Lectures of Ultrastructure of Cell

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The Cytoplasm

Cytoplasm represents the basic inner environment of the cell, it's the part located outside nucleus filling space between nuclear envelop and plasma membrane, it's composed mainly of water (80-90)%. It also includes a considerable number of ions, inorganic and organic compounds (e.g., fatty acids, amino acids, lipids, carbohydrates, nucleic acids, proteins). It consists of:

1. Cytosol is a semi-liquid mass, which should be in form of liquid or gel (is an aqueous gel called cytoplasmic matrix). The matrix consists of a variety of solutes, including inorganic ions and organic molecules. Cell controls the concentration of solutes within the matrix, which influences the rate of metabolic activity within the cytoplasmic compartment. Cytosol also contains enzymes, O2, CO2, electrolytes, metabolites, and waste products. All diffuse through cytosol either freely or bound, entering or leaving organelles where they are used or produced.

2. Organelles represent little organs which are swimming metabolically active structures (Membranous: nucleus, endoplasmic reticulum, lysosomes, mitochondria, Golgi apparatus, peroxisomes. Non-membranous: ribosomes, centrosome).

3. Cytoskeleton is protein component of cytoplasm which determines the shape and motility of cells (cytoskeleton includes: microtubules, intermediate filaments, microfilaments).

4. Inclusions are minor cytoplasmic structures that are not usually surrounded by a membrane. They consist of such diverse materials as crystals, pigment granules, lipids, glycogen, and other stored waste products (they are chemical substances that differ in nature in different types of cells).

Cytoplasm Functions

1. Is the site of many biochemical reactions that are vital and crucial for maintaining life.
2. It provides a medium for the organelles to remain suspended (prevents grouping of organelles that would impede their function).
3. Cytoskeleton of the cytoplasm provides shape to the cell, and it also facilitates movement.
4. It also aids in the movement of the different cellular elements.

General Characteristics of Cytoplasm:

1. It shows differential staining properties.
2. It is heterogeneous mixture of compounds which gives it colloidal nature.
3. It has a high percentage of water and particles of various shapes and sizes are suspended in it.
4. Chemically, it contains 90% water and 10% include a mixture of organic and inorganic compounds in various proportions.

Inorganic Compounds

1. Water/ constitutes the highest percentage of chemical compounds, as it represents about 90% of the total weight of various cells, with some exceptions, such as bones. Water is a natural solvent for mineral ions and it's indispensable at metabolic processes that take place in a watery environment. It's also essential for the colloidal system of protoplasm, in addition, it contributes to many enzymatic reactions and can arise from metabolic processes. In general, water exists in a cell in two forms:

(a). Free water: the form that moves freely between the components of cell, and it's involved in metabolism, it also acts as a medium for chemical reactions. This form constitutes (85%) of total water in cell.

(b). Bound water: this is attached to the structural molecules of cell by chemical bonds, that is included in the composition of cell components. It is estimated at about (4-5%) of total water in cell.

Water has some unique chemical and physical properties that made it very suitable for vital/biosystems, the most important of which are polarity and formation of a hydrogen bond, in addition to its high specific heat, which made it suitable for most cellular activities.

2. Salts and Ions/ are necessary compounds to maintain the osmotic pressure and acid-base balance of the cell. As the osmotic pressure increases inside the cell with an increase of concentration of ions, which leads to entry of water into the cell.

Ion's concentration varies in the cellular fluid according to their quality/type, e.g., the concentration of potassium and magnesium high inside the cell, while sodium and chloride are found mainly outside the cell. Phosphate is the main source inside the cell, as well as the bicarbonate ion. As for calcium, it is present in both cells and bloodstream.

In bones, calcium binds with phosphate and carbonate ions to form crystalline arrangements, while phosphate is free in blood and tissue fluid, but most phosphate is bound in form of phospholipids, nucleotides, phosphoproteins, and sugar phosphates. Monophosphates and diphosphates have a role in stabilizing the pH of blood and tissue fluids. There are other ions present in tissue such as sulfurs, carbons, bicarbonates, magnesium, and amino acids, as well as minerals that are found in non-ionized forms such as iron in ferritin molecule and cytochromes, a few effects of metals (manganese, copper, cobalt, iodine, selenium, nickel, molybdenum and zinc) are necessary to maintain the activity of cell.

3. Gases/

(a). Oxygen is necessary for oxidation process at cells (cellular respiration) to produce energy and carry out various activities.

(b). Carbon dioxide is one of metabolic products. (its importance appears in plants and algae to its necessary in photosynthesis to convert light energy into chemical energy and build carbohydrates in cells).

Organic Compounds

They are long chains composed of repeating certain units bind to each other by chemical bonds, these structures are called monomers (large molecule composed of repeating monomers is called a polymer), difference in number of monomers that form a macromolecule leads to different molecules possess characteristic features. Cell organic components include carbohydrates, proteins, lipids and nucleic acids.

1. Carbohydrates/ are compounds containing carbon, hydrogen and oxygen. They form the main source of energy for all living beings, in addition to being involved with the formation of some cell contents such as proteins, lipids and nucleic acids. Carbohydrates are polyhydric aldehydes or ketones, of which they contain three carbon atoms that are known as Trioses, and those that contain four, five, six or seven carbon atoms in their chains are called Tetroses, Pentoses, Hexoses, and Heptoses respectively. When carbonic group at the end of chain that means the sugar carries an aldehyde group, so it is called Aldose, but if the carbonic group is in another location at the end of chain, then the sugar carries a ketogenic group, so it is called Ketose.

Carbohydrates can be classified according to their hydrolysis ability and consequences into:

(a). Monosaccharides cannot be hydrolysis into other simpler forms, and they are important for body, e.g., ribose sugar is included in the chemical structure of nucleotides, while hexoses sugar is an important source of energy.

(b). Disaccharides by their hydrolysis result in two monosaccharides of one or two different types, such as:

- lactose hydrolyses into two different monosaccharides, glucose + galactose.
- sucrose hydrolyses into two different monosaccharides, glucose + fructose.
- maltose hydrolyses to one type of monosaccharide, glucose + glucose.

(c). Polysaccharides consist of very long chains from repeating mono-saccharides structure units for one or two different types, they are classified into two types:

- homogeneous: consisting of one type of monosaccharide, such as **starch** which plant stores in seeds and tubers, **glycogen** which is stored in liver and muscles, **cellulose** which forms most of the walls of plant cells.
- heterogeneous: consisting of more than one type of monosaccharides such as glue and hyaluronic acid.

2. Proteins/ the basic component of organisms, as they are involved in composition of protoplasm for all cells. Proteins consist of carbon, oxygen, hydrogen and nitrogen. Some proteins contain also sulfur, phosphor and several other elements such as iron, copper, manganese and iodine. The proportion of these materials varies according to protein sources. Protein molecule consists of one or more peptide chains consisting of amino acids that linked to each other by peptide bonds.

Structural Levels of Protein

Shape of protein molecule is determined by four basic levels according to arrangement and organization of its structural units (amino acids), because any changing in arrangement of amino acid sequence (even one) in a protein molecule leads to a change in biological and functional property of that molecule.

- Primary structure/ is sequence of amino acids within a straight chain of polypeptide constituting protein molecule (it may consist of two or more amino acids). When a defect occurs in this structure of a particular protein, Pathological or Physiological effects may occur e.g., when a defect occur in hemoglobin synthesis, the result is Sickle Cell Anemia, because of replacement glutamic acid with valine, and form sickle-shaped cells which block small blood vessels and stop transport of oxygen (blood supply) to different tissues, usually leads to death at childhood stages.

- Secondary structure/ represents peptide chains (hundreds of amino acids) that form a ring in a helical shape around themselves or around other chains, the most important bonds that stabilize this structure (which show at three different forms) are hydrogen bonds:

* α-helix: it has a single peptide chain that coils on itself along the chain in a helical coil.
* β-sheet: it is a simple structure in which a single peptide chain extends to form sheets.
* y-form: it contains both alpha and beta models, as well as random shapes that are not determined by a particular system.

- Tertiary structure/ does not form long helical chains, but there are curves in chain, caused in most by R side chain of amino acids. In this type, peptide chains form a ring on each other, so there is a spherical and a fibrous shape (in three dimensions) characterized with flexibility. Activity of enzymes depends on this type of structure, which is fixed by several bonds, including electrostatic and hydrogenic.

- Quaternary structure/ determines the level of assembly or polymerization of protein molecule (appears through linked of two chains of polypeptides or more) as many protein molecules consist of small units assembled to form the total part of protein, like phosphorylase enzyme which contains four small identical subunits, its activity is formed only by assembling them together, so if they are separated the enzyme becomes inactive. Bonds that stabilize this type of protein structure are the same as the stabilization of tertiary structure.

Classification of Proteins

1. according to their chemical structure:

(a). simple proteins: composed of only amino acids at hydrolysis, such as albumin, glutamine, globulin, protamine, and histones.

(b). conjugated proteins: composed of amino acids, organic and inorganic compounds during hydrolysis, such as nucleoproteins (chromosomal proteins), glycoproteins and lipoproteins (plasma membrane proteins), chromoproteins (hemocyanin), metalloproteins (hemoglobin).

2. according to their shape (overall dimensions):

(a). vesicular or globular proteins: they are polypeptide chains that are twisted or convoluted, such as: albumin, insulin, and almost all enzymes. They can move and dissolve in aqueous solutions.

(b). fibrous proteins: they are extended polypeptide chains do not dissolve in aqueous solutions, form structural or protective elements for organism, such as keratin and myosin, or they form a group of twisted and helical-curved chains that are held together by cross-links such as hydrogen bonds.

3. according to their function (biological activity):

This classification explains their great importance such as cellular structural proteins (tubulin, actin, collagen, keratin) and dynamic proteins (enzymes, hormones, respiratory proteins, storage proteins, transport proteins, antigens, cytokines, and immunoglobulins). Some proteins may perform both a structural and a dynamic function e.g., actin.

3. Lipids/ consist of high molecular weight fatty acids and other substances such as phosphatides, sterols and carotenoids. It is also known as a group of biological substances that do not dissolve in water but in organic solvents such as alcohol, ether and chloroform.

Lipids represent the second source of energy (carbohydrates the first), heat insulator, involved in formation of cellular membranes and steroid hormones.

Lipid Types

They are classified according to their ester components into:

(a). simple lipids: esters of fatty acids such as glycerin as in fats and oils or monohydroxy alcohols as in waxes. The difference between fats and waxes is only alcohol included in the composition of ester and in quality of fatty acids that are composed of, so simple lipids include fats, oils and waxes.

(b). compound lipids: esters of fatty acids with alcohol and other compounds such as phosphoric acid. This group of lipids is classified according to type of alcohol involved in formation of the ester such as phospholipids and sphingolipids.

(c). derived lipids: include fatty acids, cholesterol, sterols and other alcohols. These lipids are classified as hydrocarbons, sterols and terpenes.

4. Nucleic Acids/ large molecules carry genetic information, classified into two types: Ribonucleic acid (RNA) and Deoxyribonucleic acid (DNA).

Note: details in a separate/independent lecture.