**Topic 1: Molecules of Life**

*Campbell Chapters 2,3,4,5,8,9,10 16, and 17*

*\*It is strongly recommended that you read and take column notes on all of chapters 3 and 5 in addition to answering the “Understandings” and “Sample Questions and Assessment Statements” below. For all other chapters, simply reading the suggested pages and doing any more work that you deem necessary will be enough.*

**Molecules to Metabolism: Chapters 2,3,4 and 8**

**Essential Idea:** Living organisms control their composition by a complex web of chemical reactions.

**Nature of Science:**

• Falsification of theories—the artificial synthesis of urea helped to falsify vitalism.

**Understandings:**

1. Molecular biology explains living processes in terms of the chemical substances involved.
2. Carbon atoms can form four covalent bonds allowing a diversity of stable compounds to exist. ***60-63***
3. Life is based on carbon compounds (***58-59)*** including carbohydrates ***(69-74)***, lipids ***74-77)***, proteins ***(77-86)*** and nucleic acids ***(86-89)***.
4. Metabolism is the web of all the enzyme-catalyzed reactions in a cell or organism ***(151-159)***.
5. Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions ***68-69; 142-143***.
6. Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers ***68-69; 142-143***.

**Applications and Skills:**

• **Application:** Urea as an example of a compound that is produced by living organisms but can also be artificially synthesized. ***60-61***

• **Skill**: Drawing molecular diagrams of glucose ***(70-74)***, ribose ***(87-88)***, a saturated fatty acid ***(74-77)*** and a generalized amino acid ***(78)***.

**• Skill:** Identification of biochemicals such as sugars ***(69-74)***, lipids ***(74-77)*** or amino acids ***(77-86)*** from molecular diagrams.

**Sample Questions and Assessment Statements:**

• State that the most frequently occurring chemical elements in living things are carbon, hydrogen, oxygen and nitrogen. ***32***

• State that a variety of other elements are needed by living organisms, including sulfur, calcium, phosphorus, iron and sodium. ***32***

• State one role for each of the following elements: sulfur, calcium, phosphorus, iron and sodium. ***58-59***

• Distinguish between organic and inorganic compounds. ***58-59***

• Identify amino acids ***(65, 79)***, glucose ***(73)***, ribose ***(87)*** and fatty acids ***(75)*** from diagrams showing their structure.

• List three examples each of monosaccharides, disaccharides and polysaccharides. ***69, 73***

• State one function of glucose, lactose and glycogen in animals, and of fructose, sucrose and cellulose in plants. ***71-73***

• Outline the role of condensation and hydrolysis in the relationships between monosaccharides, disaccharides and polysaccharides; between fatty acids, glycerol and triglycerides; and between amino acids and polypeptides. ***68-69***

• Compare the use of carbohydrates and lipids in energy storage. ***74-76***

**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.

**Aims:**

**• Aim 7:** IC 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.

**Water: Chapter 3**

**Essential Idea:** Water is the medium of life.

**Nature of Science:**

• Use theories to explain natural phenomena—the theory that hydrogen bonds form between water molecules explains the properties of water.

**Understandings:**

1. Water molecules are polar and hydrogen bonds form between them. ***46-47***
2. Hydrogen bonding and dipolarity explain the cohesive, adhesive, thermal and solvent properties of water. ***46-52***
3. Substances can be hydrophilic or hydrophobic. ***51***

**Applications and Skills:**

**• Application:** Comparison of the thermal properties of water with those of methane. ***38-41***

**• Application:** Use of water as a coolant in sweat. ***48-49***

**• Application:** Modes of transport of glucose, amino acids, cholesterol, fats, oxygen and sodium chloride in blood in relation to their solubility in water. ***Online***

**Sample Questions and Assessment Statements:**

• Draw and label a diagram showing the structure of water molecules to show their polarity and hydrogen bond formation. ***46-47***

• Draw and label a diagram showing the structure of water molecules to show their polarity and hydrogen bond formation. ***46-47***

• Outline the thermal, cohesive, and solvent properties of water. ***46-52***

• Explain the relationship between the properties of water and its uses in living organisms as a coolant, medium for metabolic reactions and transport medium. ***46-52***

**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.

**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.

**TOK:**

• 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?

**Aims:**

**• Aim 6:** Probes can be used to determine the effect of different factors likely to influence the cooling with water.

**Carbohydrates and Lipids: Chapter 5**

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

**Nature of Science:**

• Evaluating claims—health claims made about lipids in diets needs to be assessed.

**Understandings:**

1. Monosaccharide monomers are linked together by condensation reactions to form disaccharides and polysaccharide polymers. ***68-69, 71-73***
2. Fatty acids can be saturated, monounsaturated, or polyunsaturated. ***74-77; Online***
3. Unsaturated fatty acids can be *cis* or *trans* isomers. ***74-76***
4. Triglycerides are formed by condensation from three fatty acids and one glycerol. ***74-77***

**Applications and Skills:**

**• Application:**  Structure and function of cellulose and starch in plants and glycogen in humans. ***69-74***

**• Application:** Scientific evidence for health risks of trans fats and saturated fatty acids. ***75-76; Online***

**• Application:** Lipids are more suitable for long-term energy storage in humans than carbohydrates. ***76; Online***

**• Application:** Evaluation of evidence and the methods used to obtain the evidence for health claims made about lipids. ***Online***

**• Skill:** Determination of body mass index by calculation or use of a nomogram. ***Online***

**Sample Questions and Assessment Statements:**

• List three examples each of monosaccharides, disaccharides and polysaccharides. ***69, 73***

• State one function of glucose, lactose and glycogen in animals, and of fructose, sucrose and cellulose in plants. ***71-73***

• Compare the use of carbohydrates and lipids in energy storage. ***74-76***

**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.

**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 hearth disease.

**TOK**:

• 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.

**Aims:**

**• Aim 8:** There are social implications of obesity.

**Proteins: Chapter 5**

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

**Nature of Science:**

• Looking for patterns, trends and discrepancies—most but not all organism assemble proteins from the same amino acids.

**Understandings:**

1. Amino acids are linked together by condensation to form polypeptides. ***68-69; 78-81***
2. There are 20 different amino acids in polypeptides synthesized on ribosomes. ***78-80***
3. Amino acids can be linked together in any sequence giving a huge range of possible polypeptides. ***80***
4. The amino acid sequence of polypeptides is coded for by genes. ***82; 86-87; 329-330***
5. A protein may consist of a single polypeptide or more than one polypeptide linked together. ***83***
6. The amino acid sequence determines the three-dimensional conformation of a protein. ***78-86***
7. Living organism synthesize many different proteins with a wide range of functions. ***77-78***
8. Every individual has a unique proteome. ***431-432***

**Application and Skill:**

• **Application:** Rubisco ***(198)***, insulin ***(78, 80, 409, 418, 893-894, 982-984, 977)***, immunoglobins ***(937, 939-940)***, rhodopsin ***(1102, online)***, collagen ***(78, 83, 119, 120, Online)*** and spider silk ***(82, Online)*** are examples of the range of protein functions.

• **Application:** Denaturation of proteins by heat or by deviation of pH from the optimum. ***84-86***

• **Skill:** Drawing molecular diagrams to show the formation of a peptide bond. ***Activity and online***

**Sample Questions and Assessment Statements:**

• Outline the role of condensation and hydrolysis in the relationships between monosaccharides, disaccharides and polysaccharides; between fatty acids, glycerol and triglycerides; and between amino acids and polypeptides. ***68-69***

• Explain the four levels of protein structure, indicating the significance of each level. ***81-86, esp. 82-83***

• Outline the difference between fibrous ***(81)*** and globular proteins ***(81)***, with reference to two examples of each protein type. ***Also see handout.***

• Explain the significance of polar and non-polar amino acids. ***Online***.

• State four functions of proteins, giving a named example of each. ***78***

**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.

**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 endeavor with many ethical issues.

**Structure of DNA and RNA: Chapter 5**

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

**Nature of Science:**

• Using models as representation of the real world—Crick and Watson used model making to discover the structure of DNA.

**Understandings:**

1. The nucleic acids DNA and RNA are polymers of nucleotides. ***86-89***
2. DNA differs from RNA in the number of strands present, the base composition and the type of pentose. ***86-89; Online***
3. DNA is a double helix made of two antiparallel strands of nucleotides linked by hydrogen bonding between complementary base pairs. ***86-89; Online***

**Applications and Skills:**

**• Application:** Crick and Watson’s elucidation of the structure of DNA using model making. ***88; 308-310***

**• 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. ***87; Online***

**Sample Questions and Assessment Statements:**

• Outline DNA nucleotide structure in terms of sugar (deoxyribose), base and phosphate. ***87***

• State the names of the four bases in DNA. ***87***

• Outline how DNA nucleotides are linked together by covalent bonds into a single strand. ***86-88***

• Explain how a DNA double helix is formed using complementary base pairing and hydrogen bonds. ***86-89; 308-310***

**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 base pairs.

**TOK:**

• The story of the elucidation of the structure of DNA illustrates that cooperation and collaboration among scientists exist 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 science?