# Option B: Human biochemistry (15/22 hours)

The aim of this option is to give students an understanding of the chemistry of important molecules found in the human body, and the need for a balanced and healthy diet. Although the role that these molecules play in the body should be appreciated, the emphasis is placed on their chemistry, and students who have not followed a course in biology will not be at a disadvantage. Students will not be required to memorize complex structures, but they will be expected to recognize functional groups and types of bonding within and between molecules. Structures of some important biological molecules are given in the *Chemistry data booklet*. Teachers are encouraged to foster students' awareness of local and global issues.

**Core material:** B1–B6 are core material for SL and HL (15 hours).

**Extension material:** B7–B9 are extension material for HL only (7 hours).

## B1 Energy

**0.5 hour**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.1.1 | Calculate the energy value of a food from enthalpy of combustion data. | 2 | |

## B2 Proteins

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.2.1 | Draw the general formula of 2-amino acids. | 1 | |
| B.2.2 | Describe the characteristic properties of 2-amino acids | 2 | Properties should include isoelectric point, formation of a zwitterion and buffer action. |
| B.2.3 | Describe the condensation reaction of 2-amino acids to form polypeptides. | 2 | Reactions involving up to three amino acids will be assessed. |
| B.2.4 | Describe and explain the primary, secondary (α-helix and β-pleated sheets), tertiary and quaternary structure of proteins. | 3 | Include all bonds and interactions (both intramolecular and intermolecular) responsible for the protein structure. |
| B.2.5 | Explain how proteins can be analysed by chromatography and electrophoresis. | 3 | |
| B.2.6 | List the major functions of proteins in the body. | 1 | Include structural proteins (for example, collagen), enzymes, hormones (for example, insulin), immunoproteins (antibodies), transport proteins (for example, hemoglobin) and as an energy source. |

## B3 Carbohydrates

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.3.1 | Describe the structural features of monosaccharides. | 2 | Monosaccharides contain a carbonyl group (C=O) and at least two –OH groups, and have the empirical formula $CH_2O$. |
| B.3.2 | Draw the straight-chain and ring structural formulas of glucose and fructose. | 1 | Students should be made aware of the structural difference between α and β isomers. |
| B.3.3 | Describe the condensation of monosaccharides to form disaccharides and polysaccharides. | 2 | Examples include:<br>• disaccharides—lactose, maltose and sucrose<br>• polysaccharides—starch (α-glucose), glycogen (α-glucose) and cellulose (β-glucose). |
| B.3.4 | List the major functions of carbohydrates in the human body. | 1 | Include energy source (glucose), energy reserves (glycogen) and precursors for other biologically important molecules. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.3.5 | Compare the structural properties of starch and cellulose, and explain why humans can digest starch but not cellulose. | 3 | Both are polymers of glucose units. Starch has two forms: amylose, which is a straight-chain polymer (α-1,4 linkage), and amylopectin, which is a branched structure with both α-1,4 and α-1,6 linkages. Cellulose has a β-1,4 linkage; this can be hydrolysed by the enzyme cellulase, which is absent in most animals, including mammals. |
| B.3.6 | State what is meant by the term dietary fibre. | 1 | Dietary fibre is mainly plant material that is not hydrolysed by enzymes secreted by the human digestive tract but may be digested by microflora in the gut. Examples include cellulose, hemicellulose, lignin and pectin. |
| B.3.7 | Describe the importance of a diet high in dietary fibre. | 2 | **Aim 8:** Dietary fibre may be helpful in the prevention of conditions such as diverticulosis, irritable bowel syndrome, constipation, obesity, Crohn's disease, hemorrhoids and diabetes mellitus. |

## B4 Lipids

**3.5 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.4.1 | Compare the composition of the three types of lipids found in the human body. | 3 | Examples include triglycerides (fats and oils), phospholipid (lecithin) and steroids (cholesterol). |
| B.4.2 | Outline the difference between HDL and LDL cholesterol and outline its importance. | 2 | |
| B.4.3 | Describe the difference in structure between saturated and unsaturated fatty acids. | 2 | Most naturally occurring fats contain a mixture of saturated, mono-unsaturated and poly-unsaturated fatty acids and are classified according to the predominant type of unsaturation present. |
| B.4.4 | Compare the structures of the two essential fatty acids linoleic (omega–6 fatty acid) and linolenic (omega–3 fatty acid) and state their importance. | 3 | |
| B.4.5 | Define the term *iodine number* and calculate the number of C=C double bonds in an unsaturated fat/oil using addition reactions. | 2 | The number of moles of $I_2$ reacting with one mole of fat/oil indicates the number of double bonds present in the fat/oil molecule. |
| B.4.6 | Describe the condensation of glycerol and three fatty acid molecules to make a triglyceride. | 2 | |
| B.4.7 | Describe the enzyme-catalysed hydrolysis of triglycerides during digestion. | 2 | |
| B.4.8 | Explain the higher energy value of fats as compared to carbohydrates. | 3 | |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.4.9 | Describe the important roles of lipids in the body and the negative effects that they can have on health. | 2 | Important roles include:<br>• energy storage<br>• insulation and protection of organs<br>• steroid hormones<br>• structural component of cell membrane<br>• omega-3 poly-unsaturated fatty acids reduce the risk of heart disease<br>• poly-unsaturated fats may lower levels of LDL cholesterol.<br>Negative effects include:<br>• increased risk of heart disease from elevated levels of LDL cholesterol and *trans* fatty acids; the major source of LDL cholesterol is saturated fats, in particular lauric ($C_{12}$), myristic ($C_{14}$) and palmitic ($C_{16}$) acids<br>• obesity. |

## B5 Micronutrients and macronutrients

**2 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.5.1 | Outline the difference between micronutrients and macronutrients. | 2 | Micronutrients are substances required in very small amounts (mg or µg) and that mainly function as a co-factor of enzymes (<0.005% body weight).<br>Examples include vitamins and trace minerals (Fe, Cu, F, Zn, I, Se, Mn, Mo, Cr, Co and B).<br>Macronutrients are chemical substances that are required in relatively large amounts (>0.005% body weight).<br>Examples include proteins, fats, carbohydrates and minerals (Na, Mg, K, Ca, P, S and Cl). |
| B.5.2 | Compare the structures of retinol (vitamin A), calciferol (vitamin D) and ascorbic acid (vitamin C). | 3 | |
| B.5.3 | Deduce whether a vitamin is water- or fat-soluble from its structure. | 3 | Examples include:<br>• water-soluble—vitamins B and C<br>• fat-soluble—vitamins A, D, E and K. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.5.4 | Discuss the causes and effects of nutrient deficiencies in different countries and suggest solutions. | 3 | Micronutrient deficiencies include:<br>• iron—anemia<br>• iodine—goitre<br>• retinol (vitamin A)—xerophthalmia, night blindness<br>• niacin (vitamin $B_3$)—pellagra<br>• thiamin (vitamin $B_1$)—beriberi<br>• ascorbic acid (vitamin C)—scurvy<br>• calciferol (vitamin D)—rickets.<br>Macronutrient deficiencies include:<br>• protein—marasmus and kwashiorkor.<br>Some causes of malnutrition may be discussed here.<br>Solutions include:<br>• providing food rations that are composed of fresh and vitamin- and mineral-rich foods<br>• adding nutrients missing in commonly consumed foods<br>• genetic modification of food<br>• providing nutritional supplements<br>• providing selenium supplements to people eating foods grown in selenium-poor soil. |

## B6 Hormones

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.6.1 | Outline the production and function of hormones in the body. | 2 | Hormones are chemical messengers. They are secreted directly into the blood by endocrine glands. Examples include ADH, aldosterone, estrogen, progesterone and testosterone, insulin, epinephrine (adrenaline) and thyroxine. |
| B.6.2 | Compare the structures of cholesterol and the sex hormones. | 3 | Stress the common steroid backbone but the difference in functional groups. |
| B.6.3 | Describe the mode of action of oral contraceptives. | 2 | **Aim 8** |
| B.6.4 | Outline the use and abuse of steroids. | 2 | **Aim 8** |

## HL B7 Enzymes

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.7.1 | Describe the characteristics of biological catalysts (enzymes). | 2 | Include: enzymes are proteins; activity depends on tertiary and quaternary structure; and the specificity of enzyme action. |
| B.7.2 | Compare inorganic catalysts and biological catalysts (enzymes). | 3 | |
| B.7.3 | Describe the relationship between substrate concentration and enzyme activity. | 2 | |
| B.7.4 | Determine $V_{max}$ and the value of the Michaelis constant ($K_m$) by graphical means and explain its significance. | 3 | |
| B.7.5 | Describe the mechanism of enzyme action, including enzyme substrate complex, active site and induced fit model. | 2 | |
| B.7.6 | Compare competitive inhibition and non-competitive inhibition. | 3 | |
| B.7.7 | State and explain the effects of heavy-metal ions, temperature changes and pH changes on enzyme activity. | 3 | |

## HL B8 Nucleic acids

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.8.1 | Describe the structure of nucleotides and their condensation polymers (nucleic acids or polynucleotides). | 2 | Nucleic acids are polymers made up of nucleotides. A nucleotide contains a phosphate group, a pentose sugar and an organic nitrogenous base. Students should recognize, but do not need to recall, the structures of the five bases: adenine (A), cytosine (C), guanine (G), thymine (T) and uracil (U). Nucleic acids are joined by covalent bonds between the phosphate of one nucleotide and the sugar of the next, resulting in a backbone with a repeating pattern of sugar–phosphate–sugar–phosphate. Nitrogenous bases are attached to the sugar of the backbone. |
| B.8.2 | Distinguish between the structures of DNA and RNA. | 2 | RNA has ribose as its pentose sugar; DNA has deoxyribose. Deoxyribose lacks an oxygen atom on C2. RNA has uracil instead of thymine as its base. RNA is a single-strand nucleic acid; DNA is a double-strand nucleic acid. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.8.3 | Explain the double helical structure of DNA. | 3 | The structure has two nucleic acid strands that spiral around an axis. Students should describe the hydrogen bonding between specific pairs of nucleotide bases.<br>**TOK:** What are the implications of the discovery of the molecular basis of life in other areas of knowledge? |
| B.8.4 | Describe the role of DNA as the repository of genetic information, and explain its role in protein synthesis. | 2 | DNA is the genetic material that an individual inherits from its parents. It directs mRNA synthesis (transcription) and, through mRNA, directs protein synthesis (translation) using a triplet code. |
| B.8.5 | Outline the steps involved in DNA profiling and state its use. | 2 | **Aim 8:** Include forensic and paternity cases. |

## HL B9 Respiration

**1 hour**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| B.9.1 | Compare aerobic and anaerobic respiration of glucose in terms of oxidation/reduction and energy released. | 3 | In aerobic respiration, glucose is converted into pyruvate, which, in the presence of oxygen, changes to carbon dioxide and water. Overall, glucose undergoes oxidation and oxygen undergoes reduction. In anaerobic respiration, pyruvate is converted to lactate in human beings, whereas yeast converts pyruvate to ethanol and carbon dioxide. Redox equations should be used as appropriate. |
| B.9.2 | Outline the role of copper ions in electron transport and iron ions in oxygen transport. | 2 | Cytochromes and hemoglobin are suitable examples. |