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AP Biology

Name:.....

AP Biology

Structural Biochemistry Packet I

Biochemical Nature of the Cell

The Role of Water

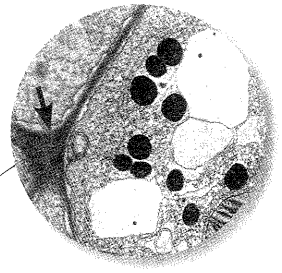
Organic Molecules

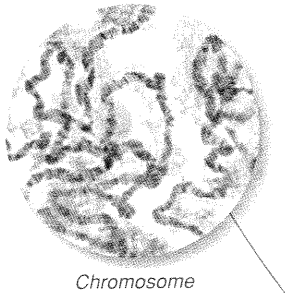
Build an Organism

The molecules that make up living things can be grouped into five broad classes: carbohydrates, lipids, proteins, nucleic acids, and water. Water is the main component of organisms and provides an environment in which metabolic reactions can occur. Apart from water, most other substances in cells are compounds of carbon, hydrogen, oxygen, nitrogen and phosphorus. These elements form strong, stable covalent bonds by sharing electrons. The combination of carbon atoms with the atoms of other elements provides a huge variety of molecular structures. Many of these **biological molecules**, e.g. DNA, are very large and contain millions of atoms. The role of these molecules in cells is outlined below on the diagram of a typical plant cell.

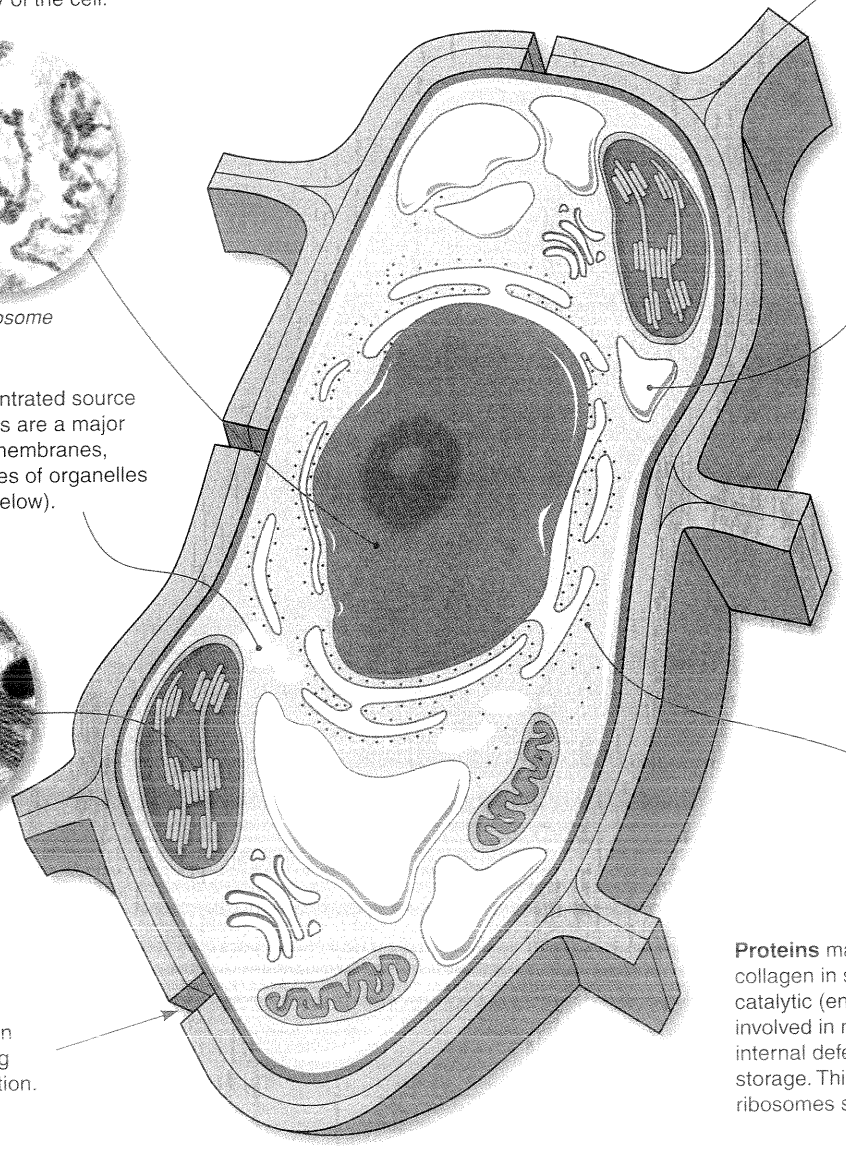
Nucleotides and nucleic acids
Nucleic acids encode information for the construction and functioning of an organism. The nucleotide ATP is the energy currency of the cell.

Carbohydrates form the structural components of cells, e.g. cellulose cell walls (arrowed). They are important in energy storage, and they are involved in cellular recognition.



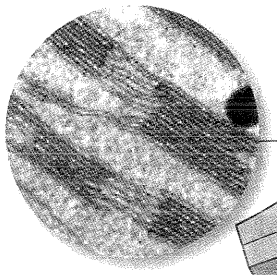


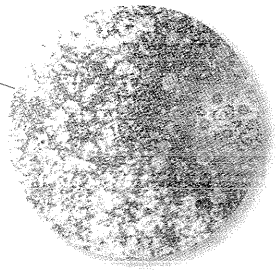
Chromosome



Water is a major component of cells: many substances dissolve in it, metabolic reactions occur in it, and it provides support and turgor.

Lipids provide a concentrated source of energy. Phospholipids are a major component of cellular membranes, including the membranes of organelles such as chloroplasts (below).





Proteins may be structural (e.g. collagen in skin, proteins in ribosomes), catalytic (enzymes), or they may be involved in movement, signalling, internal defence and transport, or storage. This micrograph shows ribosomes synthesizing proteins.

Plasmodesmata are microscopic channels in plant cell walls enabling cell-to-cell communication.

1. Explain the importance of the molecular structure of water to life on Earth: _____

_____

2. Summarize the biological role of each of the following biological molecules:

   (a) Carbohydrates: _____

   (b) Lipids: _____

   (c) Proteins: _____

   (d) Nucleic acids: _____

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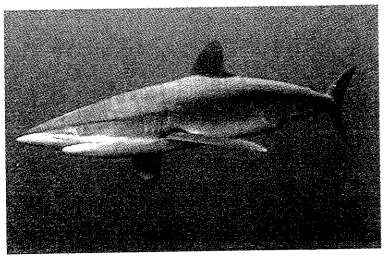
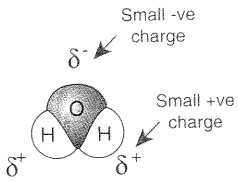
The Role of Water

Water is the most abundant of the smaller molecules making up living things, and typically makes up about two-thirds of any organism. Water is a liquid at room temperature and many substances dissolve in it. It is a medium inside cells and for aquatic life. Water takes part in, and is a common product of, many reactions. Water molecules are **polar** and have a weak attraction for each other and inorganic ions, forming large numbers of weak hydrogen bonds. It is this feature that gives water many of its unique properties, including its low viscosity and its chemical behavior as a **universal solvent**.

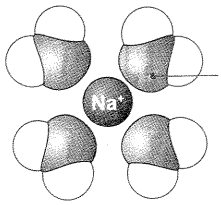
Important Properties of Water



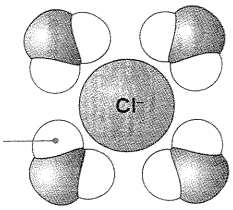
A lot of energy is required before water will change state so aquatic environments are thermally stable and sweating and transpiration cause rapid cooling.



Water molecule
Formula: H_2O



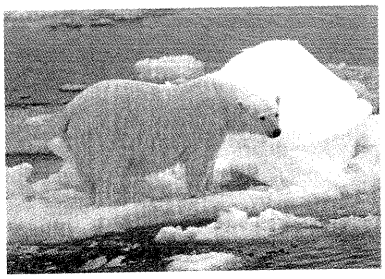
Water surrounding a positive ion (Na^+)



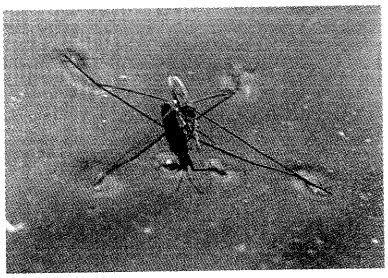
Water surrounding a negative ion (Cl^-)

The most important feature of the chemical behaviour of water is its dipole nature. It has a small positive charge on each of the two hydrogens and a small negative charge on the oxygen.

Water is colorless, with a high transmission of visible light, so light penetrates tissue and aquatic environments.



Ice is less dense than water. Consequently ice floats, insulating the underlying water and providing valuable habitat.



Water has low viscosity, strong cohesive properties, and high surface tension. It can flow freely through small spaces.

1. On the diagram above, showing a positive and a negative ion surrounded by water molecules, indicate the polarity of the water molecules (as shown in the example provided).

2. Explain the importance of the **dipole nature** of water molecules to the chemistry of life: _____

   _____

   _____

3. For (a)-(f), identify the important property of water, and describe an example of that property's biological significance:

   (a) Property important in the clarity of seawater: _____

   Biological significance: _____

   (b) Property important in the transport of water in xylem: _____

   Biological significance: _____

   (c) Property important in the relatively stable temperature of bodies of water: _____

   Biological significance: _____

   (d) Property important in the transport of glucose around the body: _____

   Biological significance: _____

   (e) Property important in the cooling effect of evaporation: _____

   Biological significance: _____

   (f) Property important in ice floating: _____

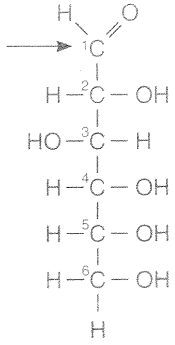
   Biological significance: _____

Organic Molecules

Organic molecules are those chemical compounds containing carbon that are found in living things. Specific groups of atoms, called **functional groups**, attach to a carbon-hydrogen core and confer specific chemical properties on the molecule. Some organic molecules in organisms are small and simple, containing only one or a few functional groups, while others are large complex assemblies called **macromolecules**. The macromolecules that make up living things can be grouped into four classes: carbohydrates, lipids, proteins, and nucleic acids. An understanding of the structure and function of these molecules is necessary to many branches of biology, especially biochemistry, physiology, and molecular genetics. The diagram below illustrates some of the common ways in which biological molecules are portrayed. Note that the **molecular formula** expresses the number of atoms in a molecule, but does not convey its structure; this is indicated by the **structural formula**. Molecules can also be represented as **models**. A ball and stick model shows the arrangement and type of bonds while a space filling model gives a more realistic appearance of a molecule, showing how close the atoms really are.

Portraying Biological Molecules

The numbers next to the carbon atoms are used for identification when the molecule changes shape

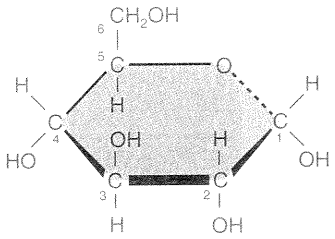


$C_6H_{12}O_6$

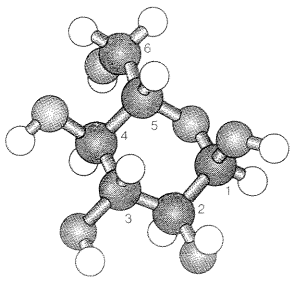
Glucose

Molecular formula

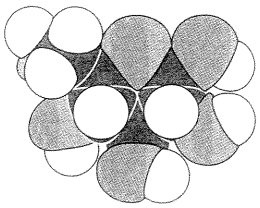
Structural formula
Glucose (straight form)



Structural formula
α glucose (ring form)



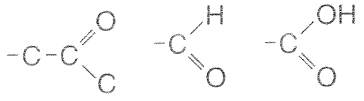
Ball and stick model
Glucose



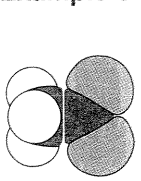
Space filling model
β-D-glucose

Example of Biological Molecules

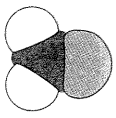
Biological molecules may also include atoms other than carbon, oxygen, and hydrogen atoms. Nitrogen and sulfur are components of molecules such as amino acids and nucleotides. Some molecules contain the C=O (carbonyl) group. If this group is joined to at least one hydrogen atom it forms an aldehyde. If it is located between two carbon atoms, it forms a ketone.



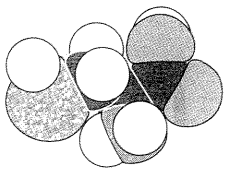
Ketone **Aldehyde** **Carboxyl**



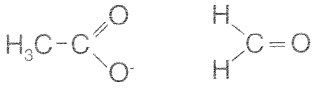
Acetate

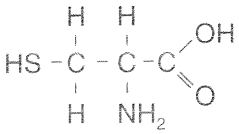


Methanal

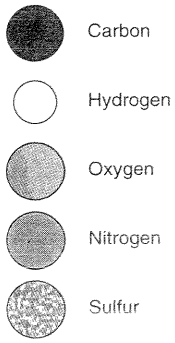


Cysteine





Key to Symbols



1. Which three main elements make up the structure of organic molecules? _____
2. Name two other elements that are also frequently part of organic molecules: _____
3. State how many covalent bonds a carbon atom can form with neighboring atoms: _____
4. Distinguish between molecular and structural formulae for a given molecule: _____

   _____

   _____
5. What is a functional group? _____

   _____
6. Classify methanal according to the position of the C=O group: _____
7. Identify a functional group always present in amino acids: _____
8. Identify the significance of cysteine in its formation of disulfide bonds: _____

   _____

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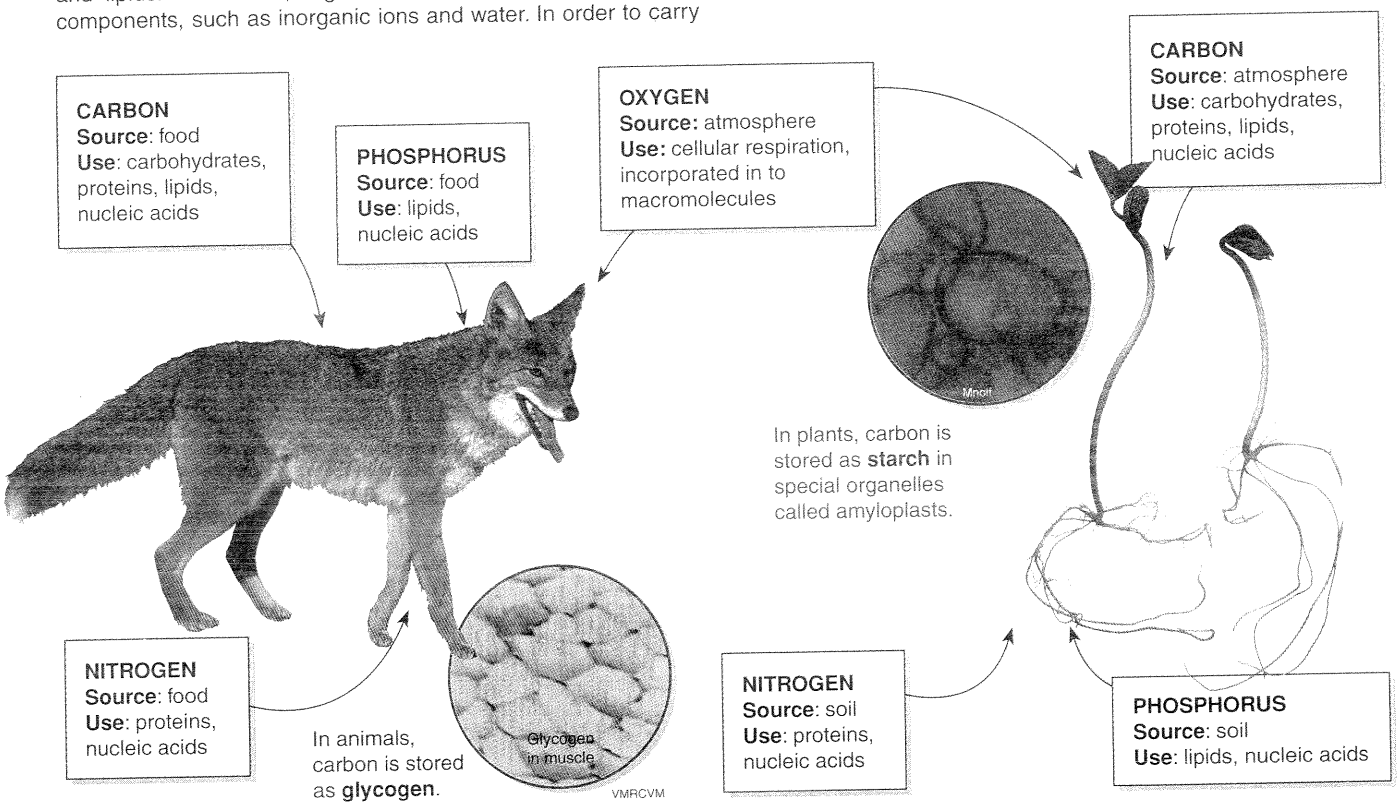
Building an Organism

Living organisms are very complex biological structures, containing many different components. The major components are the four macromolecules: proteins, nucleic acids, carbohydrates, and lipids. In addition, organisms also contain many smaller components, such as inorganic ions and water. In order to carry out life processes, organisms must obtain nutrients from the environment. In animals, this is achieved by the consumption of other organisms. In plants, nutrients are obtained from the soil (via roots) or from the atmosphere.



Inorganic ions are important for the structure and metabolism of all living organisms. An ion is simply an atom (or group of atoms) that has gained or lost one or more electrons. Many of these ions are water soluble.

Some of the inorganic ions required by organisms and examples of their biological roles are described in this table (right). A deficiency in any of these ions can result in specific deficiency disorders.

Ion	Name	Example of Biological Roles
Ca^{2+}	Calcium	Component of bones and teeth, required for muscle contraction
Mg^{2+}	Magnesium	Component of chlorophyll, role in energy metabolism
Fe^{2+}	Iron (II)	Component of hemoglobin and cytochromes
NO_3^-	Nitrate	Component of amino acids
Na^+	Sodium	Component of extracellular fluid and the need for nerve function
K^+	Potassium	Important intracellular ion, needed for heart and nerve function
Cl^-	Chloride	Component of extracellular fluid in multicellular organisms

1. State the main source of carbon, phosphorus, and nitrogen for animals: _____

2. (a) State the main source of carbon for plants: _____

   (b) State the main source of phosphorus and nitrogen for plants: _____

3. List the four main macromolecule components of living organisms: _____

   _____

4. Explain why carbon is so important for building the molecular components of an organism: _____

   _____

   _____