IB BIOLOGY SYLLABUS

CORE: Topic 1: Cell Biology Topic 2: Molecular Biology Topic 3: Genetics Topic 4: Ecology Topic 5: Evolution and Biodiversity Topic 6: Human Physiology **ADDITIONAL HIGHER LEVEL:** Topic 7: Nucleic Acids Topic 8: Metabolism, Cell Respiration & Photosynthesis Topic 9: Plant Biology Topic 10: Genetics and Evolution Topic 11: Animal Physiology	**OPTIONS:** schools can pick which option topic to cover. At SHS we have traditionally further Human Physiology (D) option. Even though called an option, this topic is not *optional* to learn. Option A: Neurobiology and behavior Option B: Biotechnology and Bioinformatics Option C: Ecology and Conservation Option D: Human Physiology

The IB Biology syllabus is a list of all the understandings, applications and skills that the IB Organization mandates are taught throughout the two years of the IB Biology higher level course. While we will not necessarily progress through the syllabus statements in order, they are presented in order to you here. ***Note:*** *the numbering of the understandings, applications and skills is utilized by SHS for organization, and is not a component of the IB Biology syllabus as provided by the IBO.*

U	"understanding" – specific content concepts
A	"application" – illustrative examples or significant experiments in biology history
S	"skill" –practical activities or data analysis
NOS	"nature of science" – the methods and limitations of biology as a scientific endeavor

Topic 1: Cell Biology

1.1 Introduction to Cells

Essential Idea: The evolution of multicellular organisms allowed for cell specialization and cell replacement.

U	1	Living organisms are composed of cells.
U	2	Unicellular organisms carry out all functions of life.
U	3	Cell Surface to volume is an important limitation to cell size.
U	4	Multicellular organisms have properties that emerge due to the interaction of their cellular components.
U	5	Specialized tissues can develop by cell differentiation in multicellular organisms.
U	6	Differentiation involves the expressions of some genes and not others in a cell's genome.
U	7	The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses.
A	1	Questioning the cell theory using atypical examples, including striated muscle, giant algae and aseptate fungal hyphae.
A	2	Investigation of functions of life in Paramecium and one named photosynthetic unicellular organism.
A	3	Use of stem cells to treat Stargardt's disease and one other named condition.
A	4	Ethics of the therapeutic use of stem cells from specially created embryos, from the umbilical cord blood of a new-born baby and from an adult's own tissues.
S	1	Use of a light microscope to investigate the structure of cells and tissues, with drawing of cells. Calculation of the magnification of drawings and the actual size of structures and ultrastructures shown in drawings or micrographs. (Practical 1)
NOS	1	Looking for trends and discrepancies- although most organisms conform to cell theory, there are exceptions.
NOS	2	Ethical implications of research- research involving stem cells is growing in importance and raises ethical issues.

1.2 Ultrastructure of Cells

Essential Idea: Eukaryotes have a much more complex cell structure than prokaryotes.

U	1	Prokaryotes have a simple cell structure without compartmentalization.
U	2	Eukaryotes have a compartmentalized cell structure.
U	3	Electron microscopes have a much higher resolution than light microscopes.
A	1	Structure and function of organelles within exocrine gland cells of the pancreas and within palisade mesophyll cells

		of the leaf.
A	2	Prokaryotes divide by binary fission.
S	1	Drawings of the ultrastructure of prokaryotic cells based on electron micrographs.
S	2	Drawings of the ultrastructure of eukaryotic cells based on electron micrographs.
S	3	Interpretations of electron micrographs to identify organelles and deduce the function of specialized cells.
NOS	1	Developments in scientific research follows improvements in apparatus- the invention of the electron microscopes led to greater understanding of cell structure.

1.3 Membrane Structure

Essential Idea: The structure of biological membranes makes them fluid and dynamic.

U	1	Phospholipids form bilayers in water due to the amphipathic properties of phospholipid molecules.
U	2	Membrane proteins are diverse in terms of structure, position in the membranes and function.
U	3	Cholesterol is a component of animal cell membranes.
A	1	Cholesterol in mammalian membranes reduces membrane fluidity and permeability to some solutes.
S	1	Drawing of the fluid mosaic model.
S	2	Analysis of evidence from electron microscopy that led to the proposal of the Davidson-Danielli model.
S	3	Analysis of the falsification of the Davison-Danielli model that led to the Singer-Nicolson model.
NOS	1	Using models as representations of the real world-there are alternative models of membrane structures.
NOS	2	Falsification of theories with one theory being superseded by another-evidence falsified the Davison-Danielli model.

1.4 Membrane Transport

Essential Idea: Membranes control the composition of cells by active and passive transport.

U	1	Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.
U	2	The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis. Vesicles move materials within cells.
A	1	Structure and function of the sodium-potassium pumps for active transport and potassium channels for facilitated diffusion in axons.
A	2	Tissues or organs to be used in medical procedures must be bathed in a solution with the same osmolarity as the cytoplasm to prevent osmosis.
S	1	Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2)
NOS	1	Experimental design- accurate quantitative measurements in osmosis experiments are essential.

1.5 Origin of Cells

Essential Idea: There is an unbroken chain of life from the first cells on Earth to all cells in organisms alive today.

U	1	Cells can only be formed by division of pre-existing cells.
U	2	The first cells must have arisen from non-living material.
U	3	The origin of eukaryotic cells can be explained by the endosymbiotic theory.
A	1	Evidence from Pastuer's experiments that spontaneous generation of cells and organisms does not now occur on Earth.
NOS	1	Testing the general principles that underline the natural world- the principles that cells only come from pre-existing cells needs to be verified.

1.6 Cell Division

Essential Idea: Cell division is essential but must be controlled.

U	1	Mitosis is division of the nucleus into two genetically identical daughter nuclei.
U	2	Chromosomes condense by supercoiling during mitosis.
U	3	Cytokinesis occurs after mitosis and is different in plants and animal cells.
U	4	Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm.
U	5	Cyclins are involved in the control of the cell cycle.
U	6	Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumors.
A	1	The correlation between smoking and incidence of cancers.
S	1	Identification of phases of mitosis in cells viewed with a microscope or in a micrograph.

S	2	Determination of a mitotic index from a micrograph.
NOS	1	Serendipity and scientific discoveries- the discoveries of cyclins was accidental.

Topic 2: Molecular Biology

2.1 Molecules to Metabolism

Essential Idea: Living Organisms control their composition by complex web of chemical reactions.

U	1	Molecular biology explains living processes in terms of the chemical substances involved
U	2	Carbon atoms can form four covalent bonds allowing a diversity of stable compounds to exist
U	3	Life is based on carbon compounds including carbohydrates, lipids proteins and nucleic acids
U	4	Metabolism is the web of all the enzyme-catalyzed reactions in a cell or organism
U	5	Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions
U	6	Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers
A	1	Urea as an example of a compound that is produced by living organisms but can also be artificially synthesized
S	1	Drawing molecular diagrams of glucose, ribose, a saturated fatty acid and a generalized amino acid
S	2	Identification of biochemical such as sugars, lipids, or amino acids from molecular drawings
NOS	1	Falsification of theories- the artificial synthesis of urea helped to falsify vitalism.

2.2 Water

Essential Idea: Water is the medium of life.

U	1	Water molecules are polar and hydrogen bonds form between them.
U	2	Hydrogen bonding and dipolarity explain the cohesive, adhesive, thermal and solvent properties of water.
U	3	Substances can be hydrophilic or hydrophobic.
A	1	Comparison of the thermal properties of water with those of methane.
A	2	Use of water as a coolant in sweat.
A	3	Modes of transport of glucose, amino acids, cholesterol, fats. Oxygen, and sodium in blood in relations to their solubility in water.
NOS	1	Use of theories to explain natural phenomena- the theory that hydrogen bonds form between water molecules explain the properties of water.

2.3 Carbohydrates and Lipids

Essential Idea: Compounds of carbon, hydrogen and oxygen are used to supply and store energy.

U	1	Monosaccharide monomers are linked together by condensation reactions to form disaccharides and polysaccharide polymers.
U	2	Fatty acids can be saturated, monounsaturated and polyunsaturated.
U	3	Unsaturated fatty acids can be cis or trans isomers.
U	4	Triglycerides are formed by condensation from three fatty acids and one glycerol.
A	1	Structure and function of cellulose and starch in plants and glycogen in humans.
A	2	Scientific evidence for health risks of trans fat and saturated fatty acids.
A	3	Lipids are more suitable for long term energy storage in humans than carbohydrates.
A	4	Evaluation of evidence and the methods used to obtain the evidence for health claims made about lipids.
S	1	Use of molecular visualization software to compare cellulose, starch and glycogen.
S	2	Determination of body mass index by calculation or use of a nomogram.
NOS	1	Evaluating claims- health claims made about lipids in diets need to be assessed.

2.4 Proteins

Essential Idea: Proteins have a very wide range of functions in living organisms.

U	1	Amino Acids are linked together by condensation to form polypeptides.
U	2	There are 20 different amino acids in polypeptides synthesized on ribosomes.
U	3	Amino Acids can be linked together in any sequence giving a huge range of possible polypeptides.
U	4	The amino acid sequence of polypeptides is coded for by genes.

U	5	A protein may consist of a single polypeptide or more than one polypeptide linked together.
U	6	The amino acid sequence determines the three-dimensional conformation of a protein.
U	7	Living organisms synthesize many different proteins with a wide range of functions.
U	8	Every individual has a unique proteome.
A	1	Rubisco, insulin immunoglobulins, rhodopsin, collagen and spider silk as examples of the range of protein functions.
A	2	Denaturation of proteins by heat or by deviation of pH from the optimum.
S	1	Drawing molecular diagrams to show the formation of a peptide bond.
NOS	1	Looking for patterns, trends, and discrepancies- most but not all organisms assemble proteins from the same amino acids.

2.5 Enzymes

Essential Idea: Enzymes control the metabolism of the cell.

U	1	Enzymes have an active site to which specific substrates bind.
U	2	Enzyme catalysis involves molecular motion and the collision of substrates with the active site.
U	3	Temperature, pH and substrate concentration affect the rate of activity of enzymes.
U	4	Enzymes are denatured.
U	5	Immobilized enzymes are widely used in industry.
A	1	Methods of production of lactose-free milk and its advantages.
S	1	Design of experiments to test the effect of temperature, pH, and substrate concentration on the activity of enzymes.
S	2	Experimental investigation of a factor affecting enzyme activity. (Practical 3)
NOS	1	Experimental design-accurate, quantitative measurements in enzyme experiments require replicates to ensure reliability.

2.6 Structure of DNA and RNA

Essential Idea: The structure of DNA allows efficient storage of genetic information.

U	1	The nucleic acids DNA and RNA are polymers of nucleotides.
U	2	DNA differs from RNA in the number of strands present, the base composition and the type of pentose.
U	3	DNA is double helix made of two antiparallel strands of nucleotides linked by hydrogen bonding between complimentary base pairs.
A	1	Crick and Watson's elucidation of the structure of DNA using model making.
S	1	Drawing simple diagrams of the structure of single nucleotides of DNA and RNA, using circles, pentagons, and rectangles to represent phosphates, pentoses and bases.
NOS	1	Using models as representation of the real world- Crick and Watson used model making to discover the structure of DNA.

2.7 DNA Replications, Transcription and Translation

Essential Idea: Genetic information in DNA can be accurately copied and can be translated to make the proteins needed by the cell.

U	1	The replication of DNA is semi-conservative and depends on complimentary base pairing.
U	2	Helicase unwinds the double helix and separates the two strands by breaking hydrogen bonds.
U	3	DNA polymerase links nucleotides together to form a new strand, using a pre-existing strand as a template.
U	4	Transcription is the synthesis of mRNA copied from the DNA base sequences by RNA polymerase.
U	5	Translation is the synthesis of polypeptides on ribosomes.
U	6	The amino acid sequence of polypeptides is determined by mRNA according to the genetic code.
U	7	Codons of three bases on mRNA correspond to one amino acid in a polypeptide.
U	8	Translation depends on complimentary base-pairing between codons on mRNA and anticodons on tRNA.
A	1	Use of Taq DNA polymerase to produce multiple copies of DNA rapidly by the polymerase chain reaction (PCR).
A	2	Production of human insulin in bacteria as an example of the universality of the genetic code allowing gene transfer between species.
S	1	Use a table of the genetic code to deduce which codons corresponds to which amino acids.
S	2	Analysis of Messelson and Stahl's results to obtain support for the theory of semi-conservative replication of DNA.
S	3	Use a table of mRNA codons and their corresponding amino acids to deduce the sequence of amino acids coded by a short mRNA strand of known base sequence.
S	4	Deducing the DNA base sequence for the mRNA strand.
NOS	1	Obtaining of evidence for scientific theories- Messelson and Stahl obtained evidence for the semi-conservative

replication of DNA.

2.8 Cell Respiration

Essential Idea: Cell respiration supplies energy for the functions of life.

U	1	Cell respiration is the controlled release of energy from organic compounds to produce ATP.
U	2	ATP from cell respiration is immediately available as a source of energy in the cell.
U	3	Anaerobic cell respiration gives a small yield of ATP from glucose.
U	4	Aerobic cell respiration requires oxygen and gives a large yield of ATP from glucose.
A	1	Use of anaerobic cell respiration in yeasts to produce ethanol and carbon dioxide in baking.
A	2	Lactate production in humans when anaerobic respiration is used to maximize the power of muscle contractions.
S	1	Analysis of results from experiments involving measurement of respiration rates in germinating seeds or invertebrates using a respirometer.
NOS	1	Assessing the ethics of scientific research- the use of invertebrates in respirometers experiments.

2.9 Photosynthesis

Essential Idea: Photosynthesis uses the energy in sunlight to produce the chemical energy needed for life.

U	1	Photosynthesis is the production of carbon compounds in cells using light energy.
U	2	Visible light has a range of wavelengths with violet the shortest wavelength and red the longest.
U	3	Chlorophyll absorbs red and blue light most effectively and reflects green light more than other colours.
U	4	Oxygen is produced in photosynthesis from the photolysis of water.
U	5	Energy is needed to produce carbohydrates and other carbon compounds from carbon dioxide.
U	6	Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate photosynthesis.
A	1	Changes to the Earth's atmosphere, oceans and rock deposition due to photosynthesis.
S	1	Drawing an absorption spectrum for chlorophyll and an action spectrum for photosynthesis.
S	2	Design an absorption spectrum for chlorophyll and an action spectrum for photosynthesis.
S	3	Separation of photosynthetic pigments by chromatograph. (Practical 4)
NOS	1	Experimental design- controlling relevant variables in photosynthesis experiments is essential.

Topic 3: Genetics

3.1 Genes

Essential Idea: Every living organism inherits a blueprint for life from its parents.

U	1	A gene is a heritable factor that consists of a length of DNA and influences a specific characteristic.
U	2	A gene occupies a specific position on a chromosome.
U	3	The various specific forms of a gene are alleles.
U	4	Alleles differ from each other by one or only a few bases.
U	5	New alleles are formed by mutation.
U	6	The genome is the whole of the genetic information of an organism.
U	7	The entire base sequence of human genes was sequenced in the Human Genome Project.
A	1	The causes of sickle cell anemia, including a base substitution mutation, a change to the base sequence of mRNA transcribed from it and a change to the sequence of a polypeptide in hemoglobin.
A	2	Comparison of the number of genes in humans with other species.
S	1	Use of a database to determine differences in the base sequence of a gene in two species.
NOS	1	Developments in scientific research follow improvements in technology-gene sequencers are used for the sequencing of genes.

3.2 Chromosomes

Essential Idea: Chromosomes carry genes in a linear sequence that is shared by members of a species.

U	1	Prokaryotes have one chromosome consisting of a circular DNA molecule.
U	2	Some prokaryotes also have plasmids but eukaryotes do not.

U	3	Eukaryote chromosomes are linear DNA molecules associated with histone proteins.
U	4	In a eukaryote species there are different chromosomes that carry different genes.
U	5	Homologous chromosomes carry the same sequence of genes but not necessarily the same alleles of those genes.
U	6	Diploid nuclei have pairs of homologous chromosomes.
U	7	Haploid nuclei have one chromosomes of each pair.
U	8	The number of chromosomes is a characteristic feature of member of a species.
U	9	A karyogram shows the chromosomes of an organism in homologous pairs of decreasing length.
U	10	Sex is determined by sex chromosomes and autosomes are chromosomes that do not determine sex.
A	1	Cairns' technique for measuring the length of DNA by autoradiography.
A	2	Comparison of genome size in T2 phage, *Escherichia coli, Drosophila melanogaster, Homo sapiens, Paris japonica*.
A	3	Comparison of diploid chromosome numbers of *Homo sapiens, Pan troglodytes, Canis familiaris, Oryza sativa, Parascarsis equorum.*
A	4	Use karyograms to deduce sex and diagnose Down Syndrome in humans.
S	1	Use of databases to identify the focus of a human gene and its polypeptide product.
NOS	1	Developments in research follow improvements in techniques- autoradiography was used to establish the length of DNA molecules in chromosomes.

3.3 Meiosis

Essential Idea: Alleles segregate during meiosis allowing new combinations to be formed by the fusion of gametes.

U	1	One of diploid nucleus divides by meiosis to produce four haploid nuclei.
U	2	The halving of the chromosomes number allows a sexual life cycle with fusion of gametes.
U	3	DNA is replicated before meiosis so that all chromosomes consist of two sister chromatids.
U	4	The early stages of meiosis involved pairing of homologous chromosomes and crossing over followed condensation.
U	5	Orientation of pairs of homologous chromosomes prior to separation is random.
U	6	Separation of pairs of homologous chromosomes in the first division of meiosis halves the chromosome number .
U	7	Crossing over and random orientation promotes genetic variation.
U	8	Fusion of gametes from different parents promotes genetic variation.
A	1	Non-disjunction can cause Down syndrome and other chromosome abnormalities.
A	2	Studies showing age of parents influences chances of non-disjunction.
A	3	Description of methods used to obtain cells for karyotype analysis e.g. chorionic villus sampling and amniocentesis and the associated risks.
S	1	Drawing diagrams to show the stages of meiosis resulting in the formation of four haploid cells.
NOS	1	Making careful observations- meiosis was discovered by microscope examination of dividing germ-line cells.

3.4 Inheritance

Essential Idea: The inheritance of genes follows patterns.

U	1	Mendel discovered the principles of inheritance with experiments in which large numbers of pea plants were crossed.
U	2	Gametes are haploid so contain only one allele of each gene.
U	3	The alleles of each gene separate into different haploid daughter nuclei during meiosis.
U	4	Fusion of gametes results in diploid zygotes with two alleles of each gene that may be the same allele or different alleles.
U	5	Dominant alleles mask the effect of recessive alleles but co-dominant alleles have joint effects.
U	6	Many genetic diseases in human are due to excessive alleles of autosomal genes, although some genetic diseases are due to dominant or co-dominant alleles.
U	7	Some genetic diseases are sex-linked. The pattern of inheritance is different with sex-linked genes due to to their location on sex chromosomes.
U	8	Many genetic diseases have been identified in humans but most are very rare.
U	9	Radiation and mutagenic chemicals increase the mutation rate and can cause genetic diseases and cancer.
A	1	Inheritance of ABO blood groups.

A	2	Re-green color blindness and hemophilia as examples of sex-linked inheritance.
A	3	Inheritance of cystic fibrosis and Huntington's disease.
A	4	Consequences of radiation after nuclear bombing of Hiroshima and accident at Chernobyl.
S	1	Construction of Punnett grids for predicting the outcomes of monohybrid genetic crosses.
S	2	Comparison of predicted and actual outcomes of genetic crosses using real data.
S	3	Analysis of pedigree charts to deduce the pattern of inheritance of genetic diseases.
NOS	1	Making quantitative measurements with replicates to ensure reliability, Mendel's genetic crosses with peas plants generated numerical data.

3.5 Genetic Modification and Biotechnology

Essential Idea: Biologists have developed techniques for artificial manipulation of DNA, cells and organisms.

U	1	Gel electrophoresis is used to separate proteins or fragments of DNA according to size.
U	2	PCR can be used to amplify small amounts of DNA.
U	3	DNA profiling involves comparison of DNA.
U	4	Genetic modification is carried out by gene transfer between species.
U	5	Clones are groups of genetically identical organisms, derived from a single original parent cell.
U	6	Many plants species and some animal species have natural methods of cloning.
U	7	Animals can be cloned at the embryo stage by breaking up the embryo into more than one group of cells.
U	8	Methods have been developed for cloning adult animals using differentiated cells.
A	1	Use of DNA profiling in paternity and forensic investigations.
A	2	Gene transfer in bacteria using plasmids makes use of restriction endonucleases and DNA ligases.
A	3	Assessment of potential risks and benefits associated with genetic modification of crops.
A	4	Production of clones embryos produced by somatic-cell nuclear transfer.
S	1	Design of an experiment to assess one factor affecting the rooting of stem-cuttings.
S	2	Analysis of examples of DNA profiles.
S	3	Analysis of data on risks to monarch butterflies of Bt crops.
NOS	1	Assessing risks associated with scientific research- scientists attempt to assess the risks associated with genetically modified crops or livestock.

Topic 4: Ecology

4.1 Species, Communities and Ecosystems

Essential Idea: The continued survival of living organisms including humans depends on sustainable communities.

U	1	Species are groups of organisms that can potentially interbreed to produce fertile offspring.
U	2	Members of a species may be reproductively isolated in separate populations.
U	3	Species have either an autotrophic or heterotrophic method of nutrition (a few species have both methods).
U	4	Consumers are heterotrophs that feed on living organisms by ingestion.
U	5	Detrivores are heterotrophs that obtain organic nutrients from detritus by internal digestion.
U	6	Saprotrophs are heterotrophs that obtain organic nutrients from dead organisms by external digestion.
U	7	A community is formed by populations of different species living together and interacting with each other.
U	8	A community forms an ecosystem by its interactions with the abiotic environment.
U	9	Autotrophs obtain inorganic nutrients from the abiotic environment.
U	10	The supply of inorganic nutrients is maintained by nutrient recycling.
U	11	Ecosystems have the potential to be sustainable over long periods of time.
S	1	Classifying species as autotrophs, consumers, detrivores or saprotrophs from a knowledge of their mode of nutrition.
S	2	Setting up sealed mecocosms to try to establish sustainability. (Practical 5)
S	3	Testing for association between two species using the chi-squared test with data obtained from quadrat sampling.
S	4	Recognizing and interpreting statistical significance.
NOS	1	Looking for patterns, trends and discrepancies- plants and algae are mostly autotrophic but some are not.

4.2 Energy Flow

Essential Idea: Ecosystems require a continuous supply of energy to fuel life processes and to replace energy lost as heat.

U	1	Most ecosystems rely on a supply of energy from sunlight.
U	2	Light energy is converted to chemical energy in carbon compounds by photosynthesis.
U	3	Chemical energy in carbon compounds flows through food chains by means of feeding.
U	4	Energy released from carbon compounds by respiration is used in living organisms and converted to heat.
U	5	Living organisms cannot convert heat to other forms of energy.
U	6	Heat is lost from ecosystems.
U	7	Energy losses between trophic levels restrict the length of food chains and the biomass of higher trophic levels.
S	1	Quantitative representations of energy flow using pyramids of energy.
NOS	1	Use theories to explain natural phenomena- the concepts of energy flow explains the limited length of food chains.

4.3 Carbon Cycling

Essential Idea: Continued availability of carbon in ecosystems depends on carbon cycling.

U	1	Autotrophs convert carbon dioxide into carbohydrates and other carbon compounds.
U	2	In aquatic ecosystems carbon is present as dissolved carbon dioxide and hydrogen carbonate ions.
U	3	Carbon dioxide diffuses from the atmosphere or water into autotrophs.
U	4	Carbon dioxide is produced by respiration and diffuses out of organisms into water or the atmosphere.
U	5	Methane is produced from organic matter in anaerobic conditions by methanogenic archaeans and some diffuses into the atmosphere or accumulates in the ground.
U	6	Methane is oxidized to carbon dioxide and water in the atmosphere.
U	7	Peat forms when organic matter is not fully decomposed because of acidic and/or anaerobic conditions in waterlogged soils.
U	8	Partially decomposed organic matter from past geological eras was converted either into coal or into oil and gase that accumulate in porous rocks.
U	9	Carbon dioxide is produced by combustion of biomass and fossilized organic matter.
U	10	Animals such as reef-building corals and Mollusca have hard parts that are composed of calcium carbonate and can become fossilized in limestone.
A	1	Estimation of carbon fluxes due to processes in the carbon cycle.
A	2	Analysis of data from air monitoring stations to explain annual fluctuations.
S	1	Construct a diagram of the carbon cycle.
NOS	1	Making accurate, quantitative measurements-it is important to obtain reliable data on the concentrations of carbon dioxide and methane in the atmosphere.

4.4 Climate Change

Essential Idea: Concentrations of gases in the atmosphere affect climates experienced at the Earth's surface.

U	1	Carbon dioxide and water vapor are the most significant greenhouse gases.
U	2	Other gases including methane and nitrogen oxides have less impact.
U	3	The impact of a gas depends on its ability to absorb long wave radiation as well as on its concentration in the atmosphere.
U	4	The warmed Earth emits longer wavelength radiation (heat).
U	5	Longer wave radiation is absorbed by greenhouse gases that retain the heat in the atmosphere.
U	6	Global temperatures and climate patterns are influenced by concentrations of greenhouse gases.
U	7	There is a correlation between rising atmospheric concentrations of carbon dioxide since the start of the industrial revolution 200 years ago and average global temperatures.
U	8	Recent increases in atmospheric carbon dioxide are largely due to increases in the combustion of fossilized organic matter.
A	1	Threats to coral reefs from increasing concentrations of dissolved carbon dioxide.
A	2	Correlations between global temperatures and carbon dioxide concentrations on Earth.
A	3	Evaluating claims that human activities are not causing climate change.
NOS	1	Assessing claims- assessment of the claims that human activities are producing climate change.

Topic 5: Evolution and Biodiversity

5.1 Evidence for Evolution

Essential Idea: There is overwhelming evidence for the evolution of life on Earth.

U	1	Evolution occurs when heritable characteristics of species change.
U	2	The fossil record provides evidence for evolution.
U	3	Selective breeding of domesticated animals shows that artificial selection can cause evolution.
U	4	Evolution of homologous structures by adaptive radiation explains similarities in structure when there are differences in function.
U	5	Populations of a species can gradually diverge into separate species by evolution.
U	6	Continuous variation across the geographical range of related populations matches the concept of gradual divergence.
A	1	Development of melanistic insects in polluted areas.
A	2	Comparison of the pentadactyl limb of mammals, birds, amphibians, and reptiles with different methods of locomotion.
NOS	1	Looking for patterns, trends and discrepancies- there are common features in the bone structure of vertebrate limbs despite their varied use.

5.2 Natural Selection

Essential Idea: The diversity of life has evolved and continues to evolve by natural selection.

U	1	Natural selection can only occur if there is variation among members of the same species.
U	2	Mutation, meiosis and sexual reproduction cause variation between individuals in a species.
U	3	Adaptations are characteristics that make an individual suited to its environment and way of life.
U	4	Species tend to produce more offspring than the environment can support.
U	5	Individuals that are better adapted tend to survive and produce more offspring while the less well adapted tend to die or produce fewer offspring.
U	6	Individuals that reproduce pass on characteristics to their offspring.
U	7	Natural selection increases the frequency of characteristics that make individuals better adapted and decreases the frequency of other characteristics leading to changes within the species.
A	1	Changes in beaks of finches on Daphne Major.
A	2	Evolution of antibiotic resistance in bacteria.
NOS	1	Use theories to explain natural phenomena- the theory of evolution by natural selection can explain the development of antibiotic resistance in bacteria.

5.3 Classification and Biodiversity

Essential Idea: Species are named and classified using an internationally agreed system.

U	1	The binomial system of names for species is universal among biologists and has been agreed and developed at a series of congresses.
U	2	When species are discovered they are given scientific names using the binomial system.
U	3	Taxonomists classify species using a hierarchy of taxa.
U	4	All organisms are classified into three domains.
U	5	The principal taxa for classifying eukaryotes are kingdom, phylum, class, order, family and genus and species.
U	6	In a natural classification, the genus and accompanying higher taxa consist of all the species that have evolved from one common ancestral species.
U	7	Taxonomists sometimes reclassify groups of species when new evidence shows that a previous taxon contains species that have evolved from different ancestral species.
U	8	Natural classification helps in identification of species and allows the prediction of characteristics shared by species within a group.
A	1	Classification of one plant and one animal species from domain to species level.
A	2	Recognition features of bryophyte, filicinophyta, coniferophyta, and angiospermophyta.
A	3	Recognition features of porifera, cnidarian pletyhelmintha, annelida, Mollusca, arthropda and chordata.
A	4	Recognition of features of birds, mammals, amphibians, reptiles and fish.
S	1	Construction of dichotomous keys for use in identifying specimens
NOS	1	Cooperation and collaboration between groups of scientists- scientists use the binomial system to identify a species rather than the many different local names.

5.4 Cladistics

Essential Idea: The ancestry of groups of species can be deduced by comparing their base or amino acid sequences.

U	1	A clade is a group of organisms that have evolved from a common ancestor.
U	2	Evidence for which species are part of a clade can be obtained from the base sequences of a gene or the corresponding amino acid sequence of a protein.
U	3	Sequence differences accumulate gradually so there is a positive correlation between the number of differences between two species and the time since they diverged from a common ancestor.
U	4	Traits can be analogous or homologous.
U	5	Cladograms are tree diagrams that show the most probable sequence of divergence in clades.
U	6	Evidence from cladistics has shown that classifications of some groups based on structure did not correspond with the evolutionary origins of a group or species.
A	1	Cladograms including human and other primates.
A	2	Reclassification of the figwort family using evidence from cladistics.
S	1	Analysis of cladograms to deduce evolutionary relationships.
NOS	1	Falsification of theories with one theory being superseded by another- plant families have been reclassified as a result of evidence from cladistics.

Topic 6: Human Physiology

6.1 Digestion and Absorption

Essential Idea: The structure of the wall of the small intestine allows it to move, digest and absorb food.

U	1	The contraction of circular and longitudinal muscle of the small intestine mixes the food with enzymes and moves it along the gut.
U	2	The pancreas secretes enzymes into the lumen of the small intestine.
U	3	Enzymes digest most macromolecules in food into monomers in the small intestine.
U	4	Villi increase the surface area of epithelium over which absorption is carried out.
U	5	Villi absorb monomers formed by digestion as well as mineral ions and vitamins.
U	6	Different methods of membrane transport are required to absorb different nutrients.
A	1	Processes occurring in the small intestine that results in the digestion of starch and transport of the products of digestion to the liver.
A	2	Use of dialysis tubing to model absorption of digested food in the intestine.
S	1	Production of an annotated diagram of the digestive system.
S	2	Identification of tissue layers in transverse sections of the small intestine viewed with a microscope or in a micrograph.
NOS	1	Use models as representations of the real world-dialysis tubing can be used to model absorption in the intestine.

6.2 The Blood System

Essential Idea: The blood system continuously transports substances to cells and simultaneously collects waste products.

U	1	Arteries convey blood at high pressure from the ventricles to the tissues of the body.
U	2	Arteries have muscle cells and elastic fibres in their walls.
U	3	The muscle and elastic fibres assist in maintaining blood pressure between pump cycles.
U	4	Blood flows through tissues in capillaries. Capillaries have permeable walls that allow exchange of materials between cells in the tissue and the blood in the capillary.
U	5	Veins collect blood at low pressure from the tissues of the body and return it to the atria of the heart.
U	6	Valves in veins and the heart ensure circulation of blood by preventing backflow.
U	7	There is a separate circulation for the lungs.
U	8	The heart beat is initiated by a group of specialized muscle cells in the right atrium called the sinoatrial node.
U	9	The sinoatrial node acts as a pacemaker.
U	10	The sinoatrial node sends out an electrical signal that stimulates contraction as it is propagated through the walls of the atria and then the walls of the ventricles.
U	11	The heart rate can be increased or decreased by impulses brought to the heart through two nerves from the medulla of the brain.
U	12	Epinephrine increases the heart rate to prepare for vigorous physical activity.
A	1	William Harvey's discovery of the circulation of the blood with the heart acting as the pump.
A	2	Pressure changes in the left atrium, left ventricle and aorta during the cardiac cycle.

A	3	Causes and consequences of occlusion of the coronary arteries.
S	1	Identification of the blood vessels as arteries, capillaries or veins from the structure of their walls.
S	2	Recognition of the chambers and valves of the heart and the blood vessels connected to it in dissected hearts or in diagrams of heart structure.
NOS	1	Theories are regarded as uncertain- William Harvey overturned theories developed by the ancient Greek philosophy Galen on movement of blood in the body.

6.3 Defense Against Infectious Disease

Essential Idea: The human body has structures and processes that resist the continuous threat of invasion by pathogens.

U	1	The skin and mucous membranes form a primary defense against pathogens that cause infectious disease.
U	2	Cuts in the skin are sealed by blood clotting.
U	3	Clotting factors are released from platelets.
U	4	The cascade results in the rapid conversion of fibrinogen to fibrin by thrombrin.
U	5	Ingestion of pathogens by phagocytic white blood cells gives non-specific immunity to diseases.
U	6	Production of antibodies by lymphocytes in response to particular pathogens gives specific immunity.
U	7	Antibiotic blocks processes that occur in prokaryotic cells but not in eukaryotic cells.
U	8	Viruses lack a metabolism and cannot therefore be treated with antibiotics.
U	9	Some strains of bacteria have evolved with genes that confer resistance to antibiotics and some strains of bacteria have multiple resistance.
A	1	Causes and consequences of blood clot formation in coronary arteries
A	2	Florey and Chain's experiments to test penicillin on bacterial infections in mice
A	3	Effects of HIV on the immune system and methods of transmission
NOS	1	Risks associated with scientific research- Florey and Chain's tests on the safety of penicillin would not be compliant with current protocol on testing.

6.4 Gas Exchange

Essential Idea: The lungs are actively ventilated to ensure that gas exchange can occur passively.

U	1	Ventilation maintains concentration gradients of oxygen and carbon dioxide between air and alveolu and blood flowing in adjacent capillaries.
U	2	Type I pneumocytes are extremely thin alveolar cells that are adapted to carry out gas exchange.
U	3	Type II pneumocytes secrete a solution containing surfactant that creates a moist surface inside the alveoli to prevent the sides of the alveolus adhering to each other by reducing surface tension.
U	4	Air is carried to the lungs in the trachea and bronchi and then to the alveoli in bronchioles.
U	5	Muscle contraction causes the pressure changes inside the thorax that force air in and out of the lungs to ventilate them.
U	6	Different muscles are required for inspiration and expiration because muscles only do work when they contract.
A	1	Causes and consequences of lung cancer.
A	2	Causes and consequences of emphysema.
A	3	External and internal intercostal muscles, and diaphragm and abdominal muscles as examples of antagonistic muscle action.
S	1	Monitoring of ventilation in humans at rest and after mild and vigorous exercise. (Practical 6)
NOS	1	Obtain evidence for theories- epidemiological studies have contributed to our understanding of the causes of the lung cancer.

6.5 Neurons and Synapses

Essential Idea: Neurons transmit the message, synapses modulate the message.

U	1	Neurons transmit electrical impulses.
U	2	The myelination of nerve fibres allows for salutatory conduction.
U	3	Neurons pump sodium and potassium ions across their membranes to generate a resting potential.
U	4	An action potential consists of depolarization and repolarization of the neuron.
U	5	Nerve impulses are action potentials propagated along the axons f neurons.
U	6	Propagation of nerve impulses is the result of local currents that cause each successive part of the axon to reach the threshold potential.

U	7	Synapses are junctions between neurons and between neurons and receptors or effector cells.
U	8	When presynaptic neurons are depolarized they release a neurotransmitter into the synapse.
U	9	A nerve impulse is only initiated if the threshold potential is reached.
A	1	Secretion and reabsorption of acetylcholine by neurons at synapses.
A	2	Blocking of synaptic transmission at cholinergic synapses in insects by binding of neonicotinoid pesticides to acetylcholine receptors.
S	1	Analysis of oscilloscope traces showing resting potentials and action potentials.
NOS	1	Cooperation and collaboration between groups of scientists-biologists are contributing to research into memory and learning.

6.6 Hormones, Homeostasis and Reproduction

Essential Idea: Hormones are used when signals need to be widely distributed.

U	1	Insulin and glucagon are secreted by beta and alpha cells of the pancreas respectively to control blood glucose concentrations.
U	2	Thyroxin is secreted by the thyroid gland to regulate the metabolic rate and help control body temperature.
U	3	Leptin is secreted by cells in adipose tissue and acts on the hypothalamus of the brain to inhibit appetite.
U	4	Melatonin is secreted by the pineal gland to control circadian rhythms.
U	5	A gene on the Y chromosomes causes embryonic gonads to develop as testes and secretes testosterone.
U	6	Testosterone causes pre-natal development of male genitalia and both sperm production and development of male secondary sexual characteristics during puberty.
U	7	Estrogen and progesterone cause pre-natal development of female reproductive organs and female secondary sexual characteristics during puberty.
U	8	The menstrual cycle is controlled by negative and positive feedback mechanisms involving ovarian and pituitary hormones.
A	1	Causes and treatment of Type I and Type II diabetes.
A	2	Testing of leptin on patients with clinical obesity and reasons for the failure to control the disease.
A	3	Causes of jet lag and use of melatonin to alleviate it.
A	4	The use of IVF of drugs to suspend the normal secretion of hormones, followed by the use of artificial doses of hormones to induce superovulation and establish a pregnancy.
A	5	William Harvey's investigation of sexual reproduction in deer.
S	1	Annotate diagrams of the male and female reproductive system to show names of structures and their functions.
NOS	1	Developments in scientific research follow improvements in apparatus- William Harvey was hampered in his observational research into reproduction by lack of equipment. The microscope was invented 17 years after his death.

Topic 7: Nucleic Acids

7.1 DNA Structure and Replication

Essential Idea: The structure of DNA is ideally suited to its function.

U	1	Nucleosomes help to supercoil the DNA.
U	2	DNA structure suggested a mechanism for DNA replication.
U	3	DNA polymerases can only add nucleotides to the 3' end of a primer.
U	4	DNA replication is continuous on the leading strand and discontinuous on the lagging strand.
U	5	DNA replication is carried out by a complex system of enzymes.
U	6	Some regions of DNA do not code for proteins but have other important functions.
A	1	Rosalind Franklin and Maurice Wilkins' investigation of DNA structures by X-ray diffraction.
A	2	Use of nucleotides containing dideoxyrubonucleic acid to stop DNA replication in preparation of samples for base sequencing.
A	3	Tandem repeats are used in DNA profiling.
S	1	Analysis of results of the Hershey and Chase experiment providing evidence that DNA is the genetic material.
S	2	Utilization of molecular visualization software to analyze the association between protein and DNA profiling.
NOS	1	Making careful observations-Rosalind Franklin's X-ray diffraction provided crucial evidence that DNA is a double helix.

7.2 Transcription and Gene Expression

Essential Idea: Information stored as a code in DNA is copied onto mRNA.

U	1	Transcription occurs in a 5' to 3' direction.
U	2	Nucleosomes help to regulate transcription in eukaryotes.
U	3	Eukaryotic cells modify mRNA after transcription.
U	4	Splicing of mRNA increases the number of different proteins an organism can produce.
U	5	Gene expression is regulated by proteins that bind to specific base sequences in DNA.
U	6	The environment of a cell and of an organism has an impact on gene expression.
A	1	The promoter as an example of non-coding DNA with a function.
S	1	Analysis of changes in the DNA methylation patterns.
NOS	1	Looking for patterns, trends and discrepancies- there is mounting evidence that the environment can trigger heritable changes in epigenetic factors.

7.3 Translation

Essential Idea: Information transferred from DNA to mRNA is translated into an amino acid sequence.

U	1	Initiation of translation involves assembly of the components that carry out the process.
U	2	Synthesis of the polypeptide involves a repeated cycle of events.
U	3	Disassembly of the components follows termination of translation.
U	4	Free ribosomes synthesize proteins primarily for secretion or use in lysosomes.
U	5	Bound ribosomes synthesize proteins for use primarily within the cell.
U	6	Translation can occur immediately after transcription in prokaryotes due to the absence of a nuclear membrane.
U	7	The sequence and number of amino acids in the polypeptide is the primary structure.
U	8	The secondary structure is the formation of alpha helices and beta pleated sheets stabilized by hydrogen bonding.
U	9	The tertiary structure is the further folding of the polypeptide stabilized by interactions between R groups.
U	10	The quaternary structure exists in proteins with more than one polypeptide chain.
A	1	tRNA-activating enzymes illustrate enzyme-substrate specificity and the role of phosphorylation.
S	1	Identification of polysomes in electron micrographs of prokaryotes and eukaryotes.
S	2	The use of molecular visualization software to analyze the structure of eukaryotic ribosomes and tRNA molecules.
NOS	1	Developments in scientific research follow improvements in computing- the use of commuters has enabled scientists to make advances in bioinformatics applications such as locating genes within genomes and identifying conserved sequences.

Topic 8: Metabolism, Cell Respiration and Photosynthesis

8.1 Metabolism

Essential Idea: Metabolic reactions are regulated in response to the cell's needs.

U	1	Metabolic pathways consist of chains and cycles of enzyme-catalyzed reactions.
U	2	Enzymes lower the activation energy of the chemical reactions that they catalyze.
U	3	Enzyme inhibitors can be competitive or non-competitive.
U	4	Metabolic pathways can be controlled by end-product inhibition.
A	1	End-product inhibition of the pathway that converts threonine is isoleucine.
A	2	Use of databases to identify potential new anti-malarial drugs.
S	1	Calculating and plotting rates of reaction from raw experimental results.
S	2	Distinguish different types of inhibition from graphs at specified substrate concentration.
NOS	1	Developments in scientific research follow improvements in computing- developments in bioinformatics, such as the interrogation of databases have facilitated research into metabolic pathways.

8.2 Cell Respiration

Essential Idea: Energy is converted to a usable form in cell respiration.

U	1	Cell respiration involves the oxidation and reduction of electron carriers.
U	2	Phosphorylation of molecules makes them less stable.
U	3	In glycolysis, glucose is converted to pyruvate in the cytoplasm.
U	4	Glycolysis gives a small net gain of ATP without the use of oxygen.
U	5	In aerobic cell respiration pyruvate is decarboxylated and oxidized, and converted into acetyl compound and

		attached to coenzyme A to form acetyl coenzyme A in the link reaction.
U	6	In the Krebs cycle, the oxidation of acetyl groups is coupled to the reduction of hydrogen carriers, liberating carbon dioxide.
U	7	Energy released by oxidation reactions is carried to the cristae of the mitochondria by reduced NAD and FAD.
U	8	Transfer of the electrons between carriers in the electron transport chain in the membrane of the cristae is coupled to proton pumping.
U	9	In chemiosmosis protons diffuse through ATP synthase to generate ATP.
U	10	Oxygen is needed to bind with the free protons to maintain the hydrogen gradient, resulting in the formation of water.
U	11	The structure of the mitochondrion is adapted to the function it performs.
A	1	Electron tomography used to produce images of active mitochondria.
S	1	Analysis of diagrams of the pathways of aerobic respiration to decide where decarboxylation and oxidation reactions occur.
S	2	Annotations of a diagram of mitochondrion to indicate the adaptations to its function.
NOS	1	Paradigm shift-chemiosmotic theory led to a paradigm shift in the field of bioenergetics.

8.3 Photosynthesis

Essential Idea: Light energy is converted into chemical energy.

U	1	Light-dependent reactions take place in the intermembrane space of the thylakoids.
U	2	Light –independent reactions take place in the stroma.
U	3	Reduced NADP and ATP are produced in the light-dependent reactions.
U	4	Absorption of light by photosystems generates excited electrons.
U	5	Photolysis of water generates electrons for use in the light-independent reactions.
U	6	Transfer of excited electrons occurs between carriers in thylakoid membranes.
U	7	Excited electrons from Photosytem II are used to contribute to generate a proton gradient.
U	8	ATP synthase in thylakoids generates ATP using the proton gradient.
U	9	Excited electrons from Photosytem I are used to reduce NADP.
U	10	In the light-independent reaction a carboxylase catalyzes the carboxylation of ribulose-bisphosphate.
U	11	Glycerate 3-phosphate is reduced to triose phosphate using a reduced NADP and ATP.
U	12	Triose phosphate is used to regenerate RuBP and produce carbohydrates.
U	13	Ribulose bisphosphate is reformed using ATP.
U	14	The structure of the chloroplast is adapted to its function in photosynthesis.
A	1	Calvin's experiment to elucidate the carboxylation of RuBP.
S	1	Annotation of a diagram to indicate the adaptations of a chloroplast to its function.
NOS	1	Developments in scientific research follow improvements in apparatus- sources of ^{14}C and autoradiography enabled Calvin to elucidate the pathways of carbon fixation.

Topic 9: Plant Biology

9.1 Transport in the Xylem of Plants

Essential Idea: Structure and function are correlated in the xylem in plants.

U	1	Transpiration is the inevitable consequence of gas exchange in the leaf.
U	2	Plants transport water from the roots to the leaves to replace losses from transpiration.
U	3	The cohesive property of water and the structure of the xylem vessels allow transport under tension.
U	4	The adhesive property of water and evaporation generate tension forces in leaf cell walls.
U	5	Active uptake of mineral ions in the roots causes absorption of water by osmosis.
A	1	Adaptations of plants in deserts and in saline soils for water conservation.
A	2	Models of water transport in xylem using simple apparatus including blotting or filter paper, porous pots and capillary tubing.
S	1	Drawing the structure of primary xylem vessels in sections of stems based on microscope images.
S	2	Measurement of transpiration rates using photometers. (Practical 7)
S	3	Design of an experiment to test hypothesis about the effects of temperatures or humidity on transpiration rates.
NOS	1	Use models as representations of the real world-mechanisms involved in water transport in the xylem can be investigated using apparatus and material that show similarities in structure to plant tissues.

9.2 Transport in the Phloem of Plants

Essential Idea: Structure and function are correlated in the phloem in plants.

U	1	Plants transport organic compounds from sources to sinks.
U	2	Incompressibility of water allows transport along hydrostatic pressure gradients.
U	3	Active transport is used to load organic compounds into phloem sieve tubes at the source.
U	4	High concentrations of solutes in the phloem at the source lead to water uptake by osmosis.
U	5	Raised by hydrostatic pressure causes the contents of the phloem to flow toward sinks.
A	1	Structure-function relationships of phloem sieve tubes.
S	1	Identification of xylem and phloem in microscope images of stem and root.
S	2	Analysis of date from experiments measuring phloem transport rates using aphid stylets and radioactively-labelled carbon dioxide.
NOS	1	Developments in scientific research follow improvements in apparatus-experimental methods for measuring phloem transport rates using aphid stylets and radioactively-labelled carbon dioxide were only possible when radioisotopes became available.

9.3 Growth in Plants

Essential Idea: Plants adapt their growth to environmental conditions.

U	1	Undifferentiated cells in the meristems of plants allow indeterminate growth.
U	2	Mitosis and cell division in the shoot apex provide cells needed for extension of the stem and development of leaves.
U	3	Plant hormones control growth in the shot apex.
U	4	Plant shoots response to the environment by tropisms.
U	5	Auxin efflux pumps can set up concentration gradients of auxin in plants tissue.
U	6	Auxin influences of cell growth rates by changing the pattern of gene expression.
A	1	Micropropagation of plants using tissue from the shoot apex nutrient agar gels and growth hormones.
A	2	Use of micropropagation for rapid bulking up of new varieties, production of virus-free strains of existing varieties and propagation of orchids and other rare species.
NOS	1	Developments in scientific research follow improvements in analysis and eduction-improvements in analytical techniques allowing the detection of trace amounts of substances has led to advances in the understanding of plant hormones and their effect on gene expression.

9.4 Reproduction in Plants

Essential Idea: Reproduction in flowering plants is influenced by the biotic and abiotic environments.

U	1	Flowering involves a change in gene expression in the shoot apex.
U	2	The switch to flowering is a response to the length of light and dark periods in many plants.
U	3	Success in plant reproduction depends on pollination, fertilization and seed dispersal.
U	4	Most flowering plants use mutualistic relationships with pollinators in sexual reproduction.
A	1	Methods used to induce short-day plants to flower out of season.
S	1	Drawing internal structure of seeds.
S	2	Drawing of half-views of animal-pollinated flowers.
S	3	Design of experiments to test hypothesis about factors affecting germination.
NOS	1	Paradigm shift-more than 85% of the world's 250,000 species of flowering plant depend on pollinators for reproduction. This knowledge has led to protecting entire ecosystems rather than individual species.

Topic 10: Genetics and Evolution

10.1 Meiosis

Essential Idea: Meiosis leads to independent assortment of chromosomes and unique composition of alleles in daughter cells.

U	1	Chromosomes replicate in interphase before meiosis.
U	2	Crossing over is the exchange of DNA material between non-sister homologous chromatids.
U	3	Crossing over produces new combinations of alleles on the chromosomes of the haploid cells.
U	4	Chiasmata formation between non-sister chromatids can results in an exchange of alleles.
U	5	Homologous chromosomes spate in meiosis I.
U	6	Sister chromatids separate in meiosis II.

U	7	Independent assortment of genes in due to random orientation of homologous chromosomes pairs in meiosis I.
S	1	Drawing diagrams to show chiasmata formed by crossing over.
NOS	1	Making careful observations- careful observations and record keeping turned up anomalous data that Mendel's law of independent assortment could not account for. Thomas Hunt Morgan developed the notion of linked genes to account for the anomalies.

10.2 Inheritance

Essential Idea: Genes may be linked or unlinked and are inherited accordingly.

U	1	Gene loci are said to be linked if on the same chromosome.
U	2	Unlinked genes segregate independently as a result of meiosis.
U	3	Variations can be discrete or continuous.
U	4	The phenotypes of polygenic characteristics tend to show continuous variation.
U	5	Chi-squared tests are used to determine whether the difference between an observed and expected frequency distribution is statistically significant.
A	1	Morgans's discovery of non-Mendellian ratios in *Drosophilia.*
A	2	Completion and analysis of Punnett squares for dihybrid traits.
A	3	Polygenic traits such as human height may be influenced by environmental factors.
S	1	Calculation of the predicted genotypic and phenotypic ratio of offspring of dihybrid crosses involving unlinked autosomal genes.
S	2	Identification of recombinants in crosses involving two linked genes.
S	3	Use of chi-squared test on data from dihybrid crosses.
NOS	1	Looking for patterns, trends and discrepancies- Mendel used observations of the natural world to find and explain patterns and tends, Since then, scientists have looked for discrepancies and asked questions based on further observations to show exceptions to the rules. For example, Morgan discovered non-Mendellian ratios in his experiments with *Drosophilia.*

10.3 Gene Pools and Speciation

Essential Idea: Gene pools change over time.

U	1	A gene pool consists of all the genes, and their different alleles, present in an interbreeding population.
U	2	Evolution required that allele frequencies change with time in populations.
U	3	Reproductive isolation of populations can be temporal, behavioral or geographic.
U	4	Speciation due to divergence of isolated populations can be gradual.
U	5	Speciation can occur abruptly.
A	1	Identifying examples of directional, stabilizing and disruptive selection.
A	2	Speciation in the genus *Allium* by polyploidy.
S	1	Comparison of allele frequencies of geographically isolated populations.
NOS	1	Looking for patterns, trends and discrepancies- patterns of chromosome number in some genera can be explained by speciation due to polyploidy.

Topic 11: Animal Physiology

11.1 Antibody Production and Vaccination

Essential Idea: Immunity is based on recognition of self and destruction of foreign material.

U	1	Every organism has unique molecules on the surface of its cells.
U	2	Pathogens can be species-specific although others can cross species barriers.
U	3	B lymphocytes are activated by T lymphocytes in mammals.
U	4	Activated B cells multiply to form clones of plasma cells and memory cells.
U	5	Plasma cells secrete antibodies.
U	6	Antibodies aid the destruction of pathogens.
U	7	White cells release histamine in response to allergens.
U	8	Histamines cause allergic symptoms.
U	9	Immunity depends upon the persistence of memory cells.
U	10	Vaccines contain antigens that trigger immunity but do not cause the disease.
U	11	Fusion of a tumor cell with an antibody-producing plasma cell creates a hybridoma cell.

U	12	Monoclonal antibodies are produced by hybridoma cells.
A	1	Smallpox was the first infectious disease of humans to have been eradicated by vaccination.
A	2	Monoclonal antibodies to HCG are used to pregnancy test kits.
A	3	Antigens on the surface of red blood cells stimulate antibody production in a person with a different blood group.
S	1	Analysis of epidemiological data related to vaccination programs.
NOS	1	Consider ethical implications of research- Jenner tested his vaccine for smallpox in a child.

11.2 Movement

Essential Idea: The roles of musculoskeletal system are movement, support and protection.

U	1	Bones and exoskeletons provide anchorage for muscles and act as levers.
U	2	Synovial joints allow certain movements but not others.
U	3	Movement of the body requires muscles to work in antagonistic pairs.
U	4	Skeletal muscles fibres are multinucleated and contain specialized endoplasmic reticulum.
U	5	Muscle fibres contain many myofibrils.
U	6	Each myofibrils is made up of contractile sarcomeres.
U	7	The contraction of the skeletal muscle is achieved by the sliding of actin and myosin filaments.
U	8	ATP hydrolysis and cross bridge formation are necessary for the filaments to slide.
U	9	Calcium ions and the proteins tropomyosin and troponin control muscle contractions.
A	1	Antagonistic pairs of muscles in an insect leg.
S	1	Annotations of a diagram of the human elbow.
S	2	Drawing labelled diagrams of the structure of a sarcomere.
S	3	Analysis of electron micrographs to find the state of concentration of muscle fibres.
NOS	1	Developments in scientific research follow improvements in apparatus-fluorescent calcium ions have been used to study the cyclic interactions in muscle contraction.

11.3 Kidney and Osmoregulation

Essential Idea: All animals excrete nitrogenous waste products and some animals also balance water and solute concentrations.

U	1	Animals are either osmoregulators or osmoconformers.
U	2	The Malphigian tubule system in insects and the kidney carry out osmoregulation and removal of nitrogenous wastes.
U	3	The composition of blood in the renal artery is different from that in the renal vein.
U	4	The ultrastructure of the glomerulus and Bowman's capsule facilitate ultrafiltration.
U	5	The proximal convoluted tubule selectively reabsorbs useful substances by active transport.
U	6	The loop Henle maintains hypertonic conditions in the medulla.
U	7	ADH controls reabsorption of water in the collecting duct.
U	8	The length of the loop of Henle is positively correlated with the need for water conservation in animals.
U	9	The type of nitrogenous waste in animals is correlates with evolutionary history and habitat.
A	1	Consequences of dehydration and over-hydration.
A	2	Treatment of kidney failure by hemodialysis or kidney transplant.
A	3	Blood cells, glucose, proteins and drugs are detected in urinary tests.
S	1	Drawing and labelling a diagram of the human kidney.
S	2	Annotations of a diagram of the nephron.
NOS	1	Curiosity about particular phenomena- investigations were carried out to determine how desert animals prevent water loss in their wastes.

11.4 Sexual Reproduction

Essential Idea: Sexual reproduction involves the development and fusion of haploid gametes.

U	1	Spermatogenesis and oogenesis both involve mitosis, cell growth, two divisions of meiosis and differentiation.
U	2	Processes in spermatogenesis and oogenesis result in different numbers of gametes with different amounts of cytoplasm.
U	3	Fertilization in animals can be internal or external.
U	4	Fertilization involves mechanisms that prevent polyspermy.
U	5	Implantation of the blastocysts in the endometrium is essential for the continuation of pregnancy.

U	6	HCG stimulates the ovary to secrete progesterone during early pregnancy.
U	7	The placenta facilitates the exchange of materials between the mother and fetus.
U	8	Estrogen and progesterone are secreted by the placenta once it has formed.
U	9	Birth is mediated by positive feedback involving estrogen and oxytocin.
A	1	The average 38-week pregnancy in humans can be positioned on a graph showing the correlation between animals' size and development of the young at birth for other mammals.
S	1	Annotation of a diagram of seminiferous tubule and ovary to show the stages of gametogenesis.
S	2	Annotations of diagrams of mature sperm and egg to indicate functions.
NOS	1	Assessing risks and benefits associated with scientific research-the risks to human male fertility were not adequately assessed bef0re steroids related to progesterone and estrogen were released into the environment as a result of the use of female contraceptive pill.

Option D: Human Physiology

D.1 Human Nutrition

Essential Idea: A balanced diet is essential to human health.

U	1	Essential nutrients cannot be synthesized by the body; therefore they have to be included in the diet.
U	2	Dietary minerals are essential chemical elements.
U	3	Vitamins are chemically diverse carbon compounds that cannot be synthesized by the body.
U	4	Some fatty acids and some amino acids are essential.
U	5	Lack of essential amino acids affects the production of proteins.
U	6	Malnutrition may be caused by a deficiency, imbalance or excess of nutrients in the diet.
U	7	Appetite is controlled by a centre in the hypothalamus.
U	8	Overweight individuals are more likely to suffer hypertension and type II diabetes.
U	9	Starvation can lead to breakdown of body tissue.
A	1	Production of ascorbic acid by some mammals, but not others that need a dietary supply.
A	2	Cause and treatment of phenylketonuria (PKU).
A	3	Lack of Vitamin D or calcium can affect bone mineralization and cause rickets or osteomalacia.
A	4	Breakdown of heart muscle due to anorexia.
A	5	Cholesterol in blood as an indicator of the risk of coronary heart disease.
S	1	Determination of the energy content of food by combustion.
S	2	Use of databases of nutritional content of foods and software to calculate intakes of essential nutrients from a daily diet.
NOS	1	Falsification of theories with one theory being superseded by another—scurvy was thought to be specific to humans, because attempts to induce the symptoms in laboratory rats and mice were entirely unsuccessful.

D.2 Digestion

Essential Idea: Digestion is controlled by nervous and hormonal mechanisms.

U	1	Nervous and hormonal mechanisms control the secretion of digestive juices.
U	2	Exocrine glands secrete to the surface of the body or the lumen of the gut.
U	3	The volume and content of gastric secretions are controlled by nervous and hormonal mechanisms.
U	4	Acid conditions in the stomach favour some hydrolysis reactions and help to control pathogens in ingested food.
U	5	The structure of cells of the epithelium of the villi is adapted to the absorption of food.
U	6	The rate of transit of materials through the large intestine is positively correlated with their fibre content.
U	7	Materials not absorbed are egested.
A	1	The reduction of stomach acid secretion by proton pump inhibitor drugs.
A	2	Dehydration due to cholera toxin.
A	3	*Helicobacter pylori* infection as a cause of stomach ulcers.
S	1	Identification of exocrine gland cells that secrete digestive juices and villus epithelium cells that absorb digested foods from electron micrographs.
NOS	1	Serendipity and scientific discoveries—the role of gastric acid in digestion was established by William Beaumont while observing the process of digestion in an open wound caused by gunshot.

D.3 Functions of the Liver

Essential Idea: The chemical composition of the blood is regulated by the liver.

U	1	The liver removes toxins from the blood and detoxifies them.
U	2	Components of red blood cells are recycled by the liver.
U	3	The breakdown of erythrocytes starts with phagocytosis of red blood cells by Kupffer cells.
U	4	Iron is carried to the bone marrow to produce hemoglobin in new red blood cells.
U	5	Surplus cholesterol is converted to bile salts.
U	6	Endoplasmic reticulum and Golgi apparatus in hepatocytes produce plasma proteins.
U	7	The liver intercepts blood from the gut to regulate nutrient levels.
U	8	Some nutrients in excess can be stored in the liver.
A	1	Causes and consequences of jaundice.
A	2	Dual blood supply to the liver and differences between sinusoids and capillaries.
NOS	1	Educating the public on scientific claims—scientific studies have shown that high-density lipoprotein could be considered “good” cholesterol.

D.4 The Heart

Essential Idea: Internal and external factors influence heart function.

U	1	Structure of cardiac muscle cells allows propagation of stimuli through the heart wall.
U	2	Signals from the sinoatrial node that cause contraction cannot pass directly from atria to ventricles.
U	3	There is a delay between the arrival and passing on of a stimulus at the atrioventricular node.
U	4	This delay allows time for atrial systole before the atrioventricular valves close.
U	5	Conducting fibres ensure coordinated contraction of the entire ventricle wall.
U	6	Normal heart sounds are caused by the atrioventricular valves and semilunar valves closing causing changes in blood flow.
A	1	Use of artificial pacemakers to regulate the heart rate.
A	2	Use of defibrillation to treat life-threatening cardiac conditions.
A	3	Causes and consequences of hypertension and thrombosis.
S	1	Measurement and interpretation of the heart rate under different conditions.
S	2	Interpretation of systolic and diastolic blood pressure measurements.
S	3	Mapping of the cardiac cycle to a normal ECG trace.
S	4	Analysis of epidemiological data relating to the incidence of coronary heart disease.
NOS	1	Developments in scientific research followed improvements in apparatus or instrumentation—the invention of the stethoscope led to improved knowledge of the workings of the heart.

D.5 Hormones and Metabolism

Essential Idea: Hormones are not secreted at a uniform rate and exert their effect at low concentrations.

U	1	Endocrine glands secrete hormones directly into the bloodstream.
U	2	Steroid hormones bind to receptor proteins in the cytoplasm of the target cell to form a receptor–hormone complex.
U	3	The receptor–hormone complex promotes the transcription of specific genes.
U	4	Peptide hormones bind to receptors in the plasma membrane of the target cell.
U	5	Binding of hormones to membrane receptors activates a cascade mediated by a second messenger inside the cell.
U	6	The hypothalamus controls hormone secretion by the anterior and posterior lobes of the pituitary gland.
U	7	Hormones secreted by the pituitary control growth, developmental changes, reproduction and homeostasis.
A	1	Some athletes take growth hormones to build muscles.
A	2	Control of milk secretion by oxytocin and prolactin.
NOS	1	Cooperation and collaboration between groups of scientists—the International Council for the Control of Iodine Deficiency Disorders includes a number of scientists who work to eliminate the harm done by iodine deficiency.

D.6 Transport of Respiratory Gases

Essential Idea: Red blood cells are vital in the transport of respiratory gases.

U	1	Oxygen dissociation curves show the affinity of hemoglobin for oxygen.
U	2	Carbon dioxide is carried in solution and bound to hemoglobin in the blood.
U	3	Carbon dioxide is transformed in red blood cells into hydrogen carbonate ions.

U	4	The Bohr shift explains the increased release of oxygen by hemoglobin in respiring tissues.
U	5	Chemoreceptors are sensitive to changes in blood pH.
U	6	The rate of ventilation is controlled by the respiratory control centre in the medulla oblongata.
U	7	During exercise the rate of ventilation changes in response to the amount of CO_2 in the blood.
U	8	Fetal hemoglobin is different from adult hemoglobin allowing the transfer of oxygen in the placenta onto the fetal hemoglobin.
A	1	Consequences of high altitude for gas exchange.
A	2	pH of blood is regulated to stay within the narrow range of 7.35 to 7.45.
A	3	Causes and treatments of emphysema.
S	1	Analysis of dissociation curves for hemoglobin and myoglobin.
S	2	Identification of pneumocytes, capillary endothelium cells and blood cells in light micrographs and electron micrographs of lung tissue.
NOS	1	Scientists have a role in informing the public—scientific research has led to a change in public perception of smoking.