BRIEF CONTENT OF LECTURES ON DISCIPLINE “PLANTS PHYSIOLOGY

Specialty Biology

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LECTURE 8. Physiology of the plant cell**.**

1. Features of plant cells:

2. The structure of biological membranes.

3. Types of transport of substances through the membrane

1. Features of plant cells:

Robert Hooke in 1665, introduced the term "cell" (from the Greek one. «Cytos» - cell "sellula" - cavity) for describing the structure of cork, studied them with an enhanced microscope. In 1839, when M. and T. J. Shleydenom Schwann cell theory was formulated, has been recognized the universality of the cellular structure of living things.

Cell - the basic structural and functional unit of life, limited semipermeable membrane and the ability to replicate. Prokaryotes - cells have issued nucleus Eukaryotes necessarily contain a kernel.

Cell function.

All cells are able to replicate, to the use and transformation of energy, the synthesis of large and complex molecules. The cell is the result of a long evolution and is characterized by internal ordering of the structure.

The plant cell as a cell eukaryotic organism contains a nucleus with one or more nucleoli, mitochondria, Golgi apparatus, endoplasmic reticulum, microbodies, ribosomes and polyribosomes, components cytoskeleton - microtubules and microfilaments.

Features of plant cells:

1. Plastid system, arising from the autotrophic feeding.

2. Polysaccharide cell wall surrounding the cell

3. The central vacuole in mature cells, which plays an important role in maintaining turgor

4. There is no dividing cell centrioles.

The cell has a complex structural organization and is a system, differentiated into separate organelles. The plant cell has a cell wall and protoplast.

Protoplast consists of a nucleus with the nucleolus, cytoplasm, and it includes membrane (vacuole, plastids, mitochondria, Golgi apparatus, lysosomes, endoplasmic reticulum) and nemembranne (microtubules, ribosomes) organelles. All organelles are embedded in a matrix of the cytoplasm - hyaloplasm or main plasma.

Electron microscopic images indicate that the cell or plasma membrane (plasmalemma) and intracellular membranes are the basis of the ultrastructure of eukaryotic cells.

Structure characteristic of plant cells

As noted above, in the cells of higher plants are found all organelles found in animal cells, with the exception of centrioles. They have, however, and its special structure.

Cell walls. Plant cells, like the cells of prokaryotes, fungi, are in a relatively rigid cell wall. The material for the construction of this cell wall secretes itself encased in her living cell (protoplast). The chemical composition of the cell walls of plants are different from the cell walls of prokaryotes and fungi, but these structures characterized by some common features, namely the function of support and protection, in addition, they both limit the mobility of cells. The cell wall is deposited during cell division plant, called the primary cell wall. Later, as a result of enlargement, it could turn into a secondary cell wall. In this section, we describe the process of formation of the primary cell wall.

The structure of the cell wall. The primary cell wall is composed of cellulose microfibrils embedded in a matrix, and which consists of complex polysaccharides cellulose, too, is a polysaccharide. Especially important for the role that performs cellulose in the cell walls have its fibrous structure and high strength one

tear, comparable with the strength of steel. Individual cellulose molecules - is a long polysaccharide chain. The set of such molecules cross-linked to one another by transverse hydrogen bonds are collected in the strong beams, called microfibrils. Immersed into the matrix microfibrils form the framework of the cell wall.

Matrix of the cell wall is composed of polysaccharides, which for convenience of description are usually divided into pectin and hemicellulose, depending on their solubility in various solvents were used for extraction. Pectin or pectin, extraction usually identified first, because their solubility is higher. This is a mixed group of acidic polysaccharides (built from monosaccharides arabinose and galactose, galacturonic acid, belongs to the class of sugar acids, and methanol). Long molecules of pectin can be linear or branched. The median plate fastening walls of neighboring cells, is composed of sticky jelly pectate magnesium and calcium. In the cell walls of some ripening fruit insoluble pectin converted again into soluble pectin. When you add sugar this last form gels, so they are used as gelling agents.

Hemicellulose: - a mixed group of polysaccharides, soluble in alkalis (which include polymers of xylose, galactose, mannose, glucose and glyukomannose). In hemicelluloses, like cellulose molecules are shaped chain, but their chains shorter, less ordered and more branched.

Cell walls hydrated: 60-70% of their mass is usually water. On the free space of the cell wall of water moves freely. The presence of water has an effect on the chemical and physical properties of the cell wall polysaccharides.

Materials with high mechanical strength, like the cell wall material, ie, consisting of more than one component, called composites or composites, their strength is usually higher than that of each of the components separately. System of fibers and the matrix (in the basis of the composite material technology is not called matrix and matrix) are widely used in the art, so that the study of their properties, both in technique and in biology spent a lot of effort. Matrix, compression, stress fibers transmit working on stretching. It also provides abrasion resistance and, apparently, resistance to adverse chemical effects, possible in certain circumstances. In the building industry has long been used reinforced concrete, that is, a combination of concrete with steel reinforcement. Later a lighter compositions material in which the role of the matrix is plastic, and the role of reinforcement-glass or carbon fiber. Wood is a composite material, it owes its strength cell wall. An example of hard composite materials of biological origin can also serve as bone, cartilage and covers the exoskeleton of arthropods cuticle. There are flexible composite materials, such as connective tissue.

In some cells, such as a leaf mesophyll cells, throughout their lives have only primary cell wall. However, most of the cells on the inner surface of the primary cell wall (outward from the plasma membrane) deposited additional layers of cellulose, ie, a secondary cell wall. This usually happens when the cell reaches its maximum size, and only a few cells, such as cells kollenhimy continue to rise during this phase. Secondary thickening of the cell walls of plants are not to be confused with secondary thickening (secondary growth) of the plant, that is, with the thickness of the barrel by the addition of new cells.

In any secondary thickening layer cellulose fibers are under the same angle, but in different layers of the angle is different, and this provides even greater strength of the structure. Some cells, such as tracheal elements of the xylem and sclerenchyma cells undergo intensive lignification (lignification), with all the layers of cellulose (the primary and three secondary) impregnated with lignin - a complex polymeric substance not to polysaccharides. In cells protoksilemy deposition of lignin have 2 circular, spiral or mesh form. In other cases, lignification is solid, except for the so-called pore fields, ie, the areas in the primary cell wall through which the contact between adjacent cells through plasmodesmata group.

Lignin binds the cellulose fibers and holds them in place. It acts as a very hard and stiff matrix, reinforcing the strength of the cell walls of the tensile and compressive features (to prevent deflections). ***Lignin*** also provides additional protection to the cells from the adverse physical and chemical effects. Along with cellulose, which remains in the cell walls, lignin gives wood those special properties that make it an indispensable building material.

Functions of the cell wall

1. Cell walls provide the individual cells and plants in general mechanical strength and support. In some tissues strength is enhanced by the intense lignification of cell walls (a small amount of

lignin present in all cell walls).

2. The relative rigidity of the cell walls and tensile strength are responsible turgid cells when they come through the osmotic water. This strengthens the support function in all plants and is the only source of support for herbaceous plants and organs such as leaves, that is, where there is no secondary growth. Cell walls also protect cells from rupture in hypotonic medium.

3. The orientation of the cellulose microfibrils limits to some extent regulates the growth and shape of cells, because of the location depends on the ability of these cells mikrofirill to stretch, if, for example, are located across the microfibril cells, the cell, which receives water by osmosis, will be stretched in the longitudinal direction

4. The system of interconnected cell walls (apoplast) is the main way by which move water and minerals. Cell walls are fastened to each other by the median fins. The walls have small pores, through which pass the cytoplasmic strands, called plasmodesmata. Plasmodesmata connect the living contents of individual cells - combine all the protoplasts in a single system, a so-called symplast,

5. Outer cell walls of the epidermal cells are covered by a special film - cuticle, a waxy substance consisting of cutin, which reduces water loss and reduces the risk of penetration into the plant pathogens. In the cell walls of cork tissue at the end of secondary growth impregnated suberin, perform similar functions,

6. The cell walls of the xylem vessels, tracheids and sieve tubes (with sieve plates) are adapted for long-distance transport of substances through the plant.

7. Endodermal cell walls are impregnated with suberin root and therefore act as a barrier to the movement of water

8. Some cells of the modified wall store food reserves, in this way, for example, stocking hemicellulose in some seeds.

9. In cell transfer surface area of the cell walls is increased and accordingly increased the surface area of the plasma membrane, which increases the efficiency of the transfer of substances by active transport (section 14,8,6).

Plasmodesmata - are live links connecting adjacent plant cells through very small pores in the adjacent cell walls. Plasmodesmata sometimes arranged in groups, and such areas of the cell wall are called "primary pore field". The pores in one sieve plates of phloem sieve tubes 1 have roots plasmodesmata.

The cell wall. Plant cells are surrounded by a thick polysaccharide shell, lined inside plasma membrane. Cell wall is formed at telophase during mitotic cell division. Cell wall of dividing and growing tension cells called primary. After the cessation of cell growth in primary cell wall inside the new deposited layers and there is a strong secondary cell wall.

In the cell wall consists of structural components (cellulose in plants, in fungi hitiii), the components of the matrix walls (hemicellulose, pectin, proteins) inkrustiruyuidie components (lignin, suberin) and substances, to postpone "a wall surface (cutin and toe). Cell walls may also contain silicates and calcium carbonates.

Cellulose (a polymer of glucose-I-), gemiellozy (polymers of hexoses and pentoses) and pectin (uronic acid derivatives) are the carbohydrate components of the cell walls. Cellulose and pectin is adsorbed water, providing water content of the cell wall. Pectin, containing many carboxyl groups bind divalent metal ions that can be exchanged for other cations (H, K, etc.). This makes the cation exchange capacity of plant cell walls. In addition to the carbohydrate components of the matrix of the cell wall is also a structural protein called extensin. This glycoprotein, containing more than 20% I.-hydroxyproline of the amount of amino acids. According to this feature of the cell walls of plant protein is similar to the extra-cellular animal protein - collagen. The main substance encrusted cell wall is lignin. Intensive lignification of cell walls begins after cessation of cell growth. Lignin is a polymer i straight molecules consisting of aromatic alcohols (p-coumaric, coniferyl, sinapovogo). Destruction and condensation of lignin in the soil is one of the factors of the formation of humus.

In the regulation of water and heat regimes of plants involved tissue, cell walls are impregnated with suberin. The deposition of suberin makes hard wall permeable to water and solutions (eg, endoderm, periderm). The surface of the epidermal cells of plants protected by hydrophobic substances - cutin and waxes Predecessors of these compounds secreted from the cytoplasm to the surface, where it is to cure. Cutin layer usually laced wall polysaccharide components (cellulose, pectin) and forms the cuticle. Cuticle is involved in the regulation of the water regime of tissues and protects the cells from damage and infection control.

In the primary cell walls of cellulose has a share of up to 30% of the dry weight of the wall. Amount of hemicelluloses and pectins varies depending on the subject, together with proteins pectin may be about 30% of the dry weight of the cells, the protein reaches 5-10%. About 40% are accounted for hemicellulose.

Discussed how interconnected components in the cell wall?

Cellulose molecules interact with each other by hydrogen bonds and arranged in microfibrils Hydrogen bonds also exist between microfibrils of cellulose and hemicellulose, most of the remaining bonds in the cell wall covalent, between hemicellulose and pectin, between pectins and extensin, between lignin and cellulose, and lignin zkstensinom. In pectin polymers having carboxyl groups play an important role ionic bonds with mainly calcium. These interactions provide the strength of the structure of the cell wall elasticity and plasticity.

Neighboring cells by contact with each other there is a unified system of the cell walls, called the apoplast. Apoplast by bypassing the membrane barriers, from one cell to move substances. Intermolecular space in the phase of the cell wall, where the diffusion, absorption and release of water-soluble substances, is called the apparent free space

Plant cell walls are penetrated holes - pores with a diameter of 1 mm. Strands pass through them - plasmodesmata, which are carried out by cell-cell contacts. Each plasmodesmata is a channel lined with plasma membrane, continuously passing from cell to cell. The central part of the pores is desmo tube consisting of helically arranged protein subedinnts. Desmo tube communication with the ER membranes of adjacent cells. Desmo tube around a layer of cytoplasm, the endoplasmic reticulum, which may be connected with the cytoplasm of adjacent cells. Thus, communication between cells can be carried out through the cytoplasm, plasma membrane, ER, and cell walls. Unified system cytoplasm of tissues and organs is called the symplast.

A product of the metabolic activity of the protoplast, cell wall acts as a content protection cells from damage and excessive loss of water, supports a form (by turgor) and size cells, is an important component of the ion exchange cells (ion exchanger) and a place of transport of substances from cell to cell by extracellular (apoplastic transport). Biogenesis of the cell wall plays an important role in the growth and differentiation of cells.

Vacuolar system. Vacuole - a typical plant cell organelle. In meristematic cells, vacuoles are small bubbles, for mature cells characterized by a large central vacuole. Vacuolar system of plants is formed in several ways. From extended ER tanks formed provacuoles, merger which leads to larger vacuoles and vacuolar membrane creation - the tonoplast, which thus derives ER. Tonoplast invagination can form, leading to inclusion in the vacuole areas of cytoplasm. Hydrolytic enzymes in vacuoles occurred, split polymers to low molecular weight substances. An important role in the phenomenon of autophagy vacuoles play. The process begins with the ER membrane surrounding area of the cytoplasm (autophagic vacuole). The activity of acid hydrolases in the closed space of the membrane leads to the degradation of the polymer content and flow of water. Vacuoles resulting autophagy may merge with vacuoles formed in other ways.

Vacuolar sap has a complex composition and contains organic material and mineral salts. In addition to organic acids, carbohydrates, amino acids and proteins, which can be recycled in metabolism, cell sap contains phenols, tannins, alkaloids, anthocyanins, which are derived from the metabolism in the cell vacuole and thus isolated from the cytoplasm. Most enzymes vacuoles has a maximum activity at acidic pH, which allows us to consider the vacuole of plant cells as secondary lysosomes. Vacuolar acidity plow 5.0 - 6.5 pH units, but may be of 1.0

(Begonia) or 2.0 (lemon).

The substances are delivered to the vacuole by a variety of transport systems operating in the tonoplast. These include ATP-dependent H-pump, carrying H + ions from the cytoplasm to the vacuole (see Fig. 1.3). Her work provides entry into the vacuole of the anions of organic acids, sugars, as well as the entry and exit of ions K transporters localized in the tonoplast, cause accumulation in vacuoles of amino acids and other compounds. It is important to note that the vacuole can serve as a storage protein deposits (aleurone grains). Vacuolization process - a necessary condition for the growth of cells stretching.

Vacuoles. Vacuole is a fluid-filled membrane bag, the wall of which consists of a single membrane. In animal cells are relatively small vacuoles: phagocytosable, pishevaritelnye, avtofagicheskie and contractile. A different picture is found in plant cells, especially in the mature parenchyma and collenchymaю Here, the cells have a large central vacuole. Its surrounding membrane, which is called the tonoplast (Figure 7.4). The fluid that fills the central vacuole is called cell sap, a concentrated solution containing mineral salts, sugars, organic acids, oxygen, carbon dioxide, pigments and some wastes or "secondary" products of metabolism.

The functions performed by vacuoles.

1. Water usually enters the concentrated cell sap by osmosis through selectively permeable tonoplast. As a result, the cell turgor pressure develops and cytoplasm pressed against the cell wall. Osmotic absorption of water plays an important role in cell elongation during their growth, and in general the water regime of the plant.

2. Sometimes in the vacuole are present in solution pigments called anthocyanins. This group includes the anthocyanins, which have red, blue or purple color, and some related compounds, painted in yellow or cream color. It is these pigments mainly determine the color of flowers (eg, roses, violets and dahlias), and the color of the fruit, buds and leaves. The leaves, they are responsible for various shades of autumn color, which, as you know, is also dependent on photosynthetic pigments contained in chloroplasts. Coloration plays a role in attracting insects, birds and other animals involved in pollination and seed dispersal.

3. The plants in the vacuoles are sometimes hydrolytic enzymes, and then the life of the cell vacuoles at act as lysosomes. After the death of the cell tonoplast, like other membrane loses its selective permeability, and the enzymes are released from the vesicles, causing autolysis.

4. Vacuoles in plants can accumulate wastes and some secondary products of its metabolism. Of waste are sometimes found, for example, calcium oxalate crystals. The role of secondary products is not always clear. This applies, in particular, alkaloids, which can be stored in the vacuoles. It is possible that they, like their astringent tannins taste repel herbivores, ie, serve a

protective function. Tannins particularly common in cell vacuoles (as, indeed, in the cytoplasm and in the cell walls), leaves, bark, wood, immature fruit and seed shells. Can accumulate in vacuoles and latex (milky sap), usually in the form of milky emulsion, such as for example dandelion sap. Some cells (called milky cells) are specialized in the allocation of latex. In the milky sap of the Brazilian rubber tree contains enzymes and compounds required for the synthesis of rubber, and in the milk juice of poppy sleeping pills - alkaloids.

5. Some of the components of the cell sap serve as food reserves, if necessary, use the cytoplasm. Among them in the first place should be called sucrose, minerals and inulin.

Plastids. This organelle, a typical plant cells only, in higher plants they are derived from proplastids - small cells found in the meristematic regions of the plant. Plastids are surrounded by a double membrane (shell) from proplastids, depending on their location in the plant - can form different types of plastids. There are different classifications of plastids. Here we present one of the simplest.

Chloroplasts. This plastid containing chlorophyll and carotenoids and carry out photosynthesis. Chromoplasts. Nonphotosynthetic colored plastids containing mostly red, orange and yellow pigments (carotenoids). Most chromoplasts in fruits (eg, tomato and red pepper), and in the flowers, where their bright coloration serves to attract insects, birds and other animals, which is performed by means of pollination and seed dispersal. Orange pigment, which determines the color of carrot root, is also in chromoplasts.

Leucoplasts. This colorless plastids that do not contain pigments. They are suitable for storage of nutrients, and therefore they are especially numerous in storage organs - roots, seeds, and young leaves. Depending on the nature of accumulating substances leucoplasts divided into groups in the amyloplasts, for example, store starch (Fig. 15.16), in lipidoplastah (elayoplastah or oleoplastah) - lipids in the form of oils or fats (for example - the fruits of a nut gray (] iuIapz sipeRea) or sunflower seeds), and the characteristic of some seeds in proteinoplastah - proteins.

Mitochondria. In the mitochondria function of aerobic respiration and oxidative phosphorylation, providing the energy needs of the cells. In the inner membrane of the mitochondria electron transport chain components are localized and ATP synthetase complexes, transports electrons and protons and conjugate 6
ATP synthesis with it. In the matrix are enzymatic oxidation of di-and tricarboxylic acids, and a number of systems of synthesis of lipids, amino acids, etc.

Peroxisomes and glyoxysomes. In plants, there are round organelles diameter of 0.2 - 1.5 mm, limited unit membrane and containing a granular matrix of moderate electron density. They are called microbodies. In some microbodies found crystalloid protein consisting of tubes with a diameter of about 6 nm. Number of microbodies in cells close to the number of mitochondria. In plant cells revealed two types of microbodies performing different physiological functions: peroxisomes and glyoxysomes.

Numerous peroxisomes in the cells of the leaves, where they are closely associated with chloroplasts. They oxidized synthesized in chloroplasts during photosynthesis glycolic acid and amino acid glycine is formed, which is in the mitochondria becomes serine. In the leaves of higher plants, peroxisomes are involved in photorespiration (ig. 3.16).

Glyoxysomes appear during the germination of seeds, which are reserved fat, and contain the enzymes necessary for the conversion of fatty acids in the sugar: the system of fatty acid oxidation and the glyoxylate cycle (see Fig. 4.11). When working enzyme systems and peroxisome glioksisom formed hydrogen peroxide, which breaks contained in these organelles catalase.

Spherosomy. It is spherical, highly refractile education diameter of 0.5 microns. They contain lipids and therefore they are also called lipid droplets (oleosomami). In sferosomah discovered enzymes such as lipase and esterase. They carry a stock of lipid cells. When germinating seeds, store fat, sferosomy operate in conjunction with glioksisomami in the process of gluconeogenesis. Intercellular interactions in plants through plasmodesmata.

2. Cell membranes.

Plasmalemma function common to the plasma membrane.

1. Control the absorption and secretion of substances. In the plasma membrane are many transport systems, primarily for the transport of ions - ion channels, ion transporters and ion pumps. Thanks to them, is very accurate and active transport of ions into the cell as well as outside, ie optimal supply of cells necessary ions. Through the plasmalemma is also transport of macromolecules. Thus, in the plasma space transported the building blocks of the cell wall - polysaccharides and structural proteins. These compounds are usually the Golgi vesicles and released by exocytosis of them.

2. And storage of energy. Plasma membrane of any cell membrane is energized, ie in it there is a gradient of electrochemical potential is used to perform useful work, especially for the active transport of substances across the membrane.

H. Accommodation and support for the enzymes. In the plasma membrane is full of enzymes. This construction of the cell wall enzymes (tsellyulozosintaza), enzymes signaling systems (phospholipase C, A and adenylate cyclase) and a number of other enzymes (eg, cytochrome, perhaps - desaturase).

4. Receptor function. Many proteins are receptors plasmalemma different signals. We can say that plasmalemma cells - a mosaic of different receptors endogenous signals (primarily plant

hormones) and external influences. The latter include elicitors receptors (substances released by pathogens) and receptors of physical factors - temperature, pressure, etc. High stiffness changes (fluidity) of the membrane, ie, its mechanical properties. Changing these properties of plasma membrane leads to the opening or closing an mehanosensornyh its ion channels. Thus, the plasmalemma is a place of reception (perception) of different patterns of chemical and physical nature.

5. Alarm function. Many components of the plasma membrane after acceptance signals are a source of second messengers - molecules that are "broadcast" the signal to the relay and amplify it. As an act of second messenger’s inositol-1 ,4,5-triphosphate, diacylglycerol, phosphatidic acid, peroxidation of membrane lipids. These compounds are formed from plasma membrane lipids by the action of specific enzymes to be activated by the impact of signal receptors. Thus, the plasma membrane is the site of not only the reception of signals, but also to strengthen them and differentiation.

Early work in membrane permeability shown that organic solvents such as alcohol, ether or chloroform to penetrate the membrane faster than water. This indicated that the membranes have some non-polar part, in other words, that the membranes contain lipids.

The structure of biological membranes.

Currently, the greatest recognition uses a liquid-mosaic hypothesis of the structure of biological membranes. This hypothesis is based on membrane phospholipid bilayer with a number of other lipids (galactolipids sterols, fatty acids, etc.), and lipids are turned to each other with their hydrophobic ends. Unsaturated fatty acids of the polar lipids provide several garnetted (liquid) state of the bilayer at physiological temperatures. The same help and sterols. Biological membrane lipid composition is built asymmetrically, since two of their sides - external and internal - are addressed in a qualitatively different hydrophilic environment. The outer layer of the plasma membrane contains more sterols and glycolipids.

***Lipids in membranes are phospholipids, glycolipids and sterols*.**

In phospholipids (compounds containing phosphate group) of the molecule consists of a polar head and two nonpolar tails.

Glycolipids are the product of lipid-carbohydrate compounds. Like phospholipids, they consist of the polar heads and nonpolar tails.

If the surface water is distributed thin as any polar lipids, such as phospholipids, their molecules are oriented in such a way as to form a monomolecular layer, or monolayer.

Nonpolar molecules hydrophobic tails sticking out of the water at the same time, and the polar hydrophilic heads are on the surface.

If the number exceeds the number of lipids needed to cover the surface of the water, or if the mixture of lipids with water, shake it formed particles called mitsellamya: they are hidden inside the hydrophobic tails and thus protected from contact with water (Fig.).

In Fig. shows the micelle, which has a double layer of lipid molecules, the so-called lipid bilayer. Such lipid bilayers have many properties that are characteristic for membranes that are in living cells. Dawson and Danielli Davson, Danielli) in 1935 suggested that the cell membrane has a lipid bilayer, placed between two layers of protein. These authors proposed a model of the membrane is shown in Fig.

The plasma membrane of both animal and plant cell looks exactly like a three-layer structure.

In 1959, Robertson, bringing together the available data at the time, a hypothesis about the structure of the "elementary membranes," in which he postulated a structure that is common to all biological membranes:

a) All the membranes have a thickness of about 6-10 nm.

b) in the electron microscope they appear three-layer;

c) three-layer membrane form is the result of the relative position of the polar lipids and proteins, which provides a model Davson and Danielli - central lipid bilayer is between two layers of protein.

In 1972, Singer and Nicolson (Singer, Nicolson) proposed liquid-mosaic membrane model, according to which protein molecules floating in the liquid lipid bilayer to form it as a kind of mosaic. In this model, the lipid bilayer is still regarded as an elementary membrane, but here it is presented as a dynamic structure, proteins float in the lipid sea "like islands, sometimes free, sometimes as if on a leash - they keep microfilaments, penetrating into the cytoplasm. Lipids can also be moved by changing its position.

Proteins. Some membrane proteins are only partially embedded in the membrane, while others cut across its entire thickness. Usually proteins are hydrophobic regions that interact with lipids, and hydrophilic regions located on the surface of the membrane in contact with the water content of the cell. In cell membranes found thousands of different proteins.

1. Structural proteins. Proteins that perform along with structural as any other additional functions.

2. Proteins control.

3. In the composition of membranes contain proteins that act as enzymes, pumps, transporters, ion channels, as well (Figure 1.2). Carriers are transported across the membrane or another substance. Such vectors may include a component part of any active pumping mechanism. It is assumed that the protein molecules or between adjacent protein molecules are hydrophilic channels or pores. These pores penetrate the membrane, so that it can pass through the membrane of polar molecules, which, without such pores would not be able to go - a lipid component of the membrane would not let them in the cage.

4. Enzyme proteins, specific receptors that mediate electron energy converters involved in photosynthesis and respiration, etc.

5. Glycoproteins. They are on free surfaces glycosyl groups - branched oligosaccharide chains resembling antennae. These "antenna" consisting of several monosaccharides are the most diverse (though strictly defined) conformation, which is explained by a variety of links between the monosaccharide and the existence of -and .-isomers (see Sec. 5). The "antenna" is associated with the recognition of external signals, which is important for the cells for many reasons. Recognizing areas of two neighboring cells may, for example, to communicate with each other, providing adhesion of cells. Due to this the cells are correctly oriented and form a fabric in the process of differentiation. With the recognition and related activities of the various regulatory systems, as well as the immune response, in which glycoproteins act as antigens.

Recognizing areas are available and some of the molecules present in the solution, so they selectively absorbed by cells with complementary recognizes sites. Joining carbohydrate residues to proteins (glycosylation of proteins) proteins that gives the ability to recognize and are in the Golgi apparatus. Sugar, thus, can function as an information molecule, that is, in this sense, they can be compared with proteins and nucleic acids.

8. In liquid layers of lipid membranes are specialized protein complexes. Lipoproteins are immersed in the lipid phase and hydrophobic bonds held (integral proteins). Hydrophilic proteins (peripheral) are held on the inner and outer membranes by electrostatic bonds, interacting with the hydrophilic heads of the polar lipids. Major role in the formation of membranes play a hydrophobic bonds: lipid - lipid, lipid - protein, protein - protein.

Integral protein globules are in phospholipid membranes oriented layers. This orientation is determined by the characteristics of the hydrophobic surface of each protein, and the localization properties of its hydrophilic regions. Certain parts of lipoprotein globules (recognition sites) are for self-assembly polienzimnyh membrane complexes. The position of the proteins in the membrane affect the composition of phospholipids, strongly associated with the globules, the state of "free" phospholipid bilayer, as well as the magnitude of the electrostatic charge of the membrane.

9 Functional activities of the membrane and change membrane potential, followed by immersion or emersion subunits, their lateral movement. It is assumed that such a shift in the membrane proteins may be limited by their association with microfilaments and microtubules.

Lipids. Membrane lipid composition varies, and it affects their properties such as permeability and liquid, usually membrane lipids of their consistency similar to olive oil. In unsaturated lipids in the hydrocarbon tails of the molecules have so-called "kinks". These "kinks" interfere too dense packing of the molecules and make the membrane structure looser, more "liquid." As the length of the hydrocarbon tails of the lipid molecules, the membrane also becomes 6olee liquid. From the liquid state dependent activity of membranes and, in particular, the ease of merging separate membranes with each other, and the activity of membrane-bound enzymes and transport proteins.

Lipids that make up the membrane bilayer is not rigidly fixed, but continuously change places.

Movement of lipid molecules are of two types:

1) Within a monolayer (lateral diffusion). When lateral diffusion of lipid molecules undergo millions of permutations in the second, and the rate of about 5-10 m / s

2) by permutation of two lipid molecules, opposing the two monolayers ("flip-flop"). Permutations of lipid molecules from one monolayer to the other occur much less frequently, but can be accelerated by membrane proteins.

Glycolipids, glycoproteins like, contribute to the formation of recognizing sites.

General characteristics of the cell membrane

The following summarizes the known data on the structure of biological membranes.

1. Different types of membranes vary in thickness, but in most cases, the membrane thickness is 5-10 them, for example, the thickness of the plasma membrane is 7.5 nm.

2. Membrane - is the structure of lipoprotein (lipid + protein). Some of the lipid and protein molecules are attached to the outside of the carbohydrate components (glycosyl groups). Usually on the carbohydrate fraction in the membrane have from 2 to 10%.

3. Lipids spontaneously form a bilayer, this is because their molecules have polar heads and nonpolar tails. Membrane proteins have different functions.

5. Glycosyl groups linked to the mechanism of recognition.

6. The two sides of the membrane may differ from one another in composition, and properties.

7. Membrane lipids and proteins diffuse rapidly in the lateral direction (in the plane of the membrane), unless they somehow are not fixed or limited in their movements.

2.2. Transport across the plasma membrane

The primary purpose of the cell membrane was the separation of the internal environment from the external. Then, in the course of evolution arose a number of specialized intracellular compartments (compartments), which allowed the cell and hold organelles in small volumes necessary enzymes and metabolites, creating a heterogeneous physical and chemical microenvironment performed on different sides of the membrane different, sometimes opposing biochemical reactions. But with the rise of phospholipid membrane barriers were to occur and the mechanisms of transmembrane ion transport of substrates, metabolites, which in the course of evolution has become increasingly complex.

Although the thickness of the membrane is less than typically 5-10 nm, they serve as a barrier to ions and molecules, especially for polar molecules, such as glucose or amino acids, as the non-polar lipids in the membranes of these substances repel. Importance of transport of substances through the membrane:

1. Ensure the maintenance of the cell corresponding to the proper pH and ion concentration needed for the effective operation of cellular enzymes;

2. Delivery of nutrients, which are a source of energy, as well as the "raw material" for the formation of cellular components;

3. Removal from the cell of toxic waste

4. Secretion of various nutrients

5. Creation of ion gradients required for different processes.

There are four main mechanisms for entry of substances into the cell or out of their cells out:

1. Diffusion
2. Osmosis
3. Active transport.
4. Exo-and endocytosis.

The first two processes are passive, ie not require energy, the last two - the active processes related to energy consumption.

Labile structure of membranes allows them to different functions: barrier, transport, osmotic, electrical, structural, energy, biosynthetic, secretory, digestive, receptor-regulators and others. Multifaceted role of osmotic work performed biomembranes. For example, cells of freshwater protozoa and some algae (euglenophytes, volvoksovye), not to be broken, must constantly resist passive osmotic flow of water into the cell by removing excess water contractile vacuoles. For all other plants osmotic flow of water does not lead to the rupture of cells, as hydrostatic (turgor) pressure opposes counter elastically stretched cell walls. Moreover, the intense pressure of water is an important factor for plant. Turgor can keep fit neodrevesnevshim parts and is the force that ensures the growth of plant cell elongation. Finally, adjusting the concentration of osmotically active substances, plant cells absorb water from the environment, even if the water content in the environment is low.

Osmosis - the diffusion of water through a semipermeable membrane

In living cells distinguish passive (chemical and electrical gradients) and active (against the electrochemical gradient with the expenditure of metabolic energy) transport.

Passive transport is carried out:

a) through the phospholipid phase, if the substance is soluble in lipids,

b) at intervals between lipids, if gaps appear

c) by lipoprotein carriers,

d) on specialized channels caused by lipoprotein complexes (sodium, potassium and other channels). Sugars, amino acids and other substrates can be transported by special carriers in simporte (ie, working together and in the same direction) with the ions H (bacteria, fungi, and plants) or Na (in animals), and the main driving force in this If the gradient of ions and not the substrate.

Gases, such as oxygen consumed by cells during respiration, and the resulting CO_2 during respiration, in solution rapidly diffuse through the membrane, moving the diffusion gradient, ie, from a region of high concentration to areas of low concentration.

Ion and small polar molecules such as glucose, amino acids, fatty acids and glycerol, usually diffuse through the membrane slowly. Much more quickly pass through the membrane and the uncharged soluble (lipophilic) molecules.

A modification of this mechanism is the so-called facilitated diffusion, in which the substance helps to pass through the membrane any particular molecule. In this molecule may be a special channel that transmits substances only one particular type.

Channels - are transmembrane proteins that act as pores. Sometimes referred to as selective filters. Transport through the channels, usually passive. Specificity is determined by properties of the transported substances surface pores. Usually through the channels move ions. Transport rate depends on their size and charge. If it's time to open, the substances pass quickly. However, the channels are open always. There is a mechanism "Gates", which under the influence of an external signal to open or close the channel. For a long time seemed difficult to explain the high permeability of the membrane (10 mm / s) for water - the substance of the polar and insoluble in lipids. Today opened integral membrane protein of the channel through the membrane for water penetration - *aquaporins*. *Aquaporins ability* to transport water is regulated phosphorylation. It was shown that the addition of phosphate groups and return to certain amino acids aquaporins accelerates or inhibits the penetration of water, but do not affect the direction of transport.

Carriers - are specific proteins that bind to the substance being transported. In the structure of these proteins are the group in some way oriented to the outside or the inside. As a result, changes in the conformation of protein material is transferred in or out. As for the transport of each individual molecule or non-carrier must change the configuration, the rate of transport of matter is several times smaller than the transfer takes place through the channels. Shows the presence of transport proteins in the plasma membrane, not only, but also in the tonoplast.

Transport by carriers may be active or passive. In the latter case, such a transport is in the direction of the electrochemical potential and does not require energy. This type of transport is called facilitated diffusion. Thanks transporters it comes with a higher rate than ordinary diffusion.

Active transport - is coupled to energy transfer of molecules or ions through the membrane against a concentration gradient. Energy is required because the substance has to move against their natural tendency to diffuse in the opposite direction. The movement is usually one-way, while the diffusion is reversible. To the direction of diffusion of the ions is determined by two factors: one of these factors concentration, and the other - an electric charge. Ions are usually diffuse from areas of high concentration of them in the area of low concentration. In addition, they are usually attracted to the area of opposite charge and repel each area of the same charge. Thus, we say that they are moving on the electrochemical gradients, which combines the effect of electrical and concentration gradients.

The active ion transport - it is their movement against the *electrochemical gradient*. It is shown that in cells between the two sides of plasma membrane potential difference is maintained, in other words, electric charge, and that in almost all cells of the inner contents of the studied cells are negatively charged in relation to the environment. Therefore, cations (positively charged ions) generally tend to the cell, while the anions are repelled by the cell. However, their relative concentrations inside and outside the cells also play a role, and that is dependent on the concentration of the direction in which in fact diffuse nones.

In the extracellular and intracellular fluids of ions ions prevail sodium (Na^+), potassium ions (K) and chloride ions (Cl^-), the concentration of potassium in much higher than outside. Another characteristic feature is that the intracellular concentration of potassium than sodium concentration.

It was found that most of the cells in the plasma membrane sodium pump operates actively pumps out the sodium from the cell. Usually, though not always, the sodium pump is associated with potassium pump, absorbs potassium ions from the environment and transporting them in a cage. This combined pump called the sodium-potassium pump (Na^+, K^+-pump).

Transport of ions against an electrochemical gradient, ie, active transport, transport ATPases by using ATP energy. Known K, Na-ATPase, H-ATPase, Ca2-ATPase, anionic ATPase. Active transport of H can be maintained at the expense of the energy of ATP and NADH, or other oxidizing compounds plots redox chain. Trum of H^+ transfer across biological membranes using ATR 1 or NAD (P) H is called proton pump (H + or H-pump-pump). N-pump is just as important for the life of the plant cells, as well as Na-pump in animals. She is involved in such important processes as the regulation of intracellular pH, creating the membrane potential, and storage of energy transformation, and long-range transport membrane materials, the absorption of mineral salts, roots, growth and physical activity, etc. When activated H-pump membrane electrochemical potential of H^+ (..N) increases and this increase includes an increase in its electric (..N) and chemical (pH) components:

..N + .rN

Both components can be used to move materials. The electric potential energy is the basis for the absorption of cations (K, Mn^2, Ca^2, etc.), and proton - to enter the cage anions, sugars, amino acids and ions simporte H, as well as osmoregulation.

Pump **-** a special protein, localized in the membrane in such a way that it runs through its thickness. On the inner side of the membrane to sodium and he receives ATP, and the outside - potassium. Transfer of sodium and potassium across the membrane is made, is believed to be a result of conformational changes undergone by this protein. Released during the decay of the energy is used to change the configuration of most ATPase, thereby portion of the enzyme binds sodium tums and is on the other side of the membrane. Externally to the side of the membrane ion exchange reaction occurs at K Na and reverse rotation of the enzyme complex. Return to the starting position of the enzyme is accompanied by the release of potassium ions and inorganic phosphate. In this case, carries and uses ATP hydrolysis releases energy for ion transport, being just a carrier. Therefore, this type of transport is called primary active.

Primary active transport linked to ATP hydrolysis or oxidation reduction reactions in the electron transport chain of chloroplasts and mitochondria.

An example of the latter is the direct use of energy is breathing on ion transport against the gradient end-tion without prior accumulation of ATP. The mechanism of this phenomenon is that in the rez of respiration on one side of the membrane (the outer hydrogen ions accumulate, with the inside of the membrane becomes negatively charged. Cations come in, attracted to the negatively charged inner side of the membrane.

There is another mechanism of active transport in-the cat. t-called secondary-active. While vectors are special proteins, and the energy of ATP, the released with help of ATPase is spent on ih movement in the membrane. Thanks to H-ATPase is the proton yield of the cell and the membrane difference arises e / chem. potentials (..N^+). It is used to transport other ions (in-in) with the participation of carriers. Since the primary active transport of H + against a gradient E / chem pot-la mediates transport another ion on a gradient E / chem. Pot-la, so this type of transport is called T-secondary active.

The protein acts as ATPase, catalyzing the hydrolysis of ATP to release the energy that drives the pump. Please note that for every two non-absorbed potassium from cells derived three ions of sodium. Consequently, the content of the cell becomes more negative with respect to the environment, and between the two sides of the membrane potential difference. Sodium is pumped out of the cells usually passively diffuses back into the cell. However, little membrane permeable to sodium, so this diffusion in the opposite direction is very slow. Potassium ion membrane is about 100 times more permeable than sodium potassium, respectively, and diffuses much faster.

According to the ideas of the vectors, non (M) responds with a carrier (X) on the membrane surface or near it. This first response may or exchange adsorption, or a chemical reaction. Neither the carrier nor its complex with 13 ion can not pass into the environment, however, a complex with the ion transporter (MX) mobile in the membrane itself, and moves it to the opposite side. Here, the complex decomposes and releases non in the internal environment with the formation of the precursor vector (X1). This predecessor to the carrier again moved to the outside of the membrane, which is again converted from the precursor to the vehicle, which on the surface of the membrane: can connect with another ion. When introduced into the environment a substance capable of forming a stable complex with the carrier, the mass transfer is blocked. Experiments conducted on artificial lipid membranes showed that ion transport can take place under the influence of some antibiotics produced by bacteria and fungi – *ionophores.*

LECTURE 9. *Plant water exchange of plant cell and whole plant*

1. Importance of water in Plant physiology. Water features.
2. The role of water in biological systems.
3. The structure and properties of water
4. Water exchange in plant cells.
5. Structure roots absorption water and radial transport.
6. Transpiration and the top end engine.

1. Importance of water in activity of plants. Water features.

In plant tissues V. is 70-95% wet weight. The role of water is very diverse. All known organisms can not exist without water. By reducing the water content in the cells and tissues to a critical level (eg in the dispute, seeds when fully ripe) live p-ry go into a state of suspended animation.

The role of water in biological systems.

1. Water connects all parts of org-ma (molecules, tissues and organs) into a single unit. In the body of the plant aqueous phase is the continuous medium throughout the moisture extracted roots from the soil to the surface of the liquid-gas interface in the leaves, where it evaporates.

2. Water - the most important solvent and important medium for b / v reactions.

3. Water is involved in the regulation of p-p in cells. It is part of a protein molecule, determining their conformation. Removal of water from proteins by salting out or with alcohol leads to coagulation and precipitation of. In maintaining the structure of hydrophobic regions of protein molecules and lipoproteins essential role of structured water.

4. Water - a metabolite and direct component of biochemical processes. When F / C water is the donor electrons. When breathing, for example. In c. Krebs water is involved in oxidative

processes. It is necessary for hydrolysis and many synthetic processes.

5. Essential role in membrane processes is relatively high proton and electron conductivity of structured water.

6. Water - main component in the transport system of higher plants - in the xylem vessels and phloem sieve tubes, moving substances symplast and apoplast.

7. Water - thermostatic expansion factor. It protects tissues from sudden changes in temperature due to the high heat capacity and high specific heat of vaporization.

8. Water - a good shock absorber mechanical effects on the body.

9. Thanks to Osmosis and turgor (tension) water provides the elastic state of the cells and tissues of plant organisms.

During the evolution of plants organisms, we have acquired an increasing independence from the water.

Algae water - a habitat. Terrestrial spore plants still retain the dependence on liquid water drip during reproduction with gametes, traveling with flagella. Lies. plants in which the pollen is not in need of free water for sexual reproduction. They improved mechanisms for delivering and saving of water for the life of plant organisms.

The structure and properties of water:

W. can be in 3 states of aggregation – *gaseous, liquid and solid. In each of these states*, the structure of water is different. Depending on the composition of the materials being stored in water acquires new properties. The solid state of water - is of 2 types: Crystal - ice, noncrystalline - glassy, amorphous (state verification). The instantaneous freezing with liquid nitrogen molecules do not have time to line up in the crystal lattice and the water becomes a solid glassy state. This property allows you to freeze the water without damaging the living org-we, as single-celled algae. Freezing with the formation of crystalline water will damage the cells. For crystal state water has crystals -but a large variety of shapes.. Water structure reminiscent of radiolarians, ferns and flowers.

The physical properties of water.

1. Water - the most anomalous substances, although adopted as the standard measure of the density and volume for dr.v-in.
2. Density. All in the islands increase the volume when heated, reducing the density. However, at a pressure of 0.1013 MPa (1 atm) in water in the range from 0 to 40 ° C with an increase in the rate-ry volume decreases and the maximum density is observed at 40 ° C (at this temp 1 cm3 of water has a mass of 1 g) freezing water volume increases dramatically by 11%, and the melting of ice at temp 00 C is sharply reduced. With increasing pressure, temp freezing drops every 13.17 MPa (130 bar) at 10 ° C. Therefore, at great depths in freezing tempatures in the ocean water does not freeze. With the increase in the rate-ture to 1000 with the density of liquid water

is reduced by 4% (density ravna1).

The boiling point and freezing point (melting). At a pressure of 0.1013 MPa (1 atm), the freezing point and boiling point of water are at 00C and 1000C, which sharply distinguishes H2O from hydrogen compounds with elements of group VI first. s-we Mendeleev. Temperature of boiling H2O increases with increasing pressure. A freezing temperature (melting) falls.

Melting temperature. Latent heat of fusion - 335 J / g (25 for iron, sulfur - 40). This St-in reflected in the fact that the ice at normal pressure can be tempo-py -1 to 70C. Latent heat of vaporization of water (2.3 kJ / g) is almost 7 times higher than the latent heat of fusion.

Heat. Led-on heat capacity of water (quantity of heat required to raise the tempo-ry at 10C) at 5-30 times higher than that of other in-in. Only hydrogen and ammonia has a higher heat capacity.

In addition, only in liquid water and mercury beats. heat decreases with increasing tempo-ture from 0 to 350C (then begins to increase.) VA. specific heat of water at 160C conventionally taken to be unity, serving as a model for others in the-in. The high heat capacity of water protects the plants from a sharp rise in temperature at high temperature, and high heat of vaporization is involved in temperature regulation in plants. High tempature melting and boiling point, high thermal capacity to demonstrate the strong attraction between adjacent molecules, so that liquid water has a greater internal cohesion.

Surface tension and adhesion. On the surface of water due uncompensated adhesion (cohesion) of its molecules are over. tension, the value of which at 180C 0.72 mN / cm (higher only in mercury - 5 mN / cm). Water has the property of adhesion (sticking), which is found in its rise against gravity. In capillaries combination of adhesion mole-liter of water with the air in the boundary layer and its adhesion to the material of the capillary walls. In sharp those in the capillary mod-Xia concave surface of the water above the initial level e. The case of mercury, which does not have St-mi adhesion surface of the meniscus is convex.

The molecular structure of water. In the water molecule, two pairs of new e-yavl-Xia shared hydrogen nuclei and oxygen. They have a highly elongated orbit and, as well as more electro negative oxygen atom attracts us from e-hydrogen atoms have partial 15 positive charge and the oxygen atom with 2 lone pairs of electrons has a partial negative charge (Figure.).

Since the water molecule opposite charges separated in space, it is a total of electrical dipole. Due to the fact that the orbits with lone e-us oxygen atoms lie in a plane perpendicular to the plane of the molecule, and the angle between the hydrogen nuclei is 104.50 (109.50 for ice), a structure of a tetrahedron with 4 poles e-cal charges: two lay-mi and 2 is negative and.

Ionization. Because in the water molecule e-HN is strongly linked to an oxygen atom is split off protons. In sharp those observed Xia dissociation of water molecules into hydrogen ions (H +)

and hydroxyl (OH-). But free H + ion is not capable of independent existence and immediately hydrated by a water molecule to form a hydronium ion H + + H2O > < H3O.

The overall reaction is a proton transfer of 1 mols of water to another and the formation of hydronium and hydroxyl ions:

$H_2O + H_2O$ > < H_3O + + OH^-.

For simplicity hydroxonium (H_3O^+ is commonly referred to as H^+.

At 25^0 C end-tion of hydrogen or hydroxide ions in pure water make up 1.10-7 mol / l, which corresponds to pH 7.

Water as a solvent. The polarity of a molecule determines its Holy of dissolving in the islands better than other liquids. Crystal dissolution Neorg's hydration salts is due to their constituent ions. Readily soluble in water, Org. in the islands with carboxyl, hydroxyl, carbonyl and other groups which water forms a hydrogen. communication.

Electrolyte solutions. In solutions containing ions, the structure of water changes significantly. In dilute x p-tures (<0.1 mmol / l) this is due to the charged ions. The effect depends on the polarizing power of the ion, which is determined by the charge density (the ratio of the ion charge to its radius). Small ions have a high charge density are strongly in page-ru clean water in comparison with large co-ions with a low charge density. And those and others destroy the structure of water: the first draw of the water molecule, the second - in the implementation of the water due to the large size of the break ice-like framework. This may change the viscosity of the water: p-ra created slightly hydrated large ions (small charge) makes viscosity Valium lower the viscosity of water, and the denser p-ra, formed by hydrated ions causes a higher viscosity than in pure water (K^+ , Rb +, NH_4 +, Cs, + OH-).

In the electron. cation field all nearest water molecules are oriented negative poles inside (Figure), and around the inside of the anion directed positive poles of the water molecules. This is an internal, strongly associated with the ion layer of water molecules is called primary, or near hydration (solvation) (Figure)

During electrophoresis, it moves with the ion as a whole. However, ion, linking a number of water molecules from its immediate environment as a result of the ion-dipole interaction is also more far-orients the dipole water. This is called secondary hydration, or far.

In the state of the primary hydration water molecules have reduced mobility and are in exchange equilibrium with the nearest molecules. A molecule of the secondary hydration shell, while maintaining mobility, under the polarizing influence of the ion approaches an order that violates the original structure of the water. On the outside of the water retains a constant structure.

Water-related ions, called osmotically bound. It is an important component of the osmotic pressure in plant cells.

With increasing end-tion r-ra (1.5-2 mol / L) secondary hydration shells of ions and water overlap with its own structure ceases to exist: there is a transition from the structure of pure water to the crystalline structure. The more ions in the p-re, the more disturbed p-ra water and, consequently, but the less energy is required to break the hydrogen bonds and the remaining temperature increase Valium.

Effect of hydrophobic radicals in page-ru water. When dissolved in water in the islands with a large hydrophobic radical, NAP-p, tetra butyl ammonium bromide $(S_4H_9)_4$ NBr, with an increase in concentration in the solution heat in the p-re rises as nonpolar molecules increase the degree of structural organization of water. Around them with pentagon formed crystalline cells. The water in the crystalline hydrate has a high heat capacity, a crystal melts at 30^0C, and not at 0^0C as ice.

(Freezing and damage to grain crops from the ice appears in tissues in 4.50 - arr-tion of crystalline non-polar radicals around protein macromolecules).

Protein solutions. In the hydration of proteins due to the interaction of water molecules with hydrophilic (ionic and neutral in charge) and hydrophobic (non-polar) groups and immobilization in confined spaces within macromolecules in their conformational rearrangements.

When hydrated ion (interaction with the-NH_3 +, - COO - groups) and electroneutral (c - COOH, - OH,-CO,-HN,-NH_2, $CONH_2$ - groups) electrostatically bind water molecules and form monolayer primary hydration. Number of ionized groups of the protein depends on the pH of the medium. Least hydrated protein in its isoelectric point at which is lowest solubility of proteins. Hydrophobic groups of alanine, leucine, phenylalanine increase the structuring of water in these regions of the protein molecule.

In addition to the hydrophobic groups in protein molecules, the structuring of the water affects the hydrophobic lipid phase of membranes.

Immobilized water, which has appeared in a closed macromolecule may be involved in the formation of the primary hydration layer, and the rest stores the properties of ordinary water, but with limited mobility.

The solubility of proteins in water varies widely. Definite relationship between hydration and solubility not.

Therefore, macromolecules have a varied impact on the environment. Depending on the physical and chemical properties (the presence of polar, non-polar, ionized groups), the conformational state and external conditions (pH, ionic composition) may be a more or less binding of water and the formation of a stable ice-like structure.

Water exchange in plant cells.

The water content in the plant cells is a volatile and dynamic value. Varies in different species, in different parts of plants, undergoing daily and seasonal changes. Changes are due to aging tissue, availability of soil moisture and the ratio of absorption and transpiration.

Forms of water in the cell.

There are 2 forms of water-free and bound. Bound water is divided into:

1. Osmotically bound (hydrate dissolved in the islands - ions and molecules);
2. Colloidally bound, which includes intramitsellyarnuyu water that is inside the colloidal system (including immobilized) and intermicellar water (Nah-Hsia on the surface of colloids and between).
3. Capillary connected (in the cell walls and vessels conducting system).
4. Free water has sufficient mobility. If you make heavy water H182O on Wednesday, bathing the plant roots through a 1-10 min percentage of heavy water will be the same in the environment and root tissues. The permeability of the PM of root cells for water is high. In young wheat roots about of water - in vacuoles, - in the cell membrane, 1/20 - in the cytoplasm.

But in the meristem cells with only numerically small vacuoles bulk of the water - in the cytoplasm.

Water is retained in the cells by osmosis. Cell walls have a significant hygroscopic and retain water because of the high hydrophilicity of pectin and cellulose components. The moisture content in the walls of turgid cells exceeds 50% (koleoptili oats). The movement of water outside the vascular bundles occurs on the cell wall.

Cytoplasm contains up to 95% water by weight of the cytoplasm. Main hydrophilic colloids - proteins. The cytoplasm also contains sugars, salts, lipids and other compounds I am.

Plastids, Ml and nucleus separated from the cytoplasm by their own membranes. Their volume changes under the influence of osmotic forces. The water content in the chloroplasts is usually smaller than in the cytoplasm (50%) due to the presence of large quantity of the lipids and lipophilic in-in, which can be up to 40% dry. mass.

The greatest amount of water in the cell containing vacuoles (98%) of the vacuolar sap contains sugar, org. to-you, and their salts, inorganic cations (potassium, etc.) and anions (chloride), enzymes, proteins, tannins, pigments.

Salt, sugar and org. to-you are in the p-re, whereas proteins, tannins, mucus are hydrophilic colloid fraction. Vacuolar sap is considered as a true pp holding water osmotically from the election proniitsaemosti tonoplast.

Osmotic water absorption.

Osmosis and its s-HN.

Osmosis - the passage of the solvent in the p-p, separated from it by a semipermeable membrane (ie skipping the solvent molecules but not dissolved in-c).

First osmometer - 1826 by G. Dyutroshe physiologist.

Improved design with V.Pfeffera. Osmometer called artificial cell. Base - porous faforovy vessel. Inside was filled pp ferrocyanide $K_4 [Fe (CN)_6]$ and the vessel was placed in the p-p $CaSO_4$. The interaction of these in-in the pores formed a gelatinous mass zhelezosinerodistoy copper ($Cu_2 [Fe (CN)_6]$, which served as a semipermeable membrane.

The flow of water in such a cell (Fig.) increases the volume of fluid and raise the level of the manometric tube as long as the hydrostatic pressure of the liquid column F will not increase enough to prevent a further increase in p-pa. In a state of equilibrium achieved in the semi-permeable membrane units. time passes the same amount of water in both directions.

The hydrostatic pressure in this case corresponds to a potential osmotic pressure. *.

Van't Hoff showed that osmotic s-HN correspond gas laws Boyle. For the calculation of the potential pressure he proposed the formula:

P = icRT,

where - end-tion p-pa, and T is the

absolute temperature, R - gas constant, I - isotonic ratio of 1 + . (n-1), where . - degree of electrolytic dissociation, n - the number of ions into which the electrolyte molecules.

For diluted p-ditch osmotic pressure at a constant temperature determined by the end-tion of particles (molecular, ions), the solution of the first in the islands (the number of them in the units. Of Valium). Potential osmotic pressure is expressed in Pascals, and reflects the maximum pressure, which has a p-p of the end-tion, or max-ing FPIC-Th r-ra in the cell to absorb water.

The energy level of the mole-l in the islands - the speed of diffusion, called T-chemical potential of this in the islands (.). The chemical potential of pure water is called t-water potential (.N2O).

He characterized the ability of water to diffuse t, evaporate or be absorbed and cuttings Xia in Pascals.

Led to the highest water-pot-la - a chemically pure water. This led to the conventionally-accepted as 0. Therefore, the water potential of any Valium and bio-liquids has a negative x-mv set.

Waters potential includes components defined by the presence of sol-th in the islands, called the osmotic potential (..) and the potential associated with the hydrostatic pressure .r).

If rr sucrose from semipermeable material (cellophane colloidal film), letting only water, immersed in pure water, the pier-s water will move from pure water in the p-p sucrose, where con-tion less water, ie High water pot-la to the lower. Since dissolved in the islands reduce water act and diamonds in the p-re, water comes out of the cell is less than the input. This leads to an increase in sucrose and the rise of liquid in the tube osmometer. Conducted to assess the DSM-s-pressure necessary to measure the pressure that must be applied to the p-py to overcome act Th particles of pure solvent compared to their activity in the p-re and thus equalize the speed of movement of water molecules in 2 directions. Osmotic potential (..) Valium in this balance is equal in magnitude to the sweat-lu hydrostatic pressure (.r), but opposite in sign (..) and always has a negative value.

The plant cell as an osmotic system.

The plant cell is surrounded by cells. wall, which has a certain elasticity and can stretch. The force with which the water enters the cell, called a T-suction force S. It is identical to the cell water potential (.N2O). Led-on suction force is determined by osmotic pressure of the cell sap (. *) and turgor (hydrostatic) pressure in the cell (P), which is equal to the cell wall back pressure produced when its electrostatic tension (Figure)

S = . * - R.

When replacing these symbols relevant thermodynamic quantities equation takes the trail. View

- (.N2O). = - .. - .r.

When the cell is fully saturated with water (turgid) its suction force is zero, and turgor pressure is the osmotic potential: S = 0, P = .. (Fig.).

A state of complete turgor observed in cells with adequate soil moisture and air. If the water supply is reduced in the cell (in the amplification of the wind, the lack of moisture in the soil), it first appears a water deficit in the cell walls, the water potential which is lower than in the vacuoles, and the water starts to move in the cell walls. The outflow of water from the vacuole reduces turgor pressure in the cells, and the trace-but increases their suction force. With long-term lack of moisture, most cells lose turgor and the plant povyadaet. Under these conditions, P = 0, S. = . * (see Figure).

Turgor loss phenomenon can be observed ex-but putting the pieces of tissue in hypertensive rr. In this case, the outflow of cells leads to a decrease in the volume of protoplasts and their separation from the cell wall (plasmolysis). Surround-in between the wall and the reduced protoplast fills outer rr.

In the water deficit in young tissues sharp increase water loss, for example. with dry winds, can lead to the fact that turgor pressure in the cells becomes negative and protoplasts, reduced in volume, not separated from the cell walls, and pulled behind him. Cells and tissues are compressed. This phenomenon is called Xia tsitorrizom.

Osmotic end-tion for the vacuolar sap of the root cells is 0.3-1,2 MPa, and for cell surface organs - 1,0-2,6 MPa. This may expose the vertical gradient of osmotic concentration and suction force from the roots to the leaves. Very high osmotic pressure in the cells of halophytes in saline conditions: it reaches 15MPa.

Mechanisms of movement of water through the plant.

Aquatic plants are usually no shortage of water. Released to land plants have adapted to a terrestrial lifestyle with the acquisition of the ability to create within your body a continuous upward flow of water. This current begins to water absorbing root surface, penetrates all the plant and ends at evaporating surface of land, mostly leaves and the evaporation of the water leaves should be compensated by water absorption roots.

Water exchange is composed of 3 stages:

1. The water absorption of the roots.
2. Moving it to the vessels
3. Transpiration, ie evaporation of the water leaves.

Each stage consists of interrelated processes.

The state of water in the soil.

Soil-multiphase body composed of 4 main components: solid mineral particles, organic and solids (humus), soil Valium and soil air. H mineral particles and humus form polchvennuyu p-py, and the water and the air filled cavity of the p-ry.

The ability of soil to hold water depends on the composition and properties. Relatively large crystals of silicates (sand) bind water to a large extent. A variety of clay minerals, silica-alumina and heterogeneous humus in the islands, as colloids, can hold large amounts of water of hydration. The water is conventionally called Xia connected. The water contained in the capillaries of the soil, can be conditionally free. A certain amount of water is part of the mineral components of soil. This water is chemically bound and virtually unavailable to plants.

With Biological perspective, the main role is played two water attenuation in soil: 1) due to the forces acting on the phase liquid-to-air, and the surface tension balances the forces that help remove water.

2) Because of the forces acting on the interfaces between the liquid and solid phases.

On admission to the first ground water is quickly absorbed. Then the rate of infiltration of water into the lower horizons is getting slower. Cogley speed downward movement of water is sharply reduced, soil moisture is below the level called field capacity. It is used to Har-ki maximum size soil moisture. Sustainable wilting humidity - an indicator of the minimum reserve. This soil moisture, in which plants are shriveled up until the soil no water. This is the lower limit of the range of soil moisture, which could increase the plants.

Available soil moisture for the plants - amount of water that accumulates in the soil moisture level of sustainable wilting to field capacity. On average readily available to plants moisture retained in the soil strength 0.5 MPa, srednedostupnaya - up to 1.0-1.2 MPa and inaccessible - to 2.5-3.0 MPa.

The structure of the root.

All features of the morphology and anatomy of the root associated with tneobhodimostyu absorb water and minerals in the islands of the soil. In the primary structure of the root are several tissues: root cap, apical meristem rizodermu, primary cortex, endoderm, pericycle and conductive fabric, concentrated in the central cylinder or stele (Figure).

A growing part of the root is less than 1 cm in length and consists of a meristem (1.5-2 mm from the tip) and the elongation zone (2-7 mm).

On the tip - root cap cells of the outer layers which secrete mucus in the polysaccharide and exfoliated when moving root in the soil. Cells of the central part of the Case (statocytes) SOD-t much amyloplasts filled with starch (statoliths) and involved in the perception of the root direction of the force of gravity. DOS.

Function of root cap:

1. Increasing protection zone of the apical meristem from damage by contact with the soil.
2. Geo tropicheskogo perception of the stimulus, providing the correct orientation of the roots in the space.

Apical meristem cells of roots (1-2% of the total number of cells in the meristem) differ significantly from the other divisions and more rare, slow synthesis of DNA, RNA, and protein, fewer plasmodesmata to neighboring cells. They are called the stationary center. If the damage of the root apical meristem due to unfavorable conditions (drought, mechanical damage) fund its cells restored by cell division at rest center.

In each of the root meristem cell divides 6-7 times. Number of cells increases along the axis of the root. Already in meristem root tissues differentiate (Figure) formed pericycle, traced endoderm, cell walls which have no more suberic belts Caspari, begin to form phloem.

Stopped cell division go to stretching in the direction of the axis of the root. This leads to a spatial differentiation of the dividing cells of the meristem and cells growing tension.

In the stretched ends phloem differentiation and formed elements protoksilemy - cells containing cytoplasm organelles. Found in the cell walls ringed and spiral thickening, not interfering with cell growth expansion.

Differentiation of tissues of the root ends in the zone of root hairs, which completes the basic tissues of the root: risodermy, primary cortex, endodermis and the central cylinder of tissue.

Risoderma - single-ply tissue covering the root outside. In some species of plants, each cell has the potential to risodermy form fibril, others - consists of 2 types of cells: trihoblastov forming root hairs, and atrihoblastov not able to do so.

DOS. risodermy function - the absorption of water and minerals for which important area of contact with the ground root. This problem is solved as a whole organism (plant develops a root system) and at the cellular level (formation of root hairs), which increases the absorption surface

of the root.
With age, some types rizoderma replaced by secondary integumentary tissues - ekzodermoy and periderm (cork tissue). In some people, it is stored for a long time, but it changes the structure and suberiniziruetsya kutiniziruetsya, which limits its ability to absorb.
In herbaceous plants root bark is usually a few layers of living parenchyma cells located between ekzodermoy (or rizodermoy) and endoderm.
Between the cells are large intercellular spaces that provide good aeration of the root.
Endodrerma - is the inner layer of cells of the cortex, which borders the central cylinder. Transverse and radial cell walls contain it impervious to water layer of suberin and lignin, which is called in every cell belt Caspari. This layer blocks the transport of water and salts in the apoplast and in the islands pass through the cells of the endoderm to symplast, which is part of the system root symplast.
To the central cylinder or stele, is a complex of tissues, limited outside the endoderm. It contains pericycle and 2 of conducting e-Tov: xylem and phloem. Pericycle cells are single layered least a facing Stella and located directly under the endoderm. Its cells may perform a regulatory function in the way of transport, in both of the outer layers in the xylem and phloem of the cortex. Pericycle cells function as an educational fabric, capable of producing lateral roots, while the big-va dicotyledons, the roots of which are capable of secondary growth, the cells form the pericycle cambium and ray parenchyma.
Group E-ing xylem and phloem in the central cylinder rotated in a circle. Final diff-tion of xylem vessels in the root occurs simultaneously with the appearance of the walls of the girdles Caspari endoderm cells.
In the area of root hairs xylem presented with conducting metaxylem cells lacking live content. Secondary cell walls of blood vessels have a solid type of thickening. In gymnosperms perform function of tracheids - long (1 mm-12 cm) pointed cells communicating through bordered pits in the slanting walls.
In angiosperms also have tracheids, but dominated by the vessels, which are hollow tubes of the cell walls, arranged one above the other in vertical rows. Transverse walls between cells initially perforated, but gradually eroded. The average length of vessels -10 cm

Xylem vessels are interconnected through pores - depressions in the secondary cell walls. Primary cell wall between two adjacent cells are continuous phase, which water and dissolved in the islands overcome by diffusion. The pores of the vessels and tracheids are formed simultaneously in 2 adjacent cells. Xylem vessels in contact with the parenchymal cells of the central cylinder that actively transport ions in conducting xylem elements. Contact via poluokaymlennye pores in the secondary cells. wall of the vessel and the pores of the parenchymal cells. Between these cells no plasmodesmata. Water and sol-e in the islands of diffuse parenchymal cells into the cavity of the vessel through the primary cell wall. For some parenchyma cells of the vascular bundle Har-HN outgrowths (labyrinths) walls lined with plasmolemma, which greatly increases its area. These cells are actively involved in transport, in the vessels and back, called Xia transfer (transition). They can march together with the vessels of the xylem and phloem sieve tubes. Phloem transport systems provide transport org's and some minutes. in-in the aerial part of the plant to the roots.

Growth and motor root. When germinating seeds root initially focused in a gravitational field, directing its growth to the Center of the Earth (positive geotropism). Sensitivity to the direction of the center of gravity is localized in the root cap. The gravitational field is perceived statoliths (amyloplasts), which turns out to r ow th ABA transport from the root tip in the zone stretching. Unilateral increase in SOD-I PAO stretch zone inhibits growth and leads to appropriate Rostovs bends. Excess IAA coming from oversight. org-in also inhibits cell elongation in the tension zone, but contributes arr th lateral and adventitious Koreas.

Growing distal end of the root is sensitive to mechanical pressure and penetrates only in loose soil plots. With strong mechanical resistance to longitudinal growth is inhibited and at the same time in the stretch zone appears thickened (arr-set stress ethylene). This supports the soil pores and further growth of the root. Promotion of the root tip between soil particles facilitates root cap cells, which are constantly secretes mucus into the environment in the islands (polysaccharides). The lack of moisture root begins to respond to the humidity gradient. The roots are bent in the direction of greater humidity.

The lack of moisture sharp increase Xia absorbing surface area due to the intensive growth of corn. hairs. Root hair zone (zone of maximum absorption) begins after the elongation zone.

The water absorption and radial transport.

Area of the most intense absorption of water coincides with the zone of root hairs. The main function of root hairs is to *increase the suction surface of the root*.

Epidermal cells lacking hairs absorb water at the same rate per unit area as the cells bearing root hairs.

Above the root hair decreases the rate of absorption of water by suberization cells. If you start a secondary root growth, the water uptake is usually reduced even more. However, in areas of suberized roots some of the water is transported. In plants with mycorrhiza, the latter also serves as an additional absorbing surface, especially in the older parts of the root. From the root surface through the cells of the cortex, endoderm and pericyclic water must pass to xylem vessels. Through the cells of the cortex are 2 ways of transport of water and mineral in-in (rice ...) through the cytoplasm to plasmodesmata (symplastic transport) and cell walls (apoplastny transport). Water enters the cytoplasm of cells risodermy and parenchyma cells of the root by the laws of osmosis.

Since the resistance of the cell walls of water is much lower than that of the cytoplasm, a more rapid radial transport of water through roots on apoplast. But at endoderm at this type of transport is not possible because of the water-tight belts Caspari. Next,

of the cells. The regulation of the water supply at the endoderm is a fast changing one hand apoplastnogo slow symplastic transport, and on the other - so that the diameter of Staley, where water must be fed through the endoderm is 5-6 times smaller than the diameter of the cortical surface and the suction surface of the root. Impermeability grade. wall endoderm water is not absolute. In growing areas of the root, where belts Caspari endoderm cells formed not completely change the types of transport does not occur. In addition, in areas of the root, where lateral roots are laid, endoderm interrupted. But the mass flow of water through the endoderm on apopast generally limited.

Mechanisms of root pressure. In the xylem vessels of water flows due to osmotic pressure. The existence of such fur-atoms in water transport is proved that if the external environment to create an osmotic end-tion equal to the intracellular, the water in the cells do not, but if I end-osmotic up in the environment, water leaves the cell, below - is absorption. Osmotically-active in your blood vessels and cells. walls are mineral in the islands and the metabolites produced by active ion pumps, funtsioniruyuschimi plasmolemma in parenchymal cells surrounding the blood vessels. The accumulation of these in-in creates a suction force, which facilitates the osmotic water transport in the xylem.

Suction force of the vessels may be higher than that of the surrounding living cells, not only because of increased concentrations of xylem sap, and a lack of back pressure from the cells. walls that are in containers lignification, inelastic.

Therefore, In rez of active ion pumps in the root and osmotic (passive) water flowing into the vessels of the xylem vessels in the developing hydrostatic pressure - the root pressure. It provides lift xylem Valium on the xylem vessels of the root in oversight. authorities. Fur-m rise of water in the plant as a result of the developing root pressure-called t lower end engine. "Lament" plants. "- An example of the lower end engine. Spring can be seen intense xylem fluid flow upward through the incision of the trunk and even the upper branches of the crown (the wounded tree "crying." During the "weeping" root pressure reaches 1.013 MPa (10 atm). At vegetative plants in removing the stem and leaves of the remaining bound with root stump long enough allocated xylem sap, or PASOK. sap collection method is one of the experimental methods to study the functioning of the root systems. root pressure can be measured by placing a pressure gauge on the stump.

Guttation - another example of the lower end engine. When humidity is high as a result of the lower end on the end and bevel leaves allocated drip liquid water - plants gutiruet. Har-but especially for tropical plants. In conditions of high humidity, when reduced transpiration. The rise of water is only due to root pressure. Feature selection perform special-education gidatody localized in bevel leaves.

Transpiration and the top end engine. Transpiration - a physiological process of water evaporation plant. The main body of transpiration - list.

1. Increase in the surface of the leaf blade facilitates the absorption of CO2, capturing the light and it also creates a huge surface evaporation. The water will evaporate and through stomata. In sharp those cells leaf water loss reduced water potential, ie increasing the suction force. This leads to increased uptake of water from the xylem leaf veins and movement of water from the xylem of the roots to the leaves. T. arr., Top end engine can run at full engine off the lower end, and for it to work is not used metabolic energy, and the energy of the environment - temperature
and air movement.

Sheet as a body transpiration. Stem from the water moves to the leaf petiole or leaf through the vagina, followed by leaf veins. Vascular bundles are surrounded by a single layer of closely packed parenchyma cells, which form a facing the beam and at the same time act as a mechanical tissue. Outside leaves have a single-layer epidermis
the outer walls of which are covered with a cuticle, a waxy bloom. Epidermis with cuticle forms forms an effective barrier to water movement.

Leaf mesophyll consists of palisade and spongy parenchyma with large intercellular spaces in mesophylls. Water evaporated ll exposed areas of mesophyll cells.

Transpiration is composed of two processes:

a) The movement of water from the leaf veins in the superficial layers of the cell walls of the mesophyll;

b) the evaporation of water from the cell walls in the space and mezhkletnye podustichnye cavity, followed by diffusion into the surrounding atmosphere through the stomata (stomatal transpiration) or evaporation of water from the cell walls of the epidermis into the atmosphere through the cuticular transpiration.

Liquid water is transported to the evaporation surface mainly on the cell wall. In the cell walls of water meets the weaker resistance than the path from cell to cell through the protoplasts and vacuoles. Water molecules are leaving the plant, moving in the direction of lower water potential, that is, from tissues outside through stomata.

Stomatal transpiration. Stomata are essential for gas exchange between the leaf and the atmosphere is the main pathway for water vapor, CO_2 and O_2. Stomata can be on both sides, but there are species in which the stomata are located only on the underside of leaves. In shaded leaf stomata less than constantly well illuminated leaves. Transpiration from the surface of the sheet is the same rate as the surface of pure water. This is explained by the s Mr. Stephen: through small holes the rate of diffusion of gases is directly proportional to the square hole, and the diameter or circumference.

Cuticular transpiration. In open stomata loss of water vapor through leaf cuticle usually insignificant compared to the total transpiration. But when the stomata are closed, as in time of drought, cuticular transpiration is essential. Young leaves with a thin cuticle cuticular transpiration is about half the total transpiration in mature leaves - 1/10 otbey transpiration. In senescent leaves KT mt increase because of the damage and cracking of the cuticle.

Stomatal regulation of transpiration. Opening of stomata is regulated by several interacting mechanisms. The driving force that causes change in the width of stomatal slit (hole stomata) is the change in turgor closing (sometimes adjacent to stomata) cells. As stomatal guard cells osmotically absorbs water, thinner and flexible part of its cell wall, remote from the slot, stretched. Since thicker and less elastic wall section, bordering the gap stretched weaker guard cells take semicircular form, in rez stomata which are disclosed (see Figure). Of environmental factors on stomatal movement the most impact and humidity conditions of water, light and temperature, and of the interior - the partial pressure of CO_2 in the intercellular spaces with-me, the state of hydration of the plant, the ionic balance and hormones, of which cytokinin promotes opening of stomata, and abscisic acid - closing. On sosotoyanie stomata of leaves affected by the age and phase of plant development, as well as the endogenous circadian rhythms.

Dramatic effect on stomatal movement has a degree of security cells with water. Distinguish hydro passive and hydro active stomatal response. Xia-called active movement, independent of changes in the guard cells themselves, passive - a movement is determined by changes in the cells that surround the stomatal.

Hydro passive closing stomata associated with squeezes between adjacent cells in the epidermis (and hlorenhimy) in their full turgor (high water saturation). Gidropassivnoe stomatal opening can occur with the weakening of the compression in low water shortages.

Hydro active closing stomata happen as the absorption of water by transpiration exceeds the roots and reduced turgor in guard cells reach a critical level. Reaction closing of stomata on the development of water deficit in the tissues due to increasing concentration of phyto hormone abscisic-to-you in leaf cells. ABA inhibits the activity of H-pumps on the plasma membrane of guard cells, thereby reducing their turgor and the stomata close. When applied to the leaf base ABA stomata close after 3.9 minutes.

In contrast to other epidermal cells of stomata guard cells contain chloroplasts. In the light at a good water supply stomata opened more widely, the greater the intensity of light (photoactive opening mechanism)), and the operative factor is the blue light. Photosynthesis in guard cells is also involved in the regulation of stomatal movements. Increase in the synthesis of carbohydrates in the guard cells increases their suction force and causes the absorption of water, contributing to opening of stomata. Stomatal opening in the morning is regulated by light.

Afternoon with the increasing water stress deficit stomata close.
State depends on the stomatal CO_2. If the concentration of CO_2 in under stomatal stomata cavity falls below 0.03%, the turgor of the guard cells increases and the stomata open. Part of this is related to the opening of stomata sunrise: increased F / S reduces the concentration CO_2 in the intercellular spaces. Closing of stomata can cause an increase in CO_2 in the air. This occurs in the intercellular spaces of the sheet at night, when the rez and the continued absence of FS breathing CO_2 levels in the tissues increases.
Decisive influence on the degree of openness of CO_2 stomata is found in succulents has specific circadian rhythm exchange of organic acids. These plants open their stomata at night, when the partial pressure of CO_2 in the intercellular spaces of the leaves is reduced by intensive education malate, and close the stomata, when the decarboxylation of malate day osobozhdaetsya CO2, which accumulates in the intercellular spaces before further use (Figure.)

Daily fluctuations of transpiration. The trees, shade-tolerant plants, many cereals (hydro stabile species) with a perfect regulation of stomatal transpiration evaporation reaches a maximum before the establishment of the maximum daily temperature. At midday transpiration decreases and may increase early evening hours when the temperature of air. In species that can tolerate rapid changes in water content (hydro stabile species) observed a one-vertex diurnal transpiration peaking at noontime. (Fig.) transpiration rate fluctuations reflect changes in the degree of opening of stomata during the day. Closing stomata in podden may be due to the increasing levels of CO_2 in the leaves when the temperature of air (due to increased respiration and photorespiration) and the possible water deficit arising in the tissues at high temperatures, low humidity, especially in windy weather. This leads to an increase in co-abscisic to you and the closing of the stomata. Reducing the temperature in the afternoon helps stomatal opening and increased FS.

Transpiration rate is usually expressed in grams of water vapor for 1 hour per unit area or per 1 g of dry. mass, transpiration efficiency - number of CMV in grams of dry-in, formed in spending for every 1000 grams of water. Reciprocal productivity transpiration yavl-Xia transpiration ratio, ie the number of grams of water consumed in the accumulation of 1g suh.v-in.
The movement of water through the vascular system. The upward flow is the xylem. Xylem is a junction with th, supplies all tissues and organs of plants with water. Items in the root tips of growing tension contain cytoplasm. Mature vessels and tracheids with lignified cell walls devoid

of cytoplasm and perform vo4doprovodyaschuyu function.

The theory of coupling. The driving force of the upstream water in conducting elements of the xylem water potential gradient is a plant from the soil to the atmosphere. It is supported by 2 core-nents:

1) gradient osmotic potential in the root cells (from the soil to the xylem vessels), created by active transport of ions in living cells of the root, including the young living xylem elements, and

2) transpiration.

Maintaining a first gradient requires the expenditure of metabolic energy, energy is used for transpiration of solar radiation. Osmotic potential gradient provides a root water uptake.

Transpiration is Ch.

LECTURE THEME 10. *Photosynthesis. Photosynthetic apparatus plants and photosynthetic plastid pigments*

Significance of Ph.

1. *Light stage*
2. *Structure of chloroplasts concerning Ph reactions*
3. *Photosynthetic pigments*

Essence of photosynthesis as the transformation of light energy into the energy of chemical bonds.

The scale of photosynthesis on Earth, its value.

Stages of the study of photosynthesis. Sheet as the body of photosynthesis. Chloroplast ultrastructure, chemical composition.

Pigment system. Chloroplast biogenesis. Chlorophylls, phycobilins, carotenoids. Structure, spectral properties, and functions. Biosynthesis of pigments.

Light stage of photosynthesis. Primary photochemical processes. Absorption of light by chlorophyll. Electronically excited state of chlorophyll. The pigments of the reaction center and the antenna complex. Energy migration. Energy conversion in the reaction center. I and photosystem II. Electron transport chain of photosynthesis. Cyclic and non-cyclic electron transport. Reactions associated with oxygen during photosynthesis. Photophosphorylation.

The dark phase of photosynthesis. Ways assimilation of CO_2. C 3-way: the primary acceptor and the primary product. The chemistry of the reactions of the Calvin cycle. Hatch-Slack cycle: the primary acceptor and the primary product. CO_2 assimilation by type Crassulaceae (CAM-way): the primary acceptor and the primary product. The chemistry of the reactions. Photorespiration. The influence of external factors on photosynthesis. Diurnal and seasonal variation of photosynthesis. Photosynthesis and plant productivity.

Photosynthesis occurs in all plants,

algae,

cyanobacteria and

some species of bacteria.

Significance of Photosyntesis

It maintains the normal level of oxygen in the atmosphere.

All life either depends on photosynthesis directly as a source of energy, or

indirectly as the ultimate source of the energy in their food.

Photosynthesis is the metabolic process by which plants absorb solar energy in the range of visible light and convert this light energy into chemical energy.

This process uses water H_2O and carbon dioxide CO2 and releases oxygen as a by-product.

$CO_2 + 2\ H_2O + \text{light energy} \rightarrow (CH_2O)n + H_2O + O_2$

Photosynthesis encompasses two steps. The first one called photochemical (light-dependent) reaction of photosynthesis produces:

NADPH (an electron acceptor compounds) and

ATP (energy held in phosphate bonds).

The second step called biochemical (light independent; dark) reaction uses this NADPH and ATP to

convert carbon dioxide (CO_2) and water into sugars.

These sugar are used for respiration and growth.

Furthermore, these sugars are the basis of the food chain for all life.

Photosynthesis takes place in chloroplasts

These are football-shaped organelles surrounded by the lipid-made, double membrane.

Inside the chloroplast, there are located thylakoid membranes in a gel-like inner matrix, stroma.

The thylakoid membranes are long, flattened (сплюснутый) membranous disks, where the light-dependent reactions of photosynthesis occur.

In some parts of stroma, the thylakoids are folded and stacked to form of grana.

The stroma is the site where the dark phase (light-independent reaction) of photosynthesis takes place.

Chloroplasts contain photosynthetic

pigments, which absorb light.

The most important pigments for light absorption are chlorophylls.

Green plants are green because they contain a photosynthetic pigment which absorb light. The most important pigments for light absorption are chlorophylls (a and b in plants).

Chlorophyll absorbs certain wavelengths of light within the visible light spectrum.

Chlorophyll absorbs light in the red (long wavelength) and the blue (short wavelength) regions of the visible light spectrum.

Green light is not absorbed but reflected, making the plant appear green.

Chlorophyll absorbs light most strongly in blue and red but poorly in the green region of the light spectrum.
Plants usually contain about half as much chlorophyll as chlorophyll . The other crucial pigments are carotenoids (carotenes and xanthophylls) , which are red, orange and red in color.
Light is the driving force, the energy for photosynthesis.
Light is part of the electromagnetic spectrum
Light is a electromagnetic wave.
This wave has a wavelength that can be measured in meters.
Light waves are very small.
All biological energy comes from sunlight and this energy encompasses the range of the electromagnetic spectrum known as light.
The solar spectrum
Visible light covers the range of wavelengths from 400 to 700 nm.
Sunlight includes waves that are ultraviolet (280 to 400 nm) and waves that are infrared (greater than 700 nm).
The infrared wavelengths are abundant and represent the bulk of solar energy.
These provide the heat that keeps us warm and gives us summers. Also shown is the absorption spectrum for chlorophyll.
Chlorophyll absorbs blue and red light
The green pigment, chlorophyll, plays a central role in photosynthesis. The fact that it is green means that it absorbs blue and red light and reflects green when it is illuminated by white (all wavelengths) light.
Figure shows two absorption maxima in the blue and red portions in the spectrum.
An energy diagram shows how an electron can be elevated to a higher energy level in the electron cloud of chlorophyll by absorbing a high energy photon.
Blue is at the high-energy end of the spectrum, so light of this wavelength is responsible for this much excitation and explains the absorption peak in the blue.
Red wavelengths are lower in energy and only boost (увеличение) the electron to a lower energy level than can blue light.
This stable excitation state is responsible for the red absorption peak.
Molecules of chlorophyll-a, chlorophyll-b, carotene and xanthopyhll are situated in the thylakoid membranes.
Chlorophyll absorbs light in the violet and blue wavelengths and also in the red
Different pigments absorb light energy at different wavelengths.
The absorption pattern of a pigment is known as the absorption spectrum.
The absorption spectrum of chlorophyll is between 400 nm and 700 nm.
What is chlorophyll?
Chlorophyll is a compound that is known as a chelate. A chelate consists of a central metal ion bonded to a large organic molecule, composed of carbon, hydrogen, and other elements such as oxygen and nitrogen.

Chlorophyll has magnesium as its central metal ion, and the large organic molecule to which it bonds is known as a porphyrin. The porphyrin contains four nitrogen atoms bonded to the magnesium ion in a square planar arrangement. Chlorophyll occurs in a variety of forms.

Apart from coloring, has chlorophyll any other role?

The green color of chlorophyll is secondary to its importance in nature as one of the most fundamentally useful chelates. It channels the energy of sunlight into chemical energy, converting it through the process of photosynthesis. In photosynthesis, chlorophyll absorbs energy to transform carbon dioxide and water into carbohydrates and oxygen. This is the process that converts solar energy to a form that can be utilized by plants, and by the animals that eat them, to form the foundation of the food chain.

Chlorophyll is a molecule that traps light - and is called a photoreceptor.

Chlorophylls molecules look like a tennis racket.

The head of the racket is a porphyrin ring system, made of four pyrolle units linked together (tetrapyrolle).

It has a long hydrocarbon tail, called phytol (C-20), that is derived from the terpene pathway (diterpene), built from the isoprene skeleton.

Structure of Chlorophyll

Structurally all types of chlorophyll resemble one another (похожи друг на друга).

Chlorophyll molecule looks like a tadpole with porphyrin head and phytol tail.

All of Chlorophyll contain four pyrrole rings [also called porphyrin]. The pyrrole rings are linked together by methane bridges (-CH=).

The skeleton of each pyrrole ring is made up of five atoms - four carbon and one nitrogen with magnesium in the centre as nucleus.

One pyrrole ring is esterified with a long chain alcohol - phytol.

This side chain-phytol is long and is composed of insoluble carbon and hydrogen atoms which helps to anchor the chlorophyll molecules with the thylakoids.

Chlorophyll absorbs light most strongly in blue and red

but poorly in the green region of the light spectrum.

The green color of chlorophyll-containing tissues such as plant leaves.

Plants usually contain about half as much chlorophyll as

chlorophyll.

The other crucial pigments are carotenoids (carotenes and xanthophylls) , which are red, orange and red in color.

Structure of Chlorophyll

Another distinctive feature of chlorophyll from other photosynthetic pigments a is the presence of phytol, a highly hydrophobic 20-carbon alcohol, esterified to an acid side chain.

Chlorophyll structure explains its functions

The tetrapyrrole ring system is a hydrophilic portion.

It chelates a magnesium ion which, like most metal ions, has a large cloud of electrons. To this cloud electrons can be added or losed without a charge change.

The tetrapyrrole ring system that chelates this magnesium shows a system of conjugated double bonds.

These bonds expand the electron cloud by resonance of the conjugated bonds.

These bonds also provide the light absorption features of the chlorophyll molecule that give it the green color.

The long phytol tail of chlorophyll is hydrophobic and the resulting amphipathic nature of the complete molecule allows it to integrate into membranes and hydrophobic domains of membrane proteins.

Photosynthetic pigments in plants

chlorophyll a - methyl group

chlorophyll b - formyl group

phaeophytin - chlorophyll without the magnesium

chlorophyllide - chlorophyll without the tail

2. Carotene/xanthophyllsAbsorbsion of chlorophyll

Chl $_a$ is the major pigment involved in trapping light energy and converting it in to electrical and chemical energy. It acts as a reaction centre.

Chl $_b$ constitutes about 1/4thof the total chlorophyll content. It acts as an accessory pigment and helps broaden the spectrum of light absorbed during photosynthesis.

Chlorophyll b absorbs a different wavelength of light other than that absorbed by chlorophyll a.

On absorbing light, it becomes excited and transfer its to chlorophyll a molecule.

The difference in one ring distinguishes chlorophyll a (a reaction center pigment) from chlorophyll b (an antenna pigment).

Bacteriochlorophylls

are photosynthetic pigments that occur in various phototrophic bacteria. They were discovered by C. *B. van Niel* in 1932. They are related to chlorophylls, which are the primary pigments in plants, algae, and cyanobacteria. Groups that contain bacteriochlorophyll conduct photosynthesis, but do not produce oxygen.

They use wavelengths of light not absorbed by plants or Cyanobacteria. Different groups contain different types of bacteriochlorophyll

Bacteriochlorophylls

Chlorophyll and Bacteriochlorophylls

The structural similarity of these molecules to bacteriochlorophyll indicates the prokaryotic origin of chlorophyll and is further evidence for the endosymbiont theory for the origin of chloroplasts.

Bacteriochlorophylls

Chlorophyll is not the only photosynthetic pigment

Chlorophyll a plays a very important role in photosynthesis.

Plants have additional pigments that participate in photosynthesis. These are called antenna pigments. For true plants, which taxonomists are generally defining as green algae, bryophytes, ferns, and seed plants, the pigments for photosynthesis are chlorophylls a and b, carotenoids, and xanthophylls.

Accessory Pigments

Role of Accessory Pigments:

Accessory pigments help plants absorb additional light. Plants need to make these accessory pigments to maximize the amount of photosynthesis they can do.

More pigments = More glucose or food for the plant!

2. Carotene/xanthophylls

Both are terpenoid pigments, tetraterpenoids (C-40).

Carotenes are hydrocarbons, xanthophylls are oxygenated. These pigments are orange and yellow in color.

Carotenoids transfer energy from photons to chlorophyll. They also can quench (тушить) free radicals by accepting or stabilizing unpaired electrons and so protect chlorophyll molecules

carotene

Xanthophylls

Antenna pigments enhance photosynthetic efficiency

β-carotene and the two xanthophylls also have conjugated double bonds and rings at either end. This gives the molecules the ability to absorb light.

These are yellow-orange pigments and they absorb light in the blue and green areas of the visible spectrum.

The antenna pigments complement (дополняют) the absorption of light by chlorophyll.

This means that plants with these antenna pigments can use light of wavelengths that do not excite chlorophyll.

The energy absorbed by those pigments is passed to chlorophyll and used in photosynthesis.

Chlorophylls are very effective photoreceptors because they contain networks of alternating single and double bonds. Such compounds are called polyenes.

They have very strong absorption bands in the visible region of the light spectrum, where the solar output reaching Earth also is maximal.

E. When chlorophyll absorbs light?

The chlorophyll molecule becomes excited (this takes only 10^{-15} sec = femptosec) and an electron moves to an outer energy level. This is diagrammed:

CHL (ground state) → CHL* (excited state)

What happens when light is absorbed by a chlorophyll molecule?

The energy from the light excites an electron from its ground energy level to an excited energy level.

This high-energy electron can have several fates. For most compounds that absorb light, the electron simply returns to the ground state and the absorbed energy is converted into heat.

Light Absorption. The absorption of light leads to the excitation of an electron from its ground state to a higher energy level.

Blue light excites an electron to a higher energy level than red light. The electrons change spin at the first (S_1) and second (S2) excited singlet states. Electrons don’t stay excited long (10^{-9} sec), because they either:

return to the ground state and release their absorbed energy as heat (thermal deactivation);

return to ground state and release their extra energy as light (fluorescence);

transfer their energy to another molecule; kind of like hitting pool balls (resonance transfer); or

change spin and revert to a triplet state (same spin as ground state) and be used in a photochemical reaction (photochemistry).

What happens when light is absorbed by a chlorophyll molecule?

However, if a suitable electron acceptor is nearby, the excited electron can move from the initial molecule to the acceptor.

Blue light excites an electron to a higher energy level than red light. Imagine the "bell ringer" at a carnival.

The electrons change spin at the first (S_1) and second (S_2) excited singlet states.

Blue light excites an electron to a higher energy level than red light. Imagine the "bell ringer" at a carnival.

The electrons change spin at the first (S_1) and second (S_2) excited singlet states.

Electrons don’t stay excited long (10^{-9} sec), because they either:

- return to the ground state S_0 and release their absorbed energy as heat (thermal deactivation);
- return to ground state S_0 and release their extra energy as light (fluorescence);
- transfer their energy to another molecule (resonance transfer); kind of like hitting pool balls (удары шары бассейн) or
- change spin and revert to a triplet state (same spin as ground state) and be used in a photochemical reaction (photochemistry).

Excited electrons can fluoresce

When an electron is in the lower excited state (S_1), it can drop back to the ground state and the energy lost can be re-emitted as a photon of light in a process known as fluorescence.

This light is, at a lower energy level, thanks to the second law of thermodynamics. That means that the re-emitted photon is of a longer wavelength. Chlorophyll fluoresces at a deep-wine-red color at the limit of human vision.

Excited electrons can fluoresce

In an intact chloroplast the energy is seldom re-emitted; instead the energy and the excited electron are stripped from chlorophyll.

They are taken from chlorophyll and sent through and electron transfer system.

The energy is ultimately trapped (ловушке) in a phosphate bond in ATP (photophosphorylation) and in an energy rich molecule as NADPH.

The trapping (отлов) of light energy is the key to photosynthesis. The first event is the absorption of light by a photoreceptor molecule.

The principal photoreceptor in the chloroplasts of most green plants is chlorophyll a, a substituted tetrapyrrole. The four nitrogen atoms of the pyrroles are coordinated to a magnesium ion. Unlike a porphyrin such as heme, chlorophyll has a reduced pyrrole ring.

This process results in the formation of a positive charge on the initial molecule (due to the loss of an electron) and a negative charge on the acceptor and is, hence, referred to as photoinduced charge separation.

The site where the separational change occurs is called the reaction center.

From this equation some conclusions can make:

Photosynthesis is a redox reaction.

(a) Reduction - gain of electrons;

(b) Oxidation - loss of electrons;

(d) Redox reaction - reaction in which one component is oxidized and the other is reduced. Obviously, electrons must come from somewhere and go somewhere.

The reduction sequence of carbon:

carbon dioxide (most oxidized form of carbon) → carboxyl (organic acid) → carbonyl (aldehydes, ketones) → hydroxyl (alcohols) → methyl → methane (most reduced form of carbon).

Each step requires the addition (or removal) of two electrons and two protons for reduction (oxidation). Two steps also require the addition/removal of water.

How can you tell if a molecule has been oxidized or reduced?

change in valence (i.e., Fe^{2+} → Fe^{3+} represents an oxidation because an electron was lost, increasing the total positive charge);

In many biological redox reactions, oxidation is accompanied by a loss of protons (hydrogen ions) and reduction is accompanied by a gain of protons;

look for a decrease in the number of oxygen atoms.

Photosynthesis: Light Dependent Reactions

Biological redox reactions require electron donors and/or acceptors. These include:

(1) NAD^+;

(2) $NADP^+$;

(3) FAD; which are coenzymes (organic compounds, other than the substrate, required by an enzyme for activity):

LECTURE 11. *Light and dark stage of photosynthesis*

Reducing Potential - potential for components to participate in a redox reaction;

to predict the direction and tendency of electrons to flow between two electron carriers.

Photosynthesis: Light Dependent Reactions

B. CO_2 is reduced to a carbohydrate

C. H_2O is oxidized (to O_2 oxygen).

D. Water supplies the electrons for the reduction; water is cleaved in the process yielding oxygen as a byproduct.

Photosynthesis: Light Dependent Reactions

E. Light provides the energy for the reduction.

F. Photosynthesis is an energy conversion process that ultimately converts light energy to chemical energy (carbohydrate). In a broad sense, it is an example of the 1st Law of Thermodynamics - energy cannot be created nor destroyed, but it can be changed from one form to another.

Photosynthesis

is the metabolic process by which plants absorb solar energy in the range of visible light and convert this light energy into chemical energy.

Photosynthesis encompasses two steps.

The first one called ***photochemical (light-dependent) reaction of photosynthesis*** produces;

NADPH (an electron acceptor compounds) and

ATP (energy held in phosphate bonds).

The second step called biochemical (light independent; dark) reaction uses this NADPH and ATP to convert carbon dioxide (CO) and water into sugars.

These sugar are used for respiration and growth.

Furthermore, these sugars are the basis of the food chain for all life.

insert absorption spectrum of photosynthetic pigments here

Chlorophyll a and b absorb light in the red and blue regions of the visible spectrum.

The absorption spectra correspond the action spectrum of photosynthesis and hence, implicates that they are involved in the process.

Chlorophyll absorbs light in the violet and blue wavelengths and also in the red because it reflects green light, it appears green.

Different pigments absorb light energy at different wavelengths.

The absorption pattern of a pigment is known as the absorption spectrum.

The absorption spectrum of chlorophyll is between 400 nm and 700 nm.

E. What happens when chlorophyll absorbs light?

The chlorophyll molecule becomes excited (this takes only 10^{-15} sec = femptosec) and an electron moves to an outer energy level.

This electron movement is diagrammed:

CHL (ground state) → CHL* (excited state)

Chlorophyll absorbs light most strongly in blue and red

The light-dependent reactions of photosynthesis are started when light energy is absorbed by antenna complexes (groups of photosynthetic pigments arranged in aggregates within thylakoid membranes).

Light absorption causes electron excitation in a chlorophyll molecule. This excited electron is passed into a chain of associated molecules called electron transport chain.

III. Conversion 1: Photons to electrons

A. Nature of light Light is part of the electromagnetic spectrum - radiation emitted by sun. Acts as discrete particles (called photons) traveling as waves.

Wavelength - distance between any two crests (or troughs). Symbolized by lambda (λ); frequency - number of waves passing a point in one second (υ).

Frequency is inversely related to wavelength $\upsilon = c/\lambda$ where c = speed of light (3×10^{10} cm sec^{-1}). The energy of a photon is a quantum.

D. Quantity vs. Quality

Light quality - refers to the wavelengths of light that are important. Photosynthetically active radiations (PAR) range from 400 - 700 nm with peaks in the red and blue.

Light quantity - refers to the amount of light (PAR) received; units of mol m^{-2} s^{-1} , called the photon fluence rate; or units of energy, J m^{-2} s^{-1}.

Basic concept of energy transfer during photosynthesis

Conversion of Light into Electrical Energy

3. Chlorophyll biosynthesis -

ALA (Δ-aminolevulinic acid) is the first well-established precursor

ALA is derived from *α-ketoglutarate (or glutamate) (a Kreb's cycle intermediate*, from the mitochondrion)

2 ALA condense to form a unit of pyrolle 4 pyrolles condense to form porphyrin (tetrapyrolle)

Magnesium is inserted A photoreduction step occurs (converts protochlorophyllide → chlorophyllide)

the tail is added

Photosynthetic Bacteria and the Photosynthetic Reaction Centers of Green Plants Have a Common Core

Photosynthesis in plants is mediated by two kinds of membrane-bound, light-sensitive complexes—

photosystem I (PS I) and

photosystem II (PS II).

photosystem I (PS I)

PS I includes:

13 polypeptide chains,

more than 60 chlorophyll molecules,

a quinone (vitamin K_1), and

three 4Fe-4S clusters.

the Photosynthetic Reaction Centers of Green Plants and Photosynthetic Bacteria Have a Common Core

PS II is only slightly less complex with at least

10 polypeptide chains,

more than 30 chlorophyll molecules,

a nonheme iron ion, and

four manganese Mn, ions.

Photosynthetic bacteria Rhodopseudomonas viridis contain a simpler, single type of photosynthetic reaction center, the structure of which was revealed at atomic resolution.

Photosynthetic Bacteria and the Photosynthetic Reaction Centers of Green Plants Have a Common Core

The bacterial reaction center consists of four polypeptides: L (31 kd), M (36 kd), and H (28 kd) subunits and C, a c-type cytochrome.

The results of sequence comparisons and low-resolution structural studies of photosystems I and II revealed that the bacterial reaction center is homologous to the more complex plant systems. Thus, we begin our consideration of the mechanisms of the light reactions within the bacterial photosynthetic reaction center, with the understanding that many of our observations will apply to the plant systems as well.

III. Conversion 1: Photons to electrons

B. Which photons are important in photosynthesis? From action spectrum of photosynthesis is radiations between 400-700 nm are photosynthetically active (termed PAR). Specifically, red (600's) and blue (400's) light are important.

C. Photons must be absorbed to be used in a photochemical reaction.

In other words, only those molecules that absorb quanta participate in photosynthesis. The molecules absorb the red and blue light?

The electron transport chain encompasses four major protein complexes in the thylakoid membrane:

photosystem I (PSI),

photosystem II (PSII),

cytochrome b6f complex ,

ATP synthase

mobile carriers as plastoquinone (PQ) and plastocyanin,

enzymes: ferredoxin (Fd) and ferredoxin:NADP reductase (FNR).

As the electrons move through the electron transport chain, they lose energy, which is used to pump hydrogen ions (protons) into thylakoid interior (called lumen).

This generates chemiosomotic potential, which is used to create ATP from ADP and inorganic phosphate (photophosphorylation) and the electrons are used for reduction of NADP to NADPH.

Both ATP and NADPH are required for sugar synthesis in dark reaction of photosynthesis.

Electrons to replace those released at the reaction center of PSII come from water, which is split to release 2 electrons, 2 hydrogen ions and oxygen, which is released from the plant as a waste product of photosynthesis.

Lecture 12. *Significance of respiration in plant life*

Contents: Respiration as the process of enzymatic oxygen uptake.

The value of breathing in plant life.

Relationship respiration and fermentation.

Respiratory

substrates.

Mitochondria: ultrastructure, chemical composition, function.

The biogenesis of mitochondria.

The main ways of substrate oxidation breathing. Glycolysis. Krebs cycle. Glyoxylate cycle. Pentose phosphate pathway. The chemistry of these processes, the value of the plant. Communication with other respiratory functions of the plant cell.

The respiratory chain and its components: dehydrogenase flavoprotein, ubiquinone, cytochromes. The structure of the mitochondrial respiratory chain. The mechanism of phosphorylation in the respiratory chain. Chemiosmotic theory of Mitchell. Dependence of respiration on environmental factors. Change in the rate of respiration in the ontogeny of the plant.

Breath - the main form of dissimilation, in which organic matter is completely converted to energy end-poor inorganic products (CO2 and H2O) and released the energy in organic material. The value of breathing in the life of plant organisms: 1) to provide all the energy of ATP endergonic processes, 2) the formation of low-molecular precursors for synthetic processes.

Biological oxidation is different, it is catalyzed by enzymes, and more often than not, multi-tier system. It should be noted that the release of energy is not in the oxidation of carbon to CO2, and the oxidation of hydrogen to H2O., Ie in the interaction of cells with oxygen. In the metabolism of the cells have a number of ways of going with oxygen. They are catalyzed by specific enzyme systems, providing interaction of cells with oxygen: I) the reaction catalyzed by oxygenases in which there is a direct connection of the oxygen molecule to molecule metabolite. 2) The reaction in which oxygen acts as the final electron acceptor. These reactions are catalyzed by oxidases. 3) Sub-type reactions are those in which one atom of the molecule of oxygen is used to oxidize the substance, and the other is an electron acceptor. Students should be aware of the oxidoreductase - an enzyme performing an oxidation-reduction reactions (dehydrogenases, oxidases, oxygenases).

The main way of carbohydrate oxidation during respiration - is glycolysis and the Krebs cycle. Glycolysis is an anaerobic process and occurs in the cytoplasm. Hexoses are oxidized to pyruvic acid. Results in the formation of 2 molecules of ATP and NADH. Typical substrate for glycolysis type phosphorylation. Further conversion of pyruvic acid are dependent on the availability of cells with oxygen. Under anaerobic conditions, the conversion of pyruvate are associated with various types of fermentation.

Under aerobic conditions, pyruvate enters the mitochondria, where oxidized to CO2 and H2O to form a large amount of ATP. This is done in a consistent system of reactions, known as the cycle of di-and tricarboxylic acid or Krebs cycle. Oxidation of carbohydrates with the formation of reduced NADH dehydrogenase and FADN2 which then oxidized in the electron transport chain of respiration with oxygen. We need to know the chemistry of the reactions of glycolysis and the Krebs cycle. Also, please describe the oxidation of those sites where the recovery image pyridine and flavin dehydrogenase.

Organization requires special consideration respiratory electron transport chain, where the oxidation of reduced dehydrogenase and the reduction of oxygen. You need to know the components of ETC, their nature and the redox potentials. Oxidation-reduction potential, a measure of employee value of the free energy of the system, is an important characteristic that determines the direction of electron transport reactions. Spontaneous electron transfer occurs in the direction of a substance with a negative redox potential of the substance to the more positive potential. Since this electron transfer is exothermic, that is, coming with the release of energy, it can be accompanied by the formation of macroergic communication.

Phosphorylation, combined with ETC breathing, called oxidative phosphorylation of membrane type (as opposed to substrate phosphorylation). In examining the mechanism of ATP in ETC, it is useful to recall the structure of the mitochondria, as well as the localization process in the membrane system of mitochondria. The inner membrane of mitochondria contains components ETC and ATP synthase. The mechanism of ATP revealed P.Mitchellom and is called chemiosmotic theory. The movement of electrons is accompanied by ETC transport of hydrogen ions from the acid cleaved the Krebs cycle, the inside to the outside of the inner mitochondrial membrane. A separation of charge. Excreted proton and the electron is transferred to the next carrier. So, three times in the ETC protons stand on the outside of the inner membrane of mitochondria in the compartment between the outer and inner membranes. The result is a transmembrane gradient of hydrogen ions. This results in a gradient of electrochemical potential of protons across the membrane. By the energy of the building, with the participation of ATP synthase ATP is synthesized. The efficiency of the oxygen breathing path clearly characterized by comparing the amount of ATP formed during glycolysis and the Krebs cycle.

In addition to the mitochondrial cytochrome oxidase in plants operate several oxidases, such as polyphenoloxidase, askorbinoksidaza. Attention is drawn to the functional significance of the diversity of terminal oxidases as an adaptive mechanism of the plant organism to changing external conditions.

In addition, the pentose phosphate pathway can function. The student must know the pentose phosphate shunt breathing as an alternative glycolytic pathway of glucose oxidation. Parse a sequence of biochemical changes in this cycle phase decarboxylation education NADP-H2 and the regeneration phase hexoses. As a result, the cycle of one revolution every 6 hexose molecules included in the cycle, 6 CO_2 molecules are formed and recovered 5 molecules of hexose. You need to know the value of the pentose phosphate cycle for energy education and metabolically important intermediates, compared with glycolytic path.

Disassemble the reaction of the glyoxylate cycle, associated with the utilization of spare fat from oilseeds.

Important is the analysis of the breath in the ontogeny of plants and under the influence of external factors. Should pay attention to the qualitative aspects of breathing - replace oxidation pathways, changes in the degree of coupling of oxidation to phosphorylation.

Lecture 13. *The importance of plant mineral nutrition*

Contents: Need plants in mineral elements. Macronutrients, micronutrients. Nutrient mixture. Soil characteristics as a host plant substrate. Physiological and biochemical role of major nutrients. Nitrogen. Circulation of nitrogen in nature. The value of nitrogen. Fixation of molecular nitrogen. Organisms carried out nitrogen fixation. Modern views on the mechanism of reduction of molecular nitrogen. Sources of nitrogen for plants. Nitrate reduction. Ways of ammonia assimilation in plants. Formation of amino acids and amides. Transamination.

Phosphorus. The value of different types of phosphorus-containing compounds in the cell. Of phosphorus in the cell, ways of incorporating phosphorus metabolism. Sera. The main sulfur-containing compounds and their role in metabolism. Sources of sulfur. Sulfate reduction. Sulfur assimilation in plants. The value of potassium, calcium, magnesium and iron in the metabolism of plants: their intake into the plant and the inclusion in the metabolism.

Micronutrients. Modern views on the role of trace elements in plant metabolism. Physiological and biochemical role of copper, manganese, molybdenum, zinc, boron, cobalt, etc.

Ion absorption of plant cells. Diffusion and adsorption. Active and passive transport of ions across the membrane. Ion transport in the tissues of roots, stems and leaves. Simplastichesky apoplastic and the movement of ions through the plant. The role of roots in the life of the plant. The physiological basis for the use of fertilizers. Mineral nutrition and plant productivity.

Mineral nutrition of plants - a process of absorption and assimilation necessary for the life of the chemical elements in the form of ions of mineral salts. It is a combination of absorption of mineral ions from the environment, linking them (conversion, assimilation), walking on the cells and tissues to the places of possible consumption, including minerals in metabolism. Be divided on organogenic necessary elements (C, H, O, N) and ash elements (all others). C, H, O plants get from the air and water, and the rest - from the soil. Depending on the content of mineral elements are divided into macronutrients (N, S, P, K, Ca, Mg, Si) trace elements (Fe, Cu, Mo, Zn, As, Mn, Cl, Ni, Co, Na). Discussing the role of the individual elements, it is useful to adhere to such a plan:

1.Physiolgical role of macro- and micro elements.

2. Types of its assimilation.

3. Important aspects of the metabolism of this element.

4. Cycle in nature.

Nitrogen has a special place in the life of the plant. He is a member of proteins, nucleic acids, chlorophyll, ATP, as well as in a number of cell metabolites. Only some prokaryotic microorganisms and algae can use molecular nitrogen atmosphere. Other organisms absorb inorganic nitrogen in the nitrate or ammonium form. Analyzing the nitrogen metabolism in plants, we should take into account that in the process of recovery of nitrate nitrogen is played by two enzyme systems - Nitrate reductase and nitrite reductase. The first exercise recovery of nitrate nitrogen to nitrite, nitrite reduced to ammonium nitrite no free intermediates. Interesting is the dependence of the recovery of nitrate from the light.

Analysis of nitrogen assimilation process should include familiarity with the three enzyme systems - glutamagdegidrogenazoy (GDH), glutamine synthetase (GS) and glutamatsintazoy (glutamine: 2-оксоглутаратаминотрансферазой, GOGAT), which are formed on the basis of different ways of incorporating nitrogen into organic compounds. So with the assistance of GDH and GS are successive synthesis of glutamate and glutamine, and the GS and GOGAT catalyzes the synthesis of glutamine in the beginning of glutamate (HS), and then the formation of two molecules of glutamate, glutamine and oxoglutarate.

Require a separate treatment process of nitrogen fixation of free-living forms of photosynthetic organisms and microorganisms simboze with higher plants. Asking all organisms have a nitrogen fixation enzyme system associated with the restoration of nitrogen - is nitrogenase. The recovery process involving nitrogen nitrogenase is the expenditure of ATP, and is associated with the electron transport. In the active site of the enzyme system is Fe and Mo. Should represent the role of these elements in the nitrogenase-catalyzed process. For a special discussion interesting question about the influence of oxygen on nitrogen fixation.

*Sulfur i*s absorbed by plants in the form of a higher oxide, the main functional form of sulfur in the plant - restored to the sulfhydryl or disulfide. We have to show the main stages of the recovery of sulfur in the plant. The functional role of sulfur due to the fact that it is included as a ligand to a large number of enzymes and metallproteinov. The most famous and important - this iron-gray-copper-protein and protein. Sulfhydryl groups may directly participate in oxidation-reduction reactions, or be an important factor in the structure of proteins. We should take up the role of sulfur in the coenzyme A (CoA) - an important metabolite of the cell.

Phosphorus is absorbed by plants in the form of a higher oxide - ion phosphoric acid. Very important is the ability of phosphorus to form macroergic communication. Needed to characterize different groups of high-energy phosphate compounds - adenozinpolifosfaty (ATP, ADP), acetyl (1,3-phosphoglyceric acid) enolfosfaty (phosphoenolpyruvate), polyphosphates. Phosphorus is an essential component of a number of coenzyme systems (NAD, NADP, FAD). In addition, phosphorus is part of the nucleic acids, phospholipids. In all these various compounds phosphorus is in the oxidized form.

Potassium is absorbed from the environment in the form of ion K +, in the same form is carried to all parts of the plants and exerts its physiological effect. Potassium is found primarily in the ionic form, has a very high mobility and good reutiliziruetsya. Potassium absorption depends strongly on the content of it in a cage. Should analyze the possible mechanisms of regulation of the absorption of the element. In discussing the physiological role of potassium to identify the following issues: the importance of potassium in osmoregulation cells involved in ion photosynthesis and respiration, activation of potassium enzymatic reactions. Of inorganic potassium is a major osmotically active and this makes it an important factor of water exchange. He took part in the ongoing process of admission, transportation, and water evaporation plant, because of the concentration of potassium in the xylem sap of the root depends on the value of the pressure. Potassium is involved in stomatal movements. Potassium diet increases the tolerance of plants to adverse factors. Also multivalent role of potassium in photosynthesis: his participation is the phosphorylation reaction, potassium enables fixation of CO2 and has a role in the transport of the products of photosynthesis. A very large number of enzymes require the presence of potassium for maximum activity. The issue is part of potassium in a conformational transition of enzymes.

Magnesium can be found in the plant in the free diffusion state (70%) or to be associated with proteins, nucleic acids, phospholipids, polyphosphates. Discussing the physiological role of this element in the plant, we should show that many enzymatic reactions require magnesium or stimulated them. This transfer reaction or nucleotide phosphate catalyzed by phosphatases, kinases, ATP-basics, synthetases, nukleotidtransferazami, and the transport of the carboxyl groups catalyzed carboxylase. Magnesium is part of chlorophyll, the need to describe the importance of this element in the molecule. In addition, magnesium is required for ribosome association and performs a structural role in the stabilization of nucleic acids and membranes. Interesting is the role of magnesium in the light-dependent regulation of the activity of enzymes of CO2 fixation in chloroplasts: the outflow of magnesium in the stroma thylakoids to light is an activator ribulose-bisphosphate carboxylase.

In the role of calcium in the plant, highlight the main features: 1) a low concentration of the element in the cytoplasm in all eukaryotes, but a lot of the outer surface of plasma membrane, the cell wall and vacuole, 2) low physiological mobility, which is expressed in the slow rate of accumulation, transport from cell to cell and phloem transport, and 3) the importance of the processes of cell signaling as second messengers, and 4) an enzyme cofactor.

Quantitatively, the calcium is preferably in the apoplast. High concentrations within the cell are usually associated with its concentration in the vacuole in the form poorly soluble salts. In the apoplast calcium performs a protective role. It creates a favorable balance of elements and pH, delaying rupture of membranes and leakage of substances from the cell. Calcium is involved in shaping the structure of the cell wall. Characterized the role of calcium in the structural changes of the membranes. In this case, it acts as an intermolecular bonding agent. It can (forming calcium bridges) to interact with the phosphate, carboxyl groups of phospholipids protein. In this case, the conformation of the membrane and its properties - increased hydrophobicity, increased stability, reduced permeability to water. Calcium ions have a universal ability to conduct a variety of signals that have a primary effect on the cell: hormones potogenov, light, gravity, and stress. Too many external factors lead to a local increase in the concentration of cytoplasmic calcium and its interaction with various calcium-binding proteins (calmodulin, calcium-dependent calmodulin-independent protein kinase, protein kinase C), some of which change their activity, while others convey the effect of this cation to the many molecular targets.

Normal life of the plant organism is possible only under the condition that, apart from the above macro, they will be provided with trace elements is Fe, Cu, Mo, Zn, As, Mn, Cl, Ni, Co, Na. We must show the quantitative requirements of the plants in these elements and violations that occur in plants during their shortcomings. High and varied biological activity of trace elements due to the fact that they are associated with cell enzyme systems. Some of the trace elements are directly involved in the construction of the molecules needed for other enzymatic transformations as a cofactor. They may have an activating effect on the substrate - enzyme complexes.

The absorption of minerals from the soil or water solution useful to represent the four interrelated steps, including:

I) the movement of ions or salts in the soil toward the surface of the root system of the plant,

2) transport them from the root surface to the cytoplasm and vacuole of root cells, and

3) movement in a radial direction to the tissues of the root to the xylem vessels,

4) Transportation on the conduction system in the aerial parts. Each stage is localized to certain structures and has its own laws.

Characterizing patterns of ion transport in the cytoplasm of cells of the root, should discuss the cytoplasmic membrane permeability to ions and dynamics of ion transport through the membrane. Distinguish between passive transport (the gradient of electrochemical potential) and active (against gradient).

There are four types of membrane ion transport:

1. passive diffusion,
2. facilitated diffusion,
3. primary active transport,
4. secondary active transport (linked).

Specific features of the transport of ions in plant cells:

I) selectivity,

2) energy dependence, and

3) inhibition of metabolic inhibitors,

4) transport against the gradient,

5) temperature dependence.

The selectivity of the absorption process is based on the existence of the transfer stations in the membranes of cells - protein ion channels that are specific to certain ions. Depending on the nature of the ion and the charge transport dynamics and the mechanism of transport through the membrane may be different. Ion transport through the transfer of land in accordance with its electrochemical potential gradient is called facilitated diffusion.

Absorption elements against the electrochemical potential gradient is accomplished by active transport, ie by the energy of exergonic processes of cellular metabolism. Necessary to analyze the role of plasma membrane ATPase in the absorption of minerals, especially ionstimuliruemyh ATPase of plant cells.

Should consider the characteristics of the soil as substrate root plant nutrition and the role of roots in the life of the plant.

Modern intensive crop production is not possible without the use of fertilizers. Their proper use depends harvest. The theoretical basis of the use of fertilizers is the research on the physiology of mineral nutrition of plants. For the rational and efficient use of fertilizers should be applied system of fertilizers. This program is the use of fertilizers in crop rotation with the plant precursor of soil fertility, climate, and biological characteristics of plants and varieties, the composition and properties of fertilizers. Students need to know the main types of fertilizers.

Transport of substances in the plant

Contents: Transport of assimilates in the leaf blade.

Long-range transport of assimilates and other substances on the phloem. The structure of the phloem. Mechanisms of phloem transport. Regulation of phloem transport. Xylem transport. The composition of xylem sap. Xylem transport mechanisms. The dependence of the transport of substances through the plant from environmental factors.

Accumulation and release of substances (carbohydrates, organic acids, fats, proteins, salts). Cycling of matter in nature.

Long-range transport of substances in plants are the xylem and phloem, so it is necessary to characterize the structure of the transport system - xylem and phloem. Spatially they are combined to form a continuous conductive system, passing through all the organs and tissues of the plant. It is important to note that the distinctive features of the cell structure of tracheal cells and sieve tubes connected to their function. These cells do not have nuclei.

Xylem vessels in contact with the parenchymal cells of the central cylinder that actively transport ions in conducting xylem elements. When considering the xylem transport is necessary to understand the composition of xylem sap, loading and unloading mechanisms xylem elements, and the regulation of xylem transport.

Carbohydrates produced by photosynthesis in the leaves are transported through the vessels of the phloem in the form of sucrose. For each segment sieve tubes adjacent cell companion, which has a large core, many ribosomes and mitochondria and endoplasmic reticulum. Their function is to supply energy and messenger RNA.

In addition to the sugars in the phloem sieve tubes contains amino acids, hormones and minerals. Unlike xylem phloem sap movement is in the direction of the donor, ie the place where the synthesized substance, to an acceptor - where consumed or stocking products of photosynthesis. Transport in the phloem may occur even in two directions simultaneously. The direction is determined only relative position of the donor and acceptor. Sucrose is formed in the leaves, goes to the sieve tubes. The motion goes against the concentration gradient. Believe that is a joint transport of sucrose and proton through specific permeases in the plasma membrane of sieve tubes. This is due kotransport electrochemical potential gradient of hydrogen ion. This gradient is formed actively, that is, with the expenditure of energy by the proton ATPase, which pumps hydrogen ions out of the sieve tubes. Energy costs require retention of sucrose in the sieve tubes. In this regard, it is important to note the role of cell-companions in the supply of energy related sieve tubes. The most common theory to explain the mechanism of transport of assimilates to the phloem is the current theory under pressure. It is consistent with the available data on the pressure gradient and the osmotic gradient in the sieve tubes in the way of transportation.

Thus, if the process of phloem loading and retention of sucrose in the cells of the vascular bundles are energy, then the process of transport is on the purely physical gradients. However, the rate of transport depends on the rate of formation of carbohydrates in the donor areas and the rate of consumption in the acceptor and so much depends on metabolism.

The system of donor-acceptor bonds provides integration of functional systems and the integrity of the plant organism. Donor-acceptor relations are governed by the hormonal system and other, still scarcely explored regulatory factors. Transport of assimilates provides integration of photosynthesis, respiration, growth and morphogenesis and is one of the main factors of the endogenous regulation of photosynthesis

Lecture 14. The growth and development of plants.

Contents: Concept of growth, differentiation,
morphogenesis and development. Of growth common to all living organisms. The specific features of plant growth. Stages of ontogeny of higher plants. Ontogeny of plant cells. Cell division. The formation of the cell wall. Growth of protoplasm. Cell growth expansion. Growth of the cell wall. Differentiation. Mechanisms of differentiation. Differential gene activity. Mechanisms of morphogenesis. Competence. Determination. Polarity. Position effect. Correlation. Correlative stimulation and inhibition. Rhythm and timing of growth.

The principles of the regulation of growth and development. Internal factors that regulate growth and development.

Phytohormones:

auxins, gibberellins, cytokinins, abscisic acid, ethylene,
brassinosteroids, jasmonic and salicylic acid. Metabolism, transport, physiology and biochemistry of the actions of each hormone. Phenolic inhibitors. Synthetic growth regulators. External factors that regulate growth and development (light, temperature). Initiation of flowering. Vernalization. Photoperiodism. Determination of sex. Fitohromnaya sistema. Movements of plants. Mechanisms of movement. Tropisms. Infusion.

Growth - is an irreversible increase in the size and weight associated with the formation of new elements of the structure of the body. Plant growth is the sum of the growth of cells, tissues and organs.

Cell growth occurs in three phases: the division, elongation, and differentiation. The differentiation of cells - a process of transformation of meristematic cells capable of division in differentiated, ie specialized. This changes its structure and function. The emergence of functional and structural differences may occur not only at the cellular level, but also at the tissue and organism levels, then the more the term differentiation.

Morphogenesis - the process of formation, - is associated with a bookmark, growth and development of specialized tissues (hystogenesis), organs (organogenesis) plants. Development - qualitative changes in the structure and function of the plant and its parts - organs, tissues and cells that arise during ontogeny.

The life cycle of plants (ontogeny) - is the period from the formation of the zygote to the death of the organism. Passage plant life cycle depends on the nature of its genome and the external conditions that affect the expression of the various characteristics and qualities of this genotype.

Thus, two points define the shape and behavior of the organism - a genetic program embedded in the zygote, and the external environment in which the organism lives.

Should describe the stages of plant ontogenesis - fetal, juvenile, flowering, fruit and seed formation, aging and death. At each stage of ontogeny plant is formed by a combination of growth and development.

There is a pattern of growth common to all living organisms:

1) Most S-shaped growth curve. Curve consists of the following phases:

a) the latent phase of growth (lag phase), during this period there is preparation for growth, and

b) exponential growth phase (phase speed) - the growth rate increases in any parameter,

c) linear phase - in logarithmic terms is directly related to the time during this phase is very short, and

d) the deceleration phase of growth, and

e) the stationary phase, in this period, the amount of tissue, organ or plant stabilized, visible growth - minimal

e) phase of aging and death of the organism.

2) Rhythm - regularly recurring periods of active change and slow growth.

3) Polarity - orientation processes and structures in space.

Differentiation - the emergence of structural and functional differences in different cell and tissue development.

Irritability - response to changes in external factors, manifested in the change of life, in particular, the nature of growth and development.

Correlation - coordinated interaction of bodies.

Plant growth in a number of different growth characteristics in animals:

1.U plant embryonic cells form the zone of the meristem. Should describe the meristematic zone of plants. The growth of the plant organism is associated with cell division in these areas. Disassemble the types of growth characteristic plants.

2. Plants grow at all stages of ontogeny, ie inception of new organs and their growth occurs throughout ontogeny. In addition, parts of plants, such as root or stem have unlimited growth, ie

growth, which can last for a lifetime.

3. Plants have totipotence - the ability of cells to dedifferentiation and formation of a new whole body.

4. Ability to substitution of regeneration - regeneration when damaged by meristematic tissue.

5. Response to change the environment movement as tropisms and flooring.

Examining the ontogeny of the plant cell, it is necessary to know the features of the structure, metabolic activity in each phase of cell growth (embryonic, stretching and differentiation). Thus, in the meristematic cells (embryonic phase) a dominant role in the metabolism plays a core. Predominant anaerobic respiration pathway. In a phase of expansion growth is the absorption of water and an increase in the vacuole, loosening and subsequent growth of the cell wall. These processes are actively involved Golgi apparatus and endoplasmic reticulum.

However, at the same time in the cell there is a significant increase in the amount of protein, carbohydrates, DNA and RNA. All this is due to the high activity of the cytoplasm. In the process of differentiation of a variety of cells formed. Different cell types, depending on their features are different dominant processes.

What determines cell differentiation? What determines what type of cells are formed from meristematic? All cells have the property of totipotent, ie body cells contain a complete set of genetic information found in this organism. In the in vitro culture conditions, each cell, even differentiated, can give rise to new cells of different types. This means that the differentiation is not associated with qualitative difference genomes of cells, and the fact that every cell in the cycle of development is shown only part of her genetic potential, ie only active part of the gene - differential gene activity. Type of cell depends on which group of genes will be active and which will be in the inactivated state. The genes that determine growth and development, called genes switches development. Thus, at different periods of ontogeny realized only a certain part of the total stock of genetic information specific to the genotype

One of the most important foundations for the differential activity of the genome at different stages of plant development is the polarity - the specific orientation of the processes and structures in space. It leads to morphological and physiological gradients and is expressed in the difference in the properties on the opposite ends or sides of the cells, tissues, organs and the whole plant. A special role in this process belongs to the phytohormone auxin and calcium ions.

Every cell in the body is exposed to certain influences of the physical, chemical and physiological gradients and the influence of neighboring cells. As a result, cells that carried genetic information, which corresponds to the surrounding conditions. This theory is called position effect.

Determination of development - the acquisition of cells, tissues, organs and organisms get ready for development on a particular path, accompanied by a simultaneous limitations for development in other areas. During determination are necessary internal conditions for the subsequent implementation of the morphological development of a new direction.

Induction - the influence of internal and external factors, leading to the determination of development. Inductors: hormones, razlinye environmental factors (day length, light quality, temperature, etc.), some metabolites.

Competence - the ability to cell, tissue, organ, organism perceive inducing effect and react specifically to the development of a change. For example, some plants are able to go to flower in response to the induction of a favorable long day only at a certain age, when they have a relevant expertise. In the case of hormonal influences, organs and cells with competence, are targets of hormone action.

Plant organism is morphologically and physiologically integrated system and runs its ontogenetic stages in the interaction of all the organs and cells and the functioning of the regulatory systems of the body. Coordinated interaction of plants, adjustable phytohormones and ensures the development of plant growth hormone the body as a whole, is called correlation. The integrity of the plant organism systems provide different levels of regulation: intracellular (genes, enzymes, membranes), cell-cell and organism (hormonal, trophic and electrophysiological system of regulation).

Hormonal system.

Contents: Ability of the plant to coordinate the growth of individual organs and tissues by means of a specific regulatory system - a complex of plant hormones.

Hormones - substances present in the body in small amounts. They are synthesized in one part of the plant and then transported to another part, where it has a specific effect. It should identify the main criteria characterizing hormones, their common features and differences to other metabolites that have a regulatory effect on the metabolism. In considering the action of phytohormones on the physiological processes should separate the effect of stimulation and induction. Stimulation is reduced to increase the hormone already under way in the plant process, induction - inclusion under the hormone process, which did not go in his absence.

There are the following classes of plant hormones of the body, regulating growth:

auxins,

gibberellins,

cytokinins,

abscisic acid and

ethylene.

Natural auxin - indole-3-acetic acid (IAA) - synthesized in the meristems, growing embryos, ovules, in growing leaves and cotyledons. IAA is formed from the amino acid tryptophan. Auxin is transported actively, with the expenditure of energy and polarity in the stem - bazipetalno on phloem, and root - acropetally on parenchymal cells and kambialnm. In the polar auxin transport plays a significant role pH of the cytoplasm and cell wall, and is believed to have a specific carrier, located in the cell membrane at the lower end of the cell. IAA destruction carried out with participation of IAA oxidase. Enzyme activity increases in lighting conditions and this accounts for the decline of auxin content in the light.

In examining how the auxin, it must be emphasized many different effects on the plant, which it has.

Auxin affects all cellular activity (division, expansion and differentiation of cells), enhances root formation, cambial activity, growth of the ovary, callus growth in cell culture. Since the action of auxin related phenomenon of apical dominance. In discussing the mechanism of regulation of auxin growth stretching draws attention to the fact that the management of the growth of plant cells are the leading two factors: plant cell elongation and turgor pressure of the cell contents, acting on the cell wall. Feature of the auxin is that it increases the plastic extensibility of the cell walls. In examining the mechanism of action of auxin on the cell wall, it should be divided into three phases:

I) modification of polymer components of cell walls and loosening, which occurs due to the activation of H +-pump in the interaction with IAA receptors on plasma membrane, and

2) activation of the synthesis of proteins and phospholipids secreted to the cell surface, and secretion of vesicle contents to the Golgi apparatus by the interaction of auxin receptor localized in the membranes of the Golgi apparatus, and

3) the induction of transcription and activation of protein synthesis in the interaction with the receptor in the cytoplasm or the nucleoplasm.

Gibberellins - a group of important growth hormones. Currently there are more than 110 gibberellins, many of whom do not have physiological activity in plants. Gibberellins are isoprenoid compounds. Their biosynthesis proceeds through acetyl-CoA, mevalonic acid, diterpeneis. Synthesized in the intensively growing organs - stem apical buds forming seeds and roots.

The most striking manifestation of the gibberellin - stimulation of stem elongation. At the same time it increases the number of cell divisions in certain zones and stretch forming cells. Gibberellin often stimulates flowering in long-day plants. In addition, this hormone plays an important role in breaking the dormancy of tubers, bulbs and seeds, causing germination. Participation mechanism of gibberellin in the regulation of a number of morphogenetic responses such as seed germination, cell division and elongation, the laying of flowers, is the regulation of the formation of enzymes. When activated, the hydrolysis of starch in the endosperm of seeds gibberellin not only stimulates the synthesis of the enzyme.-amylase, but also promotes secretion from aleurone cells in the endosperm. Gibberellin as derepressora genes involved in the formation of mRNA molecules in the DNA matrix and thereby activates the enzyme. An important element of gibberellic signal are calcium ions. As derepressor gibberellin genes may influence the division and differentiation of cells in different parts of the plant. Which genes hormone action depends on the nature of the cells.

Cytokinins - a group of natural and synthetic compounds that are derivatives of adenine. Natural cytokinin - zeatin, synthetic - kinetin and benzylaminopurine (BAP). In plant cytokinins are synthesized in the growing root tips, are transported in the sap in the aboveground part of and participate in the regulation of growth of the aerial parts, structural and functional state of the cell sheet. Mutual effect of cytokinin and auxin is shown in a physiological phenomenon as apical dominance. The ratio of the concentrations of these hormones in the lateral buds is dependent on their position on the stem and determines their ability to bloom.

Cytokinins have a stimulating effect on cell division. Since cytokinins linked the phenomenon of delayed aging tissue. The mechanism of action of cytokinin, we should pay attention to the fact that the hormone produces an effect only after the occurrence of the interaction with the receptor. Thus, cytokinins bind to the receptor in the cytoplasm, then the hormone-receptor complex enters the nucleus and affects the activity of nuclear RNA polymerases, thereby activates the synthesis of all types of RNA. This in turn leads to the activation of protein synthesis necessary to maintain or restore their structure and functional activity. Possible effect of cytokinin on transcription and by increasing the template activity of chromatin.

Amplification of RNA synthesis accompanied by an increase in the content of the ribosomes in the cell, the formation of policy. All this leads to the activation of protein synthesis. Show that the effect of cytokinin on the process of protein synthesis is essential for plant growth. Please note that cytokinins regulate the differentiation of chloroplasts, affecting the expression of both nuclear and chloroplast genomes. Cytokinins are very active in the culture of plant cells when they are given together with the auxin. Moreover, the differentiation in tissue culture is dependent on the relative concentration of auxin and kinetin.

Ethylene and abscisic acid (ABA) - hormones that have a predominantly inhibitory effect on the growth processes involved in the regulation of aging and the rest of plants.

Ethylene is a hormone because it is formed in small quantities and can cause effects in cells that do not produce. Ethylene is formed from methionine. Ethylene provides regulatory control of morphological phenomena such as fruit ripening, abscission of leaves and fruits, wilting flowers, so it is called a hormone maturation, aging. Effect of ethylene on the ripening process of fruits is a multiple character. It increases the permeability of the membrane of the cells of the fetus, which increases the possibility of contact enzymes performing decay substances with their substrates, increases the synthesis of protein needed for maturation.

Ethylene has the effect of inhibiting the action of auxins, gibberellins and cytokinins. Ethylene is involved in the processes associated with the autumn leaf fall. With the approach of winter in the leaves decreases of cytokinins, which causes a decrease in activity of the processes of its life. But also decreases the amount of auxin, which causes changes in the excretory area of the sheet. This indicates the onset of aging paper. The action of ethylene is to accelerate the start of the aging of cells in the excretory area of the sheet. It stimulates the synthesis of cellulase - an enzyme that destroys the cell wall. As a result, cells excretory area apart under the weight of a sheet torn vessels, and the leaves fall. To understand the mechanism of action of ethylene and hormones in general is important to know that the artificial leaf ethylene treatment leads to such an effect only if you have already started the process of aging in the excretory area of the sheet, ie hormone action is mediated by body condition. It shows the general principle of the regulation of growth and development, based on the existence of two interacting systems - the hormones that provide the signal, and the condition of the cells, which is determined by the pre-development.

Abscisic acid (ABA) - a hormone that induces dormancy of plants and seeds, is sesquiterpenes, similar to the carotenoid molecule is synthesized and like them. Accumulates in the seeds fall kidneys, ABA induces and increases the period of rest, so delaying the germination of seeds and buds. The resumption of growth after the rest is usually associated with the destruction of ABA. Changing the content of ABA caused by seasonal variations in day length or temperature. Regarding the mechanism of action of ABA in the regulation of dormancy known that the hormone prevents the translation of mRNA to form an enzyme required for germination.

ABA is often formed in large quantities in response to exposure to environmental factors, so it is called the "stress hormone." Thus, the rapid synthesis of ABA is the shortage of water. In this case the hormone involved in regulation of stomatal movements, activating the flow of K + from the guard cells of stomata. As a result, stomatal closing the gap. A number of other stress effects also accompanied by dehydration plants. In these cases, the activation of ABA synthesis, which leads to the closing of the stomata.

Besides the above-mentioned hormones in recent years explored new hormones: brassinosteroids, jasmonic acid, salicylic acid.

Brassinosteroids - substances of steroid nature, are involved in the processes of photomorphogenesis. Jasmonic acid and its methyl ester control ripening and root growth, bending antennae formation of viable pollen, plant resistance to insects and pathogens.
In addition to hormones, growth inhibitory effect may have phenolic substances - coumarin, cinnamic acid, etc.
Phenolic inhibitors accumulate in the tissues of the plant during the transition to a state of rest or in the process of aging. The inhibitory effect of phenolic compounds is based on the fact that if any content decreases and increases the activity of IAA IAA oxidase. In addition, they have a divisive effect in the phosphorylation and thus slows down the process of energy production in the plant. Thus, regulation of metabolism in a multicellular organism includes a system of hormones that activate and inhibit growth. Physiological state, which is characteristic for each phase of growth, controlled by certain sootnosheniemveschestv stimulating and inhibiting the growth processes. Hormones believe nadkletochnym level of regulation in plants.

Lecture 15. Introduction on physiology of stress. Abiotic and biotic stresses

Contents: Sustainability as an adaptation of plants to the conditions of existence. Physiology of stress. Mechanisms of stress at the cellular and organismal levels. Drought resistance. Heat resistance. Cold and frost. Hardening of plants and physiological nature. Salt tolerance. Resistance of plants to heavy metals. Gas and radioresistance. Plant resistance to pathogens. Basic information about phytoimmunity. Physiology of diseased plants.

Ability to protect against damaging and adverse abiotic and biotic environmental factors - an inherent property of anyone, including the plant, the body. Adapting a combination of morphological, physiological and chemical adaptive responses to ensure the survival of a certain kind of ability of plants under the influence of adverse environmental conditions. A genetically determined process of formation stability systems to ensure the completion of the ontogenetic cycle of the organism. Adaptation strategy aimed at solving the same task - to maintain the structural integrity of macromolecules and maintaining regulatory systems, as well as providing the body with energy currency (primarily ATP), reducing agents and precursors of NK and proteins. The study of plant resistance to environmental stress conditions becomes of practical importance for agriculture, especially in areas with poor climate. This knowledge is also necessary to study the plants in the extreme conditions of existence. Plant response to damaging factor perceived genetic apparatus, with rapidly changing expression and genome rearrangement observed in protein synthesis (synthesis of various stress proteins such as heat shock proteins). Changes the organization of membranes, alteration of metabolism, synthesis and accumulation of a variety of protective (protective) compounds, such as proline, sucrose, polyamines, etc. In the long action of damaging factors are adaptive changes intended to repair damage due to energy costs, and then structural morphological transformations.

Students need to distinguish between nonspecific and specific plant response to the disturbing factor at the cellular level, the mechanisms of stress and adaptation at the organismal level.

In addition to the general theory of stability, it is necessary to have a notion of adaptation and resistance of plants to specific factors: drought and drought, low temperatures below zero and frost, low positive temperatures and cold resistance, heat resistance, and high temperature, salinity and salt tolerance, infectious diseases and various forms of immunity.

Plant resistance to biotic stresses

Contents: Plant adaptation to the herbivorous (*травоядный*) insects.

Introduction

Plants are not so vulnerable to insects.

When attacking pests, trees increase in leaves the content of phenols - caustic compounds that make up wood tar, which make the leaves "insipid". But here's what's interesting: along with the tree attacked, its neighbors take protective measures, as if they received an alarm signal.

Cyanide poisoning

This mechanism was developed by some plants (including apple and spinach) in the process of evolution, so as not to allow animals to quickly eat up the upper shoots and leaves. The plant accumulates hydrogen cyanide in the cells, which combines with carbohydrate and fat molecules and settles in the shoots and the upper part of the stem.

Hormone production

One of the components of the plant's mechanical sensation can be the hormones **jasmonates.**

They affect a variety of processes, from individual plant development to protection from pests.

When the level of jasmonates rises, in the tissues of the plant metabolites accumulate, literally causing indigestion in insect pests.

In addition, **jasmonates** help not only from insects, but also from certain fungal infections.

Their concentration in the tissues of the plant increases with mechanical action.

In this way the plants are protected from the invasion of caterpillars: the more insects creep along them, the stronger the mechanical irritation, the more defensive hormones are produced.

Alkaloids

Nicotine, cocaine, quinine, morphine, caffeine, strychnine, atropine, ephedrine.

They mimic their own hormones and insect pheromones, adversely affecting its growth, development, reproduction, or causing inappropriate behavioral responses."

Dutch botanist Marcel Dicke found that the plants affected by mites (*клещ*) attracted insects, natural enemies of mites, releasing a mixture of aromatic substances - terpenoids.

As soon as the mites (*клещ*) began to eat the bean leaves, predatory (*хищный*) insects rushed (*торопиться*) to them - there they waited for delicious food - the signal did not deceive them.

Many plants use protection from enemies (*враги*) with the help of insect-bodyguards. (*телохранители*)

Among them are cucumbers, tomatoes, corn.

In this case, the distress signal of a plant is sent sparingly, only if they are eaten by really enemies.

- **Plant resistance to viruses**

Plants have elaborate and effective defence mechanisms against viruses.

One of the most effective is the presence of ***resistance (R) genes***. Each R gene confers resistance to a particular virus by triggering localized areas of cell death around the infected cell. This stops the infection from spreading.

RNA interference is also an effective defence in plants.

When plants are infected, they often produce natural disinfectants which destroy viruses, such as *salicylic acid*, *nitric oxide* and *reactive oxygen molecules*.

- **R-gene mediated responses**

Each R gene confers resistance to a specific pathogen. The first phenotype of defence in most R-gene-mediated resistance responses is the ***hypersensitive response*** (HR). The HR includes ***programmed cell death*** (PCD), which occurs in cells at the site of infection and manifests as discrete necrotic lesions in otherwise phenotypically normal tissue.

- **Hypersensitive response**

The **hypersensitive response** (HR) is a mechanism, used by plants, to *prevent the spread of infection by microbial pathogens*. The HR is characterized by the rapid death of cells in the local region surrounding an infection. The HR serves to restrict the growth and spread of pathogens to other parts of the plant.

- **R-gene mediated responses**

The second phenotype of R-gene mediated resistance — ***systemic acquired resistance*** (SAR) — occurs in tissues that are distant from the initial infection site and renders them immune to infection by the same or closely related pathogens.

SAR is durable and can last for several weeks. SAR is characterized by the increased expression of several genes, named *pathogenesis-related genes*, that encode antimicrobial compounds.

- **Local and systemic resistance mediated by resistance (R) genes**

a) N-containing plant showing typical *hypersensitive response (HR)* necrotic lesions upon ***tobacco mosaic virus infection***. The uninfected upper leaves are symptom-free and do not contain virus.

b) During resistance, several signalling molecules are locally induced.

c) Subsequent to the HR, *systemic acquired resistance* is induced in distal uninfected tissue.

JA, jasmonic acid;

NO, nitric oxide;

SA, salicylic acid;

ROS, reactive oxygen species.

- **RNA silencing**

For decades, scientists and farmers have observed that diseased, virus-infected plants grow new, symptom-free leaves. In fact, the same (or a related) virus cannot infect the healthy upper leaves of these plants. This is described as '*recovery*', and RNA silencing has emerged as a potential mechanism of recovery.

RNA silencing is well characterized and conserved among plants, fungi, insects and animals.

Row **a** shows *Nicotiana clevelandii* plants infected with tomato black ring nepovirus. The plants recover from a primary infection (1) and are resistant to a secondary infection (2). The leaves in row **b** are mock-infected. Leaves are arranged from left to right in decreasing age.