Grade 11-12 Biology Curriculum

Unit of Study: Cells (12 hours)

Curriculum Standards	Learner Outcomes
Cell theory	• Outlines the cell theory. • Discusses the evidence for the cell theory. • States that unicellular organisms carry out all the functions of life. • Compares the relative sizes of molecules, cell membrane thickness, viruses, bacteria, organelles and cells, using the appropriate SI unit. • Calculates the linear magnification of drawings and the actual size of specimens in images of known magnification. • Explains the importance of the surface area to volume ratio as a factor limiting cell size. • States that multicellular organisms show emergent properties. • Explains that cells in multicellular organisms differentiate to carry out specialized functions by expressing some of their genes but not others. • States that stem cells retain the capacity to divide and have the ability to differentiate along different pathways. • Outlines one therapeutic use of stem cells.
Prokaryotic cells	• Draws and labels a diagram of the ultra structure of *Escherichia coli* (*E. coli*) as an example of a prokaryote. • Annotates the diagram from 2.2.1 with the functions of each named structure. • Identifies structures from 2.2.1 in electron micrographs of *E. coli*. • States those prokaryotic cells divide by binary fission.
Eukaryotic cells	• Draws and labels a diagram of the ultrastructure of a liver cell as an example of an animal cell. • Annotates the diagram from 2.3.1 with the functions of each named structure. • Identifies structures from 2.3.1 in electron micrographs of liver cells. • Compares prokaryotic and eukaryotic cells. • States three differences between plant and animal cells. • Outlines two roles of extracellular components.
Membranes	• Draws and labels a diagram to show the structure of membranes. • Explain show the hydrophobic and hydrophilic properties of phospholipids help to maintain the structure of cell membranes. • Lists the functions of membrane proteins. • Defines *diffusion* and *osmosis*. • Explains passive transport across membranes by simple diffusion and facilitated diffusion. • Explains the role of protein pumps and ATP in active transport across membranes.

	• Explains how vesicles are used to transport materials within a cell between the rough endoplasmic reticulum, Golgi apparatus and plasma membrane. • Describes how the fluidity of the membrane allows it to change shape, break and re-form during endocytosis and exocytosis.
Cell division	• Outlines the stages in the cell cycle, including interphase (G_1, S, G_2), mitosis and cytokinesis. • States that tumours (cancers) are the result of uncontrolled cell division and that these can occur in any organ or tissue. • States 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. • Describes the events that occur in the four phases of mitosis (prophase, metaphase, anaphase and telophase). • Explains how mitosis produces two genetically identical nuclei. • States that growth, embryonic development, tissue repair and asexual reproduction involve mitosis.

<u>Unit of Study</u>: The chemistry of life (15 hours)

Curriculum Standards	**Learner Outcomes**
Chemical elements and water	• States that the most frequently occurring chemical elements in living things are carbon, hydrogen, oxygen and nitrogen. • States that a variety of other elements are needed by living organisms, including sulfur, calcium, phosphorus, iron and sodium. • States one role for each of the elements mentioned in 3.1.2. • Draws and labels a diagram showing the structure of water molecules to show their polarity and hydrogen bond formation. • Outlines the thermal, cohesive and solvent properties of water. • Explains the relationship between the properties of water and its uses in living organisms as a coolant, medium for metabolic reactions and transport medium.

Carbohydrates, lipids and proteins	• Distinguishes between *organic* and *inorganic* compounds. • Identifies amino acids, glucose, ribose and fatty acids from diagrams showing their structure. • Lists three examples each of monosaccharide, disaccharides and polysaccharides. • States one function of glucose, lactose and glycogen in animals, and of fructose, sucrose and cellulose in plants. • Outlines the role of condensation and hydrolysis in the relationships between monosaccharide, disaccharides and polysaccharides; between fatty acids, glycerol and triglycerides; and between amino acids and polypeptides. • States three functions of lipids. • Compares the use of carbohydrates and lipids in energy storage.
DNA structure	• Outlines DNA nucleotide structure in terms of sugar (deoxyribose), base and phosphate. • States the names of the four bases in DNA. • Outlines how DNA nucleotides are linked together by covalent bonds into a single strand. • Explains how a DNA double helix is formed using complementary base pairing and hydrogen bonds. • Draws and labels a simple diagram of the molecular structure of DNA.
DNA replication	• Explains 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. • Explains the significance of complementary base pairing in the conservation of the base sequence of DNA. • States that DNA replication is semi- conservative.
Transcription and translation	• Compares the structure of RNA and DNA. • Outlines DNA transcription in terms of the formation of an RNA strand complementary to the DNA strand by RNA polymerase. • Describes the genetic code in terms of codons composed of triplets of bases. • Explains the process of translation, leading to polypeptide formation. • Discusses the relationship between one gene and one polypeptide.
Enzymes	• Defines *enzyme* and *active site*. • Explains enzyme–substrate specificity. • Explains the effects of temperature, pH and substrate concentration on enzyme activity. • Defines *denaturation*. • Explains the use of lactase in the production of lactose-free milk.

Cell respiration	• Defines *cell respiration*. • States that, in cell respiration, glucose in the cytoplasm is broken down by glycolysis into pyruvate, with a small yield of ATP. • Explains 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. • Explains that, during aerobic cell respiration, pyruvate can be broken down in the mitochondrion into carbon dioxide and water with a large yield of ATP.
Photosynthesis	• States that photosynthesis involves the conversion of light energy into chemical energy. • States that light from the Sun is composed of a range of wavelengths (colours). • States that chlorophyll is the main photosynthetic pigment. • Outlines the differences in absorption of red, blue and green light by chlorophyll. • States that light energy is used to produce ATP, and to split water molecules (photolysis) to form oxygen and hydrogen. • States that ATP and hydrogen (derived from the photolysis of water) are used to fix carbon dioxide to make organic molecules. • Explains 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. • Outlines the effects of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis.

<u>Unit of Study</u>: Genetics (15 hours)

Curriculum Standards	**Learner Outcomes**
Chromosomes, genes, alleles and mutations	• States that eukaryote chromosomes are made of DNA and proteins. • Defines *gene*, *allele* and *genome*. • Defines *gene mutation*. • Explains the consequence of a base substitution mutation in relation to the processes of transcription and translation, using the example of sickle-cell anemia.

Meiosis	• States that meiosis is a reduction division of a diploid nucleus to form haploid nuclei. • Defines *homologous chromosomes*. • Outlines the process of meiosis, including pairing of homologous chromosomes and crossing over, followed by two divisions, which results in four haploid cells. • Explains that non-disjunction can lead to changes in chromosome number, illustrated by reference to Down syndrome (trisomy 21). • States that, in karyotyping, chromosomes are arranged in pairs according to their size and structure. • States that karyotyping is performed using cells collected by chorionic villus sampling or amniocentesis, for pre-natal diagnosis of chromosome abnormalities. • Analyses a human karyotype to determine gender and whether non- disjunction has occurred.
Theoretical genetics	• Define *genotype*, *phenotype*, *dominant allele*, *recessive allele*, *codominant alleles*, *locus*, *homozygous*, *heteroszygous*, *carrier* and *test cross*. • Determine the genotypes and phenotypes of the offspring of a monohybrid cross using a Punnett grid. • States that ssome genes have more than two alleles (multiple alleles). • Describes ABO blood groups as an example of codominance and multiple alleles. • Explains how the sex chromosomes control gender by referring to the inheritance of X and Y chromosomes in humans. • States that some genes are present on the X chromosome and absent from the shorter Y chromosome in humans. • Defines *sex linkage*. • Describes the inheritance of color blindness and hemophilia as examples of sex linkage. • States that a human female can be homozygous or heterozygous with respect to sex-linked genes. • Explains that female carriers are heterozygous for X-linked recessive alleles. • Predicts the genotypic and phenotypic ratios of offspring of monohybrid crosses involving any of the above patterns of inheritance. • Deduces the genotypes and phenotypes of individuals in pedigree charts.
Genetic engineering and biotechnology	• Outlines the use of polymerase chain reaction (PCR) to copy and amplify minute quantities of DNA. • States that, in gel electrophoresis, fragments of DNA move in an electric field and are separated according to their size. • States that gel electrophoresis of DNA is used in DNA profiling. • Describes the application of DNA profiling to determine paternity and also in forensic investigations. • Analyzes DNA profiles to draw conclusions about paternity or forensic investigations. • Outlines three outcomes of the sequencing of the complete human genome.

	• States that, when genes are transferred between species, the amino acid sequence of polypeptides translated from them is unchanged because the genetic code is universal. • Outlines a basic technique used for gene transfer involving plasmids, a host cell (bacterium, yeast or other cell), restriction enzymes (endonucleases) and DNA ligase. • States two examples of the current uses of genetically modified crops or animals. • Discusses the potential benefits and possible harmful effects of one example of genetic modification. • Defines *clone*. • Outlines a technique for cloning using differentiated animal cells. • Discusses the ethical issues of therapeutic cloning in humans.

Unit of Study: Ecology and evolution (16 hours)

Curriculum Standards	**Learner Outcomes**
Communities and ecosystems	• Defines *species*, *habitat*, *population*, *community*, *ecosystem* and *ecology*. • Distinguishes between *autotroph* and *heterotroph*. • Distinguishes between *consumers*, *detritivores* and *saprotrophs*. • Describes what is meant by a food chain, giving three examples, each with at least three linkages (four organisms). • Describes what is meant by a food web. • Define s*trophic level*. • Deduces the trophic level of organisms in a food chain and a food web. • Constructs a food web containing up to 10 organisms, using appropriate information. • States that light is the initial energy source for almost all communities. • Explains the energy flow in a food chain. • States that energy transformations are never 100% efficient. • Explains reasons for the shape of pyramids of energy. • Explains that energy enters and leaves ecosystems, but nutrients must be recycled. • States that saprotrophic bacteria and fungi (decomposers) recycle nutrients.

The greenhouse effect	• Draws and labels a diagram of the carbon cycle to show the processes involved. • Analyzes the changes in concentration of atmospheric carbon dioxide using historical records. • Explains the relationship between rises in concentrations of atmospheric carbon dioxide, methane and oxides of nitrogen and the enhanced greenhouse effect. • Outlines the precautionary principle. • Evaluates the precautionary principle as a justification for strong action in response to the threats posed by the enhanced greenhouse effect. • Outlines the consequences of a global temperature rise on arctic ecosystems.
Population	• Outlines how population size is affected by natality, immigration, mortality and emigration. • Draws and labels a graph showing a sigmoid (S-shaped) population growth curve. • Explains the reasons for the exponential growth phase, the plateau phase and the transitional phase between these two phases. • Lists three factors that set limits to population increase.
Evolution	• Defines *evolution*. • Outlines the evidence for evolution provided by the fossil record, selective breeding of domesticated animals and homologous structures. • States that populations tend to produce more offspring than the environment can support. • Explains that the consequence of the potential overproduction of offspring is a struggle for survival. • States that the members of a species show variation. • Explains how sexual reproduction promotes variation in a species. • Explains how natural selection leads to evolution. • Explains two examples of evolution in response to environmental change; one must be antibiotic resistance in bacteria.
Classification	• Outlines the binomial system of nomenclature. • Lists 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. • Distinguishes between the following phyla of plants, using simple external recognition features: *bryophyta, filicinophyta, coniferophyta* and *angiospermophyta*. • Distinguish esbetween the following phyla of animals, using simple external recognition features: *porifera. cnidaria, platyhelminthes, annelida, mollusca* and *arthropoda*. • Applies and design a key for a group of up to eight organisms.

Unit of Study: Human health and physiology (20 hours)

Curriculum Standards	Learner Outcomes
Digestion	• Explains why digestion of large food molecules is essential. • Explains the need for enzymes in digestion. • States the source, substrate, products and optimum pH conditions for one amylase, one protease and one lipase. • Draws and labels a diagram of the digestive system. • Outline the function of the stomach, small intestine and large intestine. • Distinguishes between *absorption* and *assimilation*. • Explains how the structure of the villus is related to its role in absorption and transport of the products of digestion.
The transport system	• Draws and labels a diagram of the heart showing the four chambers, heart showing the four chambers, associated blood vessels, valves and the route of blood through the heart. • States that the coronary arteries supply heart muscle with oxygen and nutrients. • Explains the action of the heart in terms of collecting blood, pumping blood, and opening and closing of valves. • Outlines 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). • Explains the relationship between the structure and function of arteries, capillaries and veins. • States that blood is composed of plasma, erythrocytes, leucocytes (phagocytes and lymphocytes) and platelets. • States that the following are transported by the blood: nutrients, oxygen, carbon dioxide, hormones, antibodies, urea and heat.
Defense against infectious disease	• Defines *pathogen*. • Explains why antibiotics are effective against bacteria but not against viruses. • Outlines the role of skin and mucous membranes in defense against pathogens. • Outlines how phagocytic leucocytes ingest pathogens in the blood and in body tissues. • Distinguishes between *antigens* and *antibodies*. • Explains antibody production. • Outlines the effects of HIV on the immune system. • Discusses the cause, transmission and social implications of AIDS.
Gas exchange	• Distinguishes between *ventilation*, *gas exchange* and *cell respiration*. • Explains the need for a ventilation system. • Describes the features of alveoli that adapt them to gas exchange. • Draws and label a diagram of the ventilation system, including trachea, lungs, bronchi, bronchioles and alveoli. • Explains the mechanism of ventilation of the lungs in terms of volume and pressure changes caused by the internal and external intercostals muscles, the diaphragm and abdominal muscles.

Nerves, hormones and homeostasis	• States 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. • Draws and labels a diagram of the structure of a motor neuron. • States 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. • Defines *resting potential* and *action potential* (depolarization and repolarization). • Explains how a nerve impulse passes along a non-myelinated neuron. • Explains the principles of synaptic transmission. • States that the endocrine system consists of glands that release hormones that are transported in the blood. • States that homeostasis involves maintaining the internal environment between limits, including blood pH, carbon dioxide concentration, blood glucose concentration, body temperature and water balance. • Explains that homeostasis involves monitoring levels of variables and correcting changes in levels by negative feedback mechanisms. • Explains the control of body temperature, including the transfer of heat in blood, and the roles of the hypothalamus, sweat glands, skin arterioles and shivering. • Explains the control of blood glucose concentration, including the roles of glucagon, insulin and α and β cells in the pancreatic islets. • Distinguishes between *type I* and *type II* diabetes.
Reproduction	• Draws and labels diagrams of the adult male and female reproductive systems. • Outline the role of hormones in the menstrual cycle, including FSH(follicle stimulating hormone), LH (luteinizing hormone), estrogen and progesterone. • Annotates 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. • Lists three roles of testosterone in males. • Outlines the process of *in vitro* fertilization (IVF). • Discusses the ethical issues associated with IVF.

Unit of Study: Nucleic acids and proteins (11 hours)

Curriculum Standards	Learner Outcomes
DNA structure	• Describes the structure of DNA, including the antiparallel strands, 3'–5' linkages and hydrogen bonding between purines and pyrimidines. • Outlines the structure of nucleosomes. • States that nucleosomes help to supercoil chromosomes and help to regulate transcription. • Distinguishes between *unique or single-copy genes* and *highly repetitive sequences* in nuclear DNA. • States that eukaryotic genes can contain exons and introns.
DNA replication	• States that DNA replication occurs in a 5' → 3' direction. • Explains 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. • States that DNA replication is initiated at many points in eukaryotic chromosomes.
Transcription	• States that transcription is carried out in a 5' → 3' direction. • Distinguishes between the *sense* and *antisense* strands of DNA. • Explains the process of transcription in prokaryotes, including the role of the promoter region, RNA polymerase, nucleoside triphosphates and the terminator. • States that eukaryotic RNA needs the removal of introns to form mature mRNA.
Translation	• Explains that each tRNA molecule is recognized by a tRNA-activating enzyme that binds a specific amino acid to the tRNA, using ATP for energy. • Outlines the structure of ribosomes, including protein and RNA composition, large and small subunits, three tRNA binding sites and mRNA binding sites. • States that translation consists of initiation, elongation, translocation and termination. • States that translation occurs in a 5' → 3' direction. • Draws and labels a diagram showing the structure of a peptide bond between two amino acids. • Explains the process of translation, including ribosomes, polysomes, start codons and stop codons. • States that free ribosomes synthesize proteins for use primarily within the cell, and that bound ribosomes synthesize proteins primarily for secretion or for lysosomes.

Proteins	• Explains the four levels of protein structure, indicating the significance of each level. • Outline the difference between fibrous and globular proteins, with reference to two examples of each protein type. • Explains the significance of polar and non-polar amino acids. • States four functions of proteins, giving a named example of each.
Enzymes	• States that metabolic pathways consist of chains and cycles of enzyme- catalysed reactions. • Describes the induced-fit model. • Explains that enzymes lower the activation energy of the chemical reactions that they catalyse. • Explains the difference between competitive and non-competitive inhibition, with reference to one example of each. • Explains the control of metabolic pathways by end-product inhibition, including the role of allosteric sites.

Unit of Study: Cell respiration and photosynthesis (10 hours)

Curriculum Standards	Learner Outcomes
Cell respiration	• States 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. • Outlines the process of glycolysis, including phosphorylation, lysis, oxidation and ATP formation. • Draws and labels a diagram showing the structure of a mitochondrion as seen in electron micrographs. • Explains aerobic respiration, including the link reaction, the Krebs cycle, the role of NADH + H^+, the electron transport chain and the role of oxygen. • Explains oxidative phosphorylation in terms of chemiosmosis. • Explains the relationship between the structure of the mitochondrion and its function.
Photosynthesis	• Draws and labels a diagram showing the structure of a chloroplast as seen in electron micrographs. • States that photosynthesis consists of light-dependent and light- independent reactions. • Explains the light-dependent reactions. • Explains photophosphorylation in terms of chemiosmosis. • Explains the light-independent reactions. • Explains the relationship between the structure of the chloroplast and its function. • Explains the relationship between the action spectrum and the absorption spectrum of photosynthetic pigments in green plants. • Explains the concept of limiting factors in photosynthesis, with reference to light intensity, temperature and concentration of carbon dioxide.

Unit of Study: Plant science (11 hours)

Curriculum Standards	Learner Outcomes
Plant structure and growth	• Draws and labels plan diagrams to show the distribution of tissues in the stem and leaf of a dicotyledonous plant. • Outlines three differences between the structures of dicotyledonous and monocotyledonous plants. • Explains the relationship between the distribution of tissues in the leaf and the functions of these tissues. • Identifies modifications of roots, stems and leaves for different functions: bulbs, stem tubers, storage roots and tendrils. • States that dicotyledonous plants have apical and lateral meristems. • Compares growth due to apical and lateral meristems in dicotyledonous plants. • Explains the role of auxin in phototropism as an example of the control of plant growth.
Transport in angiospermophytes	• Outlines how the root system provides a large surface area for mineral ion and water uptake by means of branching and root hairs. • Lists ways in which mineral ions in the soil move to the root. • Explains the process of mineral ion absorption from the soil into roots by active transport. • States that terrestrial plants support themselves by means of thickened cellulose, cell turgor and lignified xylem. • Defines *transpiration*. • Explains how water is carried by the transpiration stream, including the structure of xylem vessels, transpiration pull, cohesion, adhesion and evaporation. • States that guard cells can regulate transpiration by opening and closing stomata. • States that the plant hormone abscisic acid causes the closing of stomata. • Explains how the abiotic factors light, temperature, wind and humidity, affect the rate of transpiration in a typical terrestrial plant. • Outlines four adaptations of xerophytes that help to reduce transpiration. • Outlines 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).
Reproduction in angiospermophytes	• Draws and labels a diagram showing the structure of a dicotyledonous animal-pollinated flower. • Distinguishes between *pollination*, *fertilization* and *seed dispersal*. • Draws and labels a diagram showing the external and internal structure of a named dicotyledonous seed. • Explains the conditions needed for the germination of a typical seed. • Outlines the metabolic processes during germination of a starchy seed. • Explains how flowering is controlled in long-day and short-day plants, including the role of phytochrome.

Unit of Study: Genetics (6 hours)

Curriculum Standards	Learner Outcomes
Meiosis	• Describes the behavior of the chromosomes in the phases of meiosis. • Outlines the formation of chiasmata in the process of crossing over. • Explains how meiosis results in an effectively infinite genetic variety in gametes through crossing over in prophase I and random orientation in metaphase I. • States Mendel's law of independent assortment. • Explains the relationship between Mendel's law of independent assortment and meiosis.
Dihybrid crosses and gene linkage	• Calculates and predicts the genotypic and phenotypic ratio of offspring of dihybrid crosses involving unlinked autosomal genes. • Distinguishes between *autosomes* and *sex chromosomes*. • Explains how crossing over between non-sister chromatids of a homologous pair in prophase I can result in an exchange of alleles. • Defines *linkage group*. • Explains an example of a cross between two linked genes. • Identifies which of the offspring are recombinants in a dihybrid cross involving linked genes.
Polygenic inheritance	• Defines *polygenic inheritance*. • Explains that polygenic inheritance can contribute to continuous variation using two examples, one of which must be human skin colour.

Unit of Study: Human health and physiology (17 hours)

Curriculum Standards	Learner Outcomes
Defence against infectious disease	• Describes the process of blood clotting. • Outlines the principle of challenge and response, clonal selection and memory cells as the basis of immunity. • Defines *active* and *passive* immunity. • Explains antibody production. • Describes the production of monoclonal antibodies and their use in diagnosis and in treatment. • Explains the principle of vaccination. • Discusses the benefits and dangers of vaccination.

Muscles and movement	• States the roles of bones, ligaments, muscles, tendons and nerves in human movement. • Labels a diagram of the human elbow joint, including cartilage, synovial fluid, joint capsule, named bones and antagonistic muscles (biceps and triceps). • Outlines the functions of the structures in the human elbow joint named in above. • Compares the movements of the hip joint and the knee joint. • Describes the structure of striated muscle fibres, including the myofibrils with light and dark bands, mitochondria, the sarcoplasmic reticulum, nuclei and the sarcolemma. • Draws and labels 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. • Explains 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. • Analyses electron micrographs to find the state of contraction of muscle fibres.
The kidney	• Defines *excretion*. • Draws and labels a diagram of the kidney. • Annotates a diagram of a glomerulus and associated nephron to show the function of each part. • Explains the process of ultrafiltration, including blood pressure, fenestrated blood capillaries and basement membrane. • Defines *osmoregulation*. • Explains the reabsorption of glucose, water and salts in the proximal convoluted tubule, including the roles of microvilli, osmosis and active transport. • Explains the roles of the loop of Henle, medulla, collecting duct and ADH(vasopressin) in maintaining the water balance of the blood. • Explains the differences in the concentration of proteins, glucose and urea between blood plasma, glomerular filtrate and urine. • Explains the presence of glucose in the urine of untreated diabetic patients.
Reproduction	• Annotates 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. • Outlines the processes involved in spermatogenesis within the testis, including mitosis, cell growth, the two divisions of meiosis and cell differentiation. • States the role of LH, testosterone and FSH in spermatogenesis. • Annotates a diagram of the ovary to show the location and function of germinal epithelium, primary follicles, mature follicle and secondary oocyte.

	• Outlines 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. • Draws and labels a diagram of a mature sperm and egg. • Outlines the role of the epididymis, seminal vesicle and prostate gland in the production of semen. • Compares the processes of spermatogenesis and oogenesis, including the number of gametes and the timing of the formation and release of gametes. • Describes the process of fertilization, including the acrosome reaction, penetration of the egg membrane by a sperm and the cortical reaction. • Outlines the role of HCG in early pregnancy. • Outlines early embryo development up to the implantation of the blastocyst. • Explains how the structure and functions of the placenta, including its hormonal role in secretion of estrogen and progesterone, maintain pregnancy. • States that the fetus is supported and protected by the amniotic sac and amniotic fluid. • States that materials are exchanged between the maternal and fetal blood in the placenta. • Outlines the process of birth and its hormonal control, including the changes in progesterone and oxytocin levels and positive feedback.

<u>Unit of Study (Option A)</u>: Human nutrition and health (15 hours)

Curriculum Standards	**Learner Outcomes**
Components of the human diet	• Defines *nutrient*. • Lists the type of nutrients that are essential in the human diet, including amino acids, fatty acids, minerals, vitamins and water. • States that non-essential amino acids can be synthesized in the body from other nutrients. • Outlines the consequences of protein deficiency malnutrition. • Explains the causes and consequences of phenylketonuria (PKU) and how early diagnosis and a special diet can reduce the consequences. • Outlines the variation in the molecular structure of fatty acids, including saturated fatty acids, *cis* and *trans* unsaturated fatty acids, monounsaturated and polyunsaturated fatty acids. • Evaluates the health consequences of diets rich in the different types of fatty acid. • Distinguishes between *minerals* and *vitamins* in terms of their chemical nature. • Outlines two of the methods that have been used to determine the recommended daily intake of vitamin C.

	• Discusses the amount of vitamin C that an adult should consume per day, including the level needed to prevent scurvy, claims that higher intakes give protection against upper respiratory tract infections, and the danger of rebound malnutrition. • Lists the sources of vitamin D in human diets. • Discusses how the risk of vitamin D deficiency from insufficient exposure to sunlight can be balanced against the risk of contracting malignant melanoma. • Explains the benefits of artificial dietary supplementation as a means of preventing malnutrition, using iodine as an example. • Outlines the importance of fiber as a component of a balanced diet.
Energy in human diets	• Compares the energy content per100 g of carbohydrate, fat and protein. • Compares the main dietary sources of energy in different ethnic groups. • Explains the possible health consequences of diets rich in carbohydrates, fats and proteins. • Outlines the function of the appetite control centre in the brain. • Calculates body mass index (BMI) from the body mass and height of a person. • Distinguishes, using the body mass index, between being *underweight, normal weight, overweight* and *obese*. • Outlines the reasons for increasing rates of clinical obesity in some countries, including availability of cheap high-energy foods, large portion sizes, increasing use of vehicles for transport, and a change from active to sedentary occupations. • Outlines the consequences of anorexia nervosa.
Special issues in human nutrition	• Distinguishes between the composition of *human milk* and *artificial milk* used for bottle-feeding babies. • Discusses the benefits of breastfeeding. • Outlines the causes and symptoms of type II diabetes. • Explains the dietary advice that should be given to a patient who has developed type II diabetes. • Discusses the ethical issues concerning the eating of animal products, including honey, eggs, milk and meat. • Evaluates the benefits of reducing dietary cholesterol in lowering the risk of coronary heart disease. • Discusses the concept of food miles and the reasons for consumers choosing foods to minimize food miles.

<u>Unit of Study (Option B)</u>: Physiology of exercise (15 hours)

Curriculum Standards	Learner Outcomes
Muscles and movement	• States the roles of bones, ligaments, muscles, tendons and nerves in human movement. • Labels a diagram of the human elbow joint, including cartilage, synovial fluid, joint capsule, named bones and antagonistic muscles (biceps and triceps). • Outlines the functions of the structures in the human elbow joint named in above. • Compare the movements of the hip joint and the knee joint. • Describes the structure of striated muscle fibers, including the myofibrils with light and dark bands, mitochondria, the sarcoplasmic reticulum, nuclei and the sarcolemma. • Draws and labels 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. • Explains 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. • Analyzes electron micrographs to find the state of contraction of muscle fibers.
Training and the pulmonary system	• Defines *total lung capacity*, *vital capacity*, *tidal volume* and *ventilation rate*. • Explains the need for increases in tidal volume and ventilation rate during exercise. • Outlines the effects of training on the pulmonary system, including changes in ventilation rate at rest, maximum ventilation rate and vital capacity.
Training and the cardiovascular system	• Defines *heart rate*, *stroke volume*, *cardiac output* and *venous return*. • Explains the changes in cardiac output and venous return during exercise. • Compares the distribution of blood flow at rest and during exercise. • Explains the effects of training on heart rate and stroke volume, both at rest and during exercise. • Evaluates the risks and benefits of using EPO (erythropoietin) and blood transfusions to improve performance in sports.
Exercise and respiration	• Defines VO_2 and VO_2 *max*. • Outlines the roles of glycogen and myoglobin in muscle fibers. • Outlines the method of ATP production used by muscle fibers during exercise of varying intensity and duration. • Evaluates the effectiveness of dietary supplements containing creatine phosphate in enhancing performance. • Outlines the relationship between the intensity of exercise, VO_2 and the proportions of carbohydrate and fat used in respiration. • States that lactate produced by anaerobic cell respiration is passed to the liver and creates an oxygen debt. • Outlines how oxygen debt is repaid.

Fitness and training	• Defines *fitness*. • Discusses speed and stamina as measures of fitness. • Distinguishes between *fast* and *slow* muscle fibers. • Distinguishes between the effects of *moderate-intensity* and *high-intensity* exercise on fast and slow muscle fibers. • Discusses the ethics of using performance-enhancing substances, including anabolic steroids.
Injuries	• Discusses the need for warm-up routines. • Describes injuries to muscles and joints, including sprains, torn muscles, torn ligaments, dislocation of joints and intervertebral disc damage.

<u>Unit of Study (Option C):</u> Cells and energy (15 hours)

Curriculum Standards	**Learner Outcomes**
Proteins	• Explains the four levels of protein structure, indicating the significance of each level. • Outlines the difference between fibrous and globular proteins, with reference to two examples of each protein type. • Explains the significance of polar and non-polar amino acids. • States four functions of proteins, giving a named example of each.
Enzymes	• States that metabolic pathways consist of chains and cycles of enzyme- catalysed reactions. • Describes the induced-fit model. • Explains that enzymes lower the activation energy of the chemical reactions that they catalyse. • Explains the difference between competitive and non-competitive inhibition, with reference to one example of each. • Explains the control of metabolic pathways by end-product inhibition, including the role of allosteric sites.
Cell respiration	• States 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. • Outlines the process of glycolysis, including phosphorylation, lysis, oxidation and ATP formation. • Draws and labels a diagram showing the structure of a mitochondrion as seen in electron micrographs. • Explains aerobic respiration, including the link reaction, the Krebs cycle, the role of $NADH + H^+$, the electron transport chain and the role of oxygen. • Explains oxidative phosphorylation in terms of chemiosmosis. • Explains the relationship between the structure of the mitochondrion and its function. • Analyses data relating to respiration.

Photosynthesis	• Draws and labels a diagram showing the structure of a chloroplast as seen in electron micrographs. • States that photosynthesis consists of light-dependent and light- independent reactions. • Explains the light-dependent reactions. • Explains photophosphorylation in terms of chemiosmosis. • Explains the light-independent reactions. • Explains the relationship between the structure of the chloroplast and its function. • Explains the relationship between the action spectrum and the absorption spectrum of photosynthetic pigments in green plants. • Explains the concept of limiting factors in photosynthesis, with reference to light intensity, temperature and concentration of carbon dioxide. • Analyses data relating to photosynthesis.

<u>Unit of Study (Option D):</u> Evolution (15/22 hours)

Curriculum Standards	**Learner Outcomes**
Origin of life on Earth	• Describes four processes needed for the spontaneous origin of life on Earth. • Outlines the experiments of Miller and Urey into the origin of organic compounds. • States that comets may have delivered organic compounds to Earth. • Discusses possible locations where conditions would have allowed the synthesis of organic compounds. • Outlines two properties of RNA that would have allowed it to play a role in the origin of life. • States that living cells may have been preceded by protobionts, with an internal chemical environment different from their surroundings. • Outlines the contribution of prokaryotes to the creation of an oxygen-rich atmosphere. • Discusses the endosymbiotic theory for the origin of eukaryotes.
Species and speciation	• Defines *allele frequency* and *gene pool*. • States that evolution involves a change in allele frequency in a population's gene pool over a number of generations. • Discusses the definition of the term species. • Describes three examples of barriers between gene pools. • Explains how polyploidy can contribute to speciation. • Compares allopatric and sympatric speciation. • Outlines the process of adaptive radiation. • Compare convergent and divergent evolution.

	• Discusses ideas on the pace of evolution, including gradualism and punctuated equilibrium. • Describes one example of transient polymorphism. • Describes sickle-cell anemia as an example of balanced polymorphism.
Human evolution	• Outlines the method for dating rocks and fossils using radioisotopes, with reference to ^{14}C and ^{40}K. • Defines *half-life*. • Deduces the approximate age of materials based on a simple decay curve for a radioisotope. • Describes the major anatomical features that define humans as primates. • Outlines 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*. • States that, at various stages in hominid evolution, several species may have coexisted. • Discusses the incompleteness of the fossil record and the resulting uncertainties about human evolution. • Discusses the correlation between the change in diet and increase in brain size during hominid evolution. • Distinguishes between *genetic* and *cultural* evolution. • Discusses the relative importance of genetic and cultural evolution in the recent evolution of humans.
The Hardy–Weinberg principle	• Explains how the Hardy–Weinberg equation is derived. • Calculates allele, genotype and phenotype frequencies for two alleles of a gene, using the Hardy–Weinberg equation. • States the assumptions made when the Hardy–Weinberg equation is used.
Phylogeny and systematics	• Outlines the value of classifying organisms. • Explains the biochemical evidence provided by the universality of DNA and protein structures for the common ancestry of living organisms. • Explains how variations in specific molecules can indicate phylogeny. • Discusses how biochemical variations can be used as an evolutionary clock. • Defines *clade* and *cladistics*. • Distinguishes, with examples, between *analogous* and *homologous* characteristics. • Outlines the methods used to construct cladograms and the conclusions that can be drawn from them. • Constructs a simple cladogram. • Analyses cladograms in terms of phylogenetic relationships. • Discusses the relationship between cladograms and the classification of living organisms.

<u>Unit of Study (Option E):</u> Neurobiology and behavior (15/22 hours)

Curriculum Standards	Learner Outcomes
Stimulus and response	• Defines the terms *stimulus*, *response* and *reflex* in the context of animal behavior. • Explains the role of receptors, sensory neurons, relay neurons, motor neurons, synapses and effectors in the response of animals to stimuli. • Draws and labels a diagram of a reflex arc for a pain withdrawal reflex, including the spinal cord and its spinal nerves, the receptor cell, sensory neuron, relay neuron, motor neuron and effector. • Explains how animal responses can be affected by natural selection, using two examples.
Perception of stimuli	• Outlines the diversity of stimuli that can be detected by human sensory receptors, including mechanoreceptors, chemo receptors, thermo receptors and photoreceptors. • Labels a diagram of the structure of the human eye. • Annotates a diagram of the retina to show the cell types and the direction in which light moves. • Compares rod and cone cells. • Explains the processing of visual stimuli, including edge enhancement and contra lateral processing. • Label sa diagram of the ear. • Explains how sound is perceived by the ear, including the roles of the eardrum, bones of the middle ear, oval and round windows, and the hair cells of the cochlea.
Innate and learned behavior	• Distinguishes between *innate* and *learned* behavior. • Designs experiments to investigate innate behavior in invertebrates, including either a taxis or a kinesis. • Analyzes data from invertebrate behavior experiments in terms of the effect on chances of survival and reproduction. • Discusses how the process of learning can improve the chance of survival. • Outlines Pavlov's experiments into conditioning of dogs. • Outlines the role of inheritance and learning in the development of birdsong in young birds.
Neurotransmitters and synapses	• States that some presynaptic neurons excite postsynaptic transmission and others inhibit postsynaptic transmission. • Explains how decision-making in the CNS can result from the interaction between the activities of excitatory and inhibitory presynaptic neurons at synapses. • Explains how psychoactive drugs affect the brain and personality by either increasing or decreasing postsynaptic transmission. • Lists three examples of excitatory and three examples of inhibitory psychoactive drugs. • Explains the effects of THC and cocaine in terms of their action at synapses in the brain. • Discusses the causes of addiction, including genetic predisposition, social factors and dopamine secretion.

The human brain	• Labels, on a diagram of the brain, the medulla oblongata, cerebellum, hypothalamus, pituitary gland and cerebral hemispheres. • Outlines the functions of each of the parts of the brain listed in above. • Explains how animal experiments, lesions and FMRI (functional magnetic resonance imaging) scanning can be used in the identification of the brain part involved in specific functions. • Explains sympathetic and parasympathetic control of the heart rate, movements of the iris and flow of blood to the gut. • Explains the pupil reflex. • Discusses the concept of brain death and the use of the pupil reflex in testing for this. • Outlines how pain is perceived and how endorphins can act as painkillers.
Further studies of behavior	• Describes the social organization of honey bee colonies and one other non-human example. • Outlines how natural selection may act at the level of the colony in the case of social organisms. • Discuss the evolution of altruistic behavior using two non-human examples. • Outlines two examples of how foraging behavior optimizes food intake, including bluegill fish foraging for *Daphnia*. • Explains how mate selection can lead to exaggerated traits. • States that animals show rhythmical variations in activity. • Outlines two examples illustrating the adaptive value of rhythmical behavior patterns.

<u>Unit of study (Option F):</u> Microbes and biotechnology (15/22 hours)

Curriculum Standards	**Learner Outcomes**
Diversity of microbes	• Outlines the classification of living organisms into three domains. • Explains the reasons for the reclassification of living organisms into three domains. • Distinguishes between the characteristics of the three domains. • Outlines the wide diversity of habitat in the Archaea as exemplified by methanogens, thermophiles and halophiles. • Outlines the diversity of Eubacteria, including shape and cell wall structure. • States, with one example, that some bacteria form aggregates that show characteristics not seen in individual bacteria. • Compares the structure of the cell walls of Gram-positive and Gram- negative Eubacteria. • Outlines the diversity of structure in viruses including: naked capsid *versus* enveloped capsid; DNA *versus* RNA; and single stranded *versus* double stranded DNA or RNA. • Outlines the diversity of microscopic eukaryotes, as illustrated by *Saccharomyces*, *Amoeba*, *Plasmodium*, *Paramecium*, *Euglena* and *Chlorella*.

Microbes and the environment	• Lists the roles of microbes in ecosystems, including producers, nitrogen fixers and decomposers. • Draws and labels a diagram of the nitrogen cycle. • State the roles of *Rhizobium*, *Azotobacter*, *Nitrosomonas*, *Nitrobacter* and *Pseudomonas denitrificans* in the nitrogen cycle. • Outlines the conditions that favour denitrification and nitrification. • Explains the consequences of releasing raw sewage and nitrate fertilizer into rivers. • Outlines the role of saprotrophic bacteria in the treatment of sewage using trickling filter beds and reed bed systems. • States that biomass can be used as raw material for the production of fuels such as methane and ethanol. • Explains the principles involved in the generation of methane from biomass, including the conditions needed, organisms involved and the basic chemical reactions that occur.
Microbes and biotechnology	• States that reverse transcriptase catalyses the production of DNA from RNA. • Explains how reverse transcriptase is used in molecular biology. • Distinguishes between *somatic* and *germ line* therapy. • Outlines the use of viral vectors in gene therapy. • Discusses the risks of gene therapy.
Microbes and food production	• Explains the use of *Saccharomyces* in the production of beer, wine and bread. • Outlines the production of soy sauce using *Aspergillus oryzae*. • Explains the use of acids and high salt or sugar concentrations in food preservation. • Outlines the symptoms, method of transmission and treatment of one named example of food poisoning.
Metabolism of microbes	• Defines the terms *photoautotroph*, *photoheterotroph*, *chemoautotroph* and *chemoheterotroph*. • States one example of a photoautotroph, photoheterotroph, chemoautotroph and chemoheterotroph. • Compares photoautotrophs with photoheterotrophs in terms of energy sources and carbon sources. • Compares chemoautotrophs with chemoheterotrophs in terms of energy sources and carbon sources. • Draws and label a diagram of a filamentous cyanobacterium. • Explains the use of bacteria in the bioremediation of soil and water. • Lists six methods by which pathogens are transmitted and gain entry to the body. • Distinguishes between *intracellular* and *extracellular* bacterial infection using *Chlamydia* and *Streptococcus* as examples. • Distinguishes between *endotoxins* and *exotoxins*.

Microbes and disease	• Evaluates methods of controlling microbial growth by irradiation, pasteurization, antiseptics and disinfectants. • Outlines the mechanism of the action of antibiotics, including inhibition of synthesis of cell walls, proteins and nucleic acids. • Outlines the lytic life cycle of the influenza virus. • Defines *epidemiology*. • Discusses the origin and epidemiology of one example of a pandemic. • Describes the cause, transmission and effects of malaria, as an example of disease caused by a protozoan. • Discusses the prion hypothesis for the cause of spongiform encephalopathies.

<u>Unit of Study (Option G):</u> Ecology and conservation (15/22 hours)

Curriculum Standards	**Learner Outcomes**
Community ecology	• Outlines the factors that affect the distribution of plant species, including temperature, water, light, soil pH, salinity and mineral nutrients. • Explains the factors that affect the distribution of animal species, including temperature, water, breeding sites, food supply and territory. • Describes one method of random sampling, based on quadrat methods, that is used to compare the population size of two plant or two animal species. • Outlines the use of a transect to correlate the distribution of plant or animal species with an abiotic variable. • Explains what is meant by the niche concept, including an organism's spatial habitat, its feeding activities and its interactions with other species. • Outlines the following interactions between species, giving two examples of each: competition, herbivory, predation, parasitism and mutualism. • Explains the principle of competitive exclusion. • Distinguishes between *fundamental* and *realized* niches. • Defines *biomass*. • Describes one method for the measurement of biomass of different trophic levels in an ecosystem.
Ecosystems and biomes	• Defines *gross production*, *net production* and *biomass*. • Calculates values for gross production and net production using the equation: gross production – respiration= net production. • Discusses the difficulties of classifying organisms into trophic levels. • Explains the small biomass and low numbers of organisms in higher trophic levels. • Constructs a pyramid of energy, given appropriate information. • Distinguishes between *primary* and *secondary* succession, using an example of each.

	• Outlines the changes in species diversity and production during primary succession. • Explains the effects of living organisms on the abiotic environment, with reference to the changes occurring during primary succession. • Distinguishes between *biome* and *biosphere*. • Explains how rainfall and temperature affect the distribution of biomes. • Outlines the characteristics of six major biomes.
Impacts of humans on ecosystems	• Calculates the Simpson diversity index for two local communities. • Analyses the biodiversity of the two local communities using the Simpson index. • Discusses reasons for the conservation of biodiversity using rainforests as an example. • Lists three examples of the introduction of alien species that have had significant impacts on ecosystems. • Discusses the impacts of alien species on ecosystems. • Outlines one example of biological control of invasive species. • Defines *biomagnification*. • Explains the cause and consequences of biomagnification, using a named example. • Outlines the effects of ultraviolet(UV) radiation on living tissues and biological productivity. • Outlines the effect of chlorofluorocarbons (CFCs) on the ozone layer. • States that ozone in the stratosphere absorbs UV radiation.
Conservation of biodiversity	• Explains the use of biotic indices and indicator species in monitoring environmental change. • Outlines the factors that contributed to the extinction of one named animal species. • Outlines the biogeographically features of nature reserves that promote the conservation of diversity. • Discusses the role of active management techniques in conservation. • Discusses the advantages of *in situ* conservation of endangered species(terrestrial and aquatic nature reserves). • Outlines the use of *ex situ* conservation measures, including captive breeding of animals, botanic gardens and seed banks.
Population ecology	• Distinguishes between *r-strategies* and *K-strategies*. • Discusses the environmental conditions that favour either r-strategies or K-strategies. • Describes one technique used to estimate the population size of an animal species based on a capture– mark–release–recapture method. • Describes the methods used to estimate the size of commercial fish stocks. • Outlines the concept of maximum sustainable yield in the conservation of fish stocks. • Discusses international measures that would promote the conservation of fish.

<u>Unit of Study (Option H)</u>: Further human physiology (22 hours)

Curriculum Standards	Learner Outcomes
Hormonal control	• States that hormones are chemical messengers secreted by endocrine glands into the blood and transported to specific target cells. • States that hormones can be steroids, proteins and tyrosine derivatives, with one example of each. • Distinguishes between the mode of action of *steroid* hormones and *protein* hormones. • Outlines the relationship between the hypothalamus and the pituitary gland. • Explains the control of ADH(vasopressin) secretion by negative feedback.
Digestion	• States 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. • Explains the structural features of exocrine gland cells. • Compares the composition of saliva, gastric juice and pancreatic juice. • Outlines the control of digestive juice secretion by nerves and hormones, using the example of secretion of gastric juice. • Outlines the role of membrane- bound enzymes on the surface of epithelial cells in the small intestine in digestion. • Outlines the reasons for cellulose not being digested in the alimentary canal. • Explains why pepsin and trypsin are initially synthesized as inactive precursors and how they are subsequently activated. • Discusses the roles of gastric acid and *Helicobacter pylori* in the development of stomach ulcers and stomach cancers. • Explains the problem of lipid digestion in a hydrophilic medium and the role of bile in overcoming this.
Absorption of digested foods	• Draws and labels a diagram showing a transverse section of the ileum as seen under a light microscope. • Explains the structural features of an epithelial cell of a villus as seen in electron micrographs, including microvilli, mitochondria, pinocytotic vesicles and tight junctions. • Explains the mechanisms used by the ileum to absorb and transport food, including facilitated diffusion, active transport and endocytosis. • Lists the materials that are not absorbed and are egested.
Functions of the liver	• Outlines the circulation of blood through liver tissue, including the hepatic artery, hepatic portal vein, sinusoids and hepatic vein. • Explains the role of the liver in regulating levels of nutrients in the blood. • Outlines the role of the liver in the storage of nutrients, including carbohydrate, iron, vitamin A and vitamin D. • States that the liver synthesizes plasma proteins and cholesterol. • States that the liver has a role in detoxification.

	• Describes the process of erythrocyte and hemoglobin breakdown in the liver, including phagocytosis, digestion of globin and bile pigment formation. • Explains the liver damage caused by excessive alcohol consumption.
The transport system	• Explains the events of the cardiac cycle, including atrial and ventricular systole and diastole, and heart sounds. • Analyses data showing pressure and volume changes in the left atrium, left ventricle and the aorta, during the cardiac cycle. • Outlines the mechanisms that control the heartbeat, including the roles of the SA (sinoatrial) node, AV (atrioventricular) node and conducting fibres in the ventricular walls. • Outlines atherosclerosis and the causes of coronary thrombosis. • Discusses factors that affect the incidence of coronary heart disease.
Gas exchange	• Defines *partial pressure*. • Explains the oxygen dissociation curves of adult hemoglobin, fetal hemoglobin and myoglobin. • Describe show carbon dioxide is carried by the blood, including the action of carbonic anhydrase, the chloride shift and buffering by plasma proteins. • Explains the role of the Bohr shift in the supply of oxygen to respiring tissues. • Explains how and why ventilation rate varies with exercise. • Outlines the possible causes of asthma and its effects on the gas exchange system. • Explain the problem of gas exchange at high altitudes and the way the body acclimatizes.