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| **Topic 2: Molecular biology (17 hours)** |
| **Essential idea:** Living organisms control their composition by a complex web of chemical reactions. |
| **2.1 Molecules to metabolism** |
| **Nature of science:****2.1.NOS1** Falsification of theories—the artificial synthesis of urea helped to falsify vitalism. (1.9) | Pg.63 |
| **Understandings:** |  |
| **2.1.U1** Molecular biology explains living processes in terms of the chemical substances involved. | Pg.62 | **Utilization:**Syllabus and cross-curricular links:ChemistryTopic 4 Chemical bonding and structureOption B Biochemistry**Aims:**• **Aim 7:** ICT can be used for molecular visualization of carbohydrates, lipids and proteins in this sub-topic and in 2.3 and 2.4.• **Aim 6:** Food tests such as the use of iodine to identify starch or Benedict’s reagent to identify reducing sugars could be carried out. |
| **2.1.U2** Carbon atoms can form four covalent bonds allowing a diversity of stable compounds to exist. | Pg.64 |
| **2.1.U3** Life is based on carbon compounds including carbohydrates, lipids, proteins and nucleic acids. | Pg.64 |
| **2.1.U4** Metabolism is the web of all the enzyme-catalysed reactions in a cell or organism. | Pg.67 |
| **2.1.U5** Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions. | Pg.67 |
| **2.1.U6** Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers | Pg.67 |
| **Applications and skills:** |
| **2.1.A1** Application: Urea as an example of a compound that is produced by living organisms but can also be artificially synthesized. | Pg.62-63 |
| **2.1.S1** Skill: Drawing molecular diagrams of glucose, ribose, a saturated fatty acid and a generalized amino acid. | Pg.65 |
| **2.1.S2** Skill: Identification of biochemicals such as sugars, lipids or amino acids from molecular diagrams. | Pg.66 |
| **Guidance:**• Only the ring forms of D-ribose, alpha–D-glucose and beta-D-glucose are expected in drawings.• 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.• 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. |  |

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| **Topic 2: Molecular biology (17 hours)** |
| **Essential idea**: Water is the medium of life. |
| **2.2 Water** |
| **Nature of science:****2.2.NOS1** Use theories to explain natural phenomena—the theory that hydrogen bonds form between water molecules explains the properties of water. (2.2) | Pg.69 |
| **Understandings:** | **International-mindedness:**• There are challenges for the increasing human population in sharing water resources equitably for drinking and irrigation, electricity generation and a range of industrial and domestic processes.**Theory of knowledge:**• Claims about the “memory of water” have been categorized as pseudoscientific. What are the criteria that can be used to distinguish scientific claims from pseudoscientific claims?**Utilization:**Syllabus and cross-curricular links:BiologyTopic 4.3 Carbon cyclingTopic 4.4 Climate changePhysicsTopic 3.1 Thermal concepts**Aims:**• **Aim 6:** Probes can be used to determine the effect of different factors likely to influence cooling with water. |
| **2.2.U1** Water molecules are polar and hydrogen bonds form between them. | Pg.68 |
| **2.2 U2** Hydrogen bonding and dipolarity explain the cohesive, adhesive, thermal and solvent properties of water. | Pg.69-70 |
| **2.2.U3** Substances can be hydrophilic or hydrophobic. | Pg.70-71 |
| **Applications and skills:** |
| **2.2.A1** Application: Comparison of the thermal properties of water with those of methane. | Pg.71 |
| **2.2.A2** Application: Use of water as a coolant in sweat. | Pg.72 |
| **2.2.A3** Application: Modes of transport of glucose, amino acids, cholesterol, fats, oxygen and sodium chloride in blood in relation to their solubility in water. | Pg.72-73 |
| **Guidance:**• 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.• Comparison of the thermal properties of water and methane assists in the understanding of the significance of hydrogen bonding in water. |  |

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| **Topic 2: Molecular biology (17 hours)** |
| **Essential idea**: Compounds of carbon, hydrogen and oxygen are used to supply and store energy. |
| **2.3 Carbohydrates and lipids** |
| **Nature of science:****2.3.NOS1** Evaluating claims—health claims made about lipids in diets need to be assessed. (5.2) | Pg.84 |
| **Understandings:** |  |
| **2.3.U1** Monosaccharide monomers are linked together by condensation reactions to form disaccharides and polysaccharide polymers. | Pg.74 | **International-mindedness:**• Variation in the prevalence of different health problems around the world could be discussed including obesity, dietary energy deficiency, kwashiorkor, anorexia nervosa and coronary heart disease.**Theory of knowledge:**• There are conflicting views as to the harms and benefits of fats in diets. How do we decide between competing views?**Utilization:**• Potatoes have been genetically modified to reduce the level of amylose to produce a more effective adhesive.Syllabus and cross-curricular links:BiologyOption B: Biotechnology and bioinformatics**Aims:**• **Aim 8:** There are social implications of obesity. |
| **2.3.U2** Fatty acids can be saturated, monounsaturated or polyunsaturated. | Pg.81-82 |
| **2.3.U3** Unsaturated fatty acids can be cis or trans isomers. | Pg.82 |
| **2.3.U4** Triglycerides are formed by condensation from three fatty acids and one glycerol. | Pg.77-78 |
| **Applications and skills:** |  |
| **2.3.A1** Application: Structure and function of cellulose and starch in plants and glycogen in humans. | Pg.76-77 |
| **2.3.A2** Application: Scientific evidence for health risks of trans fats and saturated fatty acids. | Pg.83 |
| **2.3.A3** Application: Lipids are more suitable for long-term energy storage in humans than carbohydrates. | Pg.78-79 |
| **2.3.A4** Application: Evaluation of evidence and the methods used to obtain the evidence for health claims made about lipids. | Pg.85 |
| **2.3.S1** Skill: Use of molecular visualization software to compare cellulose, starch and glycogen. | Pg.75-76 |
| **2.3.S2** Skill: Determination of body mass index by calculation or use of a nomogram. | Pg.80 |
| **Guidance:**• The structure of starch should include amylose and amylopectin.• Named examples of fatty acids are not required.• Sucrose, lactose and maltose should be included as examples of disaccharides produced by combining monosaccharides. |  |

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| **Topic 2: Molecular biology (17 hours)** |
| **Essential idea:** Proteins have a very wide range of functions in living organisms. |
| **2.4 Proteins** |
| **Nature of science:****2.4.NOS1** Looking for patterns, trends and discrepancies—most but not all organisms assemble proteins from the same amino acids. (3.1) | Pg.89 |
| **Understandings:** |  |
| **2.4.U1** Amino acids are linked together by condensation to form polypeptides. | Pg.87-88 | **Utilization:**• Proteomics and the production of proteins by cells cultured in fermenters offer many opportunities for the food, pharmaceutical and other industries.**Aims:**• **Aim 7:** ICT can be used for molecular visualization of the structure of proteins.• **Aim 8:** Obtaining samples of human blood for immunological, pharmaceutical and anthropological studies is an international endeavour with many ethical issues. |
| **2.4.U2** There are 20 different amino acids in polypeptides synthesized on ribosomes. | Pg.88-89 |
| **2.4.U3** Amino acids can be linked together in any sequence giving a huge range of possible polypeptides. | Pg. 90 |
| **2.4.U4** The amino acid sequence of polypeptides is coded for by genes. | Pg.90-91 |
| **2.4.U5** A protein may consist of a single polypeptide or more than one polypeptide linked together. | Pg.91 |
| **2.4.U6** The amino acid sequence determines the three-dimensional conformation of a protein. | Pg.91-92 |
| **2.4.U7** Living organisms synthesize many different proteins with a wide range of functions. | Pg.93 |
| **2.4.U8** Every individual has a unique proteome. | Pg.94-95 |
| **Applications and skills:** |
| **2.4.A1** Application: Rubisco, insulin, immunoglobulins, rhodopsin, collagen and spider silk as examples of the range of protein functions. | Pg.94 |
| **2.4.A2** Application: Denaturation of proteins by heat or by deviation of pH from the optimum. | Pg.92 |
| **2.4.S1** Skill: Drawing molecular diagrams to show the formation of a peptide bond. | Pg.88 |
| **Guidance:**• The detailed structure of the six proteins selected to illustrate the functions of proteins is not needed.• Egg white or albumin solutions can be used in denaturation experiments.• 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. |  |

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| **Topic 2: Molecular biology (17 hours)** |
| **Essential idea:** Enzymes control the metabolism of the cell. |
| **2.5 Enzymes** |
| **Nature of science:****2.5.NOS1** Experimental design—accurate, quantitative measurements in enzyme experiments require replicates to ensure reliability. (3.2) | Pg.100 |
| **Understandings:** | **Theory of knowledge:**• Development of some techniques benefits particular human populations more than others. For example, the development of lactose-free milk available in Europe and North America would have greater benefit in Africa/Asia where lactose intolerance is more prevalent. The development of techniques requires financial investment. Should knowledge be shared when techniques developed in one part of the world are more applicable in another?**Utilization:**• Enzymes are extensively used in industry for the production of items from fruit juice to washing powder.Syllabus and cross-curricular links:BiologyTopic 8 AHL Metabolism, cell respiration and photosynthesis |
| **2.5.U1** Enzymes have an active site to which specific substrates bind. | Pg.96 |
| **2.5.U2** Enzyme catalysis involves molecular motion and the collision of substrates with the active site. | Pg.97-98 |
| **2.5.U3** Temperature, pH and substrate concentration affect the rate of activity of enzymes. | Pg.98-99 |
| **2.5.U4** Enzymes can be denatured. | Pg.100 |
| **2.5.U5** Immobilized enzymes are widely used in industry. | Pg.103-104 |
| **Applications and skills:** |
| **2.5.A1** Application: Methods of production of lactose-free milk and its advantages. | Pg.105 |
| **2.5.S1** Skill: Design of experiments to test the effect of temperature, pH and substrate concentration on the activity of enzymes.  | Pg.101 |
| **2.5.S2** Skill: Experimental investigation of a factor affecting enzyme activity. (Practical 3) | Pg. 102 |
| **Guidance:**• Lactase can be immobilized in alginate beads and experiments can then be carried out in which the lactose in milk is hydrolysed.• 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. |  |

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| **Topic 2: Molecular biology (17 hours)** |
| **Essential idea:** Metabolic reactions are regulated in response to the cell’s needs. |
| **8.1 Metabolism** |
| **Nature of science:****8.1.NOS1** Developments in scientific research follow improvements in computing—developments in bioinformatics, such as the interrogation of databases, have facilitated research into metabolic pathways. (3.8) | Pg.377 |
| **Understandings:** | **Theory of knowledge:**• Many metabolic pathways have been described following a series of carefully controlled and repeated experiments. To what degree can looking at component parts give us knowledge of the whole?**Utilization:**• Many enzyme inhibitors have been used in medicine. For example ethanol has been used to act as a competitive inhibitor for antifreeze poisoning.• Fomepizole, which is an inhibitor of alcohol dehydrogenase, has also been used for antifreeze poisoning.Syllabus and cross-curricular links:BiologyTopic 2.7 DNA replication, transcription and translationChemistryTopic 6.1 Collision theory and rates of reaction**Aims:**• **Aim 6:** Experiments on enzyme inhibition can be performed.• **Aim 7:** Computer simulations on enzyme action including metabolic inhibition are available. |
| **8.1.U1** Metabolic pathways consist of chains and cycles of enzyme-catalysed reactions. | Pg.374 |
| **8.1.U2** Enzymes lower the activation energy of the chemical reactions that they catalyse. | Pg.374-375 |
| **8.1.U3** Enzyme inhibitors can be competitive or non-competitive. | Pg.375-376 |
| **8.1.U4** Metabolic pathways can be controlled by end-product inhibition. | Pg.377 |
| **Applications and skills:** |
| **8.1.A1** Application: End-product inhibition of the pathway that converts threonine to isoleucine. | Pg.377 |
| **8.1.A2** Application: Use of databases to identify potential new anti-malarial drugs. | Pg.378 |
| **8.1.S1** Skill: Calculating and plotting rates of reaction from raw experimental results. | Pg.378 |
| **8.1.S2** Skill: Distinguishing different types of inhibition from graphs at specified substrate concentration. | Pg.376 |
| **Guidance:**• Enzyme inhibition should be studied using one specific example for competitive and non-competitive inhibition. |  |

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| **Topic 2: Molecular biology (17 hours)** |
| **Essential idea:** The structure of DNA allows efficient storage of genetic information. |
| **2.6 Structure of DNA and RNA** |
| **Nature of science:****2.6.NOS1** Using models as representation of the real world—Crick and Watson used model making to discover the structure of DNA. (1.10) | Pg.109 |
| **Understandings:** | **Theory of knowledge:**• The story of the elucidation of the structure of DNA illustrates that cooperation and collaboration among scientists exists alongside competition between research groups. To what extent is research in secret ‘anti-scientific’?What is the relationship between shared and personal knowledge in the natural sciences?**Utilization:**Syllabus and cross-curricular links:BiologyTopic 2.2 WaterTopic 3.5 Genetic modification and biotechnologyTopic 7 Nucleic acids |
| **2.6.U1** The nucleic acids DNA and RNA are polymers of nucleotides. | Pg.106 |
| **2.6.U2** DNA differs from RNA in the number of strands present, the base composition and the type of pentose. | Pg.106 |
| **2.6.U3** DNA is a double helix made of two antiparallel strands of nucleotides linked by hydrogen bonding between complementary base pairs. | Pg.108 |
| **Applications and skills:** |
| **2.6.A1** Application: Crick and Watson’s elucidation of the structure of DNA using model making. | Pg.110 |
| **2.6.S1** Skill: Drawing simple diagrams of the structure of single nucleotides of DNA and RNA, using circles, pentagons and rectangles to represent phosphates, pentoses and bases. | Pg.107-108 |
| **Guidance:**• 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. |  |