

Topic 2. Biological molecules and processes

SL: 14 hours

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Objectives from the Biology Guide 2025, published by the IB

1.1 Carbohydrates and Lipids

Standard level and higher level: 4 hours

B1.1.1—Chemical properties of a carbon atom allowing for the formation of diverse compounds upon which life is based

Students should understand the nature of a covalent bond. Students should also understand that a carbon atom can form up to four single bonds or a combination of single and double bonds with other carbon atoms or atoms of other non-metallic elements. Include among the diversity of carbon compounds examples of molecules with branched or unbranched chains and single or multiple rings.

NOS: Students should understand that scientific conventions are based on international agreement (SI metric unit prefixes “kilo”, “centi”, “milli”, “micro” and “nano”).

B1.1.2—Production of macromolecules by condensation reactions that link monomers to form a polymer

Students should be familiar with examples of polysaccharides, polypeptides and nucleic acids.

B1.1.3—Digestion of polymers into monomers by hydrolysis reactions

Water molecules are split to provide the -H and -OH groups that are incorporated to produce monomers, hence the name of this type of reaction.

B1.1.4—Form and function of monosaccharides

Students should be able to recognize pentoses and hexoses as monosaccharides from molecular diagrams showing them in the ring forms. Use glucose as an example of the link between the properties of a monosaccharide and how it is used, emphasizing solubility, transportability, chemical stability and the yield of energy from oxidation as properties.

B1.1.5—Polysaccharides as energy storage compounds

Include the compact nature of starch in plants and glycogen in animals due to coiling and branching during polymerization, the relative insolubility of these compounds due to large molecular size and the relative ease of adding or removing alpha-glucose monomers by condensation and hydrolysis to build or mobilize energy stores.

B1.1.6—Structure of cellulose related to its function as a structural polysaccharide in plants

Include the alternating orientation of beta-glucose monomers, giving straight chains that can be grouped in bundles and cross-linked with hydrogen bonds.

B1.1.7—Role of glycoproteins in cell–cell recognition

Include ABO antigens as an example.

B1.1.8—Hydrophobic properties of lipids

Lipids are substances in living organisms that dissolve in non-polar solvents but are only sparingly soluble in aqueous solvents. Lipids include fats, oils, waxes and steroids.

B1.1.9—Formation of triglycerides and phospholipids by condensation reactions

One glycerol molecule can link three fatty acid molecules or two fatty acid molecules and one phosphate group.

B1.1.10—Difference between saturated, monounsaturated and polyunsaturated fatty acids

Include the number of double carbon (C=C) bonds and how this affects melting point. Relate this to the prevalence of different types of fatty acids in oils and fats used for energy storage in plants and endotherms respectively.

B1.1.11—Triglycerides in adipose tissues for energy storage and thermal insulation

Students should understand that the properties of triglycerides make them suited to long-term energy storage functions. Students should be able to relate the use of triglycerides as thermal insulators to body temperature and habitat.

B1.1.12—Formation of phospholipid bilayers as a consequence of the hydrophobic and hydrophilic regions

Students should use and understand the term “amphipathic”.

B1.1.13—Ability of non-polar steroids to pass through the phospholipid bilayer

Include oestradiol and testosterone as examples. Students should be able to identify compounds as steroids from molecular diagrams.

B 1.2 Proteins

Standard level and higher level: 2 hours

B1.2.1—Generalized structure of an amino acid

Students should be able to draw a diagram of a generalized amino acid showing the alpha carbon atom with amine group, carboxyl group, R-group and hydrogen attached.

B1.2.2—Condensation reactions forming dipeptides and longer chains of amino acids

Students should be able to write the word equation for this reaction and draw a generalized dipeptide after modelling the reaction with molecular models.

B1.2.3—Dietary requirements for amino acids

Essential amino acids cannot be synthesized and must be obtained from food. Non-essential amino acids can be made from other amino acids. Students are not required to give examples of essential and non-essential amino acids. Vegan diets require attention to ensure essential amino acids are consumed.

B1.2.4—Infinite variety of possible peptide chains

Include the ideas that 20 amino acids are coded for in the genetic code, that peptide chains can have any number of amino acids, from a few to thousands, and that amino acids can be in any order. Students should be familiar with examples of polypeptides.

B1.2.5—Effect of pH and temperature on protein structure

Include the term "denaturation".

C 1.1 Enzymes and Metabolism

Standard level and higher level: 3 hours

C1.1.1—Enzymes as catalysts

Students should understand the benefit of increasing rates of reaction in cells.

C1.1.2—Role of enzymes in metabolism

Students should understand that metabolism is the complex network of interdependent and interacting chemical reactions occurring in living organisms. Because of enzyme specificity, many different enzymes are required by living organisms, and control over metabolism can be exerted through these enzymes.

C1.1.3—Anabolic and catabolic reactions

Examples of anabolism should include the formation of macromolecules from monomers by condensation reactions including protein synthesis, glycogen formation and photosynthesis. Examples of catabolism should include hydrolysis of macromolecules into monomers in digestion and oxidation of substrates in respiration.

C1.1.4—Enzymes as globular proteins with an active site for catalysis

Include that the active site is composed of a few amino acids only, but interactions between amino acids within the overall three-dimensional structure of the enzyme ensure that the active site has the necessary properties for catalysis.

C1.1.5—Interactions between substrate and active site to allow induced-fit binding

Students should recognize that both substrate and enzymes change shape when binding occurs.

C1.1.6—Role of molecular motion and substrate-active site collisions in enzyme catalysis

Movement is needed for a substrate molecule and an active site to come together. Sometimes large substrate molecules are immobilized while sometimes enzymes can be immobilized by being embedded in membranes.

C1.1.7—Relationships between the structure of the active site, enzyme–substrate specificity and denaturation

Students should be able to explain these relationships.

C1.1.8—Effects of temperature, pH and substrate concentration on the rate of enzyme activity

The effects should be explained with reference to collision theory and denaturation.

Application of skills: Students should be able to interpret graphs showing the effects.

NOS: Students should be able to describe the relationship between variables as shown in graphs. They should recognize that generalized sketches of relationships are examples of models in biology. Models in the form of sketch graphs can be evaluated using results from enzyme experiments.

C1.1.9—Measurements in enzyme-catalysed reactions

Application of skills: Students should determine reaction rates through experimentation and using secondary data.

C1.1.10—Effect of enzymes on activation energy

Application of skills: Students should appreciate that energy is required to break bonds within the substrate and that there is an energy yield when bonds are made to form the products of an enzyme-catalysed reaction. Students should be able to interpret graphs showing this effect.

C 1.2 Cell Respiration

Standard level and higher level: 2 hours

C1.2.1—ATP as the molecule that distributes energy within cells

Include the full name of ATP (adenosine triphosphate) and that it is a nucleotide. Students should appreciate the properties of ATP that make it suitable for use as the energy currency within cells.

C1.2.2—Life processes within cells that ATP supplies with energy

Include active transport across membranes, synthesis of macromolecules (anabolism), movement of the whole cell or cell components such as chromosomes.

C1.2.3—Energy transfers during interconversions between ATP and ADP

Students should know that energy is released by hydrolysis of ATP (adenosine triphosphate) to ADP (adenosine diphosphate) and phosphate, but energy is required to synthesize ATP from ADP and phosphate. Students are not required to know the quantity of energy in kilojoules, but students should appreciate that it is sufficient for many tasks in the cell.

C1.2.4—Cell respiration as a system for producing ATP within the cell using energy released from carbon compounds

Students should appreciate that glucose and fatty acids are the principal substrates for cell respiration but that a wide range of carbon/organic compounds can be used. Students should be able to distinguish between the processes of cell respiration and gas exchange.

C1.2.5—Differences between anaerobic and aerobic cell respiration in humans

Include which respiratory substrates can be used, whether oxygen is required, relative yields of ATP, types of waste product and where the reactions occur in a cell. Students should be able to write simple word equations for both types of respiration, with glucose as the substrate. Students should appreciate that mitochondria are required for aerobic, but not anaerobic, respiration.

C1.2.6—Variables affecting the rate of cell respiration

Application of skills: Students should make measurements allowing for the determination of the rate of cell respiration. Students should also be able to calculate the rate of cellular respiration from raw data that they have generated experimentally or from secondary data.

C 1.3 Photosynthesis

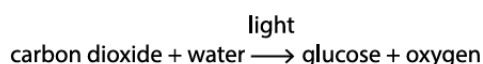
Standard level and higher level: 3 hours

C1.3.1—Transformation of light energy to chemical energy when carbon compounds are produced in photosynthesis

This energy transformation supplies most of the chemical energy needed for life processes in ecosystems.

C1.3.2—Conversion of carbon dioxide to glucose in photosynthesis using hydrogen obtained by splitting water

Students should be able to write a simple word equation for photosynthesis, with glucose as the product.



C1.3.3—Oxygen as a by-product of photosynthesis in plants, algae and cyanobacteria

Students should know the simple word equation for photosynthesis. They should know that the oxygen produced by photosynthesis comes from the splitting of water.

C1.3.4—Separation and identification of photosynthetic pigments by chromatography

Application of skills: Students should be able to calculate R_f values from the results of chromatographic separation of photosynthetic pigments and identify them by colour and by values. Thin-layer chromatography or paper chromatography can be used.

C1.3.5—Absorption of specific wavelengths of light by photosynthetic pigments

Include excitation of electrons within a pigment molecule, transformation of light energy to chemical energy and the reason that only some wavelengths are absorbed. Students should be familiar with absorption spectra. Include both wavelengths and colours of light in the horizontal axis of absorption spectra.

C1.3.6—Similarities and differences of absorption and action spectra

Application of skills: Students should be able to determine rates of photosynthesis from data for oxygen production and carbon dioxide consumption for varying wavelengths. They should also be able to plot this data to make an action spectrum.

C1.3.7—Techniques for varying concentrations of carbon dioxide, light intensity or temperature experimentally to investigate the effects of limiting factors on the rate of photosynthesis

Application of skills: Students should be able to suggest hypotheses for the effects of these limiting factors and to test these through experimentation.

NOS: Hypotheses are provisional explanations that require repeated testing. During scientific research, hypotheses can either be based on theories and then tested in an experiment or be based on evidence from an experiment already carried out. Students can decide in this case whether to suggest hypotheses for the effects of limiting factors on photosynthesis before or after performing their experiments. Students should be able to identify the dependent and independent variable in an experiment.

C1.3.8—Carbon dioxide enrichment experiments as a means of predicting future rates of photosynthesis and plant growth

Include enclosed greenhouse experiments and free-air carbon dioxide enrichment experiments (FACE).

NOS: Finding methods for careful control of variables is part of experimental design. This may be easier in the laboratory but some experiments can only be done in the field. Field experiments include those performed in natural ecosystems. Students should be able to identify a controlled variable in an experiment.