring than the environment can support.
5.4.4	Explain that the consequence of the potential overproduction of offspring is a struggle for survival.
5.4.5	State that the members of a species show variation.
5.4.6	Explain how sexual reproduction promotes variation in a species.
5.4.7	Explain how natural selection leads to evolution.
5.4.8	Explain two examples of evolution in response to environmental change; one must be antibiotic resistance in bacteria.

5.5 Classification

5.5.1	Outline the binomial system of nomenclature.
5.5.2	List seven levels in the hierarchy of taxa—kingdom, phylum, class, order, family, genus and species—using an example from two different kingdoms for each level.
5.5.3	Distinguish between the following phyla of plants, using simple external recognition features: *bryophyta, filicinophyta, coniferophyta* and *angiospermophyta*.
5.5.4	Distinguish between the following phyla of animals, using simple external recognition features: *porifera, cnidaria, platyhelminthes, annelida, mollusca* and *arthropoda*.
5.5.5	Apply and design a key for a group of up to eight organisms.

6.1 Digestion

6.1.1	Explain why digestion of large food molecules is essential.
6.1.2	Explain the need for enzymes in digestion.
6.1.3	State the source, substrate, products and optimum pH conditions for one amylase, one protease and one lipase.
6.1.4	Draw and label a diagram of the digestive system.
6.1.5	Outline the function of the stomach, small intestine and large intestine.
6.1.6	Distinguish between *absorption* and *assimilation*.
6.1.7	Explain how the structure of the villus is related to its role in absorption and transport of the products of digestion.

6.2 The transport system

6.2.1	Draw and label a diagram of the heart showing the four chambers, associated blood vessels, valves and the route of blood through the heart.
6.2.2	State that the coronary arteries supply heart muscle with oxygen and nutrients.
6.2.3	Explain the action of the heart in terms of collecting blood, pumping blood, and opening and closing of valves.
6.2.4	Outline the control of the heartbeat in terms of myogenic muscle contraction, the role of the pacemaker, nerves, the medulla of the brain and epinephrine (adrenaline).
6.2.5	Explain the relationship between the structure and function of arteries, capillaries and veins.
6.2.6	State that blood is composed of plasma, erythrocytes, leucocytes (phagocytes and lymphocytes) and platelets.

6.2.7	State that the following are transported by the blood: nutrients, oxygen, carbon dioxide, hormones, antibodies, urea and heat.

6.3 Defence against infectious disease

6.3.1	Define *pathogen*.
6.3.2	Explain why antibiotics are effective against bacteria but not against viruses.
6.3.3	Outline the role of skin and mucous membranes in defence against pathogens.
6.3.4	Outline how phagocytic leucocytes ingest pathogens in the blood and in body tissues.
6.3.5	Distinguish between *antigens* and *antibodies*.
6.3.6	Explain antibody production.
6.3.7	Outline the effects of HIV on the immune system.
6.3.8	Discuss the cause, transmission and social implications of AIDS.

6.4 Gas exchange

6.4.1	Distinguish between *ventilation*, *gas exchange* and *cell respiration*.
6.4.2	Explain the need for a ventilation system.
6.4.3	Describe the features of alveoli that adapt them to gas exchange.
6.4.4	Draw and label a diagram of the ventilation system, including trachea, lungs, bronchi, bronchioles and alveoli.
6.4.5	Explain the mechanism of ventilation of the lungs in terms of volume and pressure changes caused by the internal and external intercostal muscles, the diaphragm and abdominal muscles.

6.5 Nerves, hormones and homeostasis

6.5.1	State that the nervous system consists of the central nervous system (CNS) and peripheral nerves, and is composed of cells called neurons that can carry rapid electrical impulses.
6.5.2	Draw and label a diagram of the structure of a motor neuron.
6.5.3	State that nerve impulses are conducted from receptors to the CNS by sensory neurons, within the CNS by relay neurons, and from the CNS to effectors by motor neurons.
6.5.4	Define *resting potential* and *action potential* (depolarization and repolarization).
6.5.5	Explain how a nerve impulse passes along a non-myelinated neuron.
6.5.6	Explain the principles of synaptic transmission.
6.5.7	State that the endocrine system consists of glands that release hormones that are transported in the blood.
6.5.8	State that homeostasis involves maintaining the internal environment between limits, including blood pH, carbon dioxide concentration, blood glucose concentration, body temperature and water balance.
6.5.9	Explain that homeostasis involves monitoring levels of variables and correcting changes in levels by negative feedback mechanisms.
6.5.10	Explain the control of body temperature, including the transfer of heat in blood, and the roles of the hypothalamus, sweat glands, skin arterioles and shivering.

6.5.11	Explain the control of blood glucose concentration, including the roles of glucagon, insulin and α and β cells in the pancreatic islets.
6.5.12	Distinguish between *type I* and *type II* diabetes.

6.6 Reproduction

6.6.1	Draw and label diagrams of the adult male and female reproductive systems.
6.6.2	Outline the role of hormones in the menstrual cycle, including FSH (follicle stimulating hormone), LH (luteinizing hormone), estrogen and progesterone.
6.6.3	Annotate a graph showing hormone levels in the menstrual cycle, illustrating the relationship between changes in hormone levels and ovulation, menstruation and thickening of the endometrium.
6.6.4	List three roles of testosterone in males.
6.6.5	Outline the process of *in vitro* fertilization (IVF).
6.6.6	Discuss the ethical issues associated with IVF.

7.1 DNA structure

7.1.1	Describe the structure of DNA, including the antiparallel strands, 3'–5' linkages and hydrogen bonding between purines and pyrimidines.
7.1.2	Outline the structure of nucleosomes.
7.1.3	State that nucleosomes help to supercoil chromosomes and help to regulate transcription.
7.1.4	Distinguish between *unique or single-copy genes* and *highly repetitive sequences* in nuclear DNA.
7.1.5	State that eukaryotic genes can contain exons and introns.

7.2 DNA replication

7.2.1	State that DNA replication occurs in a $5' \rightarrow 3'$ direction.
7.2.2	Explain the process of DNA replication in prokaryotes, including the role of enzymes (helicase, DNA polymerase, RNA primase and DNA ligase), Okazaki fragments and deoxynucleoside triphosphates.
7.2.3	State that DNA replication is initiated at many points in eukaryotic chromosomes.

7.3 Transcription

7.3.1	State that transcription is carried out in a $5' \rightarrow 3'$ direction.
7.3.2	Distinguish between the *sense* and *antisense* strands of DNA.
7.3.3	Explain the process of transcription in prokaryotes, including the role of the promoter region, RNA polymerase, nucleoside triphosphates and the terminator.
7.3.4	State that eukaryotic RNA needs the removal of introns to form mature mRNA.

7.4 Translation

7.4.1	Explain that each tRNA molecule is recognized by a tRNA-activating enzyme that binds a specific amino acid to the tRNA, using ATP for energy.
7.4.2	Outline the structure of ribosomes, including protein and RNA composition, large and small subunits, three tRNA binding sites and mRNA binding sites.

7.4.3	State that translation consists of initiation, elongation, translocation and termination.
7.4.4	State that translation occurs in a $5' \rightarrow 3'$ direction.
7.4.5	Draw and label a diagram showing the structure of a peptide bond between two amino acids.
7.4.6	Explain the process of translation, including ribosomes, polysomes, start codons and stop codons.
7.4.7	State that free ribosomes synthesize proteins for use primarily within the cell, and that bound ribosomes synthesize proteins primarily for secretion or for lysosomes.

7.5 Proteins

7.5.1	Explain the four levels of protein structure, indicating the significance of each level.
7.5.2	Outline the difference between fibrous and globular proteins, with reference to two examples of each protein type.
7.5.3	Explain the significance of polar and non-polar amino acids.
7.5.4	State four functions of proteins, giving a named example of each.

7.6 Enzymes

7.6.1	State that metabolic pathways consist of chains and cycles of enzyme-catalysed reactions.
7.6.2	Describe the induced-fit model.
7.6.3	Explain that enzymes lower the activation energy of the chemical reactions that they catalyse.
7.6.4	Explain the difference between competitive and non-competitive inhibition, with reference to one example of each.
7.6.5	Explain the control of metabolic pathways by end-product inhibition, including the role of allosteric sites.

8.1 Cell respiration

8.1.1	State that oxidation involves the loss of electrons from an element, whereas reduction involves a gain of electrons; and that oxidation frequently involves gaining oxygen or losing hydrogen, whereas reduction frequently involves losing oxygen or gaining hydrogen.
8.1.2	Outline the process of glycolysis, including phosphorylation, lysis, oxidation and ATP formation.
8.1.3	Draw and label a diagram showing the structure of a mitochondrion as seen in electron micrographs.
8.1.4	Explain aerobic respiration, including the link reaction, the Krebs cycle, the role of NADH + H^+, the electron transport chain and the role of oxygen.
8.1.5	Explain oxidative phosphorylation in terms of chemiosmosis.
8.1.6	Explain the relationship between the structure of the mitochondrion and its function.

8.2 Photosynthesis

8.2.1	Draw and label a diagram showing the structure of a chloroplast as seen in electron micrographs.
8.2.2	State that photosynthesis consists of light-dependent and light-independent reactions.
8.2.3	Explain the light-dependent reactions.
8.2.4	Explain photophosphorylation in terms of chemiosmosis.

8.2.5	Explain the light-independent reactions.
8.2.6	Explain the relationship between the structure of the chloroplast and its function.
8.2.7	Explain the relationship between the action spectrum and the absorption spectrum of photosynthetic pigments in green plants.
8.2.8	Explain the concept of limiting factors in photosynthesis, with reference to light intensity, temperature and concentration of carbon dioxide.

9.1 Plant structure and growth

9.1.1	Draw and label plan diagrams to show the distribution of tissues in the stem and leaf of a dicotyledonous plant.
9.1.2	Outline three differences between the structures of dicotyledonous and monocotyledonous plants.
9.1.3	Explain the relationship between the distribution of tissues in the leaf and the functions of these tissues.
9.1.4	Identify modifications of roots, stems and leaves for different functions: bulbs, stem tubers, storage roots and tendrils.
9.1.5	State that dicotyledonous plants have apical and lateral meristems.
9.1.6	Compare growth due to apical and lateral meristems in dicotyledonous plants.
9.1.7	Explain the role of auxin in phototropism as an example of the control of plant growth.

9.2 Transport in angiospermophytes

9.2.1	Outline how the root system provides a large surface area for mineral ion and water uptake by means of branching and root hairs.
9.2.2	List ways in which mineral ions in the soil move to the root.
9.2.3	Explain the process of mineral ion absorption from the soil into roots by active transport.
9.2.4	State that terrestrial plants support themselves by means of thickened cellulose, cell turgor and lignified xylem.
9.2.5	Define *transpiration*.
9.2.6	Explain how water is carried by the transpiration stream, including the structure of xylem vessels, transpiration pull, cohesion, adhesion and evaporation.
9.2.7	State that guard cells can regulate transpiration by opening and closing stomata.
9.2.8	State that the plant hormone abscisic acid causes the closing of stomata.
9.2.9	Explain how the abiotic factors light, temperature, wind and humidity, affect the rate of transpiration in a typical terrestrial plant.
9.2.10	Outline four adaptations of xerophytes that help to reduce transpiration.
9.2.11	Outline the role of phloem in active translocation of sugars (sucrose) and amino acids from source (photosynthetic tissue and storage organs) to sink (fruits, seeds, roots).

9.3 Reproduction in angiospermophytes

9.3.1	Draw and label a diagram showing the structure of a dicotyledonous animal-pollinated flower.
9.3.2	Distinguish between *pollination*, *fertilization* and *seed dispersal*.

9.3.3	Draw and label a diagram showing the external and internal structure of a named dicotyledonous seed.
9.3.4	Explain the conditions needed for the germination of a typical seed.
9.3.5	Outline the metabolic processes during germination of a starchy seed.
9.3.6	Explain how flowering is controlled in long-day and short-day plants, including the role of phytochrome.

10.1 Meiosis

10.1.1	Describe the behaviour of the chromosomes in the phases of meiosis.
10.1.2	Outline the formation of chiasmata in the process of crossing over.
10.1.3	Explain how meiosis results in an effectively infinite genetic variety in gametes through crossing over in prophase I and random orientation in metaphase I.
10.1.4	State Mendel's law of independent assortment.
10.1.5	Explain the relationship between Mendel's law of independent assortment and meiosis.

10.2 Dihybrid crosses and gene linkage

10.2.1	Calculate and predict the genotypic and phenotypic ratio of offspring of dihybrid crosses involving unlinked autosomal genes.
10.2.2	Distinguish between *autosomes* and *sex chromosomes*.
10.2.3	Explain how crossing over between non-sister chromatids of a homologous pair in prophase I can result in an exchange of alleles.
10.2.4	Define *linkage group*.
10.2.5	Explain an example of a cross between two linked genes.
10.2.6	Identify which of the offspring are recombinants in a dihybrid cross involving linked genes.

10.3 Polygenic inheritance

10.3.1	Define *polygenic inheritance*.
10.3.2	Explain that polygenic inheritance can contribute to continuous variation using two examples, one of which must be human skin colour.

11.1 Defence against infectious disease

11.1.1	Describe the process of blood clotting.
11.1.2	Outline the principle of challenge and response, clonal selection and memory cells as the basis of immunity.
11.1.3	Define *active* and *passive* immunity.
11.1.4	Explain antibody production.
11.1.5	Describe the production of monoclonal antibodies and their use in diagnosis and in treatment.
11.1.6	Explain the principle of vaccination.
11.1.7	Discuss the benefits and dangers of vaccination.

11.2 Muscles and movement

11.2.1	State the roles of bones, ligaments, muscles, tendons and nerves in human movement.
11.2.2	Label a diagram of the human elbow joint, including cartilage, synovial fluid, joint capsule, named bones and antagonistic muscles (biceps and triceps).
11.2.3	Outline the functions of the structures in the human elbow joint named in 11.2.2.
11.2.4	Compare the movements of the hip joint and the knee joint.
11.2.5	Describe the structure of striated muscle fibres, including the myofibrils with light and dark bands, mitochondria, the sarcoplasmic reticulum, nuclei and the sarcolemma.
11.2.6	Draw and label a diagram to show the structure of a sarcomere, including Z lines, actin filaments, myosin filaments with heads, and the resultant light and dark bands.
11.2.7	Explain how skeletal muscle contracts, including the release of calcium ions from the sarcoplasmic reticulum, the formation of cross-bridges, the sliding of actin and myosin filaments, and the use of ATP to break cross-bridges and re-set myosin heads.
11.2.8	Analyse electron micrographs to find the state of contraction of muscle fibres.

11.3 The kidney

11.3.1	Define *excretion*.
11.3.2	Draw and label a diagram of the kidney.
11.3.3	Annotate a diagram of a glomerulus and associated nephron to show the function of each part.
11.3.4	Explain the process of ultrafiltration, including blood pressure, fenestrated blood capillaries and basement membrane.
11.3.5	Define *osmoregulation*.
11.3.6	Explain the reabsorption of glucose, water and salts in the proximal convoluted tubule, including the roles of microvilli, osmosis and active transport.
11.3.7	Explain the roles of the loop of Henle, medulla, collecting duct and ADH (vasopressin) in maintaining the water balance of the blood.
11.3.8	Explain the differences in the concentration of proteins, glucose and urea between blood plasma, glomerular filtrate and urine.
11.3.9	Explain the presence of glucose in the urine of untreated diabetic patients.

11.4 Reproduction

11.4.1	Annotate a light micrograph of testis tissue to show the location and function of interstitial cells (Leydig cells), germinal epithelium cells, developing spermatozoa and Sertoli cells.
11.4.2	Outline the processes involved in spermatogenesis within the testis, including mitosis, cell growth, the two divisions of meiosis and cell differentiation.
11.4.3	State the role of LH, testosterone and FSH in spermatogenesis.
11.4.4	Annotate a diagram of the ovary to show the location and function of germinal epithelium, primary follicles, mature follicle and secondary oocyte.
11.4.5	Outline the processes involved in oogenesis within the ovary, including mitosis, cell growth, the two divisions of meiosis, the unequal division of cytoplasm and the degeneration of polar body.
11.4.6	Draw and label a diagram of a mature sperm and egg.

11.4.7	Outline the role of the epididymis, seminal vesicle and prostate gland in the production of semen.
11.4.8	Compare the processes of spermatogenesis and oogenesis, including the number of gametes and the timing of the formation and release of gametes.
11.4.9	Describe the process of fertilization, including the acrosome reaction, penetration of the egg membrane by a sperm and the cortical reaction.
11.4.10	Outline the role of HCG in early pregnancy.
11.4.11	Outline early embryo development up to the implantation of the blastocyst.
11.4.12	Explain how the structure and functions of the placenta, including its hormonal role in secretion of estrogen and progesterone, maintain pregnancy.
11.4.13	State that the fetus is supported and protected by the amniotic sac and amniotic fluid.
11.4.14	State that materials are exchanged between the maternal and fetal blood in the placenta.
11.4.15	Outline the process of birth and its hormonal control, including the changes in progesterone and oxytocin levels and positive feedback.

D1 Origin of life on Earth

D.1.1	Describe four processes needed for the spontaneous origin of life on Earth.
D.1.2	Outline the experiments of Miller and Urey into the origin of organic compounds.
D.1.3	State that comets may have delivered organic compounds to Earth.
D.1.4	Discuss possible locations where conditions would have allowed the synthesis of organic compounds.
D.1.5	Outline two properties of RNA that would have allowed it to play a role in the origin of life.
D.1.6	State that living cells may have been preceded by protobionts, with an internal chemical environment different from their surroundings.
D.1.7	Outline the contribution of prokaryotes to the creation of an oxygen-rich atmosphere.
D.1.8	Discuss the endosymbiotic theory for the origin of eukaryotes.

D2 Species and speciation

D.2.1	Define *allele frequency* and *gene pool*.
D.2.2	State that evolution involves a change in allele frequency in a population’s gene pool over a number of generations.
D.2.3	Discuss the definition of the term species.
D.2.4	Describe three examples of barriers between gene pools.
D.2.5	Explain how polyploidy can contribute to speciation.
D.2.6	Compare allopatric and sympatric speciation.
D.2.7	Outline the process of adaptive radiation.
D.2.8	Compare convergent and divergent evolution.
D.2.9	Discuss ideas on the pace of evolution, including gradualism and punctuated equilibrium.
D.2.10	Describe one example of transient polymorphism.

D.2.11	Describe sickle-cell anemia as an example of balanced polymorphism.

D3 Human evolution

D.3.1	Outline the method for dating rocks and fossils using radioisotopes, with reference to ^{14}C and ^{40}K.
D.3.2	Define *half-life*.
D.3.3	Deduce the approximate age of materials based on a simple decay curve for a radioisotope.
D.3.4	Describe the major anatomical features that define humans as primates.
D.3.5	Outline the trends illustrated by the fossils of *Ardipithecus ramidus*, *Australopithecus* including *A. afarensis* and *A. africanus*, and *Homo* including *H. habilis*, *H. erectus*, *H. neanderthalensis* and *H. sapiens*.
D.3.6	State that, at various stages in hominid evolution, several species may have coexisted.
D.3.7	Discuss the incompleteness of the fossil record and the resulting uncertainties about human evolution.
D.3.8	Discuss the correlation between the change in diet and increase in brain size during hominid evolution.
D.3.9	Distinguish between *genetic* and *cultural* evolution.
D.3.10	Discuss the relative importance of genetic and cultural evolution in the recent evolution of humans.

D4 The Hardy–Weinberg principle

D.4.1	Explain how the Hardy–Weinberg equation is derived.
D.4.2	Calculate allele, genotype and phenotype frequencies for two alleles of a gene, using the Hardy–Weinberg equation.
D.4.3	State the assumptions made when the Hardy–Weinberg equation is used.

D5 Phylogeny and systematics

D.5.1	Outline the value of classifying organisms.
D.5.2	Explain the biochemical evidence provided by the universality of DNA and protein structures for the common ancestry of living organisms.
D.5.3	Explain how variations in specific molecules can indicate phylogeny.
D.5.4	Discuss how biochemical variations can be used as an evolutionary clock.
D.5.5	Define *clade* and *cladistics*.
D.5.6	Distinguish, with examples, between *analogous* and *homologous* characteristics.
D.5.7	Outline the methods used to construct cladograms and the conclusions that can be drawn from them.
D.5.8	Construct a simple cladogram.
D.5.9	Analyse cladograms in terms of phylogenetic relationships.
D.5.10	Discuss the relationship between cladograms and the classification of living organisms.

F1 Diversity of microbes

F.1.1	Outline the classification of living organisms into three domains.

F.1.2	Explain the reasons for the reclassification of living organisms into three domains.
F.1.3	Distinguish between the characteristics of the three domains.
F.1.4	Outline the wide diversity of habitat in the Archae, as exemplified by methanogens, thermophiles and halophiles.
F.1.5	Outline the diversity of Eubacteria, including shape and cell wall structure.
F.1.6	State, with one example, that some bacteria form aggregates that show characteristics not seen in individual bacteria.
F.1.7	Compare the structure of the cell walls of Gram-positive and Gram-negative Eubacteria.
F.1.8	Outline the diversity of structure in viruses including: naked capsid *versus* enveloped capsid; DNA *versus* RNA; and single stranded *versus* double stranded DNA or RNA.
F.1.9	Outline the diversity of microscopic eukaryotes, as illustrated by *Saccharomyces*, *Amoeba*, *Plasmodium*, *Paramecium*, *Euglena* and *Chlorella*.

F2 Microbes and the environment

F.2.1	List the roles of microbes in ecosystems, including producers, nitrogen fixers and decomposers.
F.2.2	Draw and label a diagram of the nitrogen cycle.
F.2.3	State the roles of *Rhizobium*, *Azotobacter*, *Nitrosomonas*, *Nitrobacter* and *Pseudomonas denitrificans* in the nitrogen cycle.
F.2.4	Outline the conditions that favour denitrification and nitrification.
F.2.5	Explain the consequences of releasing raw sewage and nitrate fertilizer into rivers.
F.2.6	Outline the role of saprotrophic bacteria in the treatment of sewage using trickling filter beds and reed bed systems.
F.2.7	State that biomass can be used as raw material for the production of fuels such as methane and ethanol.
F.2.8	Explain the principles involved in the generation of methane from biomass, including the conditions needed, organisms involved and the basic chemical reactions that occur.

F3 Microbes and biotechnology

F.3.1	State that reverse transcriptase catalyses the production of DNA from RNA.
F.3.2	Explain how reverse transcriptase is used in molecular biology.
F.3.3	Distinguish between *somatic* and *germ line* therapy.
F.3.4	Outline the use of viral vectors in gene therapy.
F.3.5	Discuss the risks of gene therapy.

F4 Microbes and food production

F.4.1	Explain the use of *Saccharomyces* in the production of beer, wine and bread.
F.4.2	Outline the production of soy sauce using *Aspergillus oryzae*.
F.4.3	Explain the use of acids and high salt or sugar concentrations in food preservation.
F.4.4	Outline the symptoms, method of transmission and treatment of one named example of food poisoning.

F5 Metabolism of microbes

F.5.1	Define the terms *photoautotroph*, *photoheterotroph*, *chemoautotroph* and *chemoheterotroph*.
F.5.2	State one example of a photoautotroph, photoheterotroph, chemoautotroph and chemoheterotroph.
F.5.3	Compare photoautotrophs with photoheterotrophs in terms of energy sources and carbon sources.
F.5.4	Compare chemoautotrophs with chemoheterotrophs in terms of energy sources and carbon sources.
F.5.5	Draw and label a diagram of a filamentous cyanobacterium.
F.5.6	Explain the use of bacteria in the bioremediation of soil and water.

F6 Microbes and disease

F.6.1	List six methods by which pathogens are transmitted and gain entry to the body.
F.6.2	Distinguish between *intracellular* and *extracellular* bacterial infection using *Chlamydia* and *Streptococcus* as examples.
F.6.3	Distinguish between *endotoxins* and *exotoxins*.
F.6.4	Evaluate methods of controlling microbial growth by irradiation, pasteurization, antiseptics and disinfectants.
F.6.5	Outline the mechanism of the action of antibiotics, including inhibition of synthesis of cell walls, proteins and nucleic acids.
F.6.6	Outline the lytic life cycle of the influenza virus.
F.6.7	Define *epidemiology*.
F.6.8	Discuss the origin and epidemiology of one example of a pandemic.
F.6.9	Describe the cause, transmission and effects of malaria, as an example of disease caused by a protozoan.
F.6.10	Discuss the prion hypothesis for the cause of spongiform encephalopathies.

H1 Hormonal control

H.1.1	State that hormones are chemical messengers secreted by endocrine glands into the blood and transported to specific target cells.
H.1.2	State that hormones can be steroids, proteins and tyrosine derivatives, with one example of each.
H.1.3	Distinguish between the mode of action of *steroid* hormones and *protein* hormones.
H.1.4	Outline the relationship between the hypothalamus and the pituitary gland.
H.1.5	Explain the control of ADH (vasopressin) secretion by negative feedback.

H2 Digestion

H.2.1	State that digestive juices are secreted into the alimentary canal by glands, including salivary glands, gastric glands in the stomach wall, the pancreas and the wall of the small intestine.
H.2.2	Explain the structural features of exocrine gland cells.
H.2.3	Compare the composition of saliva, gastric juice and pancreatic juice.
H.2.4	Outline the control of digestive juice secretion by nerves and hormones, using the example of secretion of gastric juice.

H.2.5	Outline the role of membrane-bound enzymes on the surface of epithelial cells in the small intestine in digestion.
H.2.6	Outline the reasons for cellulose not being digested in the alimentary canal.
H.2.7	Explain why pepsin and trypsin are initially synthesized as inactive precursors and how they are subsequently activated.
H.2.8	Discuss the roles of gastric acid and *Helicobacter pylori* in the development of stomach ulcers and stomach cancers.
H.2.9	Explain the problem of lipid digestion in a hydrophilic medium and the role of bile in overcoming this.

H3 Absorption of digested foods

H.3.1	Draw and label a diagram showing a transverse section of the ileum as seen under a light microscope.
H.3.2	Explain the structural features of an epithelial cell of a villus as seen in electron micrographs, including microvilli, mitochondria, pinocytotic vesicles and tight junctions.
H.3.3	Explain the mechanisms used by the ileum to absorb and transport food, including facilitated diffusion, active transport and endocytosis.
H.3.4	List the materials that are not absorbed and are egested.

H4 Functions of the liver

H.4.1	Outline the circulation of blood through liver tissue, including the hepatic artery, hepatic portal vein, sinusoids and hepatic vein.
H.4.2	Explain the role of the liver in regulating levels of nutrients in the blood.
H.4.3	Outline the role of the liver in the storage of nutrients, including carbohydrate, iron, vitamin A and vitamin D.
H.4.4	State that the liver synthesizes plasma proteins and cholesterol.
H.4.5	State that the liver has a role in detoxification.
H.4.6	Describe the process of erythrocyte and hemoglobin breakdown in the liver, including phagocytosis, digestion of globin and bile pigment formation.
H.4.7	Explain the liver damage caused by excessive alcohol consumption.

H5 The transport system

H.5.1	Explain the events of the cardiac cycle, including atrial and ventricular systole and diastole, and heart sounds.
H.5.2	Analyse data showing pressure and volume changes in the left atrium, left ventricle and the aorta, during the cardiac cycle.
H.5.3	Outline the mechanisms that control the heartbeat, including the roles of the SA (sinoatrial) node, AV (atrioventricular) node and conducting fibres in the ventricular walls.
H.5.4	Outline atherosclerosis and the causes of coronary thrombosis.
H.5.5	Discuss factors that affect the incidence of coronary heart disease.

H6Gas exchange

H.6.1	Define *partial pressure*.
H.6.2	Explain the oxygen dissociation curves of adult hemoglobin, fetal hemoglobin and myoglobin.
H.6.3	Describe how carbon dioxide is carried by the blood, including the action of carbonic anhydrase, the chloride shift and buffering by plasma proteins.
H.6.4	Explain the role of the Bohr shift in the supply of oxygen to respiring tissues.
H.6.5	Explain how and why ventilation rate varies with exercise.
H.6.6	Outline the possible causes of asthma and its effects on the gas exchange system.
H.6.7	Explain the problem of gas exchange at high altitudes and the way the body acclimatizes.