

Topic 1. Cell Composition and Water

SL: 13 hours

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Objectives from the Biology Guide 2025, published by the IB

2.2 Cell Structure

Standard level and higher level: 4 hours

A2.2.1—Cells as the basic structural unit of all living organisms

NOS: Students should be aware that deductive reason can be used to generate predictions from theories. Based on cell theory, a newly discovered organism can be predicted to consist of one or more cells.

A2.2.2—Microscopy skills

Application of skills: Students should have experience of making temporary mounts of cells and tissues, staining, measuring sizes using an eyepiece graticule, focusing with coarse and fine adjustments, calculating actual size and magnification, producing a scale bar and taking photographs.

NOS: Students should appreciate that measurement using instruments is a form of quantitative observation.

A2.2.3—Developments in microscopy

Include the advantages of electron microscopy, freeze fracture, cryogenic electron microscopy, and the use of fluorescent stains and immunofluorescence in light microscopy.

A2.2.4—Structures common to cells in all living organisms

Typical cells have DNA as genetic material and a cytoplasm composed mainly of water, which is enclosed by a plasma membrane composed of lipids. Students should understand the reasons for these structures.

A2.2.5—Prokaryote cell structure

Include these cell components: cell wall, plasma membrane, cytoplasm, naked DNA in a loop and 70S ribosomes. The type of prokaryotic cell structure required is that of Gram-positive eubacteria such as *Bacillus* and *Staphylococcus*. Students should appreciate that prokaryote cell structure varies. However, students are not required to know details of the variations such as the lack of cell walls in phytoplasmas and mycoplasmas.

A2.2.6—Eukaryote cell structure

Students should be familiar with features common to eukaryote cells: a plasma membrane enclosing a compartmentalized cytoplasm with 80S ribosomes; a nucleus with chromosomes made of DNA bound to histones, contained in a double membrane with pores; membrane-bound cytoplasmic organelles including mitochondria, endoplasmic reticulum, Golgi apparatus and a variety of vesicles or vacuoles including lysosomes; and a cytoskeleton of microtubules and microfilaments.

A2.2.7—Processes of life in unicellular organisms

Include these functions: homeostasis, metabolism, nutrition, movement, excretion, growth, response to stimuli and reproduction.

A2.2.8—Differences in eukaryotic cell structure between animals, fungi and plants

Include presence and composition of cell walls, differences in size and function of vacuoles, presence of chloroplasts and other plastids, and presence of centrioles, cilia and flagella.

A2.2.9—Atypical cell structure in eukaryotes

Use numbers of nuclei to illustrate one type of atypical cell structure in aseptate fungal hyphae, skeletal muscle, red blood cells and phloem sieve tube elements.

A2.2.10—Cell types and cell structures viewed in light and electron micrographs

Application of skills: Students should be able to identify cells in light and electron micrographs as prokaryote, plant or animal. In electron micrographs, students should be able to identify these structures: nucleoid region, prokaryotic cell wall, nucleus, mitochondrion, chloroplast, sap vacuole, Golgi apparatus, rough and smooth endoplasmic reticulum, chromosomes, ribosomes, cell wall, plasma membrane and microvilli.

A2.2.11—Drawing and annotation based on electron micrographs

Application of skills: Students should be able to draw and annotate diagrams of organelles (nucleus, mitochondria, chloroplasts, sap vacuole, Golgi apparatus, rough and smooth endoplasmic reticulum and

chromosomes) as well as other cell structures (cell wall, plasma membrane, secretory vesicles and microvilli) shown in electron micrographs. Students are required to include the functions in their annotations.

B 2.2 Organelles and Compartmentalization

Standard level and higher level: 1 hour

B2.2.1—Organelles as discrete subunits of cells that are adapted to perform specific functions
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Students should understand that the cell wall, cytoskeleton and cytoplasm are not considered organelles, and that nuclei, vesicles, ribosomes and the plasma membrane are.
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NOS: Students should recognize that progress in science often follows development of new techniques. For example, study of the function of individual organelles became possible when ultracentrifuges had been invented and methods of using them for cell fractionation had been developed.
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B2.2.3—Advantages of compartmentalization in the cytoplasm of cells

Include concentration of metabolites and enzymes and the separation of incompatible biochemical processes. Include lysosomes and phagocytic vacuoles as examples.

B 2.1 Membranes and Membrane Transport

Standard level and higher level: 4 hours

Additional higher level: 2 hours

B2.1.1—Lipid bilayers as the basis of cell membranes

Phospholipids and other amphipathic lipids naturally form continuous sheet-like bilayers in water.

B2.1.2—Lipid bilayers as barriers

Students should understand that the hydrophobic hydrocarbon chains that form the core of a membrane have low permeability to large molecules and hydrophilic particles, including ions and polar molecules, so membranes function as effective barriers between aqueous solutions.

B2.1.3—Simple diffusion across membranes

Use movement of oxygen and carbon dioxide molecules between phospholipids as an example of simple diffusion across membranes.

B2.1.4—Integral and peripheral proteins in membranes

Emphasize that membrane proteins have diverse structures, locations and functions. Integral proteins are embedded in one or both of the lipid layers of a membrane. Peripheral proteins are attached to one or other surface of the bilayer.

B2.1.5—Movement of water molecules across membranes by osmosis and the role of aquaporins

Include an explanation in terms of random movement of particles, impermeability of membranes to solutes and differences in solute concentration.

B2.1.6—Channel proteins for facilitated diffusion

Students should understand how the structure of channel proteins makes membranes selectively permeable by allowing specific ions to diffuse through when channels are open but not when they are closed.

B2.1.7—Pump proteins for active transport

Students should appreciate that pumps use energy from adenosine triphosphate (ATP) to transfer specific particles across membranes and therefore that they can move particles against a concentration gradient.

B2.1.8—Selectivity in membrane permeability

Facilitated diffusion and active transport allow selective permeability in membranes. Permeability by simple diffusion is not selective and depends only on the size and hydrophilic or hydrophobic properties of particles.

B2.1.9—Structure and function of glycoproteins and glycolipids

Limit to carbohydrate structures linked to proteins or lipids in membranes, location of carbohydrates on the extracellular side of membranes, and roles in cell adhesion and cell recognition.

B2.1.10—Fluid mosaic model of membrane structure

Students should be able to draw a two-dimensional representation of the model and include peripheral and integral proteins, glycoproteins, phospholipids and cholesterol. They should also be able to indicate hydrophobic and hydrophilic regions.

A 1.1 Water

Standard level and higher level: 2 hours

Additional higher level: 1 hour

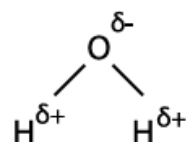
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A1.1.1—Water as the medium for life

Students should appreciate that the first cells originated in water and that water remains the medium in which most processes of life occur.

A1.1.2—Hydrogen bonds as a consequence of the polar covalent bonds within water molecules

Students should understand that polarity of covalent bonding within water molecules is due to unequal sharing of electrons and that hydrogen bonding due to this polarity occurs between water molecules. Students should be able to represent two or more water molecules and hydrogen bonds between them with the notation shown below to indicate polarity.



A1.1.3—Cohesion of water molecules due to hydrogen bonding and consequences for organisms

Include transport of water under tension in xylem and the use of water surfaces as habitats due to the effect known as surface tension.

A1.1.4—Adhesion of water to materials that are polar or charged and impacts for organisms

Include capillary action in soil and in plant cell walls.

A1.1.5—Solvent properties of water linked to its role as a medium for metabolism and for transport in plants and animals

Emphasize that a wide variety of hydrophilic molecules dissolve in water and that most enzymes catalyse reactions in aqueous solution. Students should also understand that the functions of some molecules in cells depend on them being hydrophobic and insoluble.

A1.1.6—Physical properties of water and the consequences for animals in aquatic habitats

Include buoyancy, viscosity, thermal conductivity and specific heat capacity. Contrast the physical properties of water with those of air and illustrate the consequences using examples of animals that live in water and in air or on land, such as the black-throated loon (*Gavia arctica*) and the ringed seal (*Pusa hispida*).

Note: When students are referring to an organism in an examination, either the common name or the scientific name is acceptable.

D 2.3 Water Potential

Standard level and higher level: 2 hours

Additional higher level: 2 hours

D2.3.1—Solvation with water as the solvent

Include hydrogen bond formation between solute and water molecules, and attractions between both positively and negatively charged ions and polar water molecules.

D2.3.2—Water movement from less concentrated to more concentrated solutions

Students should express the direction of movement in terms of solute concentration, not water concentration. Students should use the terms “hypertonic”, “hypotonic” and “isotonic” to compare concentration of solutions.

D2.3.3—Water movement by osmosis into or out of cells

Students should be able to predict the direction of net movement of water if the environment of a cell is hypotonic or hypertonic. They should understand that in an isotonic environment there is dynamic equilibrium rather than no movement of water.

D2.3.4—Changes due to water movement in plant tissue bathed in hypotonic and those bathed in hypertonic solutions

Application of skills: Students should be able to measure changes in tissue length and mass, and analyse data to deduce isotonic solute concentration. Students should also be able to use standard deviation and standard error to help in the analysis of data. Students are not required to memorize formulae for calculating these statistics. Standard deviation and standard error could be determined for the results of this experiment if there are repeats for each concentration. This would allow the reliability of length and mass measurements to be compared. Standard error could be shown graphically as error bars.

D2.3.5—Effects of water movement on cells that lack a cell wall

Include swelling and bursting in a hypotonic medium, and shrinkage and crenation in a hypertonic medium. Also include the need for removal of water by contractile vacuoles in freshwater unicellular organisms and the need to maintain isotonic tissue fluid in multicellular organisms to prevent harmful changes.

D2.3.6—Effects of water movement on cells with a cell wall

Include the development of turgor pressure in a hypotonic medium and plasmolysis in a hypertonic medium.

D2.3.7—Medical applications of isotonic solutions

Include intravenous fluids given as part of medical treatment and bathing of organs ready for transplantation as examples.