**Chapter 2: Molecular Biology**

|  |  |
| --- | --- |
| **Scale Level** | **Description** |
| **4** | Student will be able to evaluate industrial applications for biological molecules such as fermentation, biofuel synthesis and enzymes. |
| **3** | Student will be able to analyze the structure and function of biomolecules and describe their roles in biochemical pathways. |
| **2** | Student will be able to recognize and recall the following vocabulary:   |  |  |  | | --- | --- | --- | | Chemistry  compound  element  atomic number  atomic mass  isotope  radioactivity  electron energy level  valence electron  orbital  molecule  electronegativity  covalent bond  ionic bond  ion, cation, anion  hydrogen bond  van der Waals interactions  polar molecule  non polar molecule  cohesion  adhesion  specific heat  solution  solvent  solute  hydration shell  hydrophilic  hydrophobic  acid  base  pH  buffer  Transcription  RNA  RNA polymerase  mRNA  elongation  initiation  termination  sense strand  anti-sense strand  uracil  promoter  intron  exon  5’ cap  poly -A tail  mutation  post-transcriptional modification | Biochemistry  amine group  amino acid  carbohydrate  carboxyl group  cellulose  condensation reaction  denaturation  disaccharide  fatty acid  glycerol  glycogen  hydrolysis  hydrophilic  hydrophobic  lipid  lipid bi-layer  monomer  monosaccharide  phospholipid  polymer  polypeptide  polysaccharide  primary structure  protein  quaternary structure  R-group  secondary structure  steroid  tertiary structure  triglyceride  Enzymes  enzyme  active site  substrate  lock-and-key model  induced fit model  denaturation  metabolism  anabolism  catabolism  activation energy  catalyst  inhibitor  non-competitive inhibition  ATP  allosteric site  metabolic pathway  end-product inhibition  phosphorylation  competitive inhibition | DNA Structure  gene  mRNA  DNA  RNA  nitrogenous base  phosphate group  5’ end  3’ end  base pairing  nucleotide  purine  pyrimidine  ribose  deoxyribose  double helix  antiparallel  DNA Replication  helicase  DNA polymerase I  DNA polymerase II  DNA ligase  RNA primase  complimentary strands  semi-conservative  RNA primer  Okazaki fragment  origin of replication  replication fork  lagging strand  leading strand  template strand  deoxynucleoside triphophate  Translation  rRNA  tRNA  anti-codon  codon  genetic code  ribosome  tRNA activating enzyme  initiation  elongation  translocation  termination  start codon  stop codon  polysome |   Student will understand:   * **2:1 Essential idea: Living organisms control their composition by a complex web of chemical reactions.**   + 2.1.U1 Molecular biology explains living processes in terms of the chemical substances involved.   + 2.1.U2 Carbon atoms can form four covalent bonds allowing a diversity of stable compounds to exist.   + 2.1.U3 Life is based on carbon compounds including carbohydrates, lipids, proteins and nucleic acids. [Sugars include monosaccharides and disaccharides. Only one saturated fat is expected and its specific name is not necessary. The variable radical of amino acids can be shown as R. The structure of individual R-groups does not need to be memorized.]   + 2.1.U4 Metabolism is the web of all the enzyme-catalysed reactions in a cell or organism.   + 2.1.U5 Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions.   + 2.1.U6 Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers.   + 2.1.A1 Urea as an example of a compound that is produced by living organisms but can also be artificially synthesized.   + 2.1.S1 Drawing molecular diagrams of glucose, ribose, a saturated fatty acid and a generalized amino acid. [Only the ring forms of D-ribose, alpha–D-glucose and beta-D-glucose are expected in drawings.]   + 2.1.S2 Identification of biochemicals such as sugars, lipids or amino acids from molecular diagrams. [Students should be able to recognize from molecular diagrams that triglycerides, phospholipids and steroids are lipids. Drawings of steroids are not expected. Proteins or parts of polypeptides should be recognized from molecular diagrams showing amino acids linked by peptide bonds.] * **2.2: Essential idea**: **Water is the medium of life.**   + 2.2.U1 Water molecules are polar and hydrogen bonds form between them.   + 2.2.U2 Hydrogen bonding and dipolarity explain the cohesive, adhesive, thermal and solvent properties of water. [Students should know at least one example of a benefit to living organisms of each property of water. Transparency of water and maximum density at 4°C do not need to be included.]   + 2.2.U3 Substances can be hydrophilic or hydrophobic.   + 2.2.A1 Comparison of the thermal properties of water with those of methane. [Comparison of the thermal properties of water and methane assists in the understanding of the significance of hydrogen bonding in water.]   + 2.2.A2 Use of water as a coolant in sweat.   + 2.2.A3 Modes of transport of glucose, amino acids, cholesterol, fats, oxygen and sodium chloride in blood in relation to their solubility in water. * **2.3: Essential idea: Compounds of carbon, hydrogen and oxygen are used to supply and store energy.**   + 2.3.U1 Monosaccharide monomers are linked together by condensation reactions to form disaccharides and polysaccharide polymers. [Sucrose, lactose and maltose should be included as examples of disaccharides produced by combining monosaccharides. The structure of starch should include amylose and amylopectin.]   + 2.3.U2 Fatty acids can be saturated, monounsaturated or polyunsaturated. [Named examples of fatty acids are not required.]   + 2.3.U3 Unsaturated fatty acids can be cis or trans isomers.   + 2.3.U4 Triglycerides are formed by condensation from three fatty acids and one glycerol.   + 2.3.A1 Structure and function of cellulose and starch in plants and glycogen in humans.   + 2.3.A2 Scientific evidence for health risks of trans fats and saturated fatty acids.   + 2.3.A3 Lipids are more suitable for long-term energy storage in humans than carbohydrates.   + 2.3.A4 Evaluation of evidence and the methods used to obtain the evidence for health claims made about lipids.   + 2.3.S1 Use of molecular visualization software to compare cellulose, starch and glycogen.   + 2.3.S2 Determination of body mass index by calculation or use of a nomogram. * **2.4: Essential idea: Proteins have a very wide range of functions in living organisms.**   + 2.4.U1 Amino acids are linked together by condensation to form polypeptides.   + 2.4.U2 There are 20 different amino acids in polypeptides synthesized on ribosomes. [Students should know that most organisms use the same 20 amino acids in the same genetic code although there are some exceptions. Specific examples could be used for illustration.]   + 2.4.U3 Amino acids can be linked together in any sequence giving a huge range of possible polypeptides.   + 2.4.U4 The amino acid sequence of polypeptides is coded for by genes.   + 2.4.U5 A protein may consist of a single polypeptide or more than one polypeptide linked together.   + 2.4.U6 The amino acid sequence determines the three-dimensional conformation of a protein.   + 2.4.U7 Living organisms synthesize many different proteins with a wide range of functions.   + 2.4.U8 Every individual has a unique proteome.   + 2.4.A1 Rubisco, insulin, immunoglobulins, rhodopsin, collagen and spider silk as examples of the range of protein functions. [The detailed structure of the six proteins selected to illustrate the functions of proteins is not needed.]   + 2.4.A2 Denaturation of proteins by heat or by deviation of pH from the optimum. [Egg white or albumin solutions can be used in denaturation experiments.]   + 2.4.S1 Drawing molecular diagrams to show the formation of a peptide bond. * **2.5: Essential idea: Enzymes control the metabolism of the cell.**   + 2.5.U1 Enzymes have an active site to which specific substrates bind.   + 2.5.U2 Enzyme catalysis involves molecular motion and the collision of substrates with the active site.   + 2.5.U3 Temperature, pH and substrate concentration affect the rate of activity of enzymes. [Students should be able to sketch graphs to show the expected effects of temperature, pH and substrate concentration on the activity of enzymes. They should be able to explain the patterns or trends apparent in these graphs.]   + 2.5.U4 Enzymes can be denatured.   + 2.5.U5 Immobilized enzymes are widely used in industry.   + 2.5.A1 Methods of production of lactose-free milk and its advantages. [Lactase can be immobilized in alginate beads and experiments can then be carried out in which the lactose in milk is hydrolysed.]   + 2.5.S1 Design of experiments to test the effect of temperature, pH and substrate concentration on the activity of enzymes.   + 2.5.S2 Experimental investigation of a factor affecting enzyme activity. (Practical 3) * **2.6: Essential idea: The structure of DNA allows efficient storage of genetic information.**   + 2.6.U1 The nucleic acids DNA and RNA are polymers of nucleotides.   + 2.6.U2 DNA differs from RNA in the number of strands present, the base composition and the type of pentose.   + 2.6.U3 DNA is a double helix made of two antiparallel strands of nucleotides linked by hydrogen bonding between complementary base pairs.   + 2.6.A1 Crick and Watson’s elucidation of the structure of DNA using model making.   + 2.6.S1 Drawing simple diagrams of the structure of single nucleotides of DNA and RNA, using circles, pentagons and rectangles to represent phosphates, pentoses and bases. [In diagrams of DNA structure, the helical shape does not need to be shown, but the two strands should be shown antiparallel. Adenine should be shown paired with thymine and guanine with cytosine, but the relative lengths of the purine and pyrimidine bases do not need to be recalled, nor the numbers of hydrogen bonds between the base pairs.] * **2.7: Essential Idea: Genetic information in DNA can be accurately copied and can be translated to make the proteins needed by the cell.**   + 2.7.U1 The replication of DNA is semi-conservative and depends on complementary base pairing.   + 2.7.U2 Helicase unwinds the double helix and separates the two strands by breaking hydrogen bonds.   + 2.7.U3 DNA polymerase links nucleotides together to form a new strand, using the pre-existing strand as a template. [The different types of DNA polymerase do not need to be distinguished.]   + 2.7.U4 Transcription is the synthesis of mRNA copied from the DNA base sequences by RNA polymerase.   + 2.7.U5 Translation is the synthesis of polypeptides on ribosomes.   + 2.7.U6 The amino acid sequence of polypeptides is determined by mRNA according to the genetic code.   + 2.7.U7 Codons of three bases on mRNA correspond to one amino acid in a polypeptide.   + 2.7.U8 Translation depends on complementary base pairing between codons on mRNA and anticodons on tRNA.   + 2.7.A1 Use of Taq DNA polymerase to produce multiple copies of DNA rapidly by the polymerase chain reaction (PCR).   + 2.7.A2 Production of human insulin in bacteria as an example of the universality of the genetic code allowing gene transfer between species.   + 2.7.S1 Use a table of the genetic code to deduce which codon(s) corresponds to which amino acid.   + 2.7.S2 Analysis of Meselson and Stahl’s results to obtain support for the theory of semi-conservative replication of DNA.   + 2.7.S3 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.   + 2.7.S4 Deducing the DNA base sequence for the mRNA strand. * **2.8: Essential idea: Cell respiration supplies energy for the functions of life.**   + 2.8.U1 Cell respiration is the controlled release of energy from organic compounds to produce ATP. [Details of the metabolic pathways of cell respiration are not needed but the substrates and final waste products should be known.]   + 2.8.U2 ATP from cell respiration is immediately available as a source of energy in the cell.   + 2.8.U3 Anaerobic cell respiration gives a small yield of ATP from glucose.   + 2.8.U4 Aerobic cell respiration requires oxygen and gives a large yield of ATP from glucose.   + 2.8.A1 Use of anaerobic cell respiration in yeasts to produce ethanol and carbon dioxide in baking.   + 2.8.A2 Lactate production in humans when anaerobic respiration is used to maximize the power of muscle contractions.   + 2.8.S1 Analysis of results from experiments involving measurement of respiration rates in germinating seeds or invertebrates using a respirometer. [There are many simple respirometers which could be used. Students are expected to know that an alkali is used to absorb CO2, so reductions in volume are due to oxygen use. Temperature should be kept constant to avoid volume changes due to temperature fluctuations.] * **2.9: Essential idea: Photosynthesis uses the energy in sunlight to produce the chemical energy needed for life.**   + 2.9.U1 Photosynthesis is the production of carbon compounds in cells using light energy.   + 2.9.U2 Visible light has a range of wavelengths with violet the shortest wavelength and red the longest.   + 2.9.U3 Chlorophyll absorbs red and blue light most effectively and reflects green light more than other colours. [Students should know that visible light has wavelengths between 400 and 700 nanometres, but they are not expected to recall the wavelengths of specific colours of light.]   + 2.9.U4 Oxygen is produced in photosynthesis from the photolysis of water.   + 2.9.U5 Energy is needed to produce carbohydrates and other carbon compounds from carbon dioxide.   + 2.9.U6 Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate of photosynthesis.   + 2.9.A1 Changes to the Earth’s atmosphere, oceans and rock deposition due to photosynthesis.   + 2.9.S1 Drawing an absorption spectrum for chlorophyll and an action spectrum for photosynthesis.   + 2.9.S2 Design of experiments to investigate the effect of limiting factors on photosynthesis. [Water free of dissolved carbon dioxide for photosynthesis experiments can be produced by boiling and cooling water.]   + 2.9.S3 Separation of photosynthetic pigments by chromatograph. (Practical 4) [Paper chromatography can be used to separate photosynthetic pigments but thin layer chromatography gives better results.] |
| **1** | With help, partial success at level 2 and level 3 content |
| **0** | Even with help, no success |