**Lecture Summary**

Lecture 1. Introduction. Cell biology

The subject and tasks of cytology, its place and role in modern biology. The relationship of cytology with other disciplines: histology, embryology, genetics, biochemistry, molecular biology, biophysics, physiology, medicine, biotechnology.

A brief outline of the history of cytology. Research by R. Guk, A. Levenguk, Malpigi, Grue, F. Fontana, J. Purkinje, Brown, T. Schwann, Schleiden. The development of cytology in the second half of the 20th century.

Cell biology (also called cytology, from the Greek κύτος, kytos, "vessel") is a branch of biology that studies the structure and function of the cell, which is the basic unit of life. Cell biology is concerned with the physiological properties, metabolic processes, signaling pathways, life cycle, chemical composition, and interactions of the cell with their environment. This is done both on a microscopic and molecular level as it encompasses prokaryotic cells and eukaryotic cells. Knowing the components of cells and how cells work is fundamental to all biological sciences; it is also essential for research in bio-medical fields such as cancer, and other diseases. Research in cell biology is closely related to genetics, biochemistry, molecular biology, immunology, and cytochemistry. For some extra information, the recommendation is to check the biology resource in the external link.

Lecture 2. Cell structure

Cell

The cell (from Latin cella, meaning "small room") is the basic structural, functional, and biological unit of all known organisms. A cell is the smallest unit of life. Cells are often called the "building blocks of life". The study of cells is called cell biology or cellular biology.

Cells consist of cytoplasm enclosed within a membrane, which contains many biomolecules such as proteins and nucleic acids. Organisms can be classified as unicellular (consisting of a single cell; including bacteria) or multicellular (including plants and animals). The number of cells in plants and animals varies from species to species, it has been estimated that humans contain somewhere around 40 trillion (4×1013) cells. Most plant and animal cells are visible only under a microscope, with dimensions between 1 and 100 micrometres.

Cells were discovered by Robert Hooke in 1665, who named them for their resemblance to cells inhabited by Christian monks in a monastery. Cell theory, first developed in 1839 by Matthias Jakob Schleiden and Theodor Schwann, states that all organisms are composed of one or more cells, that cells are the fundamental unit of structure and function in all living organisms, and that all cells come from pre-existing cells. Cells emerged on Earth at least 3.5 billion years ago.

Cell types

Cells are of two types: eukaryotic, which contain a nucleus, and prokaryotic, which do not. Prokaryotes are single-celled organisms, while eukaryotes can be either single-celled or multicellular.

Prokaryotic cells

Structure of a typical prokaryotic cell

Prokaryotes include bacteria and archaea, two of the three domains of life. Prokaryotic cells were the first form of life on Earth, characterised by having vital biological processes including cell signaling. They are simpler and smaller than eukaryotic cells, and lack membrane-bound organelles such as a nucleus. The DNA of a prokaryotic cell consists of a single circular chromosome that is in direct contact with the cytoplasm. The nuclear region in the cytoplasm is called the nucleoid. Most prokaryotes are the smallest of all organisms ranging from 0.5 to 2.0 µm in diameter.

A prokaryotic cell has three architectural regions:

Enclosing the cell is the cell envelope – generally consisting of a plasma membrane covered by a cell wall which, for some bacteria, may be further covered by a third layer called a capsule. Though most prokaryotes have both a cell membrane and a cell wall, there are exceptions such as Mycoplasma (bacteria) and Thermoplasma (archaea) which only possess the cell membrane layer. The envelope gives rigidity to the cell and separates the interior of the cell from its environment, serving as a protective filter. The cell wall consists of peptidoglycan in bacteria, and acts as an additional barrier against exterior forces. It also prevents the cell from expanding and bursting (cytolysis) from osmotic pressure due to a hypotonic environment. Some eukaryotic cells (plant cells and fungal cells) also have a cell wall.

Inside the cell is the cytoplasmic region that contains the genome (DNA), ribosomes and various sorts of inclusions. The genetic material is freely found in the cytoplasm. Prokaryotes can carry extrachromosomal DNA elements called plasmids, which are usually circular. Linear bacterial plasmids have been identified in several species of spirochete bacteria, including members of the genus Borrelia notably Borrelia burgdorferi, which causes Lyme disease. Though not forming a nucleus, the DNA is condensed in a nucleoid. Plasmids encode additional genes, such as antibiotic resistance genes.

On the outside, flagella and pili project from the cell's surface. These are structures (not present in all prokaryotes) made of proteins that facilitate movement and communication between cells.

Eukaryotic cells

Plants, animals, fungi, slime moulds, protozoa, and algae are all eukaryotic. These cells are about fifteen times wider than a typical prokaryote and can be as much as a thousand times greater in volume. The main distinguishing feature of eukaryotes as compared to prokaryotes is compartmentalization: the presence of membrane-bound organelles (compartments) in which specific activities take place. Most important among these is a cell nucleus, an organelle that houses the cell's DNA. This nucleus gives the eukaryote its name, which means "true kernel (nucleus)". Other differences include:

The plasma membrane resembles that of prokaryotes in function, with minor differences in the setup. Cell walls may or may not be present.

The eukaryotic DNA is organized in one or more linear molecules, called chromosomes, which are associated with histone proteins. All chromosomal DNA is stored in the cell nucleus, separated from the cytoplasm by a membrane. Some eukaryotic organelles such as mitochondria also contain some DNA.

Many eukaryotic cells are ciliated with primary cilia. Primary cilia play important roles in chemosensation, mechanosensation, and thermosensation. Each cilium may thus be "viewed as a sensory cellular antennae that coordinates a large number of cellular signaling pathways, sometimes coupling the signaling to ciliary motility or alternatively to cell division and differentiation."

Motile eukaryotes can move using motile cilia or flagella. Motile cells are absent in conifers and flowering plants. Eukaryotic flagella are more complex than those of prokaryotes.

Lecture 3. Cell wall

A cell wall is a structural layer surrounding some types of cells, just outside the cell membrane. It can be tough, flexible, and sometimes rigid. It provides the cell with both structural support and protection, and also acts as a filtering mechanism. Cell walls are present in most prokaryotes (except mollicute bacteria), in algae, fungi and eukaryotes including plants but are absent in animals. A major function is to act as pressure vessels, preventing over-expansion of the cell when water enters.

The composition of cell walls varies between species and may depend on cell type and developmental stage. The primary cell wall of land plants is composed of the polysaccharides cellulose, hemicelluloses and pectin. Often, other polymers such as lignin, suberin or cutin are anchored to or embedded in plant cell walls. Algae possess cell walls made of glycoproteins and polysaccharides such as carrageenan and agar that are absent from land plants. In bacteria, the cell wall is composed of peptidoglycan. The cell walls of archaea have various compositions, and may be formed of glycoprotein S-layers, pseudopeptidoglycan, or polysaccharides. Fungi possess cell walls made of the N-acetylglucosamine polymer chitin. Unusually, diatoms have a cell wall composed of biogenic silica.

History

A plant cell wall was first observed and named (simply as a "wall") by Robert Hooke in 1665. However, "the dead excrusion product of the living protoplast" was forgotten, for almost three centuries, being the subject of scientific interest mainly as a resource for industrial processing or in relation to animal or human health.

In 1804, Karl Rudolphi and J.H.F. Link proved that cells had independent cell walls. Before, it had been thought that cells shared walls and that fluid passed between them this way.

The mode of formation of the cell wall was controversial in the 19th century. Hugo von Mohl (1853, 1858) advocated the idea that the cell wall grows by apposition. Carl Nägeli (1858, 1862, 1863) believed that the growth of the wall in thickness and in area was due to a process termed intussusception. Each theory was improved in the following decades: the apposition (or lamination) theory by Eduard Strasburger (1882, 1889), and the intussusception theory by Julius Wiesner (1886).

In 1930, Ernst Münch coined the term apoplast in order to separate the "living" symplast from the "dead" plant region, the latter of which included the cell wall.

By the 1980s, some authors suggested replacing the term "cell wall", particularly as it was used for plants, with the more precise term "extracellular matrix", as used for animal cells, but others preferred the older term.

Properties

Cell walls serve similar purposes in those organisms that possess them. They may give cells rigidity and strength, offering protection against mechanical stress. The chemical composition and mechanical properties of the cell wall are linked with plant cell growth and morphogenesis. In multicellular organisms, they permit the organism to build and hold a definite shape. Cell walls also limit the entry of large molecules that may be toxic to the cell. They further permit the creation of stable osmotic environments by preventing osmotic lysis and helping to retain water. Their composition, properties, and form may change during the cell cycle and depend on growth conditions.

Rigidity of cell walls

In most cells, the cell wall is flexible, meaning that it will bend rather than holding a fixed shape, but has considerable tensile strength. The apparent rigidity of primary plant tissues is enabled by cell walls, but is not due to the walls' stiffness. Hydraulic turgor pressure creates this rigidity, along with the wall structure. The flexibility of the cell walls is seen when plants wilt, so that the stems and leaves begin to droop, or in seaweeds that bend in water currents. As John Howland explains

Think of the cell wall as a wicker basket in which a balloon has been inflated so that it exerts pressure from the inside. Such a basket is very rigid and resistant to mechanical damage. Thus does the prokaryote cell (and eukaryotic cell that possesses a cell wall) gain strength from a flexible plasma membrane pressing against a rigid cell wall.

The apparent rigidity of the cell wall thus results from inflation of the cell contained within. This inflation is a result of the passive uptake of water.

In plants, a secondary cell wall is a thicker additional layer of cellulose which increases wall rigidity. Additional layers may be formed by lignin in xylem cell walls, or suberin in cork cell walls. These compounds are rigid and waterproof, making the secondary wall stiff. Both wood and bark cells of trees have secondary walls. Other parts of plants such as the leaf stalk may acquire similar reinforcement to resist the strain of physical forces.

Permeability

The primary cell wall of most plant cells is freely permeable to small molecules including small proteins, with size exclusion estimated to be 30-60 kDa. The pH is an important factor governing the transport of molecules through cell walls.

Evolution

Cell walls evolved independently in many groups.

The photosynthetic eukaryotes (so-called plant and algae) is one group with cellulose cell walls, where the cell wall is closely related to the evolution of multicellularity, terrestrialization and vascularization. The CesA cellulose synthase evolved in Cyanobacteria and was part of Archaeplastida since endosymbiosis; secondary endosymbiosis events transferred it (with the arabinogalactan proteins) further into brown algae and oomycetes. Plants later evolved various genes from CesA, including the Csl (cellulose synthase-like) family of proteins and additional Ces proteins. Combined with the various glycosyltransferases (GT), they enable more complex chemical structures to be built.

Fungi use a chitin-glucan-protein cell wall. They share the 1,3-β-glucan synthesis pathway with plants, using homologous GT48 family 1,3-Beta-glucan synthases to perform the task, suggesting that such an enzyme is very ancient within the eukaryotes. Their glycoproteins are rich in mannose. The cell wall might have evolved to deter viral infections. Proteins embedded in cell walls are variable, contained in tandem repeats subject to homologous recombination. An alternative scenario is that fungi started with a chitin-based cell wall and later acquired the GT-48 enzymes for the 1,3-β-glucans via horizontal gene transfer. The pathway leading to 1,6-β-glucan synthesis is not sufficiently known in either case.

Plant cell walls

The walls of plant cells must have sufficient tensile strength to withstand internal osmotic pressures of several times atmospheric pressure that result from the difference in solute concentration between the cell interior and external solutions. Plant cell walls vary from 0.1 to several µm in thickness.

Layers

Up to three strata or layers may be found in plant cell walls:

The primary cell wall, generally a thin, flexible and extensible layer formed while the cell is growing.

The secondary cell wall, a thick layer formed inside the primary cell wall after the cell is fully grown. It is not found in all cell types. Some cells, such as the conducting cells in xylem, possess a secondary wall containing lignin, which strengthens and waterproofs the wall.

The middle lamella, a layer rich in pectins. This outermost layer forms the interface between adjacent plant cells and glues them together.

Composition

In the primary (growing) plant cell wall, the major carbohydrates are cellulose, hemicellulose and pectin. The cellulose microfibrils are linked via hemicellulosic tethers to form the cellulose-hemicellulose network, which is embedded in the pectin matrix. The most common hemicellulose in the primary cell wall is xyloglucan. In grass cell walls, xyloglucan and pectin are reduced in abundance and partially replaced by glucuronarabinoxylan, another type of hemicellulose. Primary cell walls characteristically extend (grow) by a mechanism called acid growth, mediated by expansins, extracellular proteins activated by acidic conditions that modify the hydrogen bonds between pectin and cellulose. This functions to increase cell wall extensibility. The outer part of the primary cell wall of the plant epidermis is usually impregnated with cutin and wax, forming a permeability barrier known as the plant cuticle.

Secondary cell walls contain a wide range of additional compounds that modify their mechanical properties and permeability. The major polymers that make up wood (largely secondary cell walls) include:

cellulose, 35-50%

xylan, 20-35%, a type of hemicellulose

lignin, 10-25%, a complex phenolic polymer that penetrates the spaces in the cell wall between cellulose, hemicellulose and pectin components, driving out water and strengthening the wall.

Additionally, structural proteins (1-5%) are found in most plant cell walls; they are classified as hydroxyproline-rich glycoproteins (HRGP), arabinogalactan proteins (AGP), glycine-rich proteins (GRPs), and proline-rich proteins (PRPs). Each class of glycoprotein is defined by a characteristic, highly repetitive protein sequence. Most are glycosylated, contain hydroxyproline (Hyp) and become cross-linked in the cell wall. These proteins are often concentrated in specialized cells and in cell corners. Cell walls of the epidermis may contain cutin. The Casparian strip in the endodermis roots and cork cells of plant bark contain suberin. Both cutin and suberin are polyesters that function as permeability barriers to the movement of water. The relative composition of carbohydrates, secondary compounds and proteins varies between plants and between the cell type and age. Plant cells walls also contain numerous enzymes, such as hydrolases, esterases, peroxidases, and transglycosylases, that cut, trim and cross-link wall polymers.

Secondary walls - especially in grasses - may also contain microscopic silica crystals, which may strengthen the wall and protect it from herbivores.

Cell walls in some plant tissues also function as storage deposits for carbohydrates that can be broken down and resorbed to supply the metabolic and growth needs of the plant. For example, endosperm cell walls in the seeds of cereal grasses, nasturtium and other species, are rich in glucans and other polysaccharides that are readily digested by enzymes during seed germination to form simple sugars that nourish the growing embryo.

Formation

The middle lamella is laid down first, formed from the cell plate during cytokinesis, and the primary cell wall is then deposited inside the middle lamella. The actual structure of the cell wall is not clearly defined and several models exist - the covalently linked cross model, the tether model, the diffuse layer model and the stratified layer model. However, the primary cell wall, can be defined as composed of cellulose microfibrils aligned at all angles. Cellulose microfibrils are produced at the plasma membrane by the cellulose synthase complex, which is proposed to be made of a hexameric rosette that contains three cellulose synthase catalytic subunits for each of the six units. Microfibrils are held together by hydrogen bonds to provide a high tensile strength. The cells are held together and share the gelatinous membrane called the middle lamella, which contains magnesium and calcium pectates (salts of pectic acid). Cells interact though plasmodesmata, which are inter-connecting channels of cytoplasm that connect to the protoplasts of adjacent cells across the cell wall.

In some plants and cell types, after a maximum size or point in development has been reached, a secondary wall is constructed between the plasma membrane and primary wall. Unlike the primary wall, the cellulose microfibrils are aligned parallel in layers, the orientation changing slightly with each additional layer so that the structure becomes helicoidal. Cells with secondary cell walls can be rigid, as in the gritty sclereid cells in pear and quince fruit. Cell to cell communication is possible through pits in the secondary cell wall that allow plasmodesmata to connect cells through the secondary cell walls.

Lecture 4. Cell membrane

The cell membrane (also known as the plasma membrane (PM) or cytoplasmic membrane, and historically referred to as the plasmalemma) is a biological membrane that separates the interior of all cells from the outside environment (the extracellular space) which protects the cell from its environment. Cell membrane is consisted of a lipid bilayer, including cholesterols (a lipid component) that sit between phospholipids to maintain their fluidity under various temperature, in combination with proteins such as integral proteins, and peripheral proteins that go across inside and outside of the membrane serving as membrane transporter, and loosely attached to the outer (peripheral) side of the cell membrane acting as several kinds of enzymes shaping the cell , respectively. The cell membrane controls the movement of substances in and out of cells and organelles. In this way, it is selectively permeable to ions and organic molecules. In addition, cell membranes are involved in a variety of cellular processes such as cell adhesion, ion conductivity and cell signalling and serve as the attachment surface for several extracellular structures, including the cell wall, the carbohydrate layer called the glycocalyx, and the intracellular network of protein fibers called the cytoskeleton. In the field of synthetic biology, cell membranes can be artificially reassembled.

History

While Robert Hooke’s discovery of cells in 1665 led to the proposal of the Cell Theory, Hooke misled the cell membrane theory that all cells contained a hard cell wall since only plant cells could be observed at the time. Microscopists focused on the cell wall for well over 150 years until advances in microscopy were made. In the early 19th century, cells were recognized as being separate entities, unconnected, and bound by individual cell walls after it was found that plant cells could be separated. This theory extended to include animal cells to suggest a universal mechanism for cell protection and development. By the second half of the 19th century, microscopy was still not advanced enough to make a distinction between cell membranes and cell walls. However, some microscopists correctly identified at this time that while invisible, it could be inferred that cell membranes existed in animal cells due to intracellular movement of components internally but not externally and that membranes weren’t the equivalent of a cell wall to plant cell. It was also inferred that cell membranes weren’t vital components to all cells. Many refuted the existence of a cell membrane still towards the end of the 19th century. In 1890, an update to the Cell Theory stated that cell membranes existed, but were merely secondary structures. It wasn’t until later studies with osmosis and permeability that cell membranes gained more recognition. In 1895, Ernest Overton proposed that cell membranes were made of lipids.

The lipid bilayer hypothesis, proposed in 1925 by Gorter and Grendel, created speculation to the description of the cell membrane bilayer structure based on crystallographic studies and soap bubble observations. In an attempt to accept or reject the hypothesis, researchers measured membrane thickness. In 1925 it was determined by Fricke that the thickness of erythrocyte and yeast cell membranes ranged between 3.3 and 4 nm, a thickness compatible with a lipid monolayer. The choice of the dielectric constant used in these studies was called into question but future tests could not disprove the results of the initial experiment. Independently, the leptoscope was invented in order to measure very thin membranes by comparing the intensity of light reflected from a sample to the intensity of a membrane standard of known thickness. The instrument could resolve thicknesses that depended on pH measurements and the presence of membrane proteins that ranged from 8.6 to 23.2 nm, with the lower measurements supporting the lipid bilayer hypothesis. Later in the 1930s, the membrane structure model developed in general agreement to be the paucimolecular model of Davson and Danielli (1935). This model was based on studies of surface tension between oils and echinoderm eggs. Since the surface tension values appeared to be much lower than would be expected for an oil–water interface, it was assumed that some substance was responsible for lowering the interfacial tensions in the surface of cells. It was suggested that a lipid bilayer was in between two thin protein layers. The paucimolecular model immediately became popular and it dominated cell membrane studies for the following 30 years, until it became rivaled by the fluid mosaic model of Singer and Nicolson (1972).

Despite the numerous models of the cell membrane proposed prior to the fluid mosaic model, it remains the primary archetype for the cell membrane long after its inception in the 1970s. Although the fluid mosaic model has been modernized to detail contemporary discoveries, the basics have remained constant: the membrane is a lipid bilayer composed of hydrophilic exterior heads and a hydrophobic interior where proteins can interact with hydrophilic heads through polar interactions, but proteins that span the bilayer fully or partially have hydrophobic amino acids that interact with the non-polar lipid interior. The fluid mosaic model not only provided an accurate representation of membrane mechanics, it enhanced the study of hydrophobic forces, which would later develop into an essential descriptive limitation to describe biological macromolecules.

For many centuries, the scientists cited disagreed with the significance of the structure they were seeing as the cell membrane. For almost two centuries, the membranes were seen but mostly disregarded this as an important structure with cellular function. It was not until the 20th century that the significance of the cell membrane as it was acknowledged. Finally, two scientists Gorter and Grendel (1925) made the discovery that the membrane is “lipid-based”. From this, they furthered the idea that this structure would have to be in a formation that mimicked layers. Once studied further, it was found by comparing the sum of the cell surfaces and the surfaces of the lipids, a 2:1 ratio was estimated; thus, providing the first basis of the bilayer structure known today. This discovery initiated many new studies that arose globally within various fields of scientific studies, confirming that the structure and functions of the cell membrane are widely accepted.

The structure has been variously referred to by different writers as the ectoplast (de Vries, 1885), Plasmahaut (plasma skin, Pfeffer, 1877, 1891), Hautschicht (skin layer, Pfeffer, 1886; used with a different meaning by Hofmeister, 1867), plasmatic membrane (Pfeffer, 1900), plasma membrane, cytoplasmic membrane, cell envelope and cell membrane. Some authors who did not believe that there was a functional permeable boundary at the surface of the cell preferred to use the term plasmalemma (coined by Mast, 1924) for the external region of the cell.

Composition

Cell membranes contain a variety of biological molecules, notably lipids and proteins. Composition is not set, but constantly changing for fluidity and changes in the environment, even fluctuating during different stages of cell development. Specifically, the amount of cholesterol in human primary neuron cell membrane changes, and this change in composition affects fluidity throughout development stages.

Material is incorporated into the membrane, or deleted from it, by a variety of mechanisms:

Fusion of intracellular vesicles with the membrane (exocytosis) not only excretes the contents of the vesicle but also incorporates the vesicle membrane's components into the cell membrane. The membrane may form blebs around extracellular material that pinch off to become vesicles (endocytosis).

If a membrane is continuous with a tubular structure made of membrane material, then material from the tube can be drawn into the membrane continuously.

Although the concentration of membrane components in the aqueous phase is low (stable membrane components have low solubility in water), there is an exchange of molecules between the lipid and aqueous phases.

Lecture 5. Cytoplasm: structure, purpose, biology, biochemical aspects.

Cytoplasm. General characteristics of the structure and functions of the cytoplasm. The matrix of the cytoplasm (hyaloplasm), the trabecular system of hyaloplasm. Cytoplasmic membranes: the role of lipids and proteins in the organization of cell membranes. The structure of cell membranes, modern models of lipoprotein membranes. Membrane asymmetry: structural and functional. Vacuum system and membrane organelles in the cytoplasm.

Plasma membrane. The chemical composition and structure of the plasma membrane in different types of cells. Plasmaolem function. Transport functions: cell permeability, passive and active transport of substances through the membrane. Receptor functions of plasmolemma: protein and polysaccharide cell surface receptors. Lectins, capping and cell surface cleaning. The role of the plasma membrane in the processes of phagocytosis and pinocytosis. Other functions of the plasma membrane: the formation of intercellular contacts (simple contact, desmosomes, tight contact, gap junctions, synapses) and specialized structures (microvilli, cilia, flagella, special phytoreceptor structures).

Lecture 6. Endoplasmic reticulum, Golgi apparatus: structure, purpose, biology, biochemical aspects.

Endoplasmic reticulum. General characteristics, discovery using light and electron microscopy. The structure and functions of granular endoplasmic reticulum. The main role of the granular endoplasmic reticulum as a structure involved in the synthesis of proteins exported from the cell. Synthesis, accumulation and transport of synthesized protein in the endoplasmic reticulum. Reticulum as a source of cytoplasmic membranes. The structure and functions of the smooth (agranular) endoplasmic reticulum. The connection of a smooth endoplasmic reticulum with the synthesis of polysaccharides, fats, steroids and other molecules. The role of smooth EPS in the deactivation of various chemical agents. Sarcoplasmic reticulum in striated muscle tissue and its function.

Golgi apparatus (plate complex): general characteristics, localization in the cell, microscopic structure, ultrastructure and chemistry. Dictiosome. Golgi apparatus functions: segregation, maturation and excretion of secrets and other substances in the cell. Autoradiographic data on the ways of synthesis and excretion of secretory products in the cell. Synthetic processes in the Golgi apparatus.

Lecture 7. Mitochondria and plastids: structure, purpose, biology, biochemical aspects.

Mitochondria and plastids. The structure of mitochondria: membranes, cristae, matrix. Their role in the synthesis and accumulation of ATP. Ways of ATP synthesis in cells: anaerobic glycolysis and oxidative phosphorylation. The structure of cristae, localization of oxidative phosphorylation units in lipoprotein membranes. Changes in the structure of mitochondria depending on their functional state. Giant mitochondria. Mitochondrial matrix: RNA, ribosomes, DNA and mitochondrial proteins. Problems of the origin of mitochondria. Analogs of mitochondria in bacteria.

Plastids. General characteristics, structure, classification. The functions of chloroplasts. Photosynthetic structures of lower eukaryotic and prokaryotic cells. Ontogenesis and functional rearrangement of plastids.

Lecture 8. Cell nucleus: structure, purpose, biology, biochemical aspects.

Cell nucleus. The role of the nucleus in the life of the cell. The core functions of the nucleus are transcription, reduction, and redistribution of genetic material. The structure and chemistry of the cell nucleus: chromatin (chromosomes), nucleolus, karyoplasma, nuclear membrane, nuclear matrix.

Chromatin and chromosomes. The chemical characteristics of chromatin (DNP, DNA, histone proteins). Diffuse and condensed chromatin, euchromatin and heterochromatin, their functional significance. Chromatin structural organization: chromatin fibrils, nucleosomes and nucleomers. The structure of active and repressed chromatin.

Chromosome cycle, the concept of chromosome continuity throughout the entire life cycle of a cell. The structure, types and forms of mitotic chromosomes. Differential staining of chromosomes. The concept of a karyotype. Ultrastructural organization of chromosomes. The hypothesis of a polynemial and uninemal chromosome structure.

The nucleolus. General characteristic: the number of nucleoli in the nucleus, their chromosomal origin (nucleolar organizers). The chemical structure of the nucleolus (DNA, RNA, proteins). The nucleolus is the site of ribosomal RNA synthesis. The structure of ribosomes pro- and eukaryotes. Ultrastructural organization of the nucleolus, granular and fibrillar components. The structure of the nucleolus in connection with its function. The fate of the nucleolus during cell division.

Nuclear shell and nuclear matrix. The structure and functions of the nuclear envelope. The structure of nuclear pores. The relationship of the nuclear membrane with cytoplasmic structures and chromosomes. Nuclear envelope and nuclear plasma exchange. The fate of the nuclear membrane during cell division.

The chemical composition of karyoplasm (nuclear juice), the structure of the nuclear matrix.

Lecture 9. Ribosomes: structure, purpose, biology, biochemical aspects.

Ribosomes comprise a complex macromolecular machine, found within all living cells, that serves as the site of biological protein synthesis (translation). Ribosomes link amino acids together in the order specified by messenger RNA (mRNA) molecules. Ribosomes consist of two major components: the small ribosomal subunits, which read the mRNA, and the large subunits, which join amino acids to form a polypeptide chain. Each subunit consists of one or more ribosomal RNA (rRNA) molecules and a variety of ribosomal proteins (r-protein or rProtein). The ribosomes and associated molecules are also known as the translational apparatus.

Overview

The sequence of DNA, which encodes the sequence of the amino acids in a protein, is copied into a messenger RNA chain. It may be copied many times into RNA chains. Ribosomes can bind to a messenger RNA chain and use its sequence for determining the correct sequence of amino acids for generating a given protein. Amino acids are selected, collected, and carried to the ribosome by transfer RNA (tRNA) molecules, which enter one part of the ribosome and bind to the messenger RNA chain. It is during this binding that the correct translation of nucleic acid sequence to amino acid sequence occurs. For each coding triplet in the messenger RNA there is a distinct transfer RNA that matches and which carries the correct amino acid for that coding triplet. The attached amino acids are then linked together by another part of the ribosome. Once the protein is produced, it can then fold to produce a specific functional three-dimensional structure although during synthesis some proteins start folding into their correct form.

A ribosome is made from complexes of RNAs and proteins and is therefore a ribonucleoprotein. Each ribosome is divided into two subunits:

1) a smaller subunit which binds to a larger subunit and the mRNA pattern, and

2) a larger subunit which binds to the tRNA, the amino acids, and the smaller subunit.

When a ribosome finishes reading an mRNA molecule, these two subunits split apart. Ribosomes are ribozymes, because the catalytic peptidyl transferase activity that links amino acids together is performed by the ribosomal RNA. Ribosomes are often associated with the intracellular membranes that make up the rough endoplasmic reticulum.

Ribosomes from bacteria, archaea and eukaryotes in the three-domain system, resemble each other to a remarkable degree, evidence of a common origin. They differ in their size, sequence, structure, and the ratio of protein to RNA. The differences in structure allow some antibiotics to kill bacteria by inhibiting their ribosomes, while leaving human ribosomes unaffected. In bacteria and archaea, more than one ribosome may move along a single mRNA chain at one time, each "reading" its sequence and producing a corresponding protein molecule.

The mitochondrial ribosomes of eukaryotic cells, are produced from mitochondrial genes, and functionally resemble many features of those in bacteria, reflecting the likely evolutionary origin of mitochondria.

Lecture 10. Chloroplasts: structure, purpose, biology, biochemical aspects.

Chloroplasts are organelles that conduct photosynthesis, where the photosynthetic pigment chlorophyll captures the energy from sunlight, converts it, and stores it in the energy-storage molecules ATP and NADPH while freeing oxygen from water in plant and algal cells. They then use the ATP and NADPH to make organic molecules from carbon dioxide in a process known as the Calvin cycle. Chloroplasts carry out a number of other functions, including fatty acid synthesis, much amino acid synthesis, and the immune response in plants. The number of chloroplasts per cell varies from one, in unicellular algae, up to 100 in plants like Arabidopsis and wheat.

A chloroplast is a type of organelle known as a plastid, characterized by its two membranes and a high concentration of chlorophyll. Other plastid types, such as the leucoplast and the chromoplast, contain little chlorophyll and do not carry out photosynthesis.

Chloroplasts are highly dynamic—they circulate and are moved around within plant cells, and occasionally pinch in two to reproduce. Their behavior is strongly influenced by environmental factors like light color and intensity. Chloroplasts, like mitochondria, contain their own DNA, which is thought to be inherited from their ancestor—a photosynthetic cyanobacterium that was engulfed by an early eukaryotic cell. Chloroplasts cannot be made by the plant cell and must be inherited by each daughter cell during cell division.

With one exception (the amoeboid Paulinella chromatophora), all chloroplasts can probably be traced back to a single endosymbiotic event, when a cyanobacterium was engulfed by the eukaryote. Despite this, chloroplasts can be found in an extremely wide set of organisms, some not even directly related to each other—a consequence of many secondary and even tertiary endosymbiotic events.

The word chloroplast is derived from the Greek words chloros (χλωρός), which means green, and plastes (πλάστης), which means "the one who forms".

Lecture 11. Cell division: mitosis, meiosis.

Cell reproduction. Cell life cycle: presynthetic, synthetic, postsynthetic phase and mitosis. The significance of these phases in cell life. Division of prokaryotic cells.

The general scheme of indirect division (mitosis) of eukaryotic cells. Mitosis in protozoa.

Mitosis of animal cells. The stages of mitosis, their duration and characteristics. Cytokinesis in animals and plant cells: the formation of cell constriction and flagoplasts. The fate of cellular organelles in the process of cell division. Metabolism of dividing cells.

Regulation of mitosis, the issue of the triggering mechanism of mitosis.

Amitosis - direct cell division.

Meiosis, stages of meiosis. Chromosome conjugation, crossing over, reduction of the number of chromosomes. The biological meaning of meiosis. Chromosomes like lamp brushes. Differences between mitosis and meiosis.

Centriol: occurrence among animal cells. Ultrastructure: replication, participation in cell division. Functional changes of the centriolar apparatus in the cell life cycle. Analogs of centrioles in protozoa. The connection of centriolar structures with organelles of cell movement: basal bodies. The structure of cilia and flagella in eukaryotic cells.

Cytoskeleton. Microtubules: their fine structure and chemistry. Tubulins, their properties and role in the formation of microtubules. The role of microtubules in the formation of achromatin spindle cell division. The role of the spindle in the divergence of chromosomes in mitosis. The skeleton role of cytoplasmic microtubules. Microfilaments: composition, structure, functions. The relationship of microfilaments with the plasma membrane and other cellular organelles. Microfibrils, or intermediate microfilaments, their characteristics and role. Tonofibrils.

Lecture 12. Non-cellular life forms and cell division. Cell theory

The role of viruses in cell biology. The role of viruses in the evolution of the organic world.

Virus (lat. Virus - poison) is a non-cellular infectious agent that can be reproduced only inside living cells. Viruses infect all types of organisms, from plants and animals to bacteria and archaea (bacterial viruses are commonly called bacteriophages). Viruses capable of replicating only in the presence of other viruses (satellite viruses) have also been detected.

Since the publication in 1892 of an article by Dmitry Ivanovsky describing the non-bacterial pathogen of tobacco plants and the discovery in 1898 by Martin Beyerink of the tobacco mosaic virus, more than 6 thousand types of viruses have been described in detail, although they suggest that there are more than one hundred million of them. Viruses are found in almost every ecosystem on Earth, they are the most numerous biological form. The study of viruses is the science of virology, a section of microbiology.

In animals, viral infections cause an immune response, which most often leads to the destruction of the pathogenic virus. The immune response can also be triggered by vaccines that give active acquired immunity against a specific viral infection. However, some viruses, including the human immunodeficiency virus and causative agents of viral hepatitis, manage to elude the immune response, causing a chronic disease. Antibiotics do not act on viruses, but several antiviral drugs have been developed.

Cell theory

A cell is an elementary unit of the living. Prokaryotic and eukaryotic cells. Homology in the structure of cells. A cell as a unit of structure, functioning, development, pathological changes in an organism. Cell division is the only way to increase their number.

Differentiation as a process of formation of specialized cells.

Lecture 13. Cellular inclusions. Lysosomes.

Cellular inclusions.

Lysosomes. The history of their discovery, structure, their chemical characteristics, types of lysosomes. The functional significance of lysosomes, their origin. The relationship of lysosomes with intracellular digestion, phagocytosis and the work of the Golgi apparatus. Autophagosomes.

Lecture 14. Methods of cell research.

Methods for the study of cells and tissues

Light and electron microscopy (the basis of methods and application in the study of the structure and function of cells). Methods of studying living cells (cell culture outside the body, dark-field, phase-contrast, polarizing, luminescent microscopy, time-lapse micrograph). Methods for the study of fixed cells (cytochemical qualitative and quantitative methods).

Immunochemical methods for studying cellular components (Koons reaction, hybridomas, obtaining monoclonal antibodies).

Lecture 15. Applied aspects of cell biology. Cell differentiation. Cell pathology.

Applied aspects of cell biology: 3D printing, cell bioengineering and so on.

Cell differentiation - the emergence of a heterogeneous cellular composition of the body, providing a variety of its functions. The role of the nucleus and cytoplasm in cell differentiation. Factors of differentiation and regulation of this process. Fetal determination.

Induction effects. Humoral and nerve differentiation factors. Tumor transformation.

The effect of damaging factors on the cell. Theory of paranecrosis. Change in the structure of organelles during cell damage. Intracellular repair. Cell death: cytological signs of cell death. The effect of alcohol on cells.