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MEDICAL FACULTY

Department of Histology, Embryology, Cytology

COURSE OF LECTURES ON GENERAL HISTOLOGY

Manual

Approved by the Ministry of Education and Science
of the Kyrgyz Republic as a manual
for students of higher education institutions

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The course of lectures on General histology is based on the modern educational standard and curriculum for the discipline "Histology" for medical schools. It contains the main provisions of the subject, information (98 figures, 3 tables) and didactic materials necessary for the successful development of the course of General histology.

The content of lectures corresponds to the qualification characteristics of medical University graduates.

The material is intended for students of medical universities majoring in "General Medicine", "Dentistry" and "Pediatrics" in order to organize and improve the effectiveness of independent work in preparation for classes.

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CONTENT

PREFACE

Dear colleagues!

This publication reflects the authors long-term experience in teaching of histology. The need for this publication – to concentrate modern scientific knowledge on General histology – is long overdue.

The course of lectures on General histology contains sections: epithelial and connective tissues, muscle tissue, and nerve tissue. This sequence in the study of the subject by first-year students is logically justified and contributes to the understanding and assimilation in the future of materials on special sections of histology. Presents up-to-date information on the issues presented.

The advantage of this publication is that each topic provides basic material, which is accompanied by numerous drawings that facilitate the perception and memorization of educational material. As illustrations, we use the most important drawings from these literary sources.

The main goal of the compilers was to provide students with a compact work in which the structure of human tissues is described briefly, concretely, clearly, at a high scientific level.

The completeness of the main material allows us to recommend this publication to students of medical universities. Using the materials of lectures, students can independently prepare for classes in the section "General histology", as well as consciously use ideas about the body functioning in their future profession.

We take this opportunity to express our gratitude to all the authors who shared their scientific knowledge and experience in teaching histology with us.

The authors express their gratitude to the leading specialist of the Department of Histology M.M. Yakubova for providing leading Specialist technical assistance in compiling the course of lectures.

INTRODUCTION

Interaction of the organism with the environment, adaptation (adaptability) of the organism to different conditions of existence caused the emergence of various structures – cells, tissues and organs, as well as certain functions that are inextricably linked to them.

General histology studies general patterns of tissue structure, or the actual doctrine of tissues.

Tissue is a historically (phylogenetically) developed system of cells and non-cellular structures that has a common structure and function.

To describe the material about any tissue you need to answer 4 questions: 1) sources of tissue development; 2) tissue localization; 3) structure and 4) function.

In embryogenesis, tissues develop from three germ leaves. The transformation of the germ into tissue-histogenesis – is a process during which cells and intercellular formations of each germ specialize in different directions – differentiate, acquire specific structures characteristic of each tissue and corresponding physiological and chemical properties (differentiation is temporary, spatial, and biochemical). The process of differentiation of tissue cells is regulated by the nervous, endocrine systems and tissue mechanisms. Intra-tissue mechanisms of regulation include keylons, substances produced by mature (differentiated) cells that can suppress the differentiation of undifferentiated cells.

The structure of the tissue may include: cells, supracellular structures (simplasts, syncytia), intercellular substance (collagen, elastic, reticular fibers, amorphous substance). Each tissue contains a strictly defined set of listed elements and their specific representatives. In turn, each organ contains a certain set of tissues (or their elements) of different types and (or) groups. In this case, cells of the same type of tissue in different organs may have certain features. All tissues are

deterministic (defined), i.e., their properties are fixed in evolution and the transformation of one tissue into another is normally impossible.

In 1857, F. Leydig proposed a classification of tissues, according to which they are divided into four types: epithelial, connective, muscular and nervous.

According to the number of functions performed, there are general and special tissues. General tissues perform many functions. These include epithelial and connective tissues.

Tissues of a special nature perform one specific function. These include muscle and nerve tissues.

Epithelial tissues are characterized by morphologically close association of cells in layers. They perform the functions of protection, absorption and secretion.

Muscle tissue provides movement of internal organs and the body as a whole. There are smooth muscle tissue consisting of elongated cells, and striated muscle tissue, which is composed of skeletal muscle tissue consisting of muscle fibers – simplasts, and cardiac muscle tissue consisting of cells – cardiomyocytes.

The nervous tissue consists of nerve cells – neurocytes, whose main function is to perceive and conduct excitation, and gliocytes, which perform trophic, supporting, protective, differentiating and secretory functions.

In the course of life, the body is affected by many factors that damage tissues. Most tissues have the ability to regenerate, i.e. recover from natural death or damage (physiological and reparative regeneration).

The regenerative process in different tissues proceeds differently. On this basis, several types of regeneration can be distinguished: intracellular, cellular, histotypic, and organotypic. For example, epithelial tissues are resistant to the damaging effects of external factors, since they have a high degree of regeneration, due to the presence of cambial cells (blood stem cells). There are active mitotic processes and intracellular regeneration in the skin epithelium. In cardiac

muscle tissue of cambial cells (misallocation) no. When it is damaged, only histotypic regeneration occurs, i.e. the replacement of muscle cells with connective tissue.

Thus, a detailed knowledge of the elements of general histology will lay the foundation for a scientific structural and functional approach to the analysis of the human body's vital activity in normal and pathological conditions.

EPITHELIAL TISSUE

Epithelial tissues cover the surfaces and line the body cavities, form mucous and serous membranes of internal organs (stomach, intestines, bladder, kidneys, lungs, etc.), and are also part of the body's glands.

The epithelium of the skin performs a protective function, protecting against damage to other tissues of the body. Intestinal epithelium has trophic and secretory functions, because it participates in the processes of digestion and absorption of nutrients. The epithelium of the lungs performs the function of gas exchange, and the epithelium of the kidneys – excretory function. The epithelium of the glands has a secretory function.

Epithelial tissue has 7 distinctive features:

1) borderline location between external and internal environment;
2) always consists in the form of a layer of cells;
3) connection to the basal membrane;
4) has a polarity;
5) has no blood vessels;
6) high regeneration ability;
7) lack of intercellular substance.

Firstly, epithelial tissue occupies a border position, since it is located on the border with the external and internal environment of the body.

Secondly, the epithelium consists of epithelial cells that form continuous layers.

Third, epithelial cells lie on the basement membrane.

Fourth, epithelial cells are characterized by a polarity – basal pole and apical pole. The nucleus is always displaced to the basal pole and elongated along the physiological axis. The endoplasmic reticulum is shifted to the basal pole. The basal pole is adjacent to the basal membrane.

Fifth, there are no blood vessels in the epithelial layers and cell nutrition is provided by the diffusion of nutrients from the underlying connective tissue.

Sixth, epithelial cells die very quickly and also multiply quickly.

Seventh, the epithelial tissue has no intercellular substance-fibers and the main substance.

Genetic classification of epithelial tissue by N. G. Khlopin

The classification is based on the sources of epithelial development. Distinguish epidermal (skin), enterodermal (intestinal), tselonephrodermal, ependimoglial, angiodermal types of epithelium (Table 1).

The epidermal (skin) type of epithelium develops from the skin ectoderm (external germ leaf), has a multi-layer structure (multi-layer flat keratinized skin epithelium), performs a protective function.

Enterodermal (intestinal) type of epithelium develops from the intestinal endoderm (internal germ leaf), is a single-layer prismatic epithelium in structure, performs the function of absorption of substances (single-layer edged epithelium of the small intestine).

Tselonefrodermal type of epithelium develops from the mesoderm (middle germ leaf), the structure - a single-layer flat, cubic, prismatic epithelium (flat epithelium of serous membranes-mesothelium, cubic and prismatic epithelium in the urinary tubules of the kidneys), performs excretory, barrier functions.

Ependymoglial type of epithelium, developed from the neural tube, is an epithelium lining the brain cavity.

Angiodermal type of epithelium develops from the mesenchyme, structure – single-layer of single squamous epithelium (epithelium of blood vessels), is involved in metabolism.

Table 1

Classification of epithelium by origin (N.G. Khlopin)

Source	Epithelium type	Examples
1. ectoderm	**epidermal**	skin epithelium, sebaceous, sweat, salivary glands
2. endoderm	**endodermal**	epithelium of the stomach, small intestine and almost the entire colon; parenchyma of the liver and pancreas
3. mesoderm	**tselonephrodermal**	epithelium of serous membranes, epithelium of renal tubules
4. neural tube	**ependymoglial**	epithelium of the brain cavities
5. mesenchyme	**angiodermal**	vascular endothelium

Morphological classification of epithelium

By location, the glandular epithelium and the integumentary epithelium are distinguished.

Glandular secretory epithelium forms most of the glands (pancreas, salivary glands, etc.).

The integumentary epithelium is located on the border with the external or internal environment of the body.

Morphological classification of the integumentary epithelium is based on three features: the number of cell layers, the shape of cells and the structure of their free (apical) surface (Figure 1).

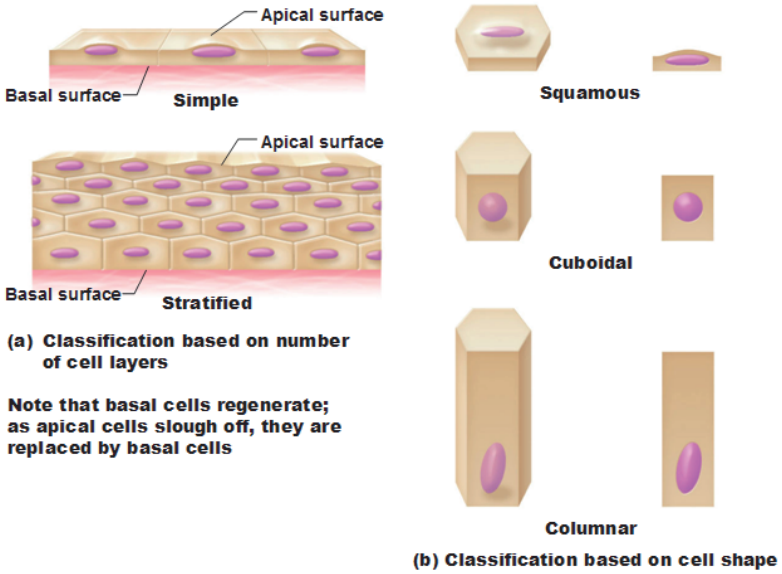
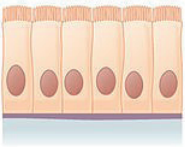
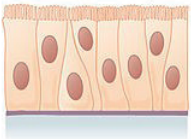
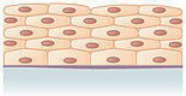
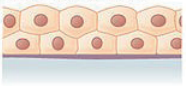
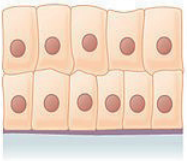
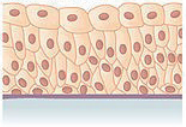


Figure 1. Classifications of epithelium

Based on the number of cell layers, the epithelium is divided into single-layer and multi-layer. In a single-layer epithelium, all cells are connected to the basement membrane, and in a multi-layer epithelium, only the lower (basal) layer is connected to the basement membrane, and the remaining layers are devoid of such a connection and are connected to each other. In turn, the single-layer epithelium is divided into single-row and multi-row according to the location of the nuclei. In a single-row epithelium, all the cell nuclei are located at the same level, in a single row. In a multi-row epithelium, the cell nuclei are located at different levels, in several rows. According to the shape of the cells, the epithelium is divided into flat, cubic, prismatic or cylindrical. In this case, the multilayer epithelium takes into account only the shape of the outer layers of cells, and not the lower layers (Table 2).

Table 2

Morphological classification of epithelium

Cells	Location	Function
Simple squamous epithelium 	Air sacs of lungs and the lining of the heart, blood vessels, and lymphatic vessels	Allows materials to pass through by diffusion and filtration, and secretes lubricating substance
Simple cuboidal epithelium 	In ducts and secretory portions of small glands and in kidney tubules	Secretes and absorbs
Simple columnar epithelium 	Ciliated tissues are in bronchi, uterine tubes, and uterus; smooth (nonciliated tissues) are in the digestive tract, bladder	Absorbs; it also secretes mucous and enzymes
Pseudostratified columnar epithelium 	Ciliated tissue lines the trachea and much of the upper respiratory tract	Secretes mucus; ciliated tissue moves mucus
Stratified squamous epithelium 	Lines the esophagus, mouth, and vagina	Protects against abrasion
Stratified cuboidal epithelium 	Sweat glands, salivary glands, and the mammary glands	Protective tissue
Stratified columnar epithelium 	The male urethra and the ducts of some glands	Secretes and protects
Transitional epithelium 	Lines the bladder, uretha, and the ureters	Allows the urinary organs to expand and stretch

Multilayered epithelium is transitional, nonkeratinized and keratinized.

An example of a transitional epithelium can be the epithelium of the human bladder, which is distinguished by two or three layers depending on the stretching of the walls of the organ when its volume changes.

In a multi-layer flat nonkeratinized epithelium, there are three layers. In this type of epithelium, there are no processes of keratinization.

The epithelium in which there is keratinization is called a multilayered flat keratinizing epithelium.

Keratinization processes are associated with the transformation of the cells of the upper layers into horny scales. In this epithelium, there are four or five layers depending on the type of skin (thin skin – four layers, thick skin – five layers).

Epithelial cells on their free (upper, apical) surface may have cilia, microvilli. These structural features are also taken into account when classifying the epithelium (Figure 2).

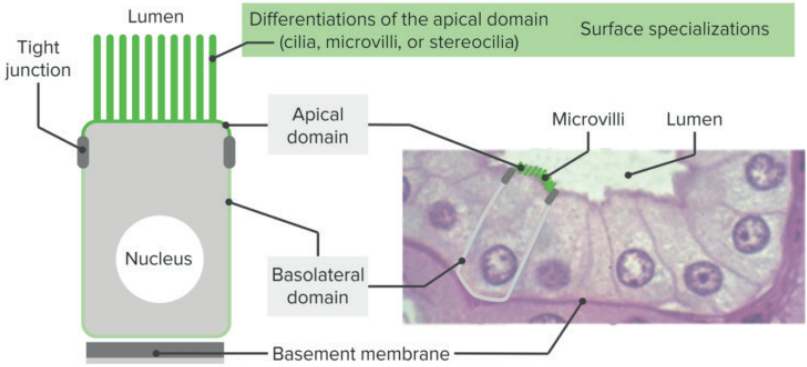


Figure 2. Characteristics of epithelial cells

So the epithelium of the human respiratory tract is equipped with cilia and therefore it is called a single-layer multi-row prismatic ciliated or scintillating epithelium.

The epithelium of the human intestine has microvilli, the combination of which forms a brush border. This epithelium is called a single-layer single-row edged epithelium. Epithelial cells are firmly connected to each other by desmosomes.

Single-layer single-row flat epithelium

This type of epithelium has a flat shape. The nuclei are oval in shape, lie closer to the basal pole and are located at the same level (Figure 3). All epithelial cells are connected to the basement membrane. It covers the surface of the pulmonary alveoli and the posterior surface of the cornea of the eye. There are also endothelium and mesothelium.

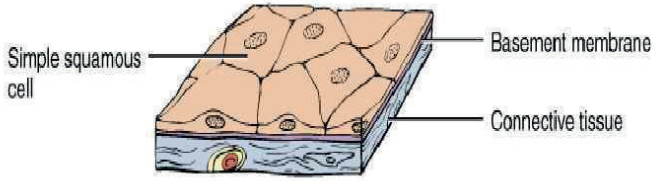


Figure 3. Simple squamous epithelium

The endothelium lines the blood vessels and chambers of the heart. It is a layer of flat cells-endotheliocytes, lying in a single layer on the basement membrane. Organelles are few and located in the near-nuclear zone. The endothelium regulates the metabolism between blood and other tissues.

The mesothelium that covers the serous membrane – the pleural layers, the visceral and parietal peritoneum, the pericardial SAC. It is a very thin layer of flat cells with a slight thickening in the area of the nucleus location. Through the mesothelium, serous fluid is secreted

and absorbed. Thanks to its smooth surface is easy to slide the internal organs. Mesothelium prevents the formation of connective tissue adhesions, the development of which is possible if its integrity is violated.

Single-layer single-row cubic epithelium

This type of epithelium lines the tubules of the kidney, small ducts of the pancreas, liver, salivary glands, and respiratory bronchioles. These cells have a cubic shape (Figure 4). The nuclei are rounded, lie closer to the basal pole and are located at the same level. In the epithelium of the renal excretory tubules, cells in the basal part have a strongly folded basal membrane that extends deep into the cytoplasm, increasing the basal surface of cells and promoting water reabsorption.

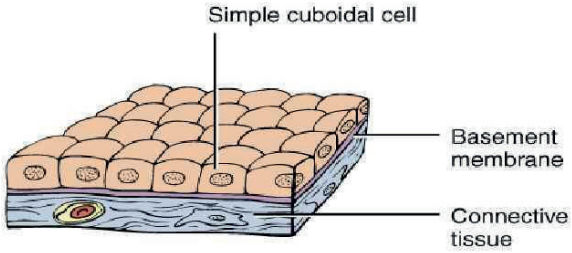


Figure 4. Simple cuboidal epithelium

Cells can have a basal striation formed by internal folds of the cytolemma in the basal part of the cell and mitochondria located between them. The epithelium of the renal tubules performs the function of reverse absorption (reabsorption) of a number of substances from the primary urine into the blood.

Single-layer single-row prismatic epithelium

This type of epithelium is more common in the middle part of the digestive system (stomach, small intestine, colon, gall bladder). The epithelium is formed by prismatic (cylindrical) cells. All epithelial cells are connected to the basement membrane. Their oval-shaped nuclei lie closer to the basal pole of the cell and are arranged in a single row. A single-layer, single-row prismatic epithelium on the apical part may have microvilli, which is why such an epithelium is called a marginal epithelium (Figure 5). This epithelium lines the intestine, so it is called the intestinal epithelium. The set of microvilli forms a brush border. The presence of villi increases the free surface area of the epithelial cell. Microvilli play an extremely important role in the process of wall digestion: they adsorb various substances on their surface, which are concentrated at the base of the microvilli, and then enter the cytoplasm of the cell. Through the epithelium formed products are absorbed into the blood.

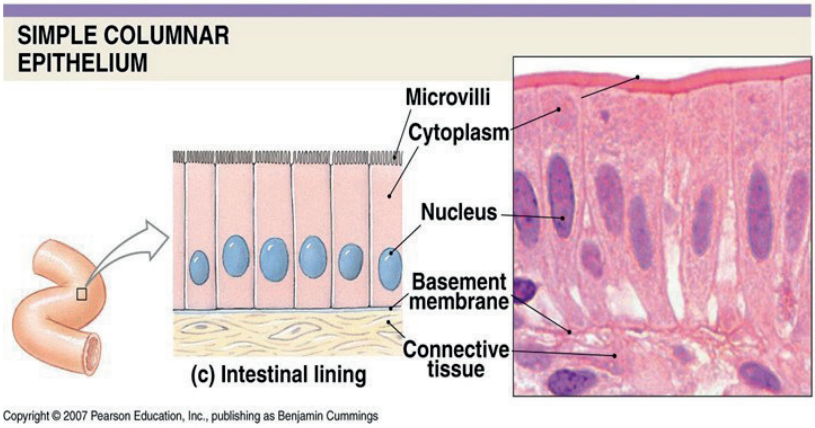


Figure 5. Simple columnar epithelium

Single-layer multi-row ciliated epithelium

This type of epithelium lines the airways. In the airways, multi-row epithelium is also called ciliated or ciliated. In the epithelium, there are ciliated cells (scintillating), goblet-shaped, basal, and endocrine. All epithelial cells of this type lie on the basement membrane, and the nuclei of epithelial cells are located at different levels. Basal cells have a triangular shape, small, able to divide and turn into ciliated and goblet-shaped cells. They are also called cambial cells or insertion cells.

Ciliated cells are scintillating cells. Their shape is prismatic. There are up to 250 cilia on the free surface of each scintillating cell. The movements of the cilia are undulating and very fast. The cilia flicker in the opposite direction to the inhaled air, most intensely at a temperature of 18–33 °C. The movement of the cilia helps to remove dust and microorganisms from the airways (Figure 6).

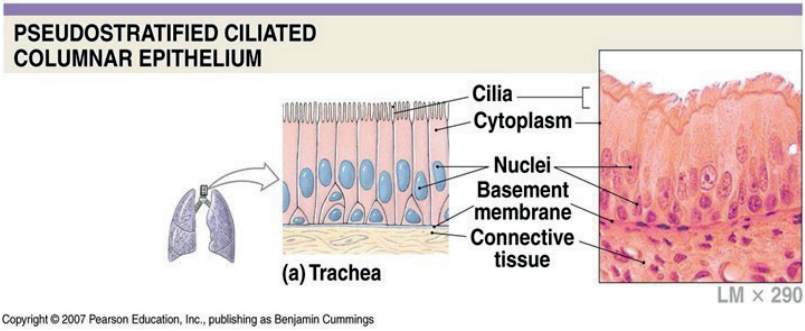


Figure 6. Pseudostratified ciliated columnar epithelium

Goblet cells – unicellular mucous glands endoepithelially (Figure 7). They secrete a mucous secret (mucin) on the surface of the scintillating epithelium. The mucus secret moistens the epithelium and creates conditions for sticking dust particles that get into the air and are removed when coughing. The nuclei of goblet cells are displaced to the basal membrane.

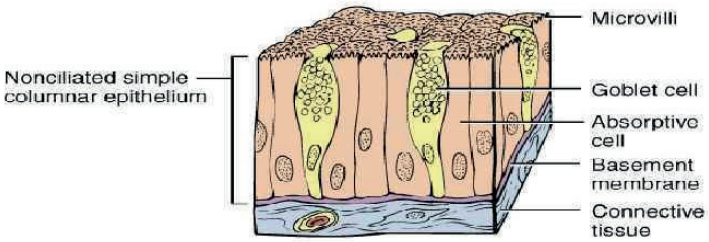


Figure 7. Simple columnar epithelium

In the cytoplasm of these cells are large drops of secretions, which gradually shift to the apical end of the cell, so that the cell becomes goblet-shaped.

Endocrine (basal-granular) cells have a pyramidal shape, a rounded core and secretory granules. Secretory granules are located at the basal pole of the cell, which is why the endocrine cell is called basal-granular. Granules contain hormones and biogenic amines: norepinephrine, serotonin, dopamine, which regulate the contraction of muscle cells in the airways.

In a single-layer multi-row prismatic ciliated epithelium, several rows of nuclei can be distinguished. This epithelium consists of cells of various shapes and heights, their nuclei lying on different levels, that is, in several rows.

Stratified squamous nonkeratinized epithelium

Covers the outside of the cornea of the eye, lining the mouth and esophagus. There are three layers: basal, spiny, and flat. The basal layer consists of prismatic epithelial cells located on the basal membrane. Cells are capable of mitotic division. The spiked layer consists of irregular polygonal epithelial cells that are strongly linked by numerous desmosomes. In places of desmosomes on the surface of cells there are tiny outgrowths – "spines", directed towards each other.

In the basal and spiny layers, the cells have well-developed tonofibrils, and the cells themselves multiply intensively by mitosis, forming a growth zone.

The upper layers of the epithelium are formed by flat cells. Their nutrition deteriorates, they die and fall off the surface of the epithelium (Figure 8).

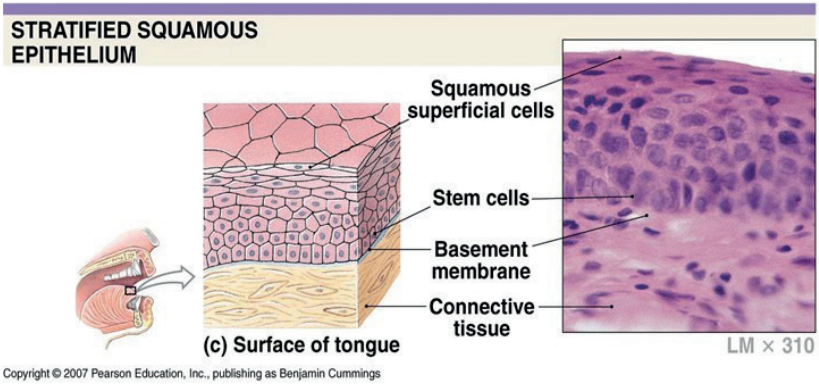


Figure 8. Keratinized and non-keratinized stratified squamous epithelium

Stratified squamous keratinizing epithelium

It covers the surface of the skin, forming its epidermis. In the epidermis of the skin of the palms and soles, there are 5 main layers: basal, spiny, grainy, shiny and Horny. The skin of the rest of the body has an epidermis, which lacks a shiny layer. The basal layer consists of cylindrical cells that are located on the basal membrane and multiply intensively by mitosis. These cells are attached to the basement membrane by semidesmosomes. The spiked layer is formed by polygonal cells that are connected by desmosomes. The cells of the spiny layer are capable of mitotic division and they are combined with the cells of the basal layer into one – the germ zone. Granular layer consists of flattened cells, in the cytoplasm which contain tokoferoly and granules keratohyalin. The shiny layer is formed by flat cells containing

the protein eleidin. The core and organoids in them disappear. The corneal layer is formed by Horny scales filled with a corneal substance-soft keratin. Dead epithelial cells peel off and are called horn scales (Figure 9).

The formation of corneal matter is called keratinization. The process of keratinization involves the transformation of keratohyalin into eleidin, and then in keratin of the Horny substance. The corneal layer of the epithelium is important for protecting the skin from mechanical influences.

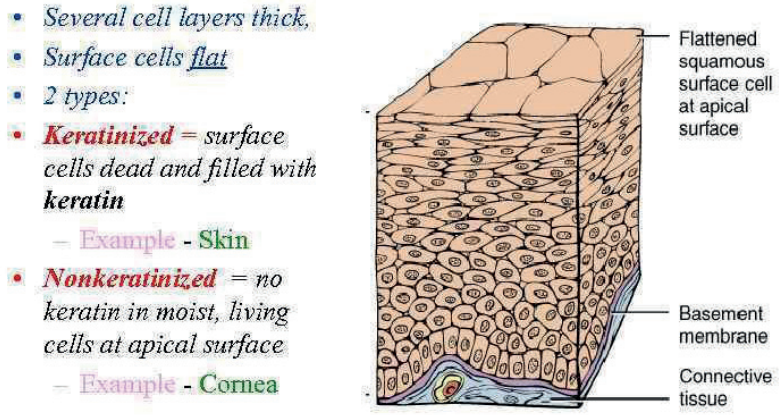


Figure 9. Stratified squamous epithelium

The transitional epithelium

This type of epithelium lines the urinary tract – the ureters, the bladder, the walls of which are subject to significant stretching when filled with urine. During the stretching of the organ wall, the epithelium becomes thinner – two-layer. When the organ is reduced, the thickness of the epithelial layer increases sharply, the epithelium becomes three-layered. When the walls of the organ stretch and fall, the shape of the cells changes, flat cells take a domed shape. This feature of

epithelial cells is reflected in the name – transitional. It is distinguished by three layers – basal, intermediate, and surface.

The basal layer is formed by rounded cells located on the basal membrane. The cells of this layer are poorly differentiated and constantly divide mitotically. The intermediate layer contains cells of various polygonal shapes. This layer consists of one or two rows of irregularly shaped cells, some cells are connected by cytoplasmic processes to the basement membrane. The cells are closely adjacent to each other, most often they are pear-shaped.

The surface layer consists of large multinucleated cells that have a flattened or domed shape depending on the state of the organ wall. When the wall is stretched due to the filling of the organ with urine, the epithelium becomes two-layer and is represented by the basal layer and the surface layer. The cells of the surface layer have several nuclei and a flat shape.

When the organ wall is reduced, the epithelium becomes three-layered and is represented by basal, intermediate and surface layers. The cells of the surface layer have a domed shape (Figure 10). Dense contacts were found between the surface cells, which are important for preventing the penetration of fluid through the wall of an organ (for example, the bladder).

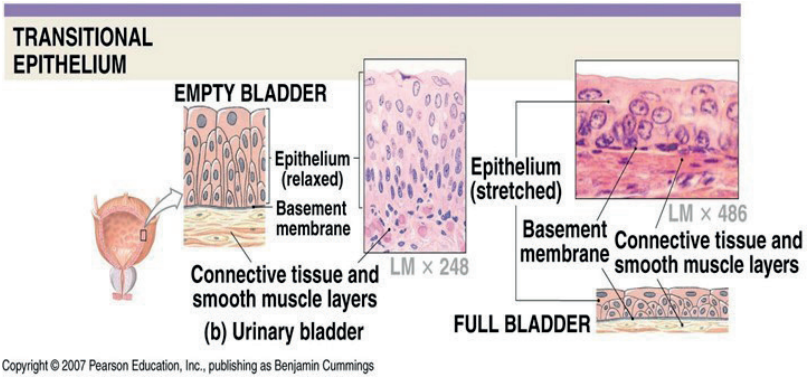


Figure 10. Transitional epithelium in a relaxed and distended states

Glandular epithelium

The glandular epithelium consists of secretory cells glandulocytes in which is formed a secret. Their form is varied and varies depending on the phase of secretion. Most cells are characterized by polarity, the nucleus is located closer to the basement membrane. In all secretory cells, the endoplasmic network is very well developed. In the cytoplasm of cells that produce a secret of a protein nature, the granular endoplasmic network is well developed.

In cells that synthesize lipids and carbohydrates, the agranular endoplasmic network is better developed. In the apical sections, secretory granules are usually present. Glandulocytes lie on the basement membrane predominantly in one layer or in several layers. As, for example, goblet cells, the main glandular cells of the stomach glands, additional mucous cells of the glands of the bottom of the stomach.

Glandulocytes carry out the synthesis and release from the cells of substances necessary for the functioning of the body.

The function of the glandular epithelium is secretion. This is a complex process involving **4 phases**: 1) absorption of initial substances by glandulocytes; 2) synthesis and accumulation of a secret in them; 3) secretion from glandulocytes - extrusion; 4) restoration of the structure of glandulocytes. These phases can occur in granulocytic cyclically, that is, one after another, in the form of so-called secretory cycle.

Phases of the secretory cycle

The first phase is the absorption of the initial substances by glandulocytes. This phase of secretion consists in the fact that from the blood to the glandulocytes from the basal surface come various substances-organic, inorganic, water, etc.

The second phase is the synthesis and accumulation of secret in the glandulocytes. Secrets are synthesized from these substances

in the endoplasmic reticulum. The secret is synthesized at the endoplasmic reticulum moves to the area of the Golgi complex, where it gradually accumulates and is made in the form of pellets. Secretory granules are unlaced from the Golgi complex.

The third phase is the secretion of from glandulocites. This occurs differently, and therefore there are three types of secretion: merocrine, apocrine, and holocrine (Figure 11.1–11.2).

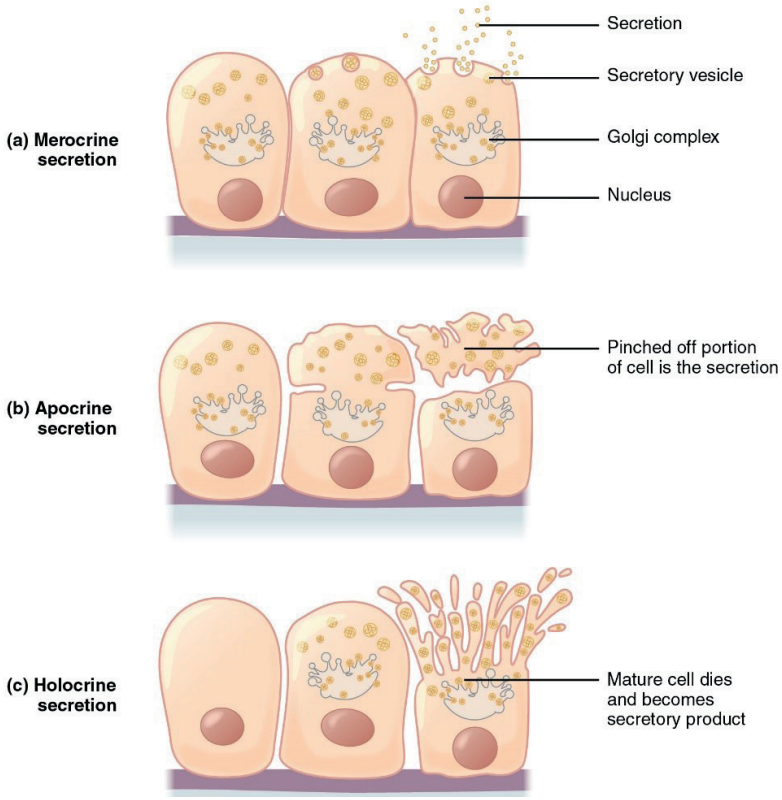
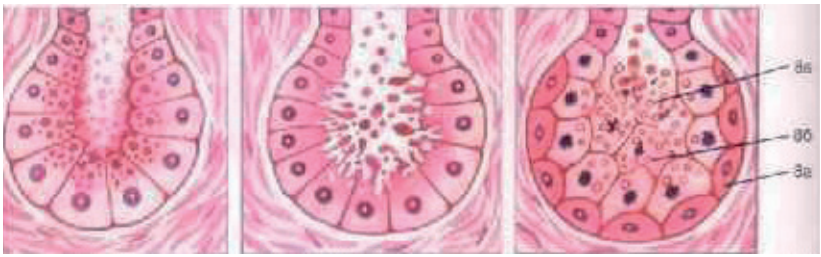


Figure 11.1. Types of secration.
(a) In merocrine secretion, the cell remains intact (b).
In apocrine secretion, the apical portion of the cell is released, as well (c).
In holocrine secretion, the cell is destroyed as it releases its product
and the cell itself becomes part of the secretion.



6 7 8

Figure 11.2. Type of secretion.
6 – merocrine secretion; 7 – apocrine secretion;
8 – holocrine secretion, 8a – growth layer cells;
8б – cells in the death stage; 8в – cells in the stage of destruction

In the merocrine type of secretion, glandular cells completely retain their structure (salivary gland cells). Secretory granules move from the Golgi complex to the cytolemma of the glandular cell, then the secret is diffused through the membrane of the secretory granule and the cytolemma of the cell.

When apocrine type of secretion occurs partial destruction of glandulocites, destroyed the apical part of the cell. With apocrine secretion, the secret accumulates in the apical part of the cell, resulting in the formation of outgrowths of the cytoplasm, which are unlaced and detached from the cell, which leads to a decrease in its height. Together with secretory granules, separates the apical part of glandulocites (cells of the mammary glands).

When holocrine type of secretion involves the complete destruction of the glandular cells glandulocites. The holocrine type of secretion is accompanied by the accumulation of fat in the cytoplasm of the cell. All contents of glandulosity becomes a secret, and the cell dies. This type of secretion is observed in the sebaceous glands of the skin.

The fourth phase of secretion is restoration of the glandulocyte structure. This phase consists in restoring the original state of glandular cells.

Glands

Derivatives of glandular epithelium are glands. The glands perform a secretory function in the body. The secrets produced in the glands are important for the processes of digestion, growth, development, and interaction with the environment. The glands are divided into two groups: endocrine or internal secretions, and exocrine or external secretions (Figure 12).

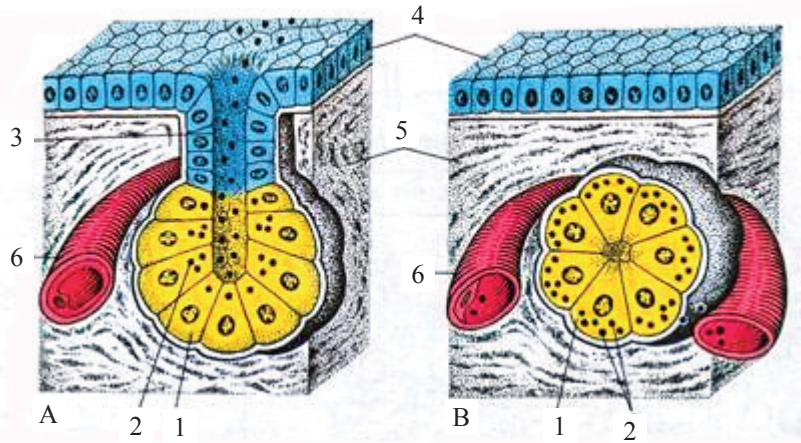


Figure 12. Glands.
A – exocrine gland; B – endocrine gland: 1 – end section;
2 – secretory granules; 3 – excretory duct of the exocrine gland;
4 – integumentary epithelium; 5 – connective tissue; 6 – blood vessel

Endocrine glands do not have excretory ducts and their secret (hormones) enters directly into the blood. These glands consist only of glandular cells. They form the endocrine system of the body.

Exocrine glands produce secrets that are released through the excretory ducts to the external environment – on the surface of the skin, mucous membranes, in the cavity of internal organs.

Exocrine glands are extremely diverse, differ from each other in structure, type of secretion, that is, the way the secret is secreted and its composition. These features are the basis for the classification of glands.

Exocrine glands are divided into endoepithelial and exoepithelial glands.

Endoepithelial glands are called when epithelial glandular cells do not sink into the underlying tissues, but are located within the layer of epithelial cells. Endoepitheliall exocrine. Exocrine endoepithelia glands can be **unicellular** and multicellular. An example of exocrine endoepithelial unicellular glands can be goblet cells located in the epithelial lining of the small and large intestine, as well as in the epithelium of the trachea and bronchi.

Exoepithelial glands called glands when glandular cells are immersed from the epithelium to underlying tissue. Exocrine exoepithelial **multicellular** glands represent the bulk of the body's glands – salivary, sweat, and sebaceous. They consist of two parts: secretory or terminal departments and excretory ducts. End the divisions formed by glandulocytes lying on the basal membrane. The excretory ducts are lined with various types of epithelium, depending on the origin of the glands (from the ectoderm – a multi – layer nonkeratinized epithelium, from the endoderm-a single-layer epithelium).

According to the structure of exocrine exoepithelial multicellular glands, depending on the number of excretory ducts, they are divided into simple and complex (Figure 13). In simple glands, there is one excretory duct and the secretory parts of the gland communicate directly with it. The complex glands have a system of excretory ducts that flow into the common duct of the gland. These glands have excretory ducts of complex structure.

Depending on the number of secretory departments, exocrine glands are divided into unbranched and branched. Unbranched glands have a single secretory or terminal Department. Branched glands have many terminal divisions. Simple glands can be unbranched and branched,

and complex glands can only be branched. Depending on the shape of the secretory departments, exocrine glands are divided into tubular, alveolar, and tubular-alveolar.

Depending on the nature (chemical composition) of the secret, exocrine glands are divided into protein, mucosal, protein-mucosal, and sebaceous (Figure 14).

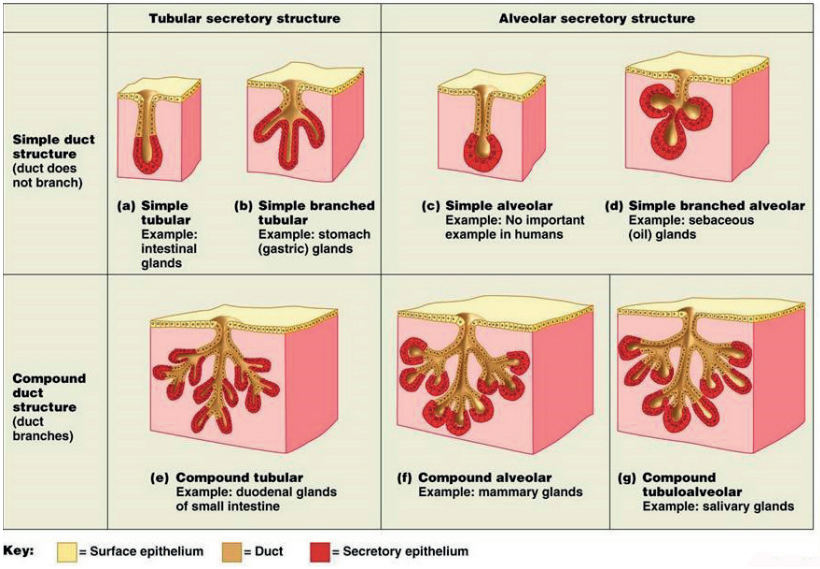


Figure 13. Types of multicellular exocrine glands

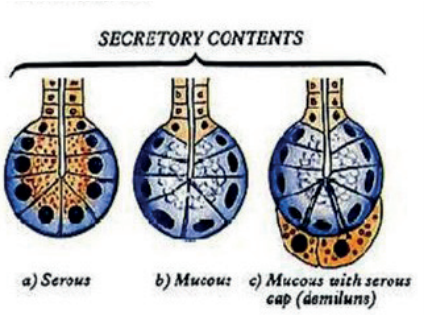


Figure 14. Secretory contents

Regeneration of epithelial tissue

Regeneration of the integumentary epithelial tissue is very intensive. Occupying a borderline position, epithelial tissue is constantly exposed to the external environment, which leads to rapid aging and death of epithelial cells. The dead epithelial cells of the surface layer are exfoliated, rejected and replaced by younger epithelial cells. The process of replacing dead epithelial cells with younger cells is called physiological regeneration of epithelial tissue. Physiological regeneration of the epithelium occurs by mitotic division of epithelial cells. In a single-layer epithelium, most cells are capable of division (crypt epithelium in the small intestine, neck epithelium of own glands in the stomach, etc.). In a multi-row epithelium, basal cells (short insertion) are capable of division.

Reparative regeneration occurs when the epithelial layer is damaged. When a single-layer, single-row, flat and cubic epithelium is damaged, the cells shrink in size, acquire a spherical shape, move away from each other and break off from the basement membrane, freeing the path for macrophages from the underlying connective tissue, since the inflammatory process begins with damage.

Mass amitotic and mitotic division of epithelial cells along the periphery of the lesion, which fill the defect, accompany the process of damage to epithelial tissue.

Epithelization of the wound, in turn, inhibits excessive growth of connective tissue in the area of inflammation.

BLOOD, HEMOPOIESIS

Blood-liquid connective tissue. Connective tissue with pronounced trophic and protective functions includes blood and lymph. Blood and lymph develop from mesenchyma of mesodermal origin (from the middle germ leaf). Mesenchyma quickly differentiates.

The development of a blood (hemopoiesis, hematopoiesis)

Hematopoiesis-development of blood. There are embryonic and postembryonic hematopoiesis. Embryonic hematopoiesis occurs in the embryo. Post-embryonic hemopoiesis – the process of physiological regeneration of blood. The development of red blood cells is called erythrocytopoiesis, the development of granulocytes-granulocytopoiesis, the development of monocytes-monocytopoiesis, the development of lymphocytes-lymphocytopoiesis, the development of platelets-thrombopoiesis.If in the embryonic period of development, blood is formed as tissue, then in the period of postnatal ontogenesis, hematopoiesis is a process of physiological blood regeneration.

Embryonic hematopoiesis

The development of blood as tissue occurs in the embryo first in the mesenchyma of the wall of the yolk sac, then in the liver, bone marrow and lymphoid organs (thymus, spleen, lymph nodes). Mesenchyma exists only in the early stages of embryonic development, being a source of formation of various connective tissues. It fills the gaps between the germ leaves. Mesenchymal cells have a stellate shape with processes. Some cells are in contact with processes of other cells of the mesenchyme. The stellate shape of cells and the nature of their connection between each other determine the mesh structure of the tissue. Mesenchyma of mesodermal origin (middle germ leaf) quickly differentiates into blood cells. Mesenchymal cells acquire

a spherical shape, lose their processes and turn into primary blood cells that arise in the human embryo at the beginning of the third week of development in the wall of the yolk sac. When primary blood cells multiply, they form clusters called blood Islands. Thus, the first center of hematopoiesis appears in the wall of the yolk SAC at the 3–4 week of development of the human embryo.

Primary blood cells in the center of the blood island are poorly differentiated cells that can mitotically divide, turn into any blood cell during development, and therefore they can be considered blood stem cells.

During development, blood stem cells migrate from the yolk sac along the bloodstream first to the liver, and then to the bone marrow. From the fifth month of embryonic development, the bone marrow becomes the main center of hematopoiesis. From stem cells in the bone marrow, all the shaped elements of blood are formed. Thus, the bone marrow becomes the Central organ that performs universal hematopoiesis, and remains so during postnatal life. It provides stem cells to the thymus, spleen, and lymph nodes

Postembryonic hematopoiesis is the physiological regeneration of blood. Currently, the unitary (unitaire – unified) theory of hematopoiesis, according to which all the shaped elements of blood come from a single blood stem cell, the population of which exists throughout the life of the body. The existence of a single source of hematopoiesis was predicted in the early XX century by the Russian histologist A.A. Maximov. Blood stem cells are polypotent precursors of all blood cells and belong to a self-sustaining population of cells. They rarely share. Blood stem cells are found mainly in the red bone marrow. These blood cells differentiate in two directions during hematopoiesis. One group of cells is the starting point for the development of red blood cells, granulocytes, monocytes and platelets. Their development is called myelopoiesis, and the original cells are called progenitor cells of myelopoiesis. Myelopoiesis occurs in myeloid tissue located in the epiphyses of tubular and cavities of many spongy bones. Here the shaped elements of blood develop: 1) red blood cells,

2) granulocytes and monocytes, 3) platelets; precursors of lymphocytes. Another group of cells develops in the red bone marrow, but to a greater extent migrates to the lymphoid organs and is the source for the development of lymphocytes.The development of lymphocytes is called lymphocytopoiesis, and the original cells-the precursor cells of lymphocytopoiesis. Lymphocytopoiesis occurs in the lymphoid tissue located in the thymus, spleen, and lymph nodes. The progenitor cells of lymphocytopoiesis differentiate in two directions: 1) in the cells of the precursor of B-lymphocytes, 2) in the cells of the precursor of T-lymphocytes. Each stem cell forms a single colony and is called a colony-forming unit.

There are two lines of differentiation of colony cells. One line gives rise to a polypotent half-stem cell – a precursor of the erythrocyte, granulocyte, monocyte and platelet series of hematopoiesis. The second line gives rise to a polypotent semi-stem cell – a precursor of lymphocytopoiesis. Polytology differentiation of pluripotent cells into unipotent determined by a number of specific factors, erythropoietin (for erythroblasts), granulopoietic (for myeloblasts), thrombopoetin (for megakaryoblasts), lymphopoietin (for lymphoblasts). Stem, semi-stem, and unipotent cells are morphologically very similar. These are large cells with a large nucleus in the center. There are 6 classes of hematopoiesis:

Class 1-stem cell class

Class 2-half-stem cell class

Class 3-class of unipotent cells

Class 4-class of blasts

Class 5-class of maturing cells

Class 6-class of Mature cells

The erythrogenesis

The development of red blood cells proceeds according to the scheme (Figure 15):

Class 1-stem cell
Class 2-half-barrel cage
Class 3-unipotent cell
Class 4-erythroblast
Class 5-proerythrocytes :
- basophilic
- polychromatophilic
- oxyphilic

Class 6-reticulocyte-1%
- erythrocyte

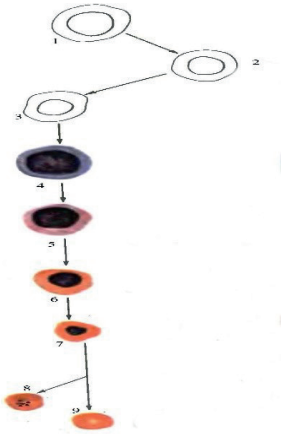


Figure 15. The erythrogenesis

During development, a number of morphological features can be identified: the cell size decreases, the nucleus thickens and disappears, the cytoplasmic basophilia weakens, and the cytoplasmic oxyphilia associated with the accumulation of hemoglobin appears. The ability to divide mitotically is weakened and lost. Organoids decrease and disappear.

Erythroblasts are large cells with a rounded nucleus. Cells are capable to divide mitotically and differenciate in proerythrocytic. Proerythrocytic in the basophilic cytoplasm is basophilic. They reproduce vigorously. In polychromatophilic proerythrocytic accumulated hemoglobin, and basophilia of the cytoplasm is attenuated. Cells divide and differentiate. Oxyphilic proerythrocyte has a small nucleus, the amount of hemoglobin in the cytoplasm increases, so the cytoplasm is stained oxyphilic. The cell does not divide, but differentiates into a reticulocyte. The reticulocyte does not have a nucleus,

the cytoplasm contains remnants of organoids, is not able to divide, then a red blood cell is formed – a Mature cell. Normally, only red blood cells and reticulocytes enter the blood from the bone marrow.

Granulocytopoiesis

The development of granulocytes (neutrophils, eosinophils, basophils) proceeds according to the scheme:

Class 1-stem cell

Class 2-half-barrel cage

Class 3-unipotent cell

Class 4-myeloblast (neutrophilic, eosinophilic, basophilic)

Class 5-promyelocyte (neutrophilic, eosinophilic, basophilic)

- myelocyte (n, e, b)
- metamyelocyte (n, e, b)
- stick-core (n, e)

Class 6-segmentonuclear (neutrophil, eosinophil), basophil (Figure 16).

As granulocytes Mature, cells shrink in size, the shape of the nuclei changes from rounded to segmented, and specific granularity accumulates in the cytoplasm.

Myeloblasts, differentiating in the direction of a granulocyte, give rise to promyelocytes. Promyelocytes are large cells containing a rounded nucleus. The cytoplasm has all organoids of General significance, while the lysosomes are called primary azurophilic granules. Promyelocytes divide mitotically. Myelocytes are distinguished by neutrophilic, eosinophilic, basophilic. In these cells, a specific granularity (secondary granules) appears, which perceive dyes differently. All organoids of General significance are found in myelocytes. The core is rounded. These cells multiply vigorously by mitosis.

Metamyelocytes no longer divide. They are called young forms. The number of specific granules increases in the cytoplasm. The core becomes bean-shaped. The number of secondary specific granules increases. Upon further maturation, metamyelocytes differentiate into rod-shaped neutrophils and eosinophils. The core takes the form of a curved stick. The rod-shaped neutrophil and the rod-shaped eosinophil are not able to divide. A basophilic metamyelocyte turns into a mature basophilic leukocyte as it matures. Specific basophilic granules exhibit metachromasia. Rod-shaped neutrophils and esinophils turn into segmentonuclear neutrophils and eosinophils. The core is segmented. The number of secondary specific granules increases. These are mature forms of white blood cells.

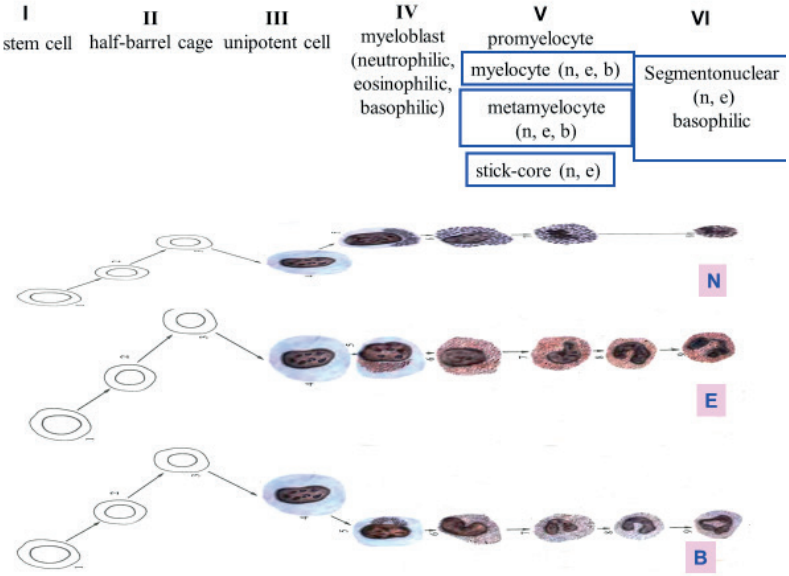


Figure 16. The granulocytopoiesis

Lymphocytopoiesis

Lymphocytopoiesis goes through the following stages: stem cell-semi-stem cell-unipotent precursor of the lymphocyte – lymphoblast-prolymphocyte-lymphocyte. (Figure 17)

T-lymphocyte progenitor cells migrate with blood flow from the bone marrow to the thymus and differentiate here. The resulting lymphoblasts, multiplying, form prolymphocytes, which turn into T-lymphocytes, first large, medium, and then small lymphocytes-killers, helpers, suppressors and memory T-cells. The cells of the precursor of lymphocytopoiesis in other lymphoid organs differentiate into the cells of the precursor of B-lymphocytes, from which b-lymphocytes arise-large, medium, small. In the presence of an antigenic stimulus, b-lymphocyte progenitor cells differentiate into plasmoblasts. Plasmoblast turns into piroplasmosis and then plasmocytes. All differentiation of these cells is associated with the granular endoplasmic network, which is well developed in plasmocytes. In the same way the plasma cells arise from B-lymphocytes.

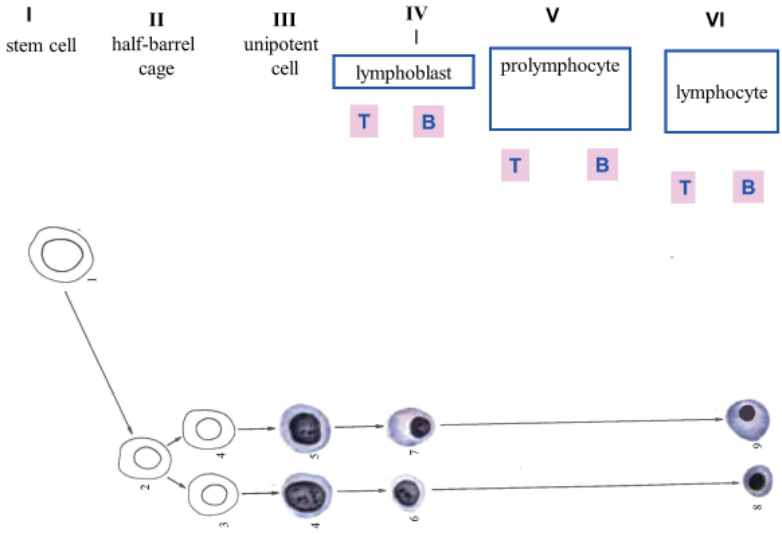


Figure 17. The lymphocytopoiesis

Monocytopoiesis

The formation of monocytes occurs from bone marrow stem cells according to the scheme: stem cell-semi-stem cell-unipotent cell-monoblast-promonocyte-monocyte. Monoblasts are large globular cells capable of mitotic division. In the future, the core and cytoplasm of the monoblast are differentiated (Figure 18). Small single azurophilic granules appear in the peripheral zone of the cytoplasm. Such cell is called promotion. With further development, the cell nucleus becomes bean-shaped, increasing the number of small primary azurophilic granules-lysosomes. This cell is called a monocyte.

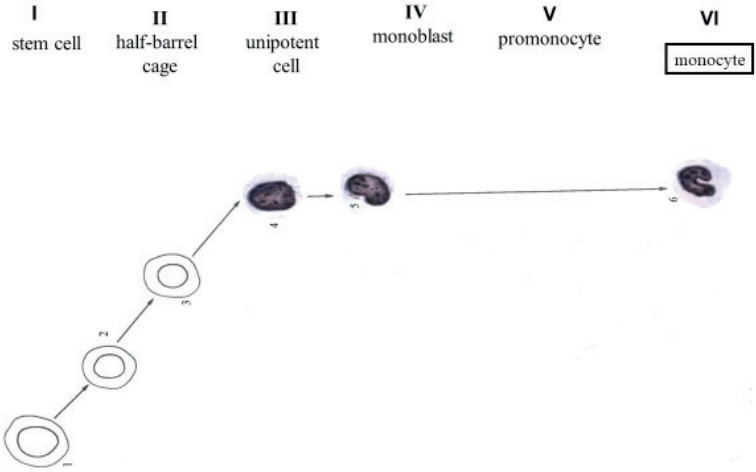


Figure 18. The monocytopoiesis

Thrombopoiesis

Platelets are formed in the bone marrow. This process consists of the following stages: stem cell – semi – stem cell – unipotent cell – megakaryoblast – promegakaryocyte – megakaryocyte-platelets

(Figure19). In the process of thrombopoiesis cells increase in size. The core is enlarged and segmented. The cytoplasm forms numerous pseudopods that are unlaced (amitosis-budding). In the area of pseudopodia, sections of the cytoplasm, i.e. platelets (blood plates), are separated.

Megakaryoblast – a large cell with a paw-like nucleus. Then there is a further increase in the size of the cell, the nucleus becomes incised, and the megakaryoblast turns into a promegakaryocyte. At the next stage of development, the promegakaryocyte turns into a megakaryocyte. The core of a megakaryocyte forms numerous constrictions and is segmented (core fragmentation). A megakaryocyte is a multicellular cell. The cell size can reach several tens of micrometers. The cytoplasm forms pseudopods. According to them, the blood plates are split off from the surface of the megakaryocyte by budding.

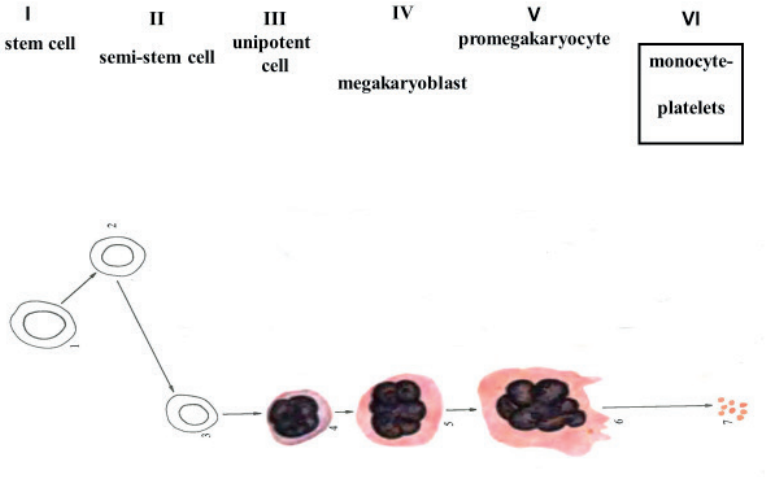


Figure 19. The thrombopoiesis

Blood

Blood is composed of cells called formed elements and the intercellular substance – plasma. Formed elements make up 40–45 % of blood, and plasma-55–60 %. Blood in the human body is 6–8 % of body weight, on average 4–5 liters of blood.

Blood functions: the main functions of blood are: transport and protective.

The transport function includes the following functions:

1) respiratory – transport of oxygen and carbon dioxide
2) trophic – transport of nutrients
3) excretory-transport of metabolic products
4) humoral-transport of hormones
5) thermoregulation-redistribution of heat in the body.

The protective function includes:

1) phagocytosis
2) cellular and humoral immunity
3) blood clotting-protection from blood loss

Blood is a mobile system that ensures the constancy of the internal environment of the body-homeostasis.

The formed elements of blood

Formed elements of blood are divided into red blood cells, white blood cells and platelets. Red blood cells or red blood cells (cells) are non-nuclear cells that have lost the nucleus and most of the organelles. Red blood cells are highly differentiated cells that are not capable of division. The main function of red blood cells is respiratory-the transport of oxygen and carbon dioxide, which is provided by hemoglobin. In addition, red blood cells are involved in the transport of antibodies, amino acids, toxins and a number of drugs, adsorbing

them on the surface of the cytolemma. The number of red blood cells in women is 4–4.5 million in 1 mm^3, in men 4.5–5 million in 1mm^3. Female sex hormones inhibit the development of red blood cells, so women have fewer red blood cells. An increase in the number of red blood cells is called erythrocytosis, and a decrease is called erythropenia. The number of red blood cells in healthy people may depend on age, emotional and muscle load, hormonal background, environmental factors, metabolism, lack of oxygen (hypoxia).

Structure of red blood cells

Red blood cells have different sizes. The diameter of most red blood cells ranges from 7.1 to 7.9 microns-75 % (Figure 20)

Distinguish:

1) normocytes-diameter-7-8 microns-75 %
2) microcytes-diameter – 4.5–6 microns –12,5 %
3) macrocytes-diameter-over 8.0 microns-12,5 %

Fluctuation in the size of red blood cells is called anisocytosis.

Red blood cells usually have the form of biconvex disks and are called discocytes. There are the following forms of red blood cells:

1) discocytes – 80 % – Mature red blood cells
2) spherocytes (spherical)
3) echinocytes – (spiny) – old
4) planocytes (with a flat surface)
5) stomatocytes (domed)
6) saddle-shaped
7) two-key
8) crescent-shaped.

Fluctuation in the shape of red blood cells is called poikilocytosis.

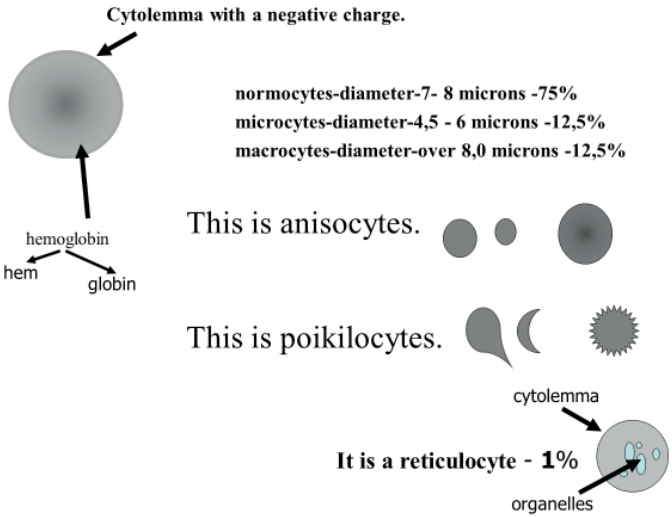


Figure 20. The red blood cell

The red blood cell has no nucleus and most organoids, and the hyaloplasm contains numerous hemoglobin granules, 4–5 nm in size. In large quantities, red blood cells due to hemoglobin give the blood a red color. Hemoglobin is a colored protein (chromoprotein) that makes up 90 % of the mass of the red blood cell. Along with mature red blood cells, the peripheral blood contains 1 % of young red blood cells-reticulocytes. Reticulocytes are round in shape and do not have a nucleus. The cytoplasm contains remnants of organoids: the endoplasmic network, ribosomes, mitochondria, and little hemoglobin.

The lifespan of red blood cells is about 120 days. In aging red blood cells, there is a violation of gas exchange function.

General characteristics and classification of white blood cells

All white blood cells have a spherical shape. 1mm3 of human blood contains 4000–9000 white blood cells. White blood cells are capable of active movement with the help of pseudopods, are not capable

of division. An increase in the content of white blood cells is called leukocytosis.

It can be physiological (during exercise, stress, after eating, during pregnancy, in newborns) and pathological – in diseases. A decrease in the number of white blood cells is called leukopenia. The main function of white blood cells is protective.

White blood cells are white blood cells that have a nucleus. The cytoplasm contains all General-purpose organoids, and lysosomes are called primary azurophilic granules.

There are two groups of white blood cells depending on the presence of specific granules in the cytoplasm: granulocytes and agranulocytes. Agranulocytes do not have specific granules. They are divided into monocytes and lymphocytes. Granulocytes have specific granules of different colors and sizes in the cytoplasm. There are three types of granulocytes depending on the affinity of granules to acidic and basic dyes: neutrophils, eosinophils, basophils. Blood is stained with a mixture of acidic (eosin) and basic (Azur) dyes using the Romanovsky-Gimza method. Neutrophils are white blood cells in which specific granules have an affinity for acidic and basic dyes. Eosinophils are white blood cells in which specific granules have an affinity for acidic dyes.

Basophils are white blood cells in which specific granules have an affinity for the main dyes. In the body, the shaped elements of blood are in certain quantitative ratios, which are called the hemogram (blood formula), and the percentage of different types of white blood cells in the blood is called the leukocyte formula.

Leukocytic formula

1) neutrophils – 65–75 % (young – 0,5 %, rod – shaped – 3–5 %, segmented – 60–65 %)

2) eosinophils – 1–5 %

3) basophils – 0,5–1 %

4) monocytes – 6–8 %

5) lymphocytes – 20–35 %

By increasing the number of young forms of neutrophils (young) talking about the shift of leukocyte formula to the left, while increasing the mature forms (segmented) – the shift to the right. Blood tests usually determine the percentage of white blood cells, since it is one of the most important clinical indicators.

Neutrophilic leukocytes (granulocytes, neutrophils)

In the blood of an adult, there are more neutrophils than other white blood cells – 65–75 % of the total number of white blood cells.

Neutrophils have a rounded shape; their diameter is 7–9 microns. The cytoplasm contains all the organelles of general purpose and pellets. There are two types of granules – primary and secondary. Primary azurophilic granules are primary lysosomes with a size of 0,8 microns. Secondary granules are specific neutrophilic granules of 0,2–0,5 microns in size. These are small dust-like granules that are colored with acidic and basic dyes in a pink-purple color. The granules contain the enzyme alkaline phosphatase. There are three types of neutrophils: young, rod-shaped, and segmented (Figure 21). Young neutrophils are rare – 0,5 %. The core is bean-shaped. Rod-shaped neutrophils make up 3–5 %. The core is in the form of a curved stick or the letter S. Segmentonuclear neutrophils make up the vast majority of white blood cells – 60–65 %. The core is segmented, consisting of 3–5 lobes connected by very thin, sometimes almost imperceptible jumpers. These are Mature cells. In the structure of neutrophil nuclei in humans, there are differences depending on gender. In the nuclei of neutrophils of women have appendages in the form of drum sticks. The perinuclear appendage is also called sexual chromatin, which contains one of the X chromosomes. In the nuclei of neutrophils of men, there are no

perinuclear appendages. Neutrophil granulocytes are very mobile cells capable of amoeboid movement. Neutrophils have a high capacity for phagocytosis. They can phagocyte up to 30 microbes each, so they are called microphages. Phagocytic microorganisms, neutrophils themselves are destroyed by the action of enzymes. The dead neutrophils together with the remains of destroyed cells and tissues form pus. The life span of neutrophils is about 8 days.

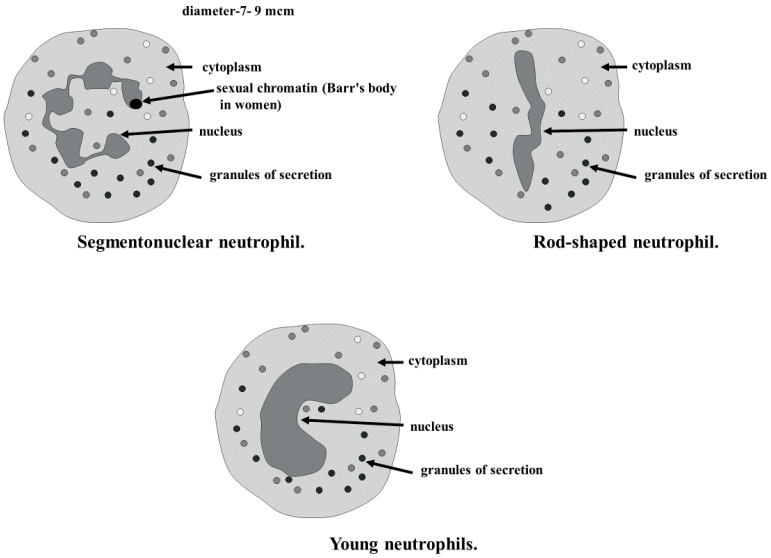


Figure 21. This is schematic representation of the structure of neutrophils

Eosinophilic leukocytes (granulocytes, oxyphilic, acidophilic, eosinophils)

The number of eosinophils in the peripheral blood is 1–5 % of the total number of white blood cells. Eosinophils – these are large cells with a size of 9–10 microns. The cell nucleus consists of two segments connected by a thin isthmus. The cytoplasm contains all the orga-

nelles of general purpose and specific secondary oxyphilic granules. The granules are the largest, with a diameter of 1,5 microns in the form of twisted cylinders. These granules are well colored with acidic dyes in red (Figure 22).

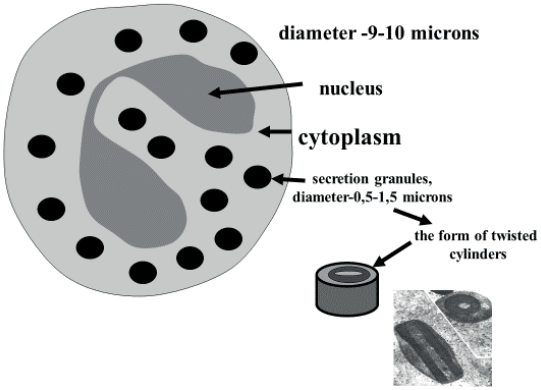


Figure 22. The eosinophilic leukocytes (granulocytes, oxyphilic, acidophilic, eosinophils)

The granules contain the enzyme histaminase, which inhibits the release of histamine from basophils and causes histamine inactivation. Eosinophils have anti-allergic and anti-inflammatory effects, have an anti-helminthic effect. The number of eosinophils increases with allergic reactions, worm infestations. Eosinophils are capable of phagocytosis, but their phagocytic activity is lower than that of neutrophils.

Basophilic granulocytes (basophilic leukocytes or basophils)

Basophils have a diameter of 9 microns. In human blood, they make up 0.5–1 % of the total number of white blood cells. Rounded cells. The core is shaped like a “crow’s foot”. The cytoplasm contains all the organelles of General purpose. Lysosomes are called prima-

ry azurophilic granules. The cytoplasm is also filled with secondary specific basophilic granules with a diameter of 0.8–1.0 microns. Granules have metachromasia (Figure 23). Metachromasia-the property of cells to be colored in a tone different from the color of the dye. Metachromatic of granules is associated with the presence of heparin in them. The granules also contain histamine. The granules are colored with the main dyes in a dark cherry color. Heparin prevents blood clotting and is an anticoagulant. Histamine increases capillary permeability and causes inflammation. Basophils are involved in allergic and inflammatory reactions.

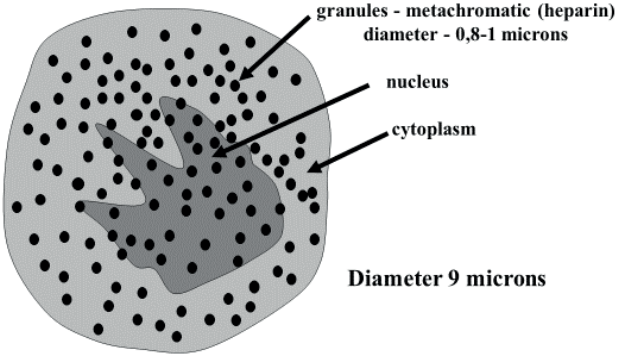


Figure 23. The basophilic granulocytes (basophilic leukocytes or basophils)

Lymphocytes (agranulocytes)

In the blood of adults, lymphocytes make up 20–35 %. There are three types of lymphocytes depending on the size (Figure 24): 1) small-diameter 4.5–6 microns; 2) medium-diameter 7–10 microns; 3) large-diameter 10 mkm or more. They differ only in the size of the cytoplasm, and the size of the nucleus of three types of lymphocytes is the same. Only small lymphocytes are considered mature,

and they are found in the peripheral blood. Lymphocytes have a rounded shape. The core is round, located in the center. The cytoplasm contains all the organelles of general purpose.

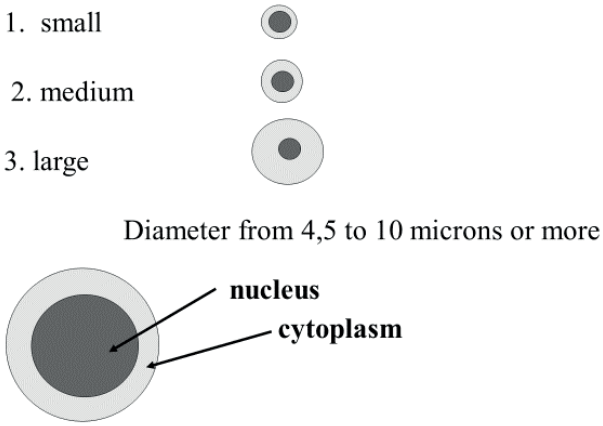


Figure 24. The lymphocytes

Lymphocytes are divided by function into T- and B-lymphocytes. There are 4 types of T-lymphocytes-1) killers – they phagocyte microbes; 2) helpers – helpers, delivering information to B-lymphocytes; 3) suppressors (oppressors), suppress the reactions of killers and B-lymphocytes; 4) people who recognize a foreign antigen and give a signal to the beginning of the immune response, can live 20 or more years. The function of B-lymphocytes is to provide humoral immunity. Formed from b - lymphocytes of effector cells, plasma cells produce special proteins – antibodies, which enter the bloodstream.

Monocytes (agranulocytes)

In the human blood, the number of monocytes is 6–8 % of the total number of white blood cells. This is a large cell size 9–12 mkm.

In the cytoplasm of monocytes there are all general-purpose organoids, well-developed lysosomes (Figure 25). The core of the monocyte is bean-shaped. Monocytes are capable of phagocytosis and perform protective functions in the body. They phagocyte up to 100 microbes, so they are called macrophages. Monocytes live up to 3 days in the blood. They belong to the macrophage system of the body.

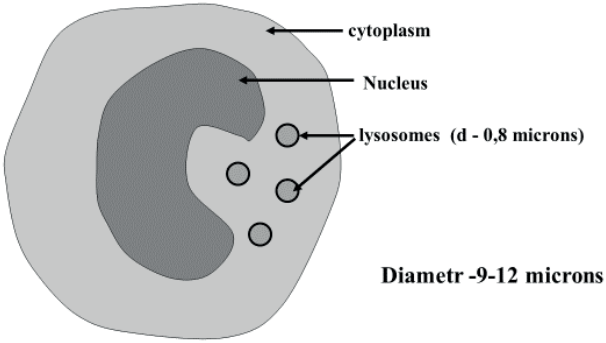


Figure 25. The monocytes (agranulocytes)

Platelets

Platelets (blood plates) have a variety of shapes with a size of 2–3 microns. They are tiny colorless corpuscles or nuclear-free fragments of the cytoplasm, separated from the megakaryocyte. There are between 200,000 and 300,000 of them in 1mm3 human blood. An increase in the amount is called thrombocytosis, and a decrease in the amount is called thrombopenia. There are 5 types of platelets: 1) young; 2) mature;3) old; 4) degenerate; 5) gigantic. Each platelet consists of hyalomere and granulomere. Hyalomere is a remnant of cytoplasm. The granulomere contains granules with a diameter of 0.2 microns. The granules contain enzymes and blood clotting factors. Platelet lifetime is 5–8 days (Figure 26).

The function of platelets is to participate in the blood clotting process. They are able to stick together into conglomerates.

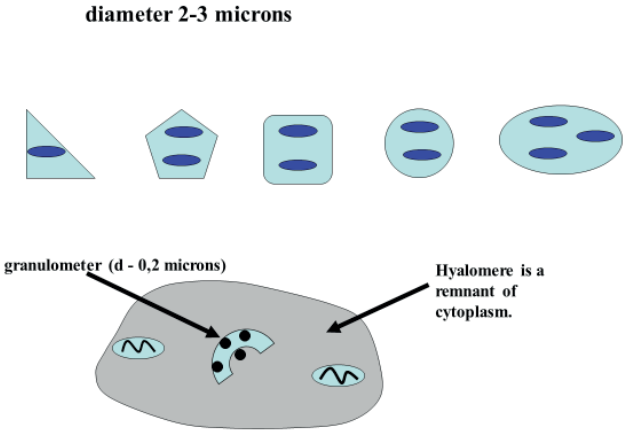


Figure 26. The platelets

Blood plasma

Blood plasma is a liquid intercellular substance. It is a yellowish viscous liquid. Plasma consists of water – 9–92 % and dry residue – 8–10 %. The dry residue consists of proteins – 6–8 %, organic substances – 1 %, and inorganic substances – 1 %. Proteins include:

1) albumins – 4–4.5 %
2) globulins – 2–2.5 %
3) fibrinogen – 0.2–0.4 %.

Organic substances are glucose, amino acids, fatty acids, lipids, vitamins, polypeptides, and urea. Inorganic substances-sodium, potassium, chlorine, calcium, magnesium and other trace elements.

THE ACTUAL CONNECTIVE TISSUE

The connective tissue itself consists of cells and intercellular substance, consisting of fibers and intercellular substance. The intercellular substance consists of fibers and the main substance.

There are loose and dense connective tissue, and dense divided into unformed and formed. The classification of connective tissue proper into loose and dense is based on the principle of the ratio of cells and intercellular substance.

If the connective tissue itself has a lot of cells and relatively few fibers of intercellular substance, then such a tissue is called a loose fibrous unformed connective tissue, in which the fibers are located randomly, in different directions.

Loose fibrous connective tissue is found in all organs, as it accompanies blood vessels and forms the stroma of many organs.

If the connective tissue itself is dominated by intercellular substance fibers over cells, then this tissue is called dense connective tissue.

Classification of dense connective tissue into unformed and formed depends on the degree of ordering of the arrangement of intercellular substance fibers. The location of intercellular substance fibers in dense connective tissue can be different. If the fibers of the intercellular substance of dense connective tissue are located in different directions, then such dense tissue is called unformed, and if in one direction-formed.

Actually, connective tissues are general-purpose tissues, since they perform many important functions: mechanical, supporting and forming-they form a capsule and stroma of many organs, tendons, a protective function - phagocytosis, mechanical protection, plastic-regeneration, wound healing, trophic-participation in metabolism.

Cells of the connective tissue proper

There are: fibroblasts, fibrocytes, macrophages, histiocytes, labrocytes, adipocytes, pigmentocytes, plasmocytes, reticular cells, adventitial cells, pericytes and endotheliocytes (Figure 26). In fact all the cells of connective tissue develop from mesenchyme except pigmentation that have neuralne origin.

Adventitious cells are poorly differentiated cells. They are found in the outer layer of blood capillaries, outside of the pericytes. They have a flattened or fusiform shape. The nucleus is oval in shape, the cytoplasm with poorly developed organelles.

In the process of differentiation, these cells can turn into fibroblasts, adipocytes.

Pericytes have a semicircular shape (previously known as Rouget cells). They are found in the middle layer of capillaries between the endothelium and adventitial cells. Pericytes or perivascular cells are poorly differentiated cells. They are able to swell, thus changing the lumen of the capillary.

Endotheliocytes (endothelium, endothelial cells) have an elongated or polygonal shape. They are found in the inner wall of blood capillaries, lying on the basement membrane. They are involved in the regulation of capillary blood supply.

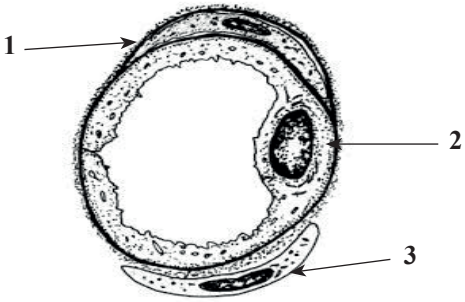


Figure 26. Capillary:
1 – pericyte; 2 – endotheliocyte; 3 – adventitial cell

Fibroblasts are the most numerous cells (50 % of the total number of cells)

There are poorly differentiated fibroblasts, differentiated (mature) fibroblasts, myofibroblasts and fibroclasts (Figure 27).

Poorly differentiated fibroblasts are young, immature, low-growth cells. The cytoplasm contains poorly developed organelles. These cells are capable of mitotic reproduction.

Differentiated fibroblasts are mature, actively functioning, specialized cells. Fibroblasts have a flattened shape, in the form of a "maple leaf". These are large cells, their cytoplasm contains all organoids, and a well-developed granular endoplasmic network – the endoplasm. The cytoplasm of fibroblasts on the periphery contains microfilaments containing proteins such as actin and myosin (ectoplasm). Fibroblasts are capable of sliding movement. Function-synthesis of collagen and elastic fibers, as well as the main intercellular substance.

Myofibroblasts develop from fibroblasts. They are similar in function to smooth muscle cells.

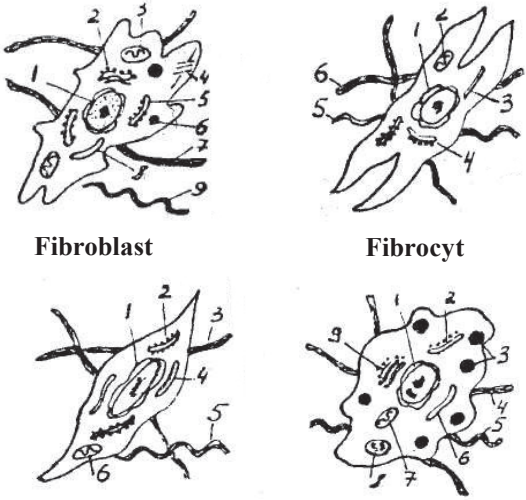
Myofibroblasts, unlike smooth muscle cells, have a well-developed endoplasmic reticulum. Such cells are found in granulation tissue during the wound process and in the uterus during pregnancy.

Fibroblasts – cells with high phagocytic activity, which contain in a large number of lysosomes. These cells are able to "dissolve" the fibers and the main intercellular substance. Fibroblasts are found in the uterus after pregnancy.

Fibrocytes are old, definitive cells that have completed the development cycle. They have a fusiform shape. Fibrocytes are not able to synthesize intercellular substance. They lose the ability to mitotic division.

Tissue basophils, labrocytes. They come from red bone marrow hematopoietic stem cells. These cells have a variety of shapes-oval, irregular, sometimes with short broad processes. The core is round

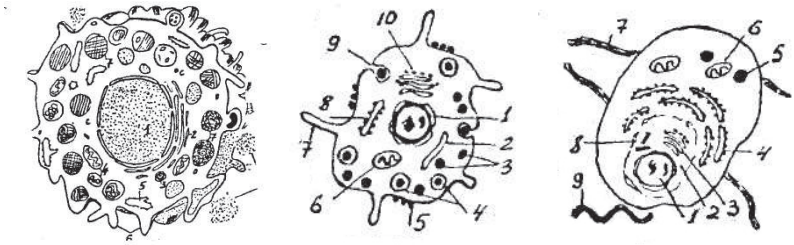
or oval in shape (Figure 28). In the cytoplasm of the labrocyte there are all organoids of general significance, but poorly developed. The cytoplasm contains numerous granules that are colored metachromatically. The size and quantity of granules vary. Most granules contain heparin and histamine. Granules have a mesh, lamellar, crystalloid and mixed structure.



Fibroblast **Fibrocyt**

Myofibroblast **Fibroclast**

Figure 27. Types of fibroblasts



Labrocyte **Macrophag** **Plasmocyt**

Figure 28. The cells of the actual connective tissue

Tissue basophils can degranulate, i.e. lose their granules. In the process of degranulation, heparin is released, which prevents blood clotting. Histamine secretion, on the contrary, occurs without breaking the consistency of the cell membrane and granules. Histamine increases the permeability of the intercellular substance, has an inflammatory effect. Labrocytes are often located in groups along the course of blood vessels of the microcirculatory bed – capillaries, arterioles, venules.

Plasmocytes (plasma cells) are formed from B-lymphocytes (Figure 28). The shape of the cells is oval. The core is round, located eccentrically. The cytoplasm contains all the organelles common values, well developed granular endoplasmic reticulum – ergastoplasm. The cytoplasm is sharply basophilic. Only a small area near the core, called the "light courtyard", is devoid of basophilia. The cell center and Golgi complex are found here. Chromatin in the nucleus is located in the form of "spokes in a cart wheel". Function-synthesis of antibodies produced when an antigen appears in the body and neutralizes it. These cells provide humoral immunity.

Adipocytes (lipocytes, fat cells) develop from adventitious cells adjacent to blood capillaries (Figure 29). Development begins with the fact that small droplets of fat appear in the cytoplasm of adventitious cells, which increase in size, gradually merge into larger droplets. In the cytoplasm, as the fat drop increases, the endoplasmic network and Golgi complex are reduced, and the adipocyte nucleus is compressed and flattened.

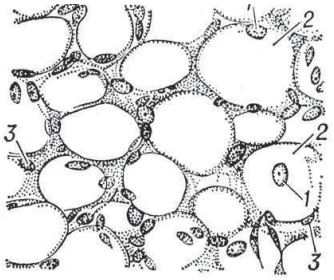


Figure 29. Adipocytes

Adipocytes have a spherical shape. A mature fat cell contains one large drop of neutral fat that occupies the entire Central part of the cell. Lipids are well colored with Sudan III in orange color or osmic acid in black color.

The core is located sharply eccentric, has a crescent shape. With the accumulation of fat inclusions in the fat cell, organoids are reduced and its size increases sharply. Both the number of fat inclusions in adipocytes and the number of fat cells themselves are subject to significant fluctuations. With increased nutrition, the number of adipocytes increases. Adipocytes can lose fat inclusions during starvation. Lipocytes are located in groups near blood vessels. These cells have the ability to accumulate large amounts of reserve fat, which is involved in trophic, energy formation and water metabolism.

Pigmentocytes (melanocytes, pigment cells) develop from the nervous scallops, not from the mesenchymem (Figure 30.1, 30.2). They are formed from melanoblasts that are isolated in embryogenesis from the neural crest.

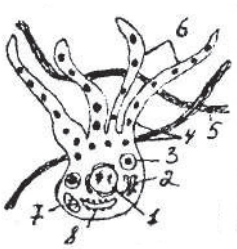


Figure 30.1. Melanocyt

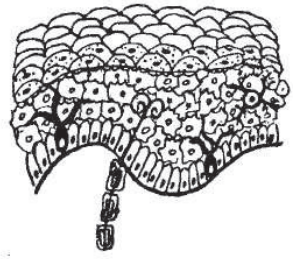


Figure 30.2. Pigment cells in the epidermis of the skin

Distinguish between melanocytes and chromatophores

Melanocytes have a neurogenic origin, they are process or basket-shaped, large sizes. The core is located in the center. The cytoplasm of a melanocyte contains all organoids of general significance, but they are poorly developed. The cytoplasm has brown and black

pigment inclusions in the form of small grains or short sticks-melanin, which is synthesized by melanocytes. The ability of melanocytes to synthesize melanin gives a positive reaction to DOPA oxidase. Melanin has a high UV absorption, so it protects the body from the damaging effects of UV radiation. Melanocytes are located in the epidermis of the skin. The amount of skin pigment in the epidermis can vary depending on both external and internal factors. The distribution of pigment in the skin is uneven: stronger pigmented skin of face, neck, back, weaker, abdomen, palms and soles. The amount of melanin pigment increases when the skin is exposed to sunlight for a long time, as a result of which people of the white race get a tan. In people of the black and yellow races, the skin color remains unchanged due to more melanin. People, the body of which is devoid of pigment and are called albinos. Pigmented spots on the skin often appear during pregnancy due to hormonal changes occurring in the body during this period.

Chromatophores are of mesenchymal origin. They are found in the dermis of the skin in the area of the anal opening and in the periarticular circles. They have a process form or in the form of a "Daisy". The nucleus is located in the center of the cell. The cytoplasm contains all the organoids, but they are poorly developed. The cytoplasm contains pigment inclusions-melanin. Chromatophores are not able to synthesize melanin and therefore do not give a positive reaction to DOPA oxidase.

They capture ready-made melanin when it is isolated from melanocytes. In this regard, the pigment cells of the dermis contain, but do not synthesize, melanin.

Pigment metabolism in the skin is closely related to the content of vitamins (A, C, PP) in it, and also depends on endocrine factors. The level of melanin pigmentation of the skin is directly affected by the hormones of the pituitary, adrenal, thyroid and gonadal glands.

Macrophages (macrophagocytes) are formed from stem hematopoietic cells, promonocytes, then monocytes. These cells are directly formed by differentiating and multiplying monocytes released into the tissues

from the bloodstream. Complete renewal of macrophages is about 10 times faster than fibroblasts.

The shape of macrophages is different: irregular, elongated, flattened, rounded. Their borders are always clearly defined, and the edges are uneven. Cytolemma macrophages forms a deep crease and a long microwires by which these cells capture foreign particles. On the surface of the macrophage cytolemma, there are receptors for immunoglobulins, T and B lymphocytes, antigens, and tumor cells. The presence of receptors to immunoglobulins determines their participation in immune responses. When macrophages come into contact with immunocompetent cells (lymphocytes), they transmit antigenic information necessary for the formation of antibodies.

Macrophages usually have a single core. All organoids of general significance are found in the cytoplasm of macrophages, but lysosomes are especially well developed. Macrophages secrete biological active factors and enzymes into the intercellular substance: interferon, lysozyme, pyrogens, proteases, acid hydrolases, etc., which provides their various protective functions. Pyrogenes are substances that increase body temperature during inflammation. Lysozyme is a bactericidal enzyme.

Macrophages are active phagocytic cells. They are capable of using pseudopods of the cytolemma to amoeboid movements. Macrophages are abundant in areas richly supplied with blood vessels. The number of them increases significantly with inflammation.

Histiocytes have a rounded shape. The cytolemma forms processes by which they cover and phagocytize various particles. The cytoplasm is rich in lysosomes, digestive vacuoles, or phagosomes, but other organoids are poorly developed. Histiocytes intensively phagocytize foreign particles and proteins, digesting them with the help of hydrolytic lysosome enzymes.

Histiocytes are often found in the immediate vicinity of small blood vessels, perform a protective function. A histiocyte is a macrophage at rest.

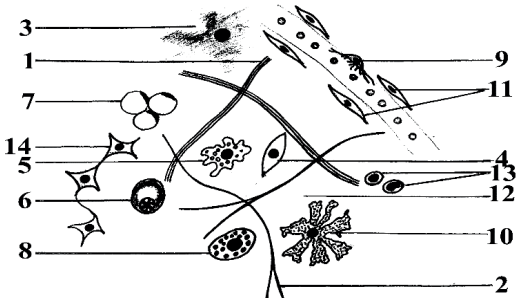


Figure 31. The structure of loose fibrous unformed connective tissue:
1. Collagen fibers. 2. Elastic fibers. 3. Fibroblast. 4. Fibrocyte.
5. Macrophage. 6. Plasmacyte. 7. Fat cell. 8. Tissue basophil (mast cell).
9. Pericite. 10. Pigment cell. 11. Adventitial cell. 12. Basic substance.
13. Blood cells (leukocytes). 14. Reticular cell

The macrophage system (reticuloendothelial system) is a collection of cells in the body that perform the function of phagocytosis and develop from blood monocytes. These cells, capable of active phagocytosis, capture, accumulate and digest foreign particles, dying cells, non-cellular structures, bacteria, products of cell decay and intercellular matter, participate in the creation of immunity and play macrophages (histiocytes) of loose fibrous connective tissue (Figure 31), stellate cells of sinusoid vessels of the liver (Kupfer cells), macrophages of hematopoietic organs (bone marrow, spleen, lymph nodes), alveolar macrophages of the lungs, osteoclasts, glial macrophages of nervous tissue (microglia). Back in the last century, the Russian scientist I.I. Mechnikov proposed to combine cells that perform the function of phagocytosis into a single system called macrophage. This system is a powerful protective device that participates in both General and local protective reactions of the body. It plays an important role in the formation of immunity, in the transfer of information to lymphocytes.

The intercellular substance of connective tissue consists of collagen, reticular, elastic fibers, as well as the main substance.

Collagen fibers are part of different types of connective tissue and determine their tensile strength. They are found in the dermis of the skin, bone, cornea, sclera, and blood vessel wall. Form collagen fibers fibroblasts, which synthesize the protein tropocollagen. Collagen fibers are strands with a thickness of 1–3 microns, having a transverse striation (64–70 nm). The structure of the collagen fiber includes bundles of thin fibers-fibrils (Figure 32). In turn, collagen fibrils consist of many even thinner microfibrils. Each microfibril consists of 5–6 protofibril. Protofibril consists of three protein chains protein tropocollagen.

Elastic fiber. Their presence in connective tissue determines its elasticity and extensibility. The thickness of elastic fibers is usually less than collagen – 1–2 mkm. Form elastic fibers fibroblasts that synthesize protein-elastin (Figure 33).

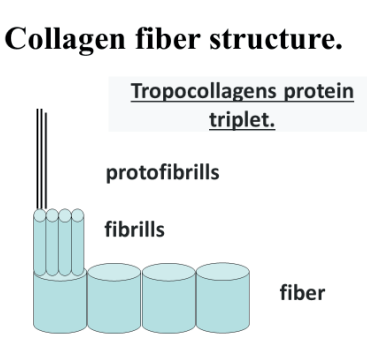


Figure 32. Collagen fibers

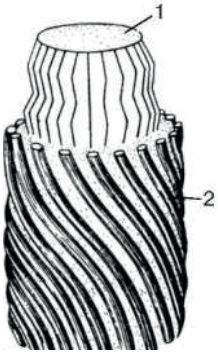


Figure 33. Elastic fiber: 1 – elastin; 2-fibrillin

Elastic fiber consists of two components – amorphous – the central homogeneous part and microfibrillar (on the periphery).

The amorphous component is represented by the protein elastin, which occupies the central part of the fiber. Elastin molecules are located without a specific orientation. On the periphery of the fiber is a microfibrillar component consisting of microfibrils.

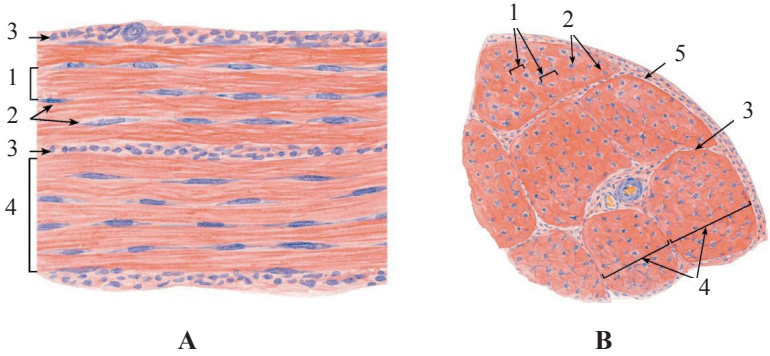


Figure 34. Dense fibrous formed connective tissue of Tendon.
A) 1 – primary tendon bundle; 2 – tendon cells (fibrocytes);
3 – endotenon; 4 – secondary tendon bundle.
B) 1 – primary tendon bundles; 2 – tendon cells (fibrocytes);
3 – endotenon; 4 – secondary tendon bundles; 5 – peritenon

Dense fibrous connective tissue is characterized by the fact that in it the fibers of intercellular substance prevail over the cells and the main substance. This tissue is divided into two types depending on the location of the fibers: dense unformed and dense formed connective tissue (Figure 34).

In dense fibrous unformed connective tissue, bundles of intercellular substance fibers are located in different directions and do not have a strict, regular orientation. Dense fibrous unformed connective tissue is characterized by an unordered arrangement of fibers. This tissue forms the dermis of the skin. Due to constant and comprehensive mechanical action, the fiber bundles are arranged in different planes and intertwine. Cells in this tissue are few, they are mainly represented by fibroblasts, fibrocytes, and occasionally there are other cells that are observed in loose fibrous unformed connective tissue.

Dense fibrous connective tissue is characterized by a strictly ordered arrangement of fibers. This tissue is found in ligaments, fibrous membranes, and tendons.

The tendon consists of tightly lying parallel bundles of collagen fibers. Between these bundles are located fibrocytes. The fibroblasts of the tendon bundles are called tendon cells. Tendon cells are triangular in shape, arranged in chains between bundles of first-order collagen fibers. The tendon is represented by bundles of the first, second, third and fourth orders, surrounded by layers of loose fibrous unformed connective tissue with the presence of blood vessels that feed the tendon.

A first-order bundle is a bundle of collagen fibers separated by fibrocytes or tendon cells.

A second-order bundle is a number of first-order bundles surrounded by a layer of loose fibrous unformed connective tissue. Layer of loose fibrous connective tissue separating bundles of the second order are called endotenonium. It is used for regeneration.

A third-order bundle is a number of second-order bundles surrounded by loose fibrous connective tissue. The layers of loose fibrous connective tissue that separate the bundles of the third order are called peritenonium.

A fourth-order bundle is a number of third-order bundles surrounded by loose fibrous connective tissue. Layer of loose fibrous connective tissue surrounding the outside of the tendon called epicranium.

Connective tissues with special properties

These tissues include reticular, fat, mucosal and pigmented. These tissues are characterized by a predominance of homogeneous cells, which is associated with the very name of these types of tissues.

Reticular tissue. This type of connective tissue has a mesh structure, which is reflected in the name of reticular tissue (reticulum – mesh). Reticular tissue consists of reticular cells and intercellular substance-reticular fibers and the main substance.

Reticular tissue from the mesenchyma develops. During embryonic histogenesis, germ mesenchymal cells differentiate into reticuloblasts, which differ from mesenchymal cells in that they form reticular fibers – the first supporting elements that ensure the normal functioning of the germ tissues. Subsequently, reticulocyte turn into reticular cells. The latter, in turn, can differentiate into macrophages, acquiring the ability to phagocytosis.

There are: reticular cells and phagocytic cells.

Reticular cells have a process shape. The cell nucleus is large, oval in shape. The cytoplasm has numerous polymorphic processes that contact with other reticular cells and intertwine with them, causing a network – like structure of the tissue. These cells are stationary, which is in communication with each other. The cytoplasm contains a well-developed granular endoplasmic network (ergastoplasm). Reticular cells are attached to reticular fibers and join with each other processes, forming a loose network.

Phagocytic cells are polymorphic. There are many lysosomes in the cytoplasm. These are free-lying cells of monocytic origin, capable of phagocytosis.

Reticular fibers are derived from reticular cells. They are found when impregnated with silver salts, so they are also called argyrophilic (argentum-silver). The chemical composition of these fibers is similar to that of collagen, but differs from them in their lower thickness, branchiness, and anastomoses.

There are two types of reticular fibers: reticular fibers proper and precollagen fibers.

Proper reticular fibers are mature, definitive, final formations containing type III collagen.

Precollagen fibers are the initial form of collagen fiber formation during embryogenesis and regeneration. In terms of extensibility, reticular fibers occupy an intermediate position between collagen and elastic fibers.

Reticular tissue forms a stroma of hematopoietic organs and a microenvironment for blood cells developing in them (Figure 35).

Reticular cells can develop from adventitial cells adjacent to blood capillaries.

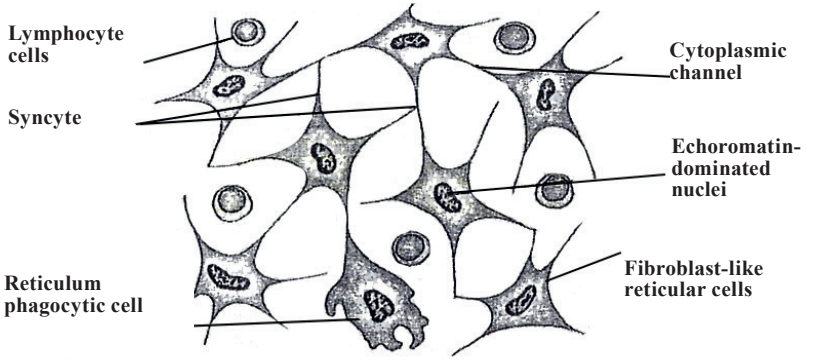


Figure 35. Reticular tissue

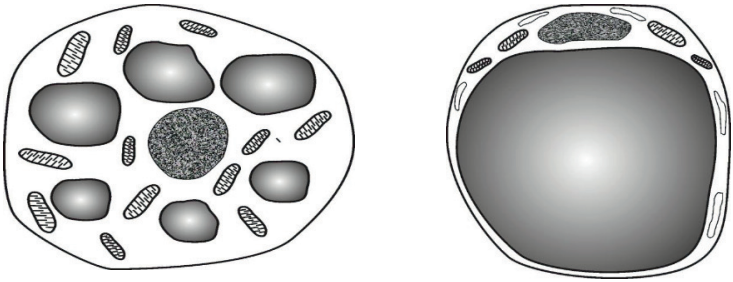
Adventitious cells during ontogenesis retain the potency to differentiate into reticular cells, being the main source for their regeneration.

Adipose tissue is a collection of fat cells. There are two types of adipose tissue – white and brown (Figure 36).

White adipose tissue in humans is located under the skin, especially in the lower part of the abdominal wall, on the buttocks and thighs, where it forms a subcutaneous fat layer, in the omentum and mesentery. Adipose tissue is divided by layers of loose fibrous unformed connective tissue into segments of various sizes and shapes.

Fat cells inside the lobes are located so tightly that their shape becomes polygonal. The blood capillaries closely cover the groups of fat cells or the lobules of white adipose tissue. In the white adipose tissue, there are active processes of metabolism of fatty acids, carbohydrates and the formation of fat from carbohydrates. When fat breaks down, a large amount of water is released and energy is released.

The amount of white adipose tissue varies depending on the diet. During fasting, adipose tissue loses fat reserves and easily gives away lipids. Function: trophic, water depot. However, in the skin of the palms and soles, adipose tissue performs a mechanical function, remaining even during fasting.



Brown adipose cell **White adipose cell**

Figure 36. Two types of adipose tissue

Brown adipose tissue is found in newborns in the area of the shoulder blades, along the spine, behind the sternum, on the neck, under the skin and between the muscles. It consists of fat cells densely entwined with hemocapillaries. In contrast to the cells of white adipose tissue, these fat cells are smaller, and fat inclusions are represented by small drops that are completely surrounded by mitochondria. The mitochondria contain pigments-cytochromes that give a brown color to the fat cell. The nucleus is rounded and located in the center of the cell. The oxidative capacity of brown fat cells is about 20 times higher than white ones. When the ambient temperature decreases, the activity of oxidative processes in brown adipose tissue increases. At the same time, heat is released that warms the blood flowing in numerous capillaries between lipocytes. When fasting, brown adipose tissue changes less than white. Brown adipose tissue takes part in the processes of heat production.

Mucosal or gelatinous connective tissue is found only in the embryo. Warton's jelly of the umbilical cord of the human fetus contains mucous tissue.

Cells of mucosal tissue are represented by cells such as fibroblasts of the mucosal. They poorly synthesize the protein collagen.

The intercellular substance consists of collagen fibers and the main substance. Collagen fibers are located loosely, their number increases as the embryo develops. The main substance has a jelly-like consistency. In the main substance, a large amount of hyaluronic acid is found. Function: protective (mechanical).

Pigmented connective tissue contains numerous pigment cells-melanocytes. It includes connective tissue areas of the skin in the area of the nipples, scrotum, near the anus, as well as in the vascular membrane and iris of the eye, birthmarks. Function: protective (from UV-radiation).

THE CARTILAGE TISSUE

The cartilage tissue

Skeletal connective tissues include cartilage and bone tissue. Cartilage is part of the respiratory system, joints, and intervertebral discs.

Cartilage tissue makes up the bulk of cartilage and is the initial tissue for the development of tubular bones of the skeleton during embryonic histogenesis. Cartilage has a supporting function, and therefore it is part of various parts of the skeleton. As well as protective, mechanical functions, participation in water-salt metabolism.

The development of cartilage

The source of development is the mesenchyma of the dorsal mesoderm sclerotome. There are three stages of development. The first stage is the formation of a chondrogenic island. In those places of the embryo's body where the cartilage is formed, mesenchymal cells thicken, lose their processes, multiply intensively and fit tightly together. These areas are called chondrogen islands. In the future, the mesenchymal cells that are part of them are differentiated into chondroblasts – cells that form cartilage tissue.

The second stage is the formation of primary cartilage tissue. The cells located in the center of the chondrogen islet are rounded, increase in size and become young chondrocytes – primary chondrocytes. In the cytoplasm of chondrocytes, a granular endoplasmic reticulum develops, which is involved in the synthesis and secretion of proteins (collagen). An intercellular substance is formed that is oxyphilic. This is primary cartilage tissue.

The third stage is the differentiation of cartilage tissue. In the further process of differentiation of cartilage tissue, young chondrocytes

synthesize and secrete glycosaminoglycans and proteoglycans into the intercellular substance. On the periphery of the cartilage bookmark, there is a supra-cartilage. The cells of the inner layer of the epiglottis intensively divide and layer on the existing cartilage along its periphery. This is how the growth of cartilage occurs by superimposing or oppositional growth – the growth of cartilage along the periphery (peripheral growth). The cartilage cells that lie in the center of the young cartilage divide and the number of these cells increases. There is a growth of cartilage from the inside – interstitial growth (by the type of intussusception). As the cartilage grows and develops, the Central parts of it begin to experience difficulties in feeding, since it is carried out diffusely from the vessels of the epiglottis. As a result, chondrocytes often do not diverge, but form isogenic groups of 2–4 chondrocytes by dividing a single cell, surrounded by a common capsule.

Structure of cartilage tissue

Cartilage tissue consists of cells and intercellular substance and is characterized by the fact that its intercellular substance is very dense.

Cartilage cells

There are two types of cartilage cells: chondroblasts and chondrocytes. Chondroblasts are small cells. They have a fusiform or flattened shape. The cytoplasm contains all the organelles of general meaning. In the cytoplasm of chondroblasts, a smooth and granular endoplasmic network is very well developed. Cells are able to divide. Multiplying by mitosis, chondroblasts displace part of the cells and gradually differentiate into chondrocytes.

Chondroblasts are found only in the inner (cellular, cambial) layer of the epiglottis.

Functions-synthesis of intercellular substance, participation in peripheral (oppositional) growth of cartilage, capable of proliferation and differentiation into chondrocytes.

Chondrocytes are the main type of cartilage tissue cells. They are located in special cavities (lacunae) in the intercellular substance alone or in groups. Groups of cells lying in a common cavity are called isogenic. Isogenic groups are small, double, and large.

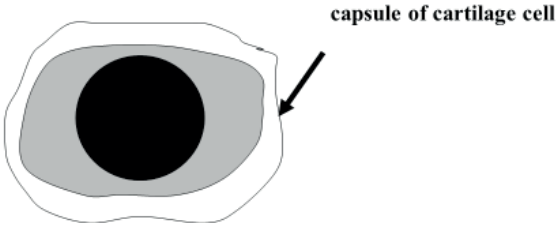
There are three types of chondrocytes in isogenic groups (the first, second, and third types). They vary in the size of the cytoplasm, and their nuclei have the same diameter (Figure 37). The first type of chondrocytes with a high nuclear-cytoplasmic ratio (the area of the nucleus is larger than the area of the cytoplasm). They have a rounded shape. The nucleus is round, located in the center of the cell. The cytoplasm contains all organoids of general significance, but poorly developed. Cells are capable of reproduction and are the source of reproduction of isogenic groups. The number of chondrocytes of the first type prevails in young, developing cartilage.

The second type of chondrocytes with an average nuclear-cytoplasmic ratio (the area of the nucleus corresponds to the area of the cytoplasm). The cells are oval in shape. The core is round, located excentrically. The cytoplasm of chondrocytes contains all organoids of general significance. A smooth (agranular) endoplasmic reticulum is well developed. Function-formation and secretion of glycosaminoglycans and proteoglycans of intercellular substance.

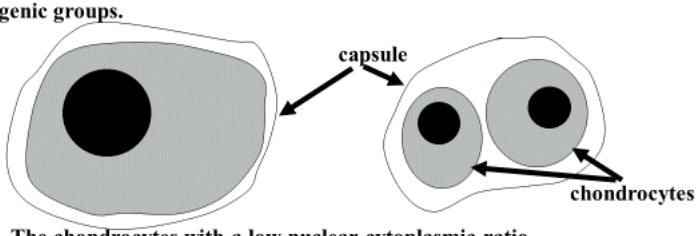
The third type of chondrocytes with a low nuclear-cytoplasmic ratio (the area of the nucleus is less than the area of the cytoplasm). Chondrocytes have a polygonal shape. The core is round and sharply excentre. The cytoplasm contains all the organelles of General meaning. A very well-developed granular endoplasmic network, in which the cylinders and tanks are arranged parallel to each other, in an orderly manner. This granular endoplasmic reticulum is called ergastoplasm. Function – the formation and secretion of the protein of intercellular substance.

1.The chondroblasts (scheme) are found only in the internal (cellular, cambial) layer of the perichondrium.

2. The chondrocytes with a high nuclear-cytoplasmic ratio lie in the zone of young cartilage.



3. The chondrocytes with an average nuclear-cytoplasmic ratio. They lie in the zone of mature cartilage as small isogenic groups.



4. The chondrocytes with a low nuclear-cytoplasmic ratio.

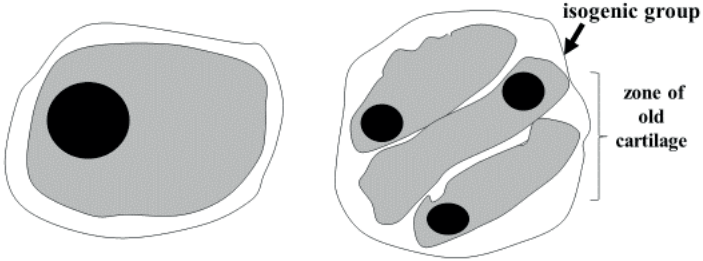


Figure 37. The schematic representation of chondroblasts and chondrocytes

Intercellular substance of cartilage

The intercellular substance of cartilage tissue consists of fibers and the main substance. There are two types of fibers-collagen (protein collagen) fibers and elastic (protein elastin) fibers. Base material are proteins, lipids, glycosaminoglycans, a proteoglycan, chondroitinase acid.

If there is mineralization of the intercellular substance of the cartilage dies. The cartilage tissue contains 70–80 % water, 10–15 % organic substances and 4–7 % mineral salts.

Classification of cartilage tissue

There are three types of cartilage tissue: hyaline, elastic and fibrous. This division of cartilage tissue is based on the structure of its intercellular substance.

Hyaline cartilage tissue. In the adult body, hyaline cartilage tissue occurs at the junction of the ribs with the sternum, in the Airways, on articular surfaces, at the junction of the epiphysis and diaphysis of tubular bones (metaepiphyseal cartilage), in the larynx.

Hyaline cartilage is also called glassy due to its transparency and bluish-white color. The structure of hyaline cartilage tissue of various organs has a lot in common (cell structure, diffuse nutrition), but differs in the location of cells, the structure of intercellular substance. This is the most solid and elastic of all types of cartilage. In this regard, it is more common to talk about cartilage as an anatomical formation, rather than about cartilage tissue.

Structure of hyaline cartilage

The hyaline cartilage is covered with epiglottis on the outside. The cartilage itself consists of three zones: the zone of young cartilage, the zone of mature cartilage, and the zone of old cartilage (Figure 38).

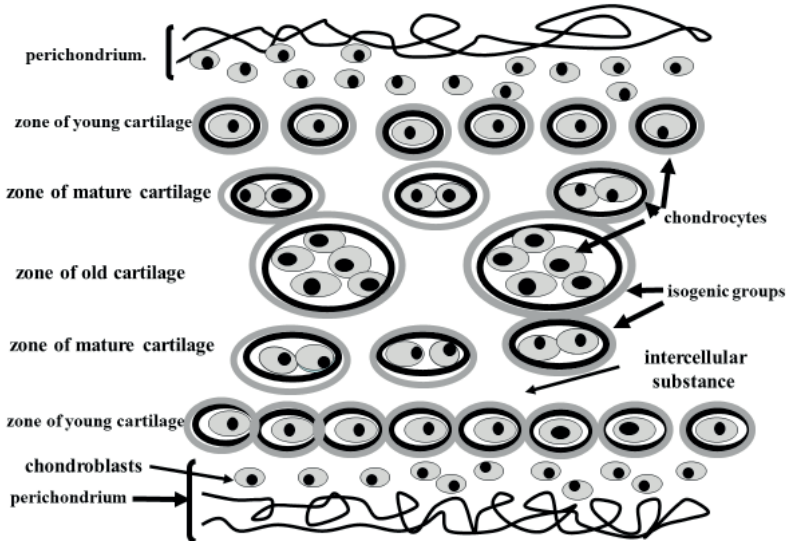


Figure 38. The schematic structure of hyaline cartilage

The peculiarity of the cartilage itself is that it does not have blood vessels, and the cartilage is fed diffusely due to the vascular network of the suprachristia.

Hyaline cartilage tissue, like any other type of cartilage tissue, consists of cells called chondroblasts and chondrocytes, as well as intercellular matter. The fibers of the intercellular substance are represented by collagen fibers, which are immersed in the main substance, consisting of acidic mucopolysaccharides – hyaluronic and chondroitinseric acids and their compounds with proteins of the chondromucoid type. Under light microscopy, the collagen fibers are not visible due to the same refractive index of their and the main substance. Collagen fibers are detected only by polarizing microscopy, as well as by special treatment of cartilage tissue.

The perichondrium

There are two layers in the perichondrium: external (fibrous) and internal (cellular, cambial, chondroblastic).

The outer layer consists of dense fibrous unformed connective tissue with blood vessels.

The inner layer contains chondroblasts

The proper cartilage. Under the perichondrium in the surface layer of cartilage is a zone of young cartilage, represented by singly located chondrocytes. The cells are surrounded by a capsule of collagen fibers impregnated with the main substance. The intercellular substance is oxyphilic. The zone of mature cartilage is represented by small double isogenic groups surrounded by a common capsule. The intercellular substance is oxyphilic and basophilic due to the uneven distribution of chemical components of the intercellular substance – proteins, chondroitinseric acid and glycosaminoglycans.

The zone of old cartilage is represented by large isogenic groups consisting of 4 chondrocytes surrounded by a common capsule.

The intercellular substance is basophilic. This zone is located deep in the cartilage. With age, as a result of changes in the composition of the intercellular substance and the deposition of calcium salts in it, its permeability decreases sharply, which leads to dystrophic changes and death of cells located in the center of the cartilage.

Hyaline cartilage of the articular surface

The peculiarity of the structure is the absence of perichondrium. The articular cartilage is covered on the outside with 1) a shiny layer of the main substance, consisting mainly of proteoglycans. Deeper, you'll 2) the surface cell layer, consisting of poorly differentiated cells, 3) the fibrous layer (Figure 39).

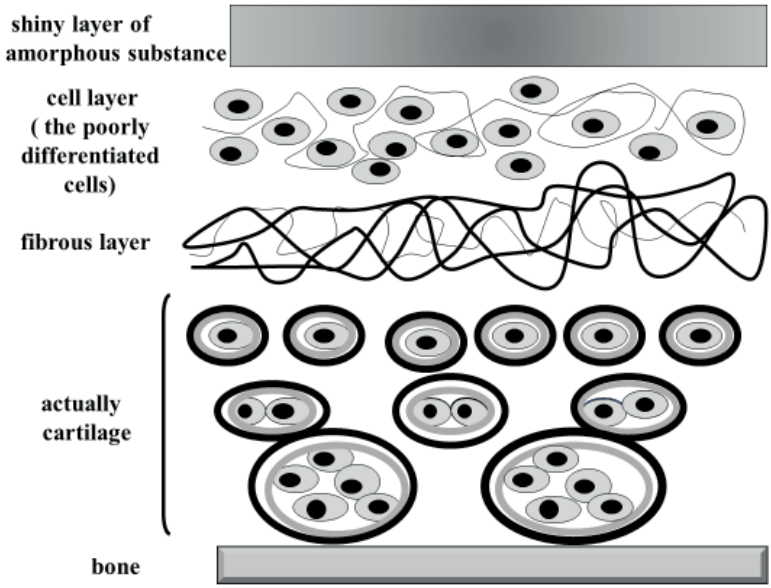


Figure 39. The schematic representation of hyaline cartilage of the articular surface

In the proper cartilage, there are three zones: external, middle, and deep.

In the outer zone there are single-lying chondrocytes. In the middle zone, there are isogenic groups in the form of columns perpendicular to the surface.

The deep zone of articular cartilage consists of calcified cartilage. Only in this zone are blood vessels detected.

Nutrition of articular cartilage is only partially carried out from the vessels of the deep zone, and mainly from the synovial fluid of the joint cavity.

Elastic cartilage tissue

Elastic cartilage tissue is found in the ear, in the epiglottis, in the external auditory canal, in the auditory tubes.

Elastic cartilage tissue forms elastic or reticular cartilage. It is built on the same principle as hyaline, but differs from the latter in that it is opaque, colored in a yellowish color, and most importantly, in the intercellular substance, along with collagen fibers, there is a network of elastic fibers visible in a light microscope. In the zone of mature and old cartilage, the isogenic groups are arranged in columns or «coin columns». There are fewer isogenic groups in elastic cartilage than in hyaline. In elastic cartilage, unlike hyaline, there is never a deposition of calcium salts and no calcification occurs (Figure 40).

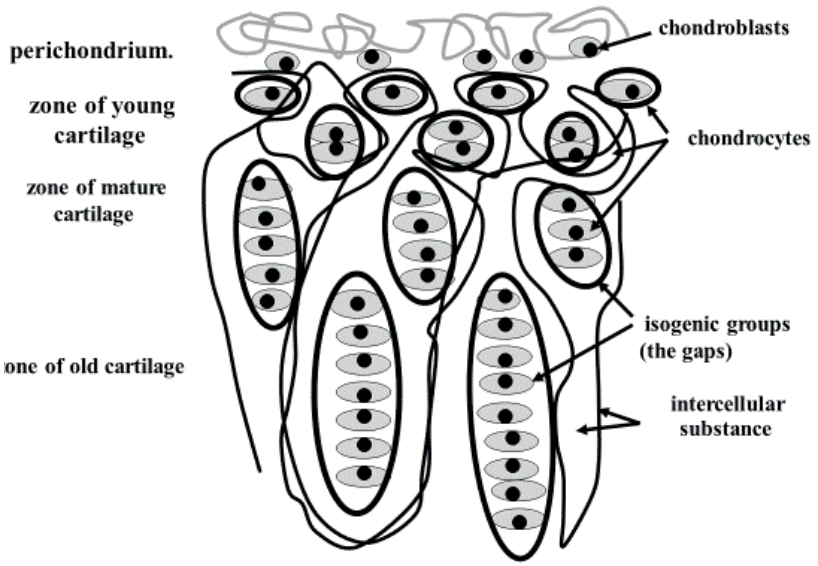


Figure 40. The elastic cartilage tissue

Fibrous cartilage tissue

The fibrous cartilaginous tissue forms a fibrous or connective-tissue cartilage. This type of cartilage is found in the intervertebral discs, the mandibular joint, and in those places where tendons and ligaments pass into hyaline cartilage, attaching to the bones.

Fibrous cartilage is built from the same structural components as hyaline, but with the difference that the collagen fibers of the intercellular substance form such large bundles that they become visible under light microscopy. The intercellular substance contains parallel-directed visible collagen fibers (Figure 41).

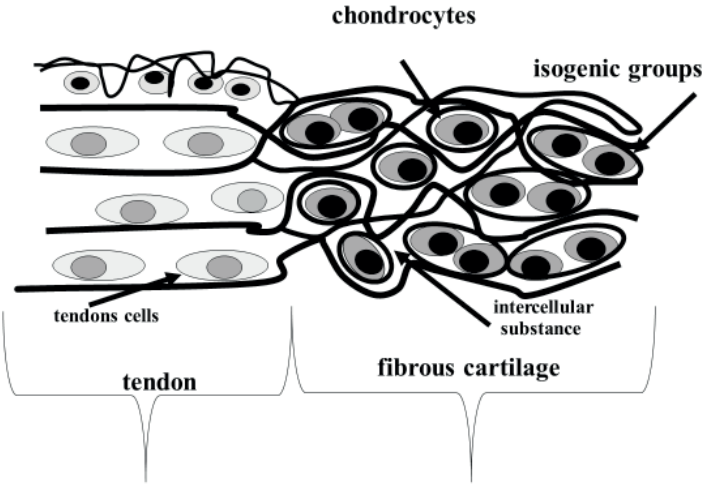


Figure 41. The fibrous cartilage tissue

Regeneration of cartilage tissue.

The regeneration of cartilage tissue is due to the supracondyle, whose pericytes, located around blood vessels, differentiate into chondroblasts. The latter reproduce and differentiate. However, this process is very slow.

BONE TISSUE

Bone tissue is skeletal connective tissue. This type of connective tissue is present in all vertebrates and humans. Bone tissue performs a supporting function, takes part in mineral metabolism. Bone tissue, forming the bone skeleton and the skeleton of the limbs, determines the shape of the body of the body, protects the organs located in the skull, in the thoracic and pelvic cavities. Bones are a protective device.

Bone tissue consists of cells and mineralized intercellular substance.

The intercellular substance consists of ossein (collagen) fibers and the main substance. The intercellular substance contains 33 % organic substances and 67 % inorganic substances.

Organic and inorganic substances combined with each other give a very strong support tissue. Bone tissue has high strength and elasticity. Of all the varieties of connective tissues, bone tissue has the most pronounced supporting, mechanical, protective functions for internal organs, and is also a depot of calcium, phosphorus, and other salts.

Development of bone tissue – osteogenesis

The source of development is the mesenchyma of the dorsal mesoderm sclerotome. Bone tissue develops from the mesenchyma in two ways:

1) **direct / intramembranous osteogenesis** – directly from the mesenchyma of the sclerotome (Figure 43, 44);

2) **indirect / endochondral osteogenesis** – on the site of previously laid cartilage.

Direct osteogenesis is the development of bone from the mesenchyma (Table 3).

The development of bone from the mesenchyma of the dorsal mesoderm sclerotome is observed in the formation of the bones of the facial skull and the integumentary bones of the medullary skull.

The development of bone tissue directly from the mesenchyma includes 4 stages (Figure 42, 43):

1 stage – formation of an osteogenic islet;

2 stage – osteoid stage or stage of organic matrix formation;

3 stage – mineralization;

4 stage – formation of lamellar bone tissue.

1 – Condensation of mesenchyme into soft sheet permeated with blood capillaries.

2 – Deposition of osteoid tissue by osteoblasts on mesenchymal surface; entrapment of firstosteocytes; formation of periosteum.

3 – Honeycomb of bony trabeculae formed by continued mineral deposition; creation of spongy bone.

4 – Surface bone filled in by bone deposition,converting spongy bone to compact bone. Persistence of spongy bone in the middle layer.

Stage 1 – formation of an osteogenic islet. In the first stage, mesenchymal cells begin to multiply intensively at the site of laying the future bone, forming dense clusters of cells – an osteogenic island.

Stage 2 – osteoid stage or organic matrix formation stage. At this stage, differentiation of islet cells occurs. Osteogenic islet cells differentiate into osteoblasts-cells that create bone. Initially, osteoblasts form a gelatinous intercellular substance, in which thin collagen fibers appear. With the increase in synthetic ability of osteoblasts to intensively produce amorphous intercellular substance and collagen fibers. These fibers form thin primary bone crossbars around which osteoblasts are located, continuing to form new collagen fibers and amorphous intercellular substance.

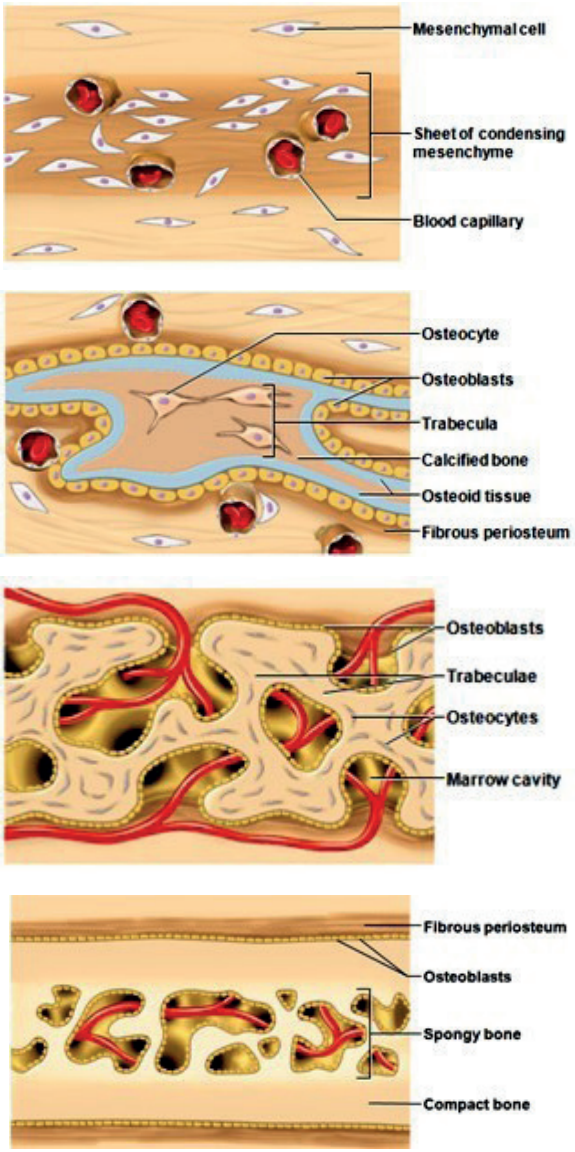


Figure 42. Intramembranous ossification

Stage 3 – mineralization stage. Many of the osteoblasts become trapped between the collagen fibers, walled up in them and turn into bone cells - osteocytes. Further development of bone tissue is accompanied by calcification of the intercellular substance. This process begins with the fact that a large amount of the phosphatase enzyme appears in the intercellular substance, which is synthesized by osteoblasts. In the future, calcium phosphate is formed, which together with calcium carbonate is deposited in the amorphous and fibrous intercellular substance in the form of small crystals. Rough-fiber bone tissue is formed, in which the collagen fibers are located in different directions.

Stage 4 – the stage of development of lamellar bone tissue. Inside the rough-fibred bone tissue, primary osteons arise – around the vessel there is a similarity of bone cylinders inserted one into the other. Since the appearance of osteons, coarse-fibrous bone tissue ceases to develop and is replaced by lamellar bone tissue, in which the collagen fibers are arranged in an orderly manner.

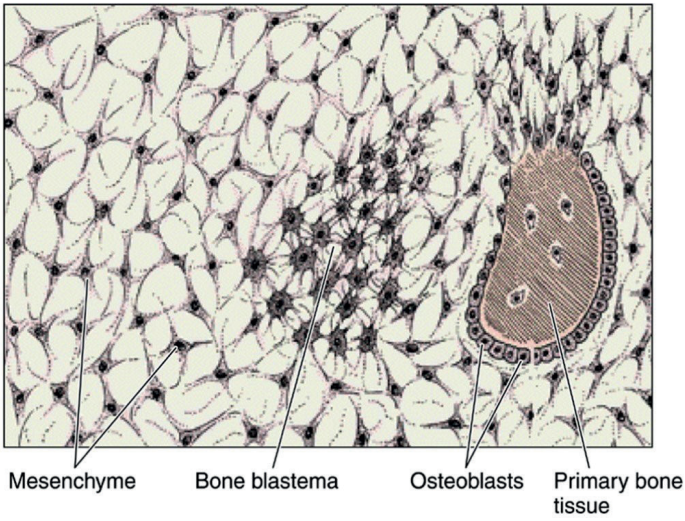


Figure 43. Intramembranous ossification

Table 3.

Intramemranous and endochondral osteogenesis

	INTRAMEMBRANOUS	ENDOCHONDRAL
ORIGIN	MESENCHYME	CARTILAGE MODEL
FORMED BONES	FLAT, SKULL BONES	TUBULAR BONES
STAGES	OSTEOGENIC ISLET	CARTILAGE MODEL
	OSTEOID FORMATION	PERICHONDRAL COLLAR FORMATION
	MINERALIZATION OF OSTEOID	PRIMARY (DIAPHYSEAL) CENTERS FORMATION
	MODELING AND REMODELING	SECONDARY (EPIPHYSEAL) CENTERS FORMATION
		MODELING AND REMODELING

Indirect osteogenesis is the development of bone in place of cartilage.

According to this type, the tubular bones of the skeleton develop. In the process of embryonic histogenesis, cartilage tissue occurs before bone tissue (Figure 44).

There are 4 stages of bone development in place of cartilage:

Stage 1 – perichondral ossification.

Stage 2 – stage of dystrophic changes.

Stage 3 – endochondral ossification.

Stage 4 – replacement of coarse-fibrous bone tissue with lamellar.

Stage 1 – perichondral ossification. The development of bone tissue in place of the cartilage model of the bone begins with the fact that blood vessels grow in the supra-cartilage and osteoblasts appear. The germ of the future bone is composed of embryonic hyaline cartilage, covered on the periphery of the perichondrium. Osteoblasts

in the perichondrium form bone tissue. The resulting coarse-fibrous bone tissue is called a bone cuff or perichondral bone ring, since it encircles the rudiment of the future bone, and the process itself is perichondral ossification.

Stage 2 – stage of dystrophic changes. The formation of a bony cuff disrupts the supply of cartilage. As a result, dystrophic changes occur in the center of the cartilage. The cartilage is destroyed, chondrocytes vacuolized nucleus picotiterplate.

Stage 3 – endochondral ossification. Under the influence of enzymes secreted by osteoclasts, the cartilage dissolves (Figure 45).

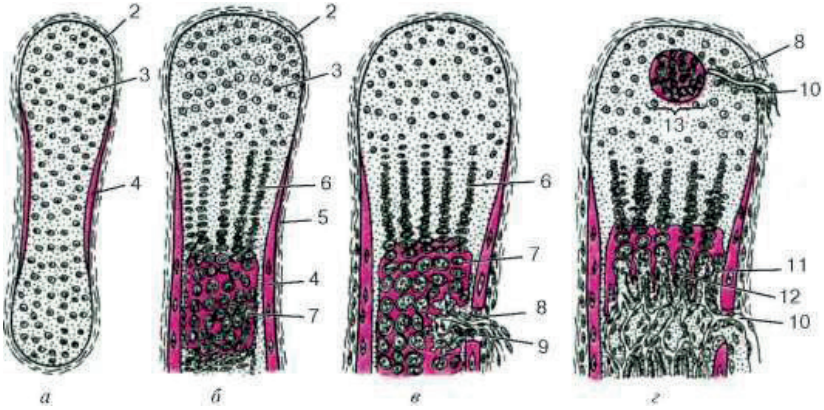


Figure 44. Indirect osteogenesis:
Formation of a cartilaginous model of bone and perichondral bone cuff (according to Yu.I. Afanasyev): a–d – stages of osteogenesis. 1 – primary cartilaginous model of the tubular bone; 2 – perichondrium; 3 – cartilage tissue; 4 – perichondral bone cuff; 5 – periosteum; 6 – columns of cartilage cells; 7 – zone of vesicular cells; 8 – mesenchyme growing into cartilage with differentiating osteoclasts (9) and blood capillaries (10); 11 – osteoblasts; 12 – endochondral bone tissue; 13 – ossification point in the pineal gland

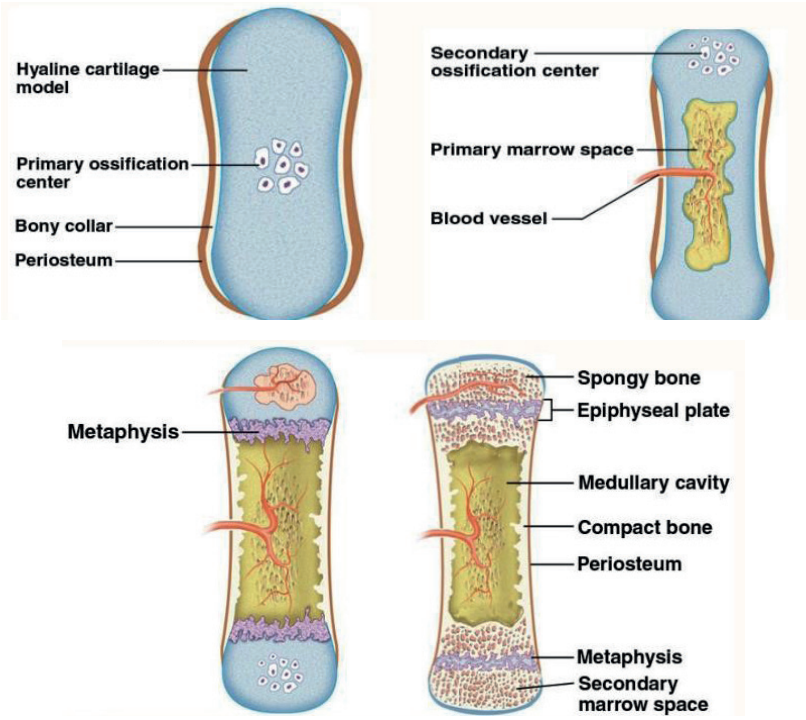


Figure 45. Endochondral ossification:
Primary ossification center; Marrow space;
metaphysis and secondary ossification center

In the future, osteoblasts with blood vessels grow through the openings of the bone cuff. In the cartilage there are elongated spaces-resorption cavities, in which osteocytes settle. Around the blood vessels begin to form concentric plates consisting of parallel-oriented collagen fibers and mineralized intercellular substance. This is how primary osteons arise. The process of bone deposition inside the cartilage germ is called endochondral ossification. This bone has a lamellar structure.

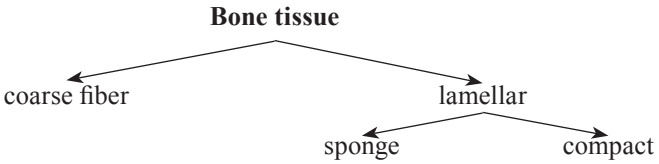
Stage 4 – replacement of coarse-fibrous bone tissue with lamellar.

Classification of bone tissue

There are two main types of bone tissue – coarse-fibrous and lamellar.

There are two types of lamellar bone tissue – spongy and compact. These types of bone tissue differ in the structure of the intercellular substance, depending on the location of collagen fibers in the intercellular substance.

Classification of bone tissue



Structure of bone tissue

Bone tissue consists of cells and intercellular substance. There are three types of cells – osteocytes, osteoblasts and osteoclasts (Figure 46).

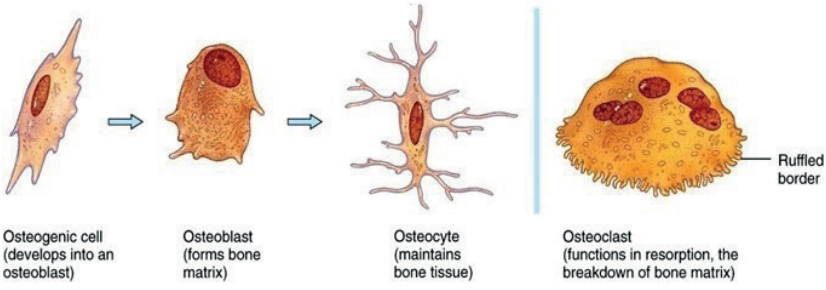


Figure 46. Structure of bone tissue

Osteocytes

In the adult body, osteocytes are the main cells of bone tissue. They have a process form with numerous long cytoplasmic processes that contact the processes of other osteocytes. The cytoplasm contains organoids of General significance, but poorly developed. There is no cell center. The nucleus is oval in shape, located in the center of the cell. Osteocytes do not multiply by mitosis. Bone cells lie in bone cavities or lacunae that follow the contours of the osteocyte. The tubules of the bone cavities anastomose with each other. Functions-ensuring the integrity of the matrix-intercellular substance, the release of calcium from bone tissue (Figure 47).

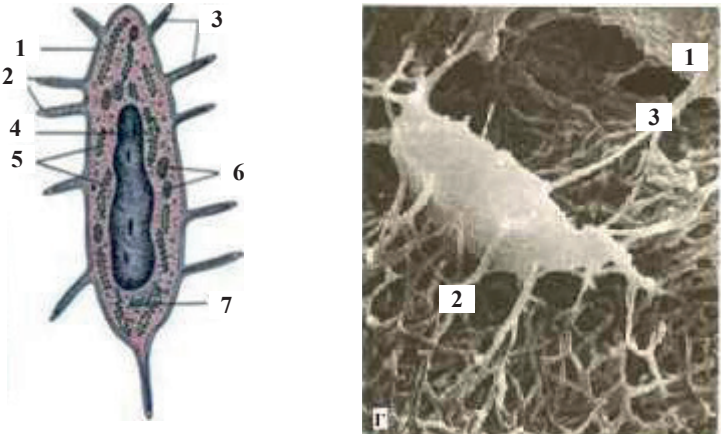


Figure 47. Osteocyte:
1 – lacunae wall; 2 – bone tubule; 3 – osteocyte process;
4 – nucleus; 5 – granular endoplasmic reticulum;
6 – mitochondria; 7 – Golgi complex

Osteoblasts

These are large cells. They come in various shapes: cubic, pyramidal, polygonal. The core is round or oval in shape, often located eccentrically. The cytoplasm contains all the organelles of General meaning.

In the cytoplasm of osteoblasts is very well developed granular endoplasmic reticulum (ergastoplasm). Osteoblasts do not divide, but differentiate into osteocytes. In the formed bone, osteoblasts are found only in the deep layers of the periosteum and in the areas of bone regeneration after its injury (Figure 48).

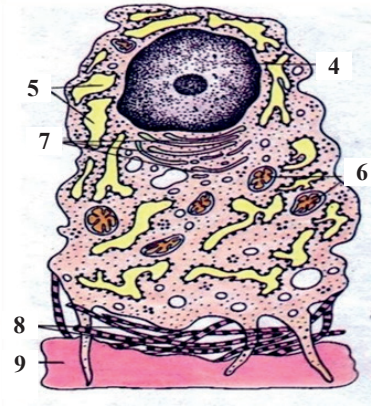


Figure 48. Osteoblasts:
1 – lacunae wall; 2 – bone tubule; 3 – osteocyte process;
4 – nucleus; 5 – granular endoplasmic reticulum; 6 – mitochondria;
7 – Golgi complex; 8 – osteoid; 9 – bone mineralized substance

Osteoblasts are cells that create bone tissue. Functions-synthesis and secretion of intercellular substance, participation in the process of mineralization.

Osteoclasts

The source of development is the monocyte.

Osteoclast – a large, multi-core cell of irregular shape.

The cytoplasm contains all organoids of General significance, and lysosomes are well developed. There are 4 zones in the osteoclast: 1) basal – zone of nuclei and organoids; 2) vesicular – zone of lysosomes; 3) light – zone of cytoplasm without organoids; 4) corru-

gated border – represented by cytoplasmic outgrowths (Figure 49). Osteoclasts are cells that destroy bone. This is a bony macrophage. They are contained in the endosteum that lines the bone on the side of the bone marrow. Function-lysis, resorption of bone tissue.

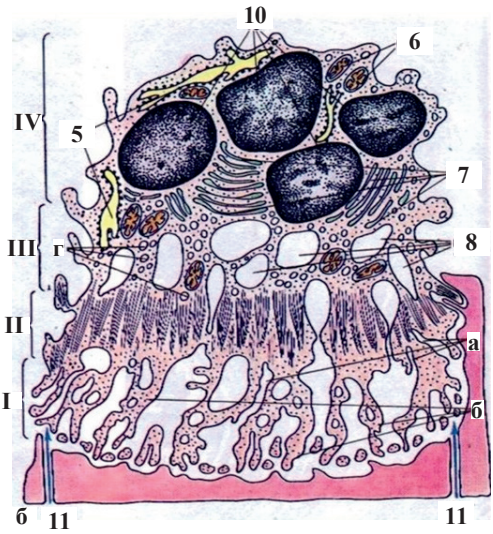


Figure 49. Osteoclast ultrastructure:
5 – granular endoplasmic reticulum; 6 – mitochondria;
7 – Golgi complex; 10 – osteoclast nuclei: а) folds of plasmolemma;
б) microvilli; в) vacuoles; г) vesicles; I – corrugated border;
II – light zone; III – vesicular zone; IV – basal zone

Coarse-fibrous bone tissue

In adults, coarse-fibrous bone tissue can be found at the site of cranial sutures, where tendons attach to bones. In this tissue, ossein (collagen) fibers, collected in thick, coarse bundles, are located in the intercellular substance in different directions.

Coarse-fibrous bone tissue is represented by the osteocytes which are in contact with each other their processes. Osteocytes are located in bone cavities or lacunae, with long anastomosing tubules (Figure 50).

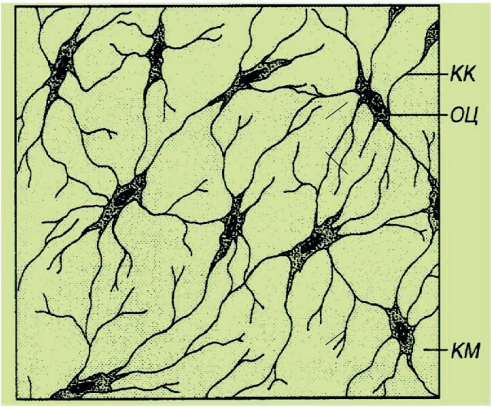


Figure 50. Coarse-fibrous bone tissue:
ОЦ – Osteocytes; КМ – bone matrix; КК – bone tubules

Lamellar spongy bone tissue consists of bony plates that go in different directions. This type of bone tissue is characteristic of the epiphyses of tubular bones (Figure 51).

In bone plates, the collagen fibers are located at an angle of 90° relative to the neighboring bone plate. Osteocytes lie between the bone plates, penetrating them with bone tubules. Each plate consists of parallel ossein (collagen) fibers.

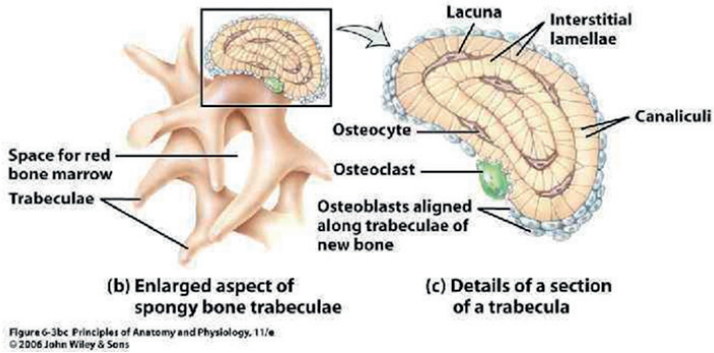


Figure 51. The structure of spongy bone (head of the femur)

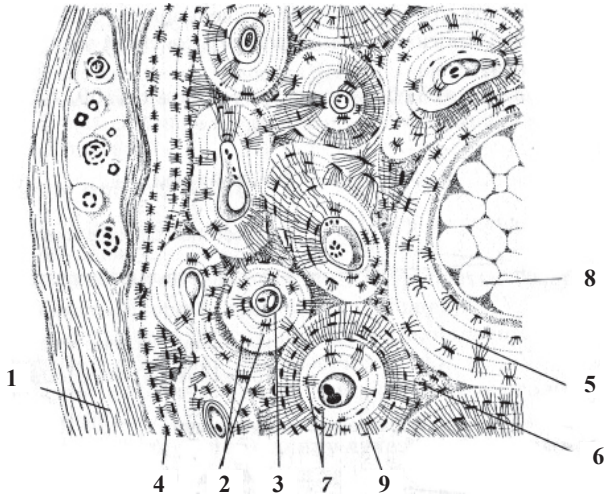


Figure 52. Lamellar bone tissue (transverse thin section):
1 – periosteum; 2 – osteon plates; 3 – osteon canals (Haversian canals);
4 – external main plates; 5 – internal main plates;
6 – insertion plates; 7 – osteocytes; 8 – bone marrow cavity; 9 – osteon

Lamellar compact bone tissue consists of bony plates that are arranged (compactly) adjacent to each other. This type of tissue can be found in the diaphysis or the middle part of the tubular bones (Figure 52, Figure 54).

Structure of the diaphysis

There are following layers in the diaphysis: periosteum, outer layer General plates actiony layer, the inner layer General plates layer and endosteum.

Periosteum. In the periosteum, there are two layers: external (fibrous) and internal (cellular). The outer layer is formed by dense fibrous unformed connective tissue with blood vessels feeding the bone.

The inner (cellular, cambial) layer contains osteoblasts of various degrees of differentiation.

The periosteum binds the bone to the surrounding tissues and participates in its trophism, development, growth and regeneration.

The outer layer of the General or General plates consists of several layers of bony plates arranged in parallel.

Osteon – the middle layer is formed by osteons-concentrically layered around the vessels of bone plates. In the middle layer, the bone plates are located mainly in the osteons, forming osteon plates, as well as insert plates lying between the osteons.

Osteon - structural and functional unit of the bone diaphysis. Osteon – concentric layers of bone plates, located around the Central channel of the osteon or Haversov channel, in which the blood vessels of the microcirculatory bed pass. The Central channels anastomose with each other. Connecting channels are called perforating (feeding) or Volkman channels (Figure 53). Each osteon is separated from neighboring osteons by a so-called adhesive line. Between the osteons, there are remnants of destroyed osteons or inset (interstitial) bone plates.

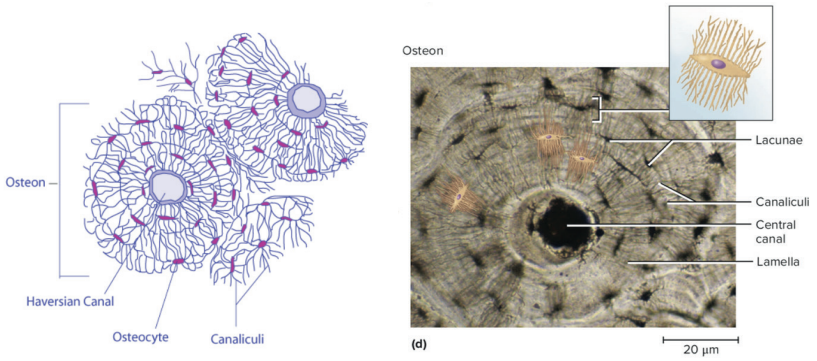


Figure 53. The structure of osteon

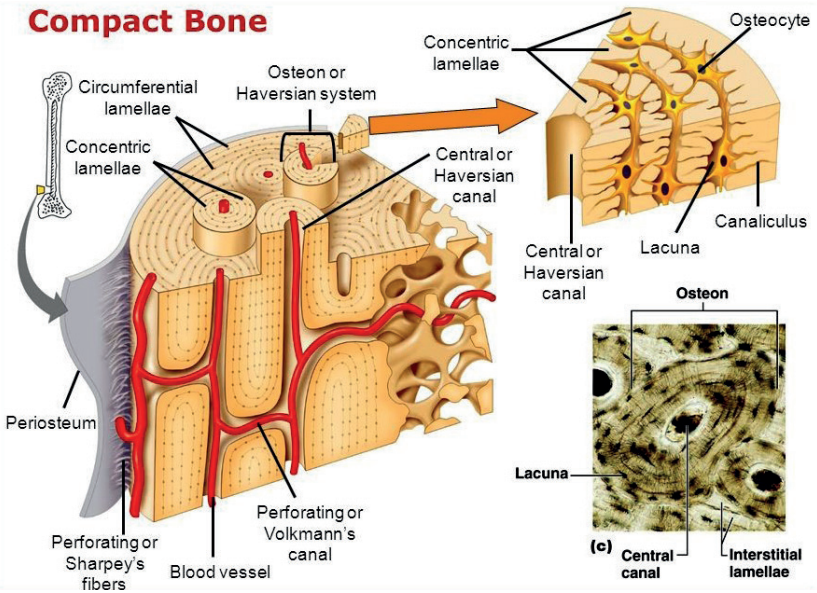


Figure 54. Compact bone tissue

The inner layer of the General or General plates consists of several layers of bony plates arranged in parallel. The internal common plates are well developed only where the compact substance of the bone directly borders the medullary cavity.

The endosteum is formed by loose fibrous unformed connective tissue, and also contains a large number of osteoclasts. This is the shell that lines the bone on the side of the bone marrow.

Bone tissue regeneration

Physiological regeneration of bone tissue occurs throughout life. It is associated with the processes of destruction and creation (Figure 55). One of the reasons that causes the process of rebuilding osteons is the change in physical load on the bone during life. Lack of physical

activity on the bone tissue (prolonged immobilization, staying in a state of weightlessness) leads to an increase in the function of osteoclasts and the removal of salts.

The food regime has a great influence on the bone tissue. If a person's diet is low in vitamin D, then the calcium coming from food is not absorbed or poorly absorbed in the gastrointestinal tract, which causes osteoporosis and bones break easily. If the amount of vitamin C is insufficient, the formation of collagen fibers decreases, which leads to the inability to form bone plates.

Sometimes women after the onset of menopause develop osteoporosis associated with a lack of estrogen.

Under the influence of osteoclasts activated by various factors, the bone plates of the osteon are destroyed and a cavity is formed in its place. This process is called bone resorption.

In the formed cavity around the remaining vessel, osteoblasts appear and the construction of new plates begins, which are concentrically layered on each other (osteones). Between the osteons are inserted plates – these are the remains of previously destroyed osteons.

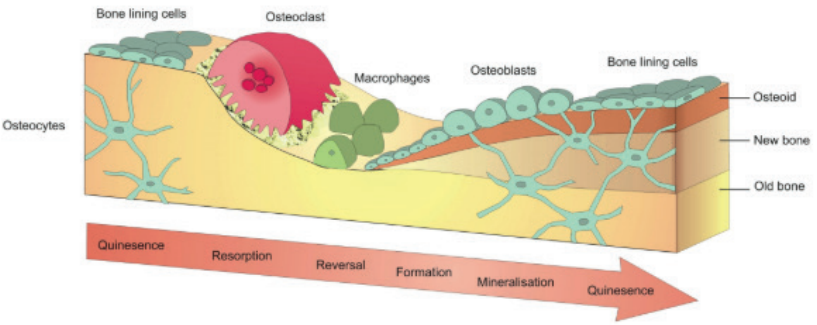


Figure 55. Remodeling of bone tissue

Reparative regeneration of bone tissue occurs when the bone is damaged. Violation of the integrity of the bone is accompanied by damage to the bone plates, blood vessels, nerves, and periosteum. In the area of damage, the bone tissue dies due to circulatory disorders. In the periosteum and endosteum, as well as around blood vessels, mass reproduction of pericytes is observed within 2 days after the injury, which then differentiate into osteoblasts. They, in turn, begin to form coarse-fibred bone tissue connecting the fragments of bone. With significant violations of the integrity of the bone, with a large damage to blood vessels, the site of the defect first develops cartilage tissue, which is then replaced by bone tissue. The cartilage and bone tissue formed at the site of the defect is called a callus. The bone callus is replaced by bone plates and turns into lamellar bone tissue (Figure 56).

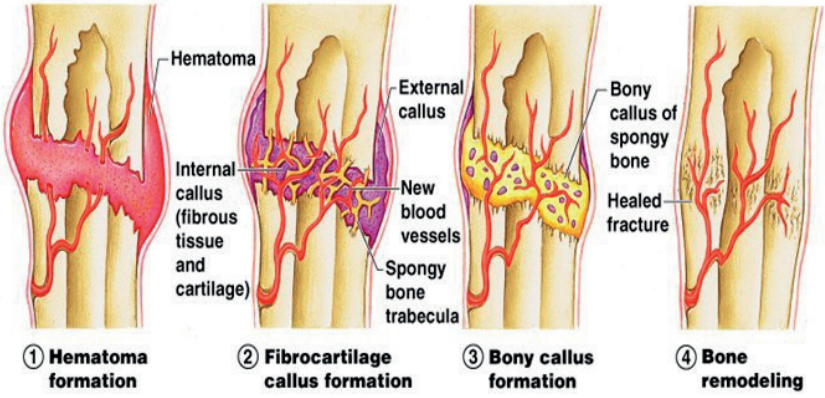


Figure 56. Reparative regeneration

MUSCLE TISSUE

Muscle tissue appeared in the course of the historical development of multicellular organisms at a later stage than the previously considered epithelial and connective tissues. The main function of muscle tissues is to provide movement in the space of the body as a whole and its parts. Muscle tissue is closely associated with the nervous tissue both in phylogenesis and in ontogenesis. The connections of these two tissues are expressed in their simultaneous appearance in phylogeny in the same systematic groups of multicellular organisms. The formation of muscle and nerve tissue in ontogenesis is also parallel. Muscle tissue is closely related to nerve tissue not only structurally, but also functionally. Both tissues are characterized by well-expressed excitability and the ability to spread excitement.

Genetic classification of muscle tissue (classification by origin). Muscle tissue develops from 5 sources and is divided into 5 histogenetic types:

1) mesenchymal-develops from the mesenchyma;

2) epidermal-develops from the skin ectoderm;

3) neural-develops from the neural tube;

4) coelomic-develop from the visceral leaf of the splanchnotome;

5) somatic-develop from somites (myota).

Morphological classification of muscle tissue (according to the structure of myofibrils).

All muscle tissues, depending on the structure of the contraction organelles (myofibrils), are divided into two groups – smooth and striated. Smooth (non-striated) muscle tissues contain contractile myofibrils that do not have a transverse striation (Figure 57). Smooth muscle tissue is divided into smooth, myoepithelial, and myoneural muscle tissue.

Striated muscle tissues contain ordered myofibrils with transverse striation. In turn, the striated muscle tissue is divided into cardiac and skeletal. Striated muscular tissues are reduced faster, than smooth.

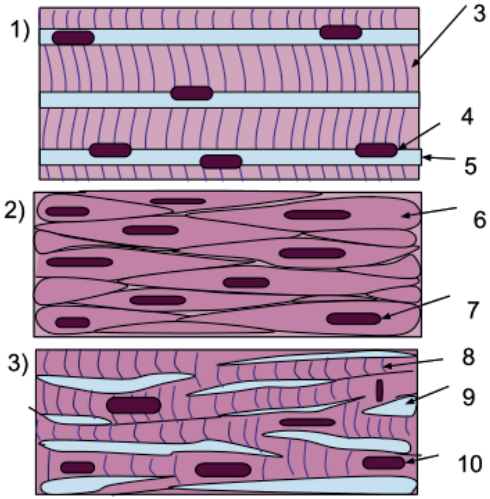


Figure 57. Muscle tissues

1) Skeletal muscle cells are long tubular cells with striations (3) and multiple nuclei (4). The nuclei are embedded in the cell membrane (5) so that they are just inside the cell. **2) Smooth muscle cells** are spindle shaped (6), and each cell has a single nucleus (7). **3) Cardiac muscle cells** have striations (8), and each cell has a single nucleus (10). adjacent cells (9)

Actually smooth muscle tissue

The actual smooth muscle tissue develops from the mesenchyme ventral mesoderm of splanchnotomy. This is the embryonic germ cells of the mesenchyme proliferate intensively, they have reduced the number of processes, the cells acquire an elongated spindle-shaped form and closing. Differentiation of mesenchymal cells into myoblasts begins when the first myofibrils appear in their cytoplasm (Figure 58).

Figure 58. Development of smooth muscle tissue:
1 – embryonic germ cells; 2 – myoblasts; 3 – smooth muscle cells

In the future, the number of myofibrils increases and myoblasts turn into cells of smooth muscle tissue-myocytes. By the ninth week of human embryonic development, smooth muscle tissue acquires all the definitive features of its structure. Differentiation of smooth muscle tissue is accompanied by the convergence of smooth muscle cells to a very dense, usually layered arrangement.

The structure of the smooth muscle tissue

Actually, smooth muscle tissue consists of smooth muscle cells-myocytes. The myocyte is fusiform in most cases, sometimes star-shaped (uterus) or in the form of spindles split at the ends (bladder).

In the center of the myocyte is an elongated, rod-shaped nucleus. When the cell shrinks, the nucleus can become corkscrew-shaped. The cytoplasm of a myocyte contains all organoids of General significance and an organoid of special significance-smooth myofibrils (Figure 59).

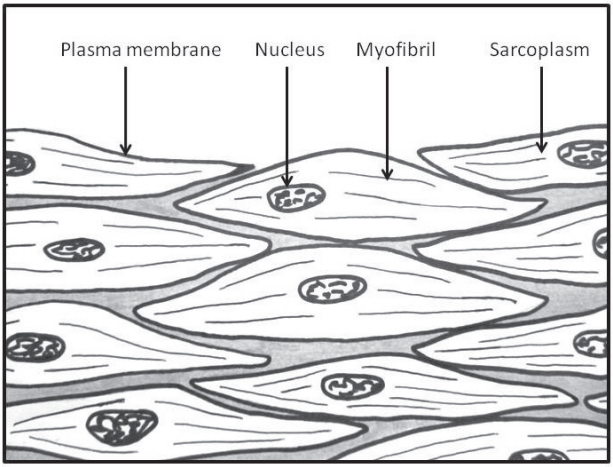


Figure 59. Smooth muscle tissue

Myofibrils consist of myofilaments that are not strictly ordered in a smooth muscle cell, but are scattered throughout the cytoplasm. There are two types of myofilaments – thin actin and thick myosin, which are attached to the cytolemma. Cytolemma forms numerous invaginations – pinocytosis bubbles. Myocytes are tightly attached to each other and are connected using slotted connections (nexuses). Between the cells is a supporting stroma-collagen and elastic fibers that form dense networks around each cell. Smooth muscle cells are combined into bundles consisting of 10–12 cells. Groups of smooth muscle cells are united by loose fibrous unformed connective tissue, between which pass vessels and nerves (Figure 60).

Smooth muscle tissue is part of the muscles located in the walls of blood vessels and hollow internal organs (digestive tube, lungs, bronchial tree, genitourinary organs).

Smooth muscle tissue contracts slowly (involuntarily) and can be in a state of contraction for a long time, which is called tonic contraction (Figure 61).

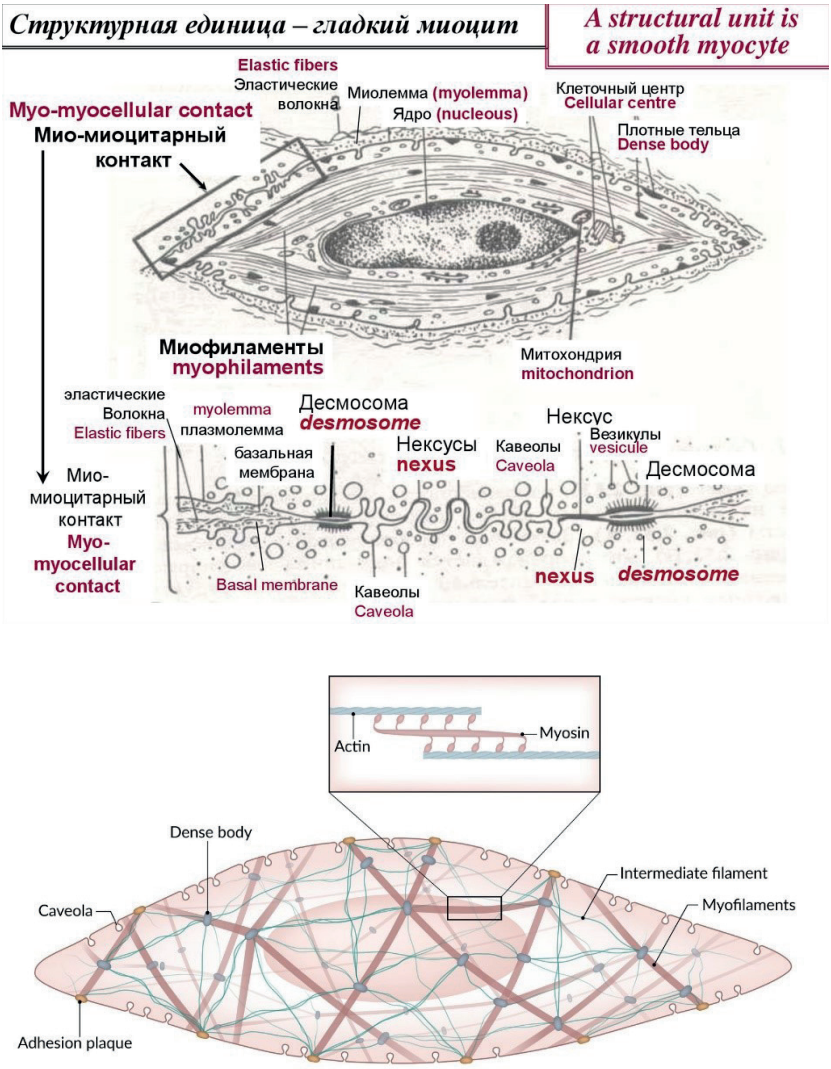


Figure 60. The structure of the smooth muscle cell

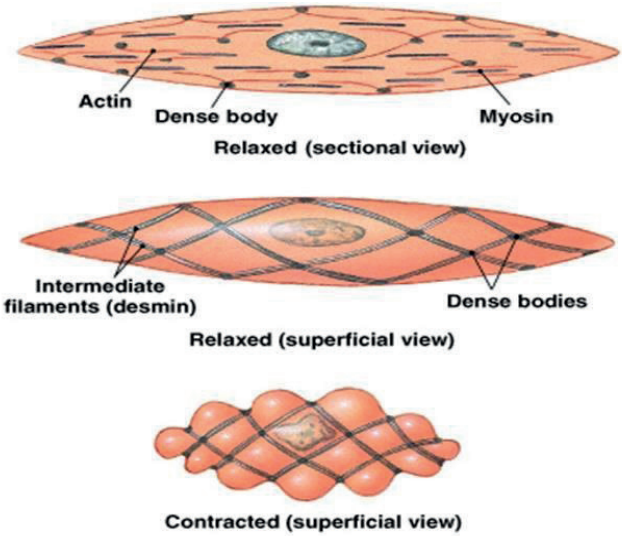


Figure 61. Smooth muscle cell (myocyte) in relaxed and contracted states

Regeneration

There are two types of regeneration – physiological and reparative. Physiological regeneration is the restoration of tissues in a healthy body. Reparative regeneration is the restoration of tissues after damage.

The physiological regeneration of the smooth muscle tissue itself goes by:

1) hyperplasia-an increase in the number of cells as a result of mitotic division;

2) compensatory hypertrophy-an increase in cell size in conditions of increased functional loads (in the uterus during pregnancy, myocytes increase in size by 10 times – from 50 to 500 microns in length);

3) connective tissue fibroblasts turn into myoblasts and then into smooth muscle cells;

4) the pericytes accompanying the capillaries differentiate into myoblasts, and then into myocytes.

In reparative regeneration, the tissue is restored in the same way.

Myoepithelial muscle tissue

The source of development is the skin ectoderm. The structural and functional unit is the myoepithelial cell, which has a stellate shape and covers the secretory departments and small excretory ducts of the exocrine glands with processes. They are also called basket-shaped. The nucleus is located in the center of the cell, the cytoplasm contains all organoids of General significance, and in the processes of organoids of special significance – myofibrils that do not have transverse striations, in the form of smooth threads.

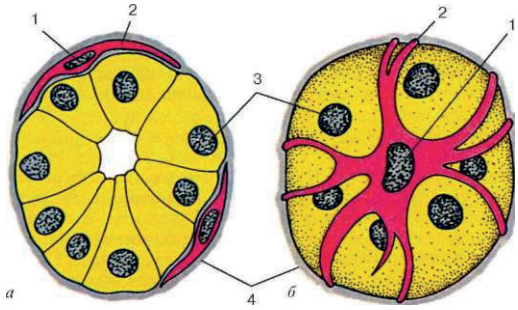


Figure 62. Myoepithelial cells of the salivary gland (scheme according to G.S. Katinas):
a – cross section; b – view from the surface.
1 – nuclei of myoepithelial cells; 2 – processes of myoepithelial cells;
3 – nuclei of secretory epithelial cells; 4 – basement membrane

Myoepithelial cells during contraction compress the secretory end sections and, therefore, facilitate the release of secretions from them. These cells are directly attached to the secretory epithelial cells of the terminal parts of the glands and are covered with a common basement membrane on top. The main function of myoepithelial cells

is the ability to contract. They are located in the sweat, milk, salivary and lacrimal glands (Figure 62).

Myoneural muscle tissue

The source of development is the neural tube. Structural and functional unit-myoneural cells. Myoneural cells have a fusiform shape. The cytoplasm contains all organoids of General significance and an organoid of special significance-smooth myofibrils.

There are two types of myoneural cells: sphincters and dilatators. They are part of the two muscles of the iris of the eye – narrowing and expanding the pupil. Sphincters-muscles that constrict the pupil, located longitudinally to the pupil. Dilatators-muscles that expand the pupil, located perpendicular to the pupil (Figure 63).

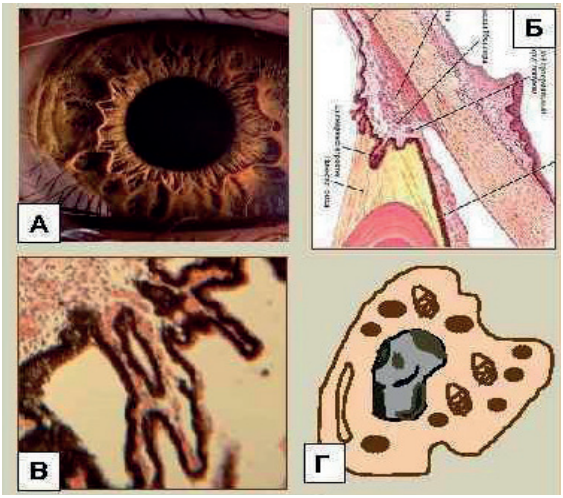


Figure 63. Myoneural muscle tissue:
А – muscle tissue of the iris and ciliary body (Б) develops from the rudiment of the nervous system. The main structural and functional unit of the muscles of the iris is a smooth mononuclear myocyte, or myopigmentocyte (Г). В – groups of myopigmentocytes of the ciliary body

Cardiac striated muscle tissue

This tissue is part of the heart's myocardium. The source of development is the myoepicardial plate. The development of striated cardiac working muscle tissue occurs from the unsegmented mesoderm, from the visceral leaf of the splanchnotome. The visceral leaf of the splanchnotome forms a bookmark of the heart, called the myoepicardial plate.

Of its cellular material occurs, the working of striated cardiac muscle tissue.

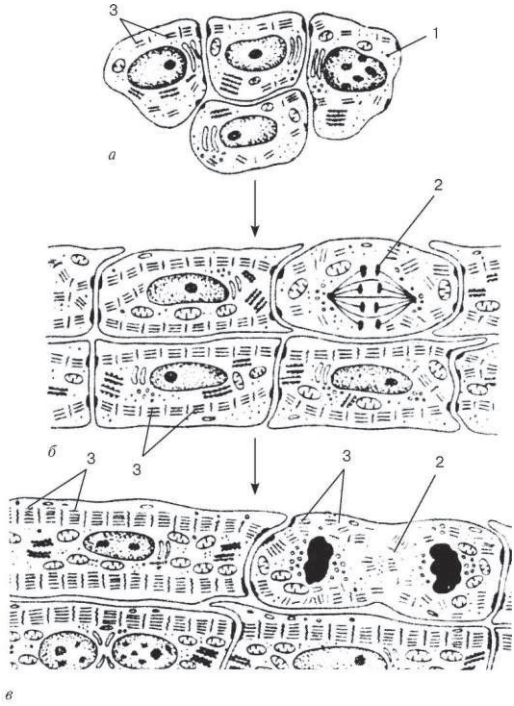


Figure 64. Histogenesis of cardiac muscle tissue (scheme according to P.P. Rumyantsev):
a – cardiomyocytes in the wall of the heart tube;
b – cardiomyocytes in late embryogenesis;
c – cardiomyocytes in the postanatal period. 1 – cardiomyocyte;
2 – mitotically dividing cardiomyocyte; 3 – myofilaments and myofibrils

Mesenchymal cells of the myoepicardial plate differentiate into myoblasts, which acquire the ability to contract. In the future, with the appearance of myoblasts in the cytoplasm of myofibrils, they turn into cardiomyocytes that have a transverse striation. Cardiomyocytes are able to divide mitotically only in embryogenesis. Some of them are differentiated into cardiomyocytes of the cardiac conducting muscle tissue. In conducting cardiomyocytes, there is no further increase in the number of myofibrils and mitochondria (Figure 64).

During histogenesis, contractile and conducting cardiomyocytes are differentiated, as well as secretory atrial cardiomyocytes (Figure 65).

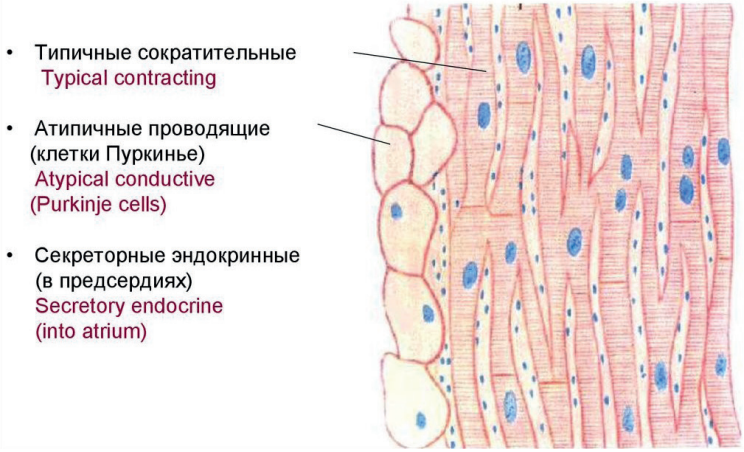


Figure 65. Types of cardiomyocytes

The structure of the contractile cardiomyocytes

The main mass of the myocardium consists of striated cardiac working muscle tissue, which consists of muscle cells-contractile working cardiomyocytes. They are rectangular in shape. The nucleus is oval in shape, located in the central part of the cell. The cytoplasm contains all organoids of General significance, an organoid of special significance-myofibrils, as well as inclusions of myoglobin,

glycogen and lipids. The cardiomyocyte is characterized by an abundance of mitochondria, myofibrils are located longitudinally, ordered on the periphery of the cell. Cardiomyocytes are not able to divide.

The cytolemma forms deep channel-like invagination-T-tubes, which includes the basal membrane that covers the outside surface of the cardiomyocyte. Cardiomyocytes are connected to each other using special connections called insertion disks. Every intercalated disk has the appearance of zigzag lines or fingerlike of invagination (like "lock") (Figure 66). The insertion disk is constructed differently: on the transverse sections, there are connections – desmosomes, and on the longitudinal sections – slotted contacts (nexuses). Cardiomyocytes are connected through processes in the form of a network, forming a functional syncytium, contributing to the synchronization of contractions. These cells are surrounded by layers of loose fibrous connective tissue unformed.

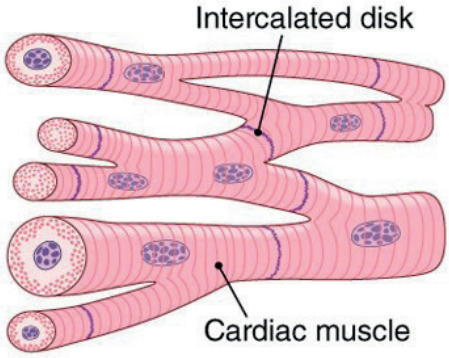


Figure 66. The structure of cardiac muscule

In loose connective tissue is a lot of blood vessels in contact with the cardiomyocytes.

Structure of conducting atypical cardiomyocytes

Conducting cardiomyocytes can have round, polygonal, flattened, oval, fusiform, pear-shaped forms and large sizes. The core is located a little eccentrically. The cytoplasm contains all organelles of General significance, and the organoid of special significance-myofibrils. Mitochondria in conducting cardiomyocytes are very small, there is no T-system. Myofibrils are not numerous, do not have a strictly linear orientation, and cross at an acute angle. Transverse striation of cardiomyocytes is very poorly expressed.

All these structural features indicate that this type of heart muscle tissue is not capable of active contraction.

The main function of conducting cardiomyocytes is that they perceive excitatory impulses and transmit them to contractile working cardiomyocytes. Atypical cardiomyocytes form the conducting system of the heart. They are located in groups, surrounded by layers of loose fibrous unformed connective tissue.

Structure of secretory cardiomyocytes

Atrial cardiomyocytes have a process shape. The cytoplasm contains all organelles of General significance and an organoid of special significance-myofibrils. There are few mitochondria and myofibrils in atrial cardiomyocytes. A distinctive feature of these cardiomyocytes is a relatively well-developed granular endoplasmic network. Atrial cardiomyocytes secrete a substance called natriuretic factor. Natriuretic factor increases the excretion of sodium ions by the kidneys and reduces blood pressure.

Regeneration of heart muscle tissue

Physiological regeneration is carried out in the myocardium mainly by intracellular regeneration, without increasing the number of cells.

With increased systematic functional loads, the total number of cells does not increase, but their size increases, and functional compensatory hypertrophy occurs.

During reparative regeneration, slightly damaged cardiac muscle tissue is replaced first by loose, and then by dense, fibrous, unformed connective tissue. Significant damage to the myocardium is fatal.

If cardiomyocytes die (heart attack), due to injury or the cessation of the flow of nutrients and oxygen through the blood vessels, they do not recover. Myocardial defects are overgrown with connective (scar) tissue.

Skeletal striated muscle tissue

Skeletal voluntary muscle tissue in mammals and humans is part of the musculature of the skeleton, the muscles of the face, mouth, tongue, pharynx, and the upper third of the esophagus.

Development of skeletal muscle tissue

The source of development is the dorsal segmented mesoderm-somite myotome.

Myogenesis (for A.N. of Stoudios).

Stage 1 – myoblast development or myoblast generation (Figure 67).

Cells of the central sections of myotomes, multiplying, form a dense cell mass, myofibrils appear in their cytoplasm and these cells differentiate into myoblasts, which are already capable of contraction.

Then myoblasts begin to migrate from myotomes to the surrounding mesenchyma. The number of myofibrils in them increases. Their differentiation continues in the places where future muscles are laid. This creates two lines of differentiation. Cells of one line are independent, differentiation in myosatellites. Cells of the other line

divide by mitosis. From one myoblast, as a result of mitotic division, 8 myoblasts are formed.

Stage 2 – muscle tube. In the process of differentiation of myoblasts they merge with each other to form multinucleated symplast. The latter are elongated, their sarcoplasma and nuclei occupy a central position, and myofibrils are located on the periphery. Such bioimplant called muscle tubes. Myosatellitocytes are attached to the surface of the myosymplast. In parallel with the development of skeletal muscle tissue, connective tissue develops, forming a connective tissue capsule.

Stage 3 – muscle fiber. In the process of further development of muscle tubes, there is an increase in the number of myofibrils in the sarcoplasm, and there is a transverse striation. In the future, myofibrils push the nuclei from the center to the periphery and occupy a central position. The muscle tubes turn into striated muscle fibers.

The striated muscle fiber (Myon) is an elongated multicore simplast to which myosatellites attach, surrounded by a connective tissue capsule into which blood vessels and nerves grow.

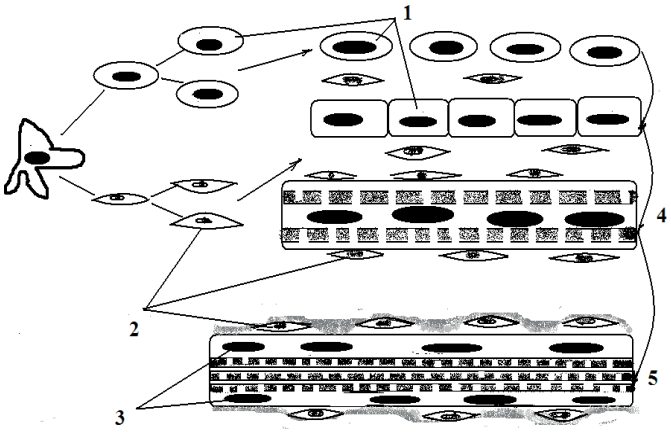


Figure 67. Histogenesis of skeletal muscle tissue:
1) myoblasts; 2) myosatellite cells; 3) myoblast nuclei;
4) muscle tube; 5) muscle fiber

Structure of skeletal muscle tissue

The structural and functional unit of skeletal muscle tissue is the striated skeletal muscle fiber or Myon (myosimplast) (Figire 68, 70). The striated muscle fiber has a cylindrical shape with rounded ends or the ends of the fiber form several small processes.

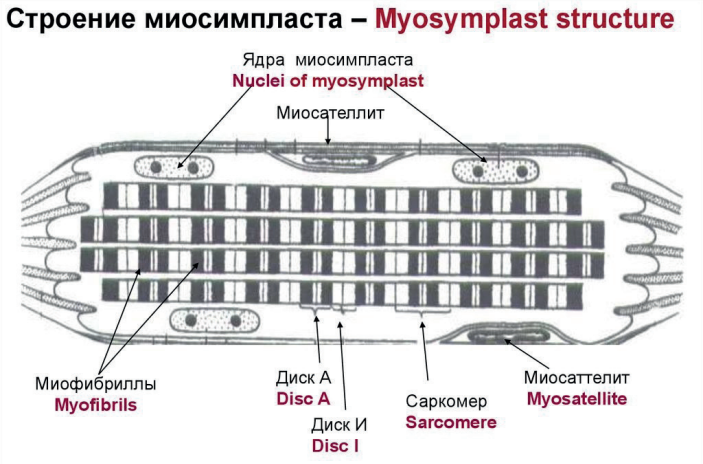


Figure 68. Myosymplast structure

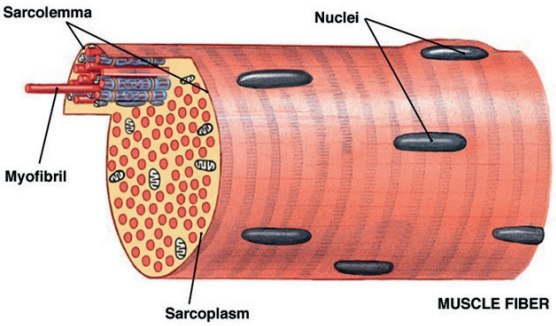


Figure 69. Muscle fiber

The shell of a skeletal muscle fiber is called a sarcolemma (Figure 69). Myosatellitocytes are attached to the sarcolemma, and the basal membrane and surrounding connective tissue lie outside. Under the sarcolemma are oval nuclei, which range from a few dozen to several hundred, depending on the length of the muscle fiber.

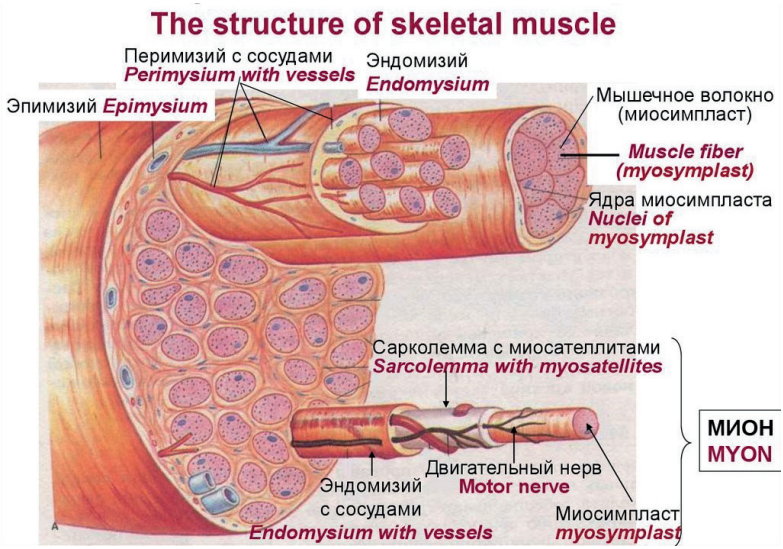


Figure 70. The structure of skeletal muscle

Skeletal muscle fiber consists of 5 apparatuses: trophic, specific membrane, contractile, support and nervous.

The trophic apparatus

It is represented by sarcoplasm with organoids of General significance and nuclei. Mitochondria or sarcosomes make up the most developed component, the endoplasmic network is called the sarcoplasmic network. There is no cell center.

Specific membrane apparatus

The sarcolemma of the skeletal muscle fiber is inserted into the sarcoplasm at regular intervals in the form of tubes. This system of transverse tubes that permeate the sarcoplasm is called the T-system (Figure 71). The cisterns of the smooth sarcoplasmic network are closely adjacent to the tubes of the T-system. The tube of the T-system in the center and the two cisterns of the smooth sarcoplasmic network on both sides form triads-they are called the specific membrane apparatus of the muscle fiber. The basal membrane does not penetrate the T-tubes.

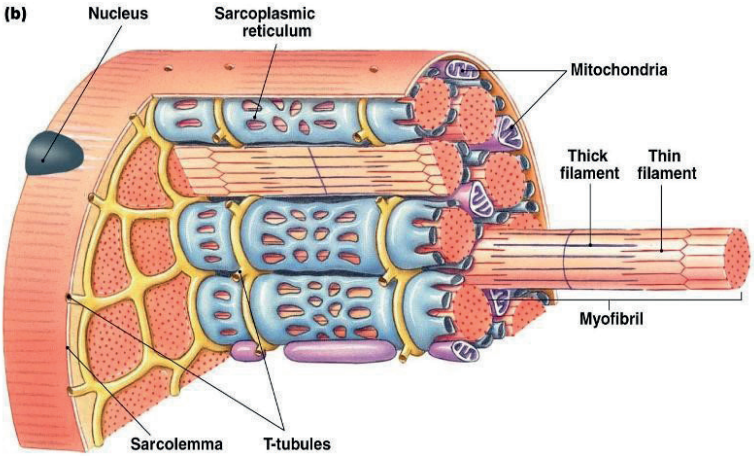


Figure 71. Structure of skeletal muscle

The contractile apparatus

It consists of myofibrils arranged in an orderly manner in the center of the muscle fiber. In the composition of myofibrils, two types of myofilaments are found – thick myosin and thin actin. Myofibrilla consists of alternating dark (myosin) and light (actin) plots. Dark areas of myofibrils twice refract light passing through them, so they are called anisotropic areas or disks A. Light areas of myofibrils have

a single-beam refraction and are called isotropic areas or disks I. In parallel running myofibrils, the location of light and dark areas coincides. This coincidence causes the transverse striation of the striated muscle fiber (Figure 72).

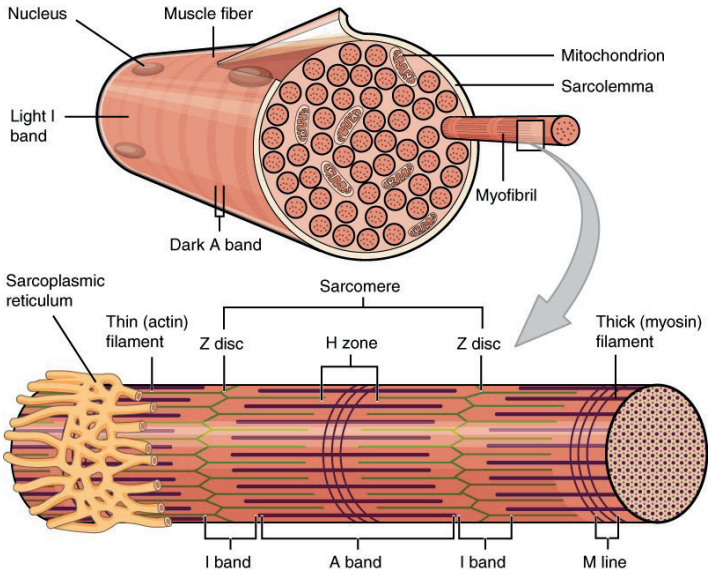


Figure 72. The structure of myofibrils

In the center of the anisotropic disk, myosin myofibrils are somewhat thickened due to the special initial orientation of myosin molecules.

These fused thicknesses have the appearance of a line dividing the disks A in half, as a result of which this line is called the median strip or mesofragma (fragmentum-piece, fragment), or the m line.

Isotropic light disks-disks I consist of thin, actinic myofibrils, in their center a dark stripe is visible-the Z line or telofragma.

The sarcomere is a segment of fiber between two Z –lines or telofragma. Telofragma, as if sewn across and fix the myofibrils. Actin myofilaments of neighboring sarcomeres are connected to each other

in the Z-line region by the tropomyosin protein. In addition to this protein, the actin myofilaments include the protein troponin. Actin myofilaments are shorter and thinner than myosin ones.

From the Z line, actin myofilaments pass through half of disk I to disk A, located around the myosin ones.

When reducing actin myofilaments slide along myosin towards each other on sarcomeres. This theory of muscle contraction is called the sliding thread Theory (Figure 73).

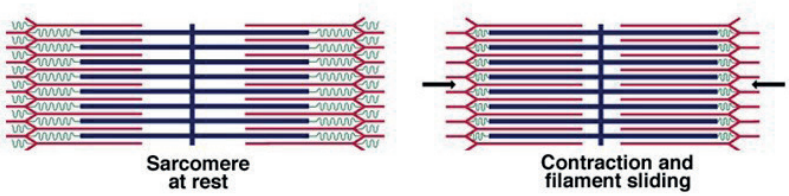
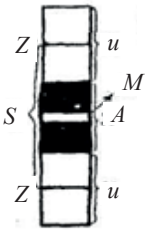


Figure 73. Sarcomer at rest and contraction

The formula of the sarcomere: **Z+1/2I+1/2A+M+1/2A+1/2I+Z**



$$\mathbf{S} = \mathbf{Z} + \frac{u}{2} + \frac{A}{2} + \mathbf{M} + \frac{A}{2} + \frac{u}{2} + \mathbf{Z}$$

Support apparatus

Striated skeletal muscle tissue is part of the muscles. Along with contractile function, muscle fibers have a supporting function, which is expressed in the support and restoration of shape.

The actual support apparatus of the muscle fiber consists of a connective tissue shell, as well as internal support structures that are part of Z-lines or telophragms.

Striated muscle fibers are united by connective tissue into an organ called a muscle. The outside of the muscle is covered with a connective tissue membrane-epimysium (Figure 74). It penetrates deep into the muscles, forming a sheath around large bundles of muscle fibers – perimysium. The connective tissue located directly between the muscle fibers is called the endomysium. Connective tissue sheath presents a loose fibrous connective tissue unformed.

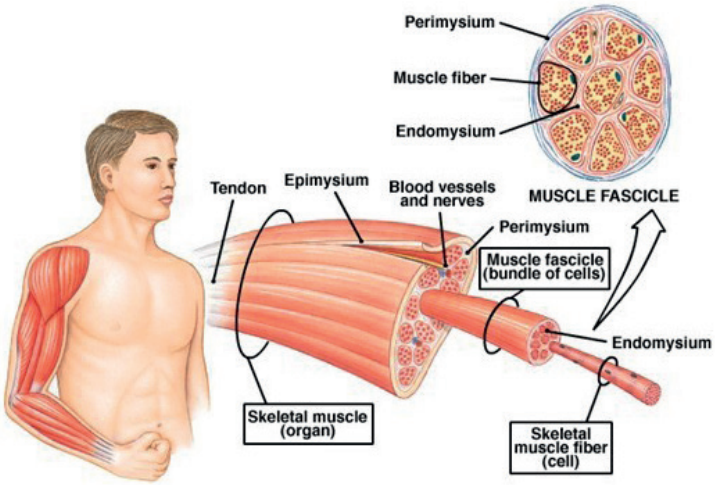


Figure 74. Skeletal muscle fiber

Nervous apparatus of the muscle fiber

The nerves that enter the muscle contain efferent (motor) and afferent (sensory) fibers (Figure 75).

The process of the nerve cell, which brings an efferent nerve impulse, penetrates the basement membrane and branches between it and the sarcolemma of the muscle fiber, participating in the formation

of the so-called motor plaque (Figure 76). Every muscle fiber is innervated by yourself and surrounded by a network of emocapella. This complex forms a morphological and functional unit of skeletal muscle – mion.

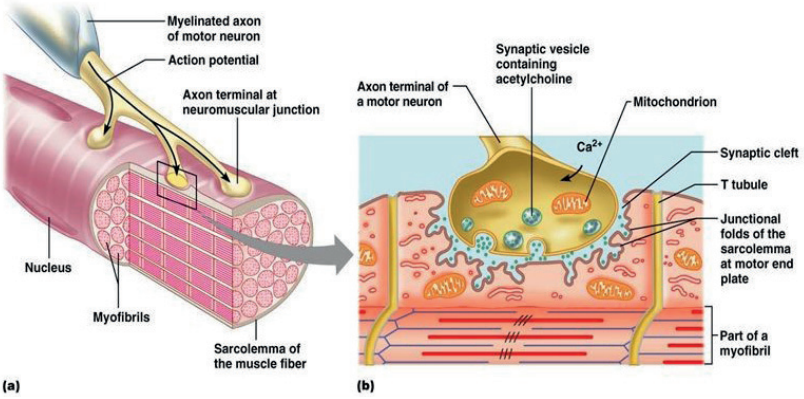


Figure 75. Innervation of skeletal muscle

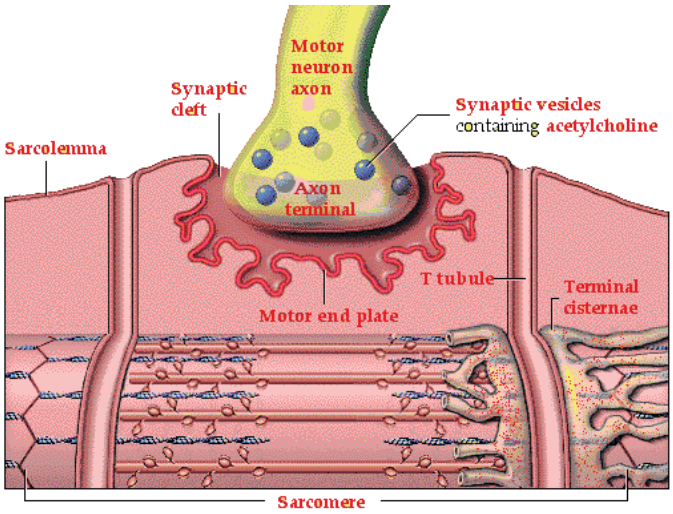


Figure 76. The motor plaque

The afferent (sensitive) nervous apparatus is represented by neuromuscular spindles. Sensitive nerve endings are not located on working muscle fibers, but are connected to specialized muscle fibers in the so-called muscle spindles. Muscle spindles are divided into two types: fibers with a nuclear bag and fibers with a nuclear chain. In fibers with a nuclear bag, the simplast nuclei form clusters in the thickened middle part of the fiber. In fibers with a nuclear chain, the simplast nuclei are located in the center of the fiber and lie one after the other. Myofibrils are located at the ends of the muscle fiber.

The structure of myosatellite

Myosatellite adjacent to the surface of myosimplast so that the sarcolemma in contact with cytolemma.

Myosatellite – mononuclear cell. The core is smaller than core myosimplast and more rounded. The cytoplasm contains all the organelles of General meaning. There are no special organelles. Miosatellites – tissue elements of skeletal muscle. The number of myosatellittes in muscle fibers varies depending on the age and stress of the working activity of the muscles. In a person at a young age and with a high functional load of muscles, myosatellites in muscle fibers are more than in old age and with a weak muscle load.

Regeneration of skeletal muscle tissue

There is no cell center in the muscle fiber, so it is not able to divide. Cambial elements are myosatellites. When the muscle fiber is cut at some distance from the injury site, complete destruction of the sarcolemma, sarcoplasm and myosatellites occurs, and the fiber remains viable outside of this zone.

Macrophages phagocytize necrotic fragments. Restoration of muscle fiber structures is carried out by two mechanisms: 1) reactive changes in the preserved part of the myosymplast and 2) multiplication of myosatellites.

The ends of myosimplasts thicken and grow towards each other. The so-called muscle kidneys are formed. Myosatellites preserved near the damage, share. Some of them migrate to the ends of damaged fibers and are incorporated into the muscle kidneys. Others merge (just like myoblasts during myogenesis) and form muscle tubes, which then differentiate into muscle fibers (myosimplasts).

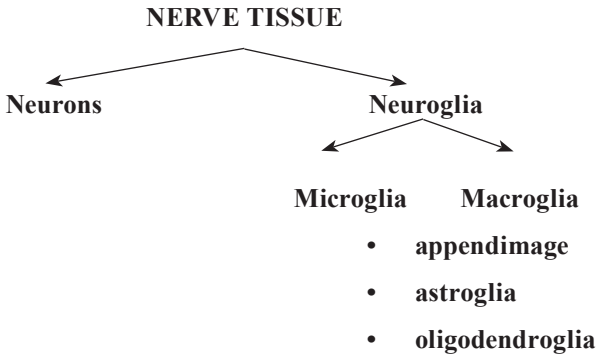
Myosatellites– the main sources of regeneration, because able to reproduce. It is believed that they also contribute to the replenishment of muscle fibers in the body. The space between the ends of damaged muscle fibers is filled with connective tissue regenerate before the ends of the muscle fibers come together, there is a connective tissue scar. Connective tissue regeneration is faster than muscle tissue.

NERVOUS TISSUE

The nervous tissue is capable of receiving information and provides a response to it throughout the body. The nervous tissue consists of two types of cells: nerve cells or neurons (neurocytes) and glial cells (neuroglia). The number of neuroglia cells is 10 times the number of neurons.

Neurons have the function of stimulating and conducting a nerve impulse. Neuroglia performs supporting, differentiating, trophic, secretory and protective functions.

Neuroglia cells are divided into two groups: macroglia and microglia. In turn, macroglia cells are divided into ependymocytes, astrocytes and oligodendrocytes, which respectively form ependymoglia, astroglia and oligodendroglia. The diagram shown in the figure gives an idea of the structure of the nervous tissue.



Development of nervous tissue

The source of development is ectoderm. The embryonic germ from which nerve tissue develops is the dorsal thickening of the ectoderm.

During the development of the embryo there are 4 stages of development of the nervous tissue: stage 1 – neural plate, stage 2 – neural groove, stage 3 – neural tube, stage 4 – differentiation of the neural tube.

Stage 1 – neural plates. At the 4th week of intrauterine development, the height of the dorsal ectoderm cells increases, the cells become prismatic, not cubic. This thickening of the dorsal ectoderm is called the neural plate (Figure 77).

Stage 2 – neural groove. Cells of the neural plate multiply intensively, divide by mitosis, and the number of cells increases (Figure 77).

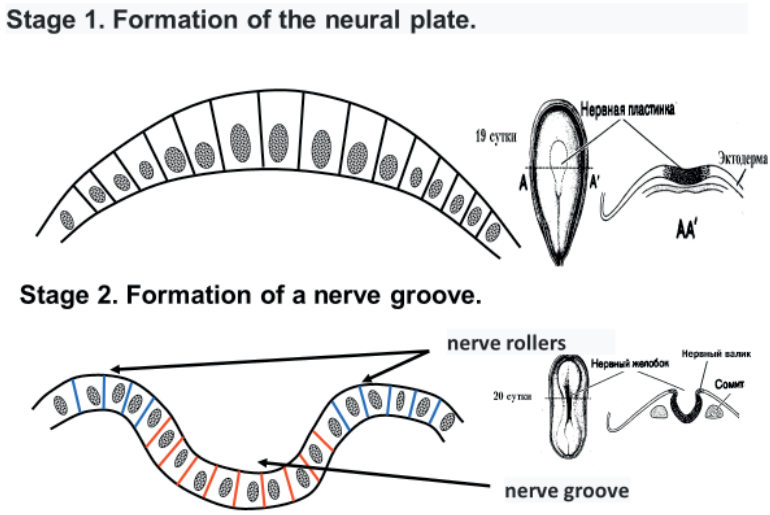


Figure 77. Formation of the neural plate and groove

The nerve plate, bending, turns into a nerve groove. The side edges of the nerve groove are raised and form nerve rollers.

Stage 3 – neural tube. The cells of the neural groove move they meet each other and close, forming a neural tube. The cells of the nerve

roller also move towards each other and, closing, form a ganglion plate (Figure 78). The remaining part of the ectoderm, closing, forms the skin ectoderm.

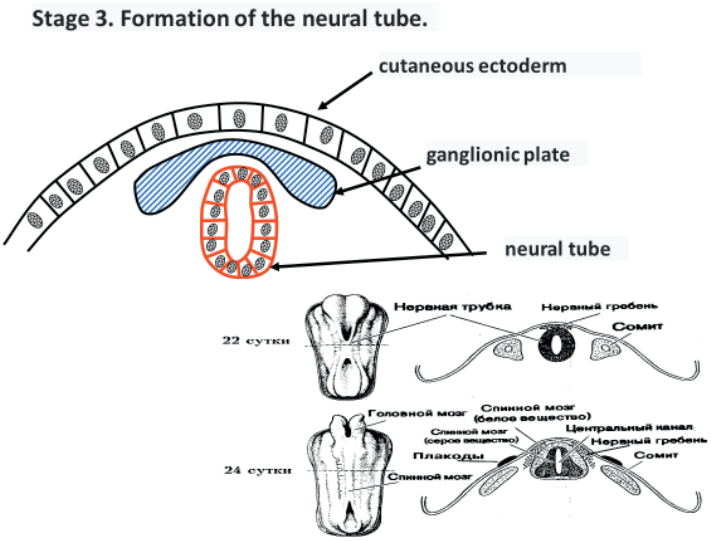


Figure 78. Formation of the neural tube

Stage 4 – differentiation of neural tube cells. The neural tube at an early stage of its development consists of a single layer of cylindrical cells, which are then intensively multiplied by mitosis and increase in number (Figure 79). As a result, the neural tube wall thickens. At this stage of development, it can be divided into three layers:

1) internal-ependymal;

2) middle-mantle (cloak) layer;

3) the outer – edge veil.

1 – the inner ependymal layer is characterized by active mitotic cell division. In the future, the cells of the inner layer turn into cylindrical ependymal (glial) cells that line the Central channel of the spinal cord.

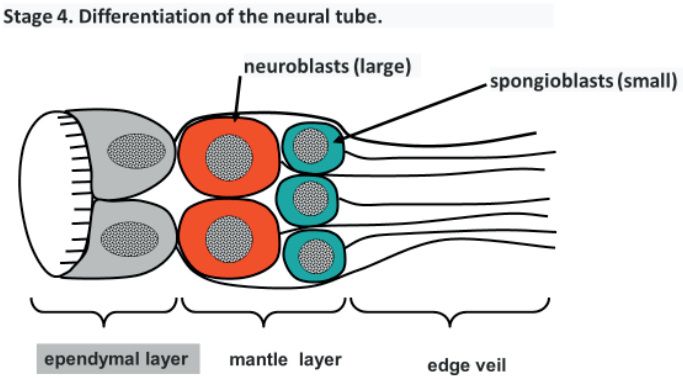


Figure 79. Differentiation of the neural tube

2 – cells of the middle mantle (cloak) layer differentiate in two directions – into neuroblasts and spongioblasts. The cellular composition is replenished both by mitotic division of cells in this layer, and by moving them from the inner ependymal layer. Neuroblasts differentiate into neurons, and spongioblasts differentiate into astrocytes and oligodendrocytes.

Differentiation of neuroblasts begins with the fact that the cell becomes pear – shaped, and from its pointed end begins to develop a process-neurite (axon). Later, other processes are differentiated-dendrites. The appearance in the cytoplasm of neurofibril indicates that it has completed the differentiation in neuroblast. Further development of neuroblasts leads to elongation of their processes, which form bundles of nerve fibers, and the growth of axons is faster than the growth of dendrites (Figure 80).

The grey matter of the brain and spinal cord is further developed from the mantle layer.

3 – the outer layer-the marginal veil, formed by the processes of the cells of the two previous layers, from which the white matter of the brain and spinal cord is further formed.

Spinal and vegetative nodes are formed from the ganglion plate.

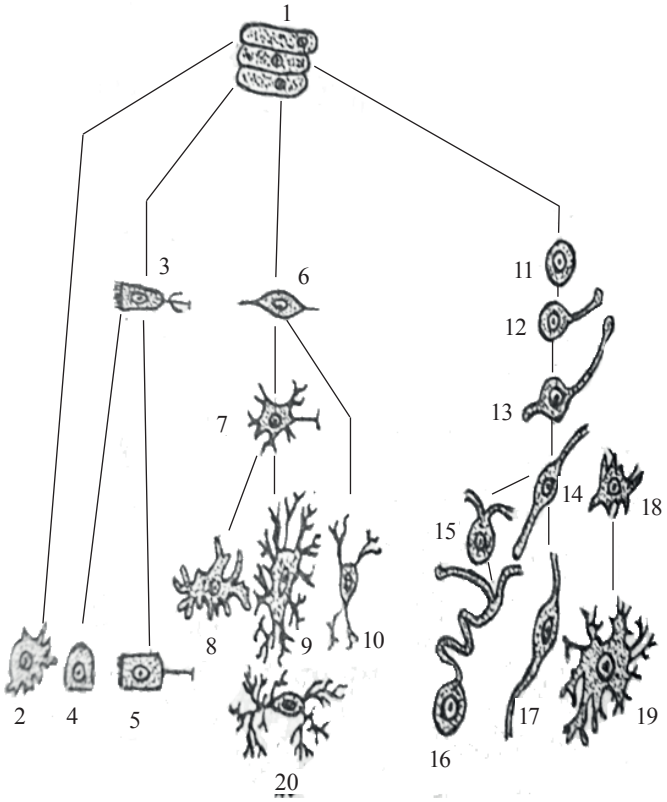


Figure 80. Cellular differentiation:
1 – wall of the neural tube; 2 – pineal cells (parenchyma of the pineal gland); 3 – ependymal spongioblast; 4 – epithelium (ependymal cells of the vascular plexus of the ventricles of the brain); 5 – ependymoglia; 6 – bipolar spongioblast; 7 – astroblast; 8 – protoplasmic short-pulsed; 9 – fibrous long-fibered astrocyte; 10 – oligodendrocyte; 11 – apolar neuroblast; 12 – unipolar neuroblast; 13 and 14 – bipolar neuroblast; 15 and 16 – developing and already developed pseudo-unipolar neuron; 17 – bipolar neuron; 18 – multipolar; 19 – multipolar neuron; 20 – microglia

Initially, the processes of neuroblasts are still devoid of pulp shells, the cells of the neuroglia form them at later stages of embryogenesis. In the fifth month of human embryonic development, synapses are formed, the number of neurofibrils in the cells increases, and pulp sheaths begin to appear. With the appearance of these structural components, the differentiation of neuroblasts into neurons is completed. Neuroblasts and neurons are divided by mitosis during embryonic development.

During embryonic histogenesis, developing astrocytes and oligodendrocytes also form processes, but these cells differ from neuroblasts in that their cytoplasm does not contain neurofibrils.

As macroglia cells differentiate, the entire tissue acquires a spongy structure, and this feature formed the basis for the name of these cells – spongioblasts (spongiosa – sponge). Further development of spongioblasts leads to the emergence of astroglia and oligodendroglia cells.

Microglia cells are derived from mesenchyma. They appear as part of the nervous tissue during the development of the Central nervous system, when blood vessels grow into the spinal cord and brain. Mesenchymal cells thus end up in the nervous tissue. In the future, mesenchymal cells and monocytes are the sources of formation of microglia cells.

Neurons or nerve cells

In humans and mammalian animals, nerve cells are concentrated in the gray matter of the brain and spinal cord, as well as in the nerve nodes or ganglia. The shape of neurons can be varied due to the fact that they depart from a different number of processes. These include pyramidal, stellate, fusiform, basket-shaped, and pear-shaped neurons. Nerve cells in the vast majority contain single core. In the cytoplasm of neurons, there are all General-purpose organoids and special-purpose organoids – neurofibrils, synaptic vesicles. Neurons are not able to share mitosis.

The cytoplasm of neurons is basophilic and contains a well – developed endoplasmic network-ergastoplasm. Ergostoplasm is a basophilic substance or Nissl substance, or tigroid, so named because when colored, the cytoplasm resembles the spotting of a tiger's skin. The tigroid is represented as large basophilic lumps. Ergastoplasm characteristic of cells actively synthesizing secretory proteins.

Nerve cells are characterized by intensive protein metabolism. Synthesized proteins are transferred from the body of the nerve cell along the axon to the periphery at a rate of up to 2 mm per day. In addition, neurons have secretory activity. They form chemical mediators that accumulate in vesicles, mainly at the ends of axons, in the synapse region, which are called synaptic vesicles. Nerve cells also form hormones, such as mammalian neurosecretory hormones (oxytocin, ADH).

In the cytoplasm of neurons pass the thinnest threads, the diameter of which is 6–10 nm. When fixing the nerve tissue and processing with a solution of silver nitrate, these filaments are glued into bundles and restore the silver, so that they become visible under light microscopy and are called neurofibrils. Neurofibrils are located in the body of the neuron randomly, and in the processes in parallel.

A characteristic feature of all mature nerve cells is the presence of appendages. They provide for the conduction of a nerve impulse through the human body from one part to another, so their length varies within large limits. The processes of nerve cells can have a significant length and reach 1.5 m in an adult (Figure 81).

According to the functional value of the processes of nerve cells are divided into 2 types – axons and dendrites. They have the same structure, but differ in function. The axon does not branch in a tree-like manner, but its lateral processes (collaterals) branch off from it, and its end splits into short, thin branches. This process is called a neurite or axon (axial cylinder), conducts excitation from the body of the nerve cell to the tissues of the working organ or to another neuron. All neurons have a single neurite.

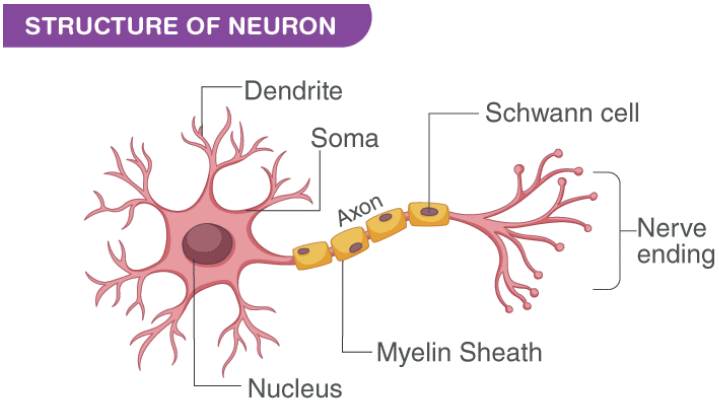


Figure 81. Structure of the neuron

Dendrites can branch in a tree (dendron – tree). They perceive the stimulus and conduct it to the neuron's body. Dendrites of sensitive cells have at their peripheral end specifically arranged receptive devices-sensitive nerve endings-receptors. The dendrites of Association and motor neurons come into synaptic connection with the neurites of other neurons.

Due to the function that neurons perform, they are divided into 3 groups: 1) receptor (sensitive, afferent), 2) associative (insertion), 3) effector (efferent, motor).

The 1st group includes neurons that transmit nerve impulses under the influence of various influences of the external or internal environment of the body. They are called receptor (sensitive, afferent) neurons.

The 2nd group consists of associative (insertion) neurons that carry out various connections between nerve cells.

The 3d group includes neurons that transmit excitement from the Central parts of the nervous system to the tissues of working organs (mus-

cles, glands), prompting them to act. They are called effector (motor, efferent) neurons.

According to the number of processes nerve cells are divided into 3 groups:

1 – unipolar (with one process-axon), 2 – bipolar (with two processes – axon and dendrite), 3 – multipolar (have three or more processes) (Figure 82). The latter are most common in the nervous system. Of the many outgrowths of such a neuron, one is represented by a neurite (axon), while all the others are dendrites.

1 – Unipolar neurons, that is, cells with a single process-the neurite (axon), are found only in embryogenesis: this form is only neuroblasts before the formation of dendrites. They are not present in the human body.

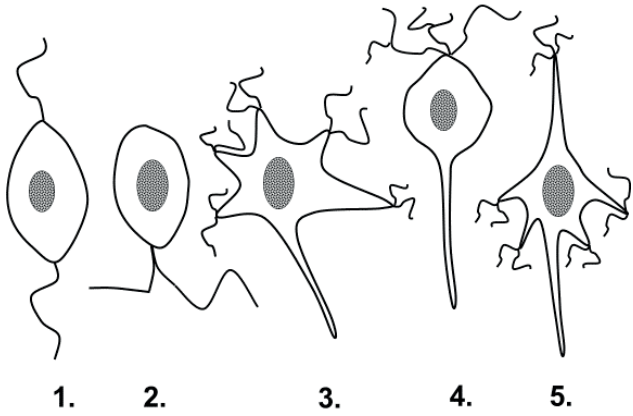


Figure 82. Types of neurons:
1 – bipolar (in retina); 2 – pseudo-unipolar (in spinal node);
3 – multipolar (motor); 4 – pyramidal (in cerebellum);
5 – pyramidal (in cerebral cortex)

2 – Bipolar neurons have two processes-an axon and a dendrite. There are two types of neurons: pseudo-bipolar and true neurons.

Pseudo-unipolar neurons are so called because, moving away from the body, the axon and dendrite first fit tightly together, creating the impression of a single process, and only then t-shaped diverge (these include the receptor neurons of the spinal ganglia).

True bipolar neurons in the human body are bipolar cells of the retina (Figure 6) ?????

Thus, the excitation of the nerve cell passes in the following sequence: along the dendrite to the body (soma) and from it along the axon (neurite). In the opposite direction, the impulses do not pass, but are slowed down.

Neuroglia

Neuroglia (neuron-neuron, glia-glue) – it is an auxiliary and very important component of the nervous tissue that is related to neurons genetically, morphologically and functionally. Neuroglia cells do not conduct nerve impulses, but they perform support, differentiation, trophic, secretory, isolation and protective functions in the nervous tissue.

By its origin, neuroglia is divided into 2 types: macroglia (gliocytes) and microglia (glial macrophages). Macroglia, like neurons, arises from the ectoderm, and microglia develops from the mesoderm and is a derivative of the mesenchyma.

Part of macroglia includes ependymal, astrocytes and oligodendroglia.

Ependymocytes line the spinal canal and all the ventricles of the brain. The cells are arranged in a single row and have a prismatic shape. From the apical pole of the ependymocyte, facing the spinal canal and the cavities of the ventricles of the brain, cilia extend, the number of which reaches 40 per cell (Figure 83). With age, the number of cilia decreases, then almost everywhere disappear and are observed only in the water supply of the midbrain. Instead of cilia, only outgrowths of the cytoplasm are preserved. Cilia contribute to the movement of cerebrospinal fluid.

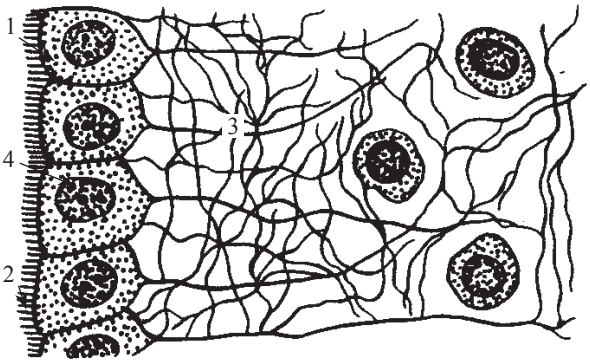


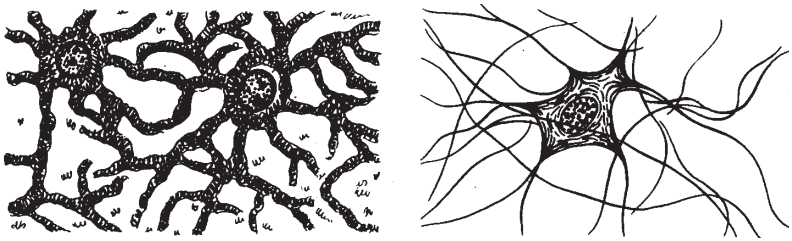
Figure 83. The structure of ependencies:
1 – ependymocyte; 2 – cilia; 3 – cell processes;
4 – contacts between cells – desmosomes

The basal end of ependymocytes narrows and the cytoplasmic process departs from it, which goes radially deep into the nervous tissue and ends with a small thickening.

The processes of ependymocytes, connecting with each other, form an external boundary membrane that restricts the cavity of the neural tube. The cell cytoplasm has a well-developed granular endoplasmic network. Ependymocytes perform a secretory function, releasing various active substances (secret) directly into the cavity of the cerebral ventricles or into the blood, thereby taking part, along with the vascular plexuses of the ventricles of the brain, in the formation and movement of spinal fluid.

Astrocytes are divided into 2 types: protoplasmic (plasma, short-process) and fibrous (fibrillar, long-process).

Protoplasmic astrocytes have numerous, strongly branched short processes (Figure 84). They are found mainly in the gray matter of the brain and spinal cord. Protoplasmic astrocytes perform trophic and delimiting functions.



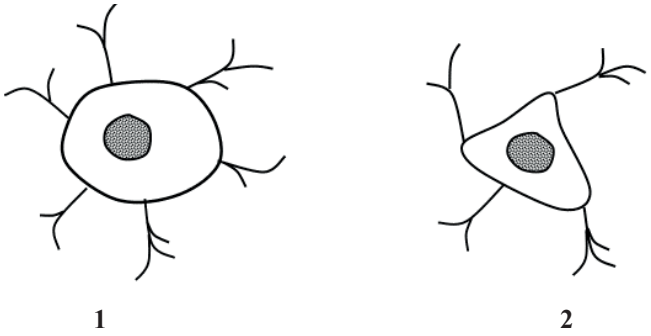
1 2

Figure 84. The structure of astrocytes:
1) protoplasmic, 2) fibrous

Fibrous astrocytes (Figure 84) have few, weakly branching long thin processes. They are located mainly in the white matter of the brain. Fibrous astrocytes perform supporting and delimiting functions.

Oligodendrocytes are the largest group of neuroglia cells. Its cells have different shapes, smaller than astrocytes, and few short, weakly branching processes leave their bodies (Figure 85). Oligodendrocytes synthesize a white substance of a lipoid nature, which is called myelin. The latter is a part of the oligodendrocyte cytolemma and has good insulating properties. By isolating the processes of nerve cells, oligodendrocytes prevent the dispersion of nervous excitement and participate in the nutrition of neurons, as well as in the water exchange of the brain. These cells are found in both the white and gray matter of the brain and spinal cord, as well as outside the Central nervous system. Oligodendrocytes are located around neurons and their processes, tightly contacting them and forming capsules and shells around them. In this case, they are called neuro-lemmocytes (lemmocytes, Schwann cells). Oligodendrocytes perform trophic, insulating and protective (mechanical) functions.

In the processes of degeneration and regeneration of nerve fibers, oligodendroglia plays an important role: as part of the nerve endings, these cells participate in the processes of reception (perception) and transmission of nerve impulses.



1 2

Figure 85. The structure of oligodendrocytes:
1) oval shape; 2) angular shape

Microglial cells -the macrophages of glial cells Hortega, grainy ball. The source of development is the blood monocyte. They are small in size, mostly of a process form, and are capable of amoeboid movements. Glial macrophages have relatively short tree-like processes. When microglia cells are irritated, their shape changes: the processes are retracted, the cells are rounded. In this form, they are called granular balls (Figure 86). Microglia performs a protective function-phagocytosis.

1 2

Figure 86. The structure of microglia:
1) glial macrophage, 2) granular ball

Nerve fiber

Nerve fibers are processes of nerve cells surrounded by a shell of oligodendrogliocytes or lemmocytes, or Schwann cells.

Nerve fibers form pathways in the spinal cord and brain, and nerves on the periphery. Nerve impulses are carried out along the nerve fibers. Nerve fibers, depending on the structure of the covering membranes, are divided into two types: myelin-free (limp) and myelin (pulp). The process of a nerve cell lying in the center of a nerve fiber is called an axial cylinder.

Myelin-free (limp) nerve fibers are found primarily in the autonomic nervous system. This fiber consists of 10–20 axial cylinders that are pressed into the lemmocyte. Shell lamonica when it bends, tightly covers the axial cylinder, closed above them, forming deep folds. Close together in the folds of the sections of the shell lamonica form a double membrane – mesaxon. Outside, the myelin-free nerve fiber is covered with a thin connective tissue basement membrane (Figure 87). Myelin-free nerve fibers conduct a nerve impulse at a speed of 1–2 m/sec.

If several axial cylinders are immersed in a lemmocyte, they form a cable-type fiber (Figure 87).

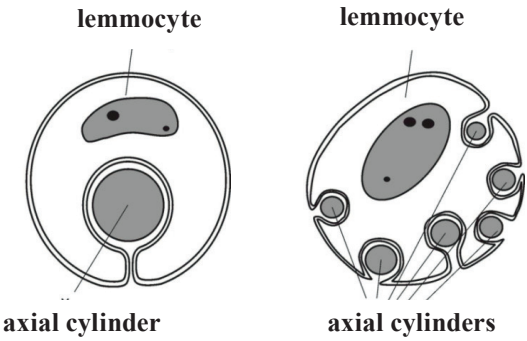


Figure 87. Structure of the myelin-free nerve fiber

Myelin (pulp) nerve fibers

Myelin nerve fibers are significantly thicker than non-myelin ones (1–20 microns). They are located in the Central and peripheral nervous system.

The process of myelination. During the development of the myelin fiber, the axial cylinder is pressed into the Schwann cell, the shell of this cell bends, forming a deep fold, and a mesaxon – double cytolemma is formed (Figure 88).

With further development, the mesaxon lengthens and is concentrically layered on the axial cylinder. The mesaxon twists around a single process of the nerve cell-the axial cylinder, forming up to twenty turns around it. The Schwann shell and the mesaxon formed by it have in their composition the lipoid myelin, so the shell was named-myelin (pulp).

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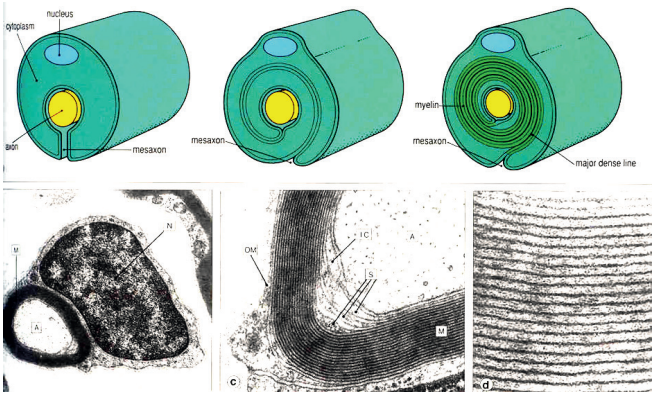

Figure 88. Formation and structure of the myelin nerve fiber (cross section)

Structure of the myelin (pulp) nerve fiber

In the formed myelin fiber, there are 2 layers: the inner, thicker-myelin layer, and the outer – thin, consisting of cytoplasm and nuclei of Schwann cells. In the center is an axial cylinder.

The myelin layer contains in its composition lipids-myelin, which when processing the nerve fiber with osmic acid intensely colors it dark brown. Areas that are not colored contain proteins in their composition and form obliquely oriented light lines-Schmidt-Lanterman notches. The borders between Schwann cells are represented by narrowed sections-Ranvier interceptions, devoid of myelin sheath. When passing from one Schwann cell to another, the myelin sheath is interrupted. At the point of contact of Schwann cells, myelin is absent, and the nerve fibers are narrowed. The area between nodes of Ranvier is called an internodal segment.

Each internodal segment of a nerve fiber there is only one Schwann cell, the nucleus and bulk of cytoplasm which are located on the periphery of the myelinated nerve fibers (Figure 89).

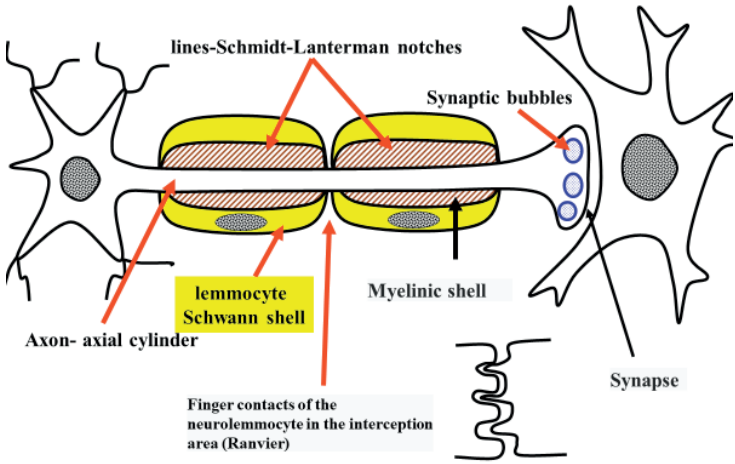

Figure 89. Structure of the myelin nerve fiber (longitudinal section)

The presence in the nerve fiber is only one process of the nerve cells, well-isolated myelin sheath and nodes of Ranvier ensures rapid (up to 120 m/sec) and accurate conduction of nerve impulses.

Nerves

Nerves are formed by numerous bundles of myelin and myelin-free nerve fibers, which are United by connective tissue that forms connective tissue sheaths. The cross section of the nerve shows sections of the axial cylinders of nerve fibers and the glial sheaths that clothe them.

Between nerve fibers are located the layer of loose fibrous connective tissue unformed (RWST). This tissue is called the endoneurium. Individual bundles of 5–6 nerve fibers are covered with perineurium. The outer sheath of the nerve – epineurium represents, rich in fibroblasts, macrophages and fat cells (Figure 90). Connective-tissue sheath of a nerve that contain blood vessels and nerve endings.

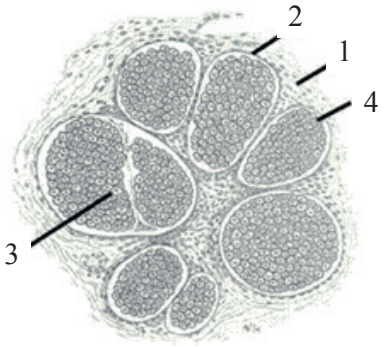

Figure 90. The structure of the nerve.
(according to Gavrilov L.F., Tatarinov V.G., 1978).
1 – epineurium; 2 – perineurium; 3 – an interlayer of loose fibrous connective tissue between the fibers – endoneurium; 4 – nerve fibers

Regeneration of the nerve fiber

Regeneration of nervous tissue in mammals and humans is difficult, because during embryonic histogenesis, all neuroblasts are differentiated into nerve cells. Due to the absence of cambial elements in the nervous tissue, new nerve cells are not formed.

Nerve cells cannot increase in their number in the post-embryonic period. There is also no regeneration of nerve cell bodies due to high differentiation of neurons. Regenerate can only processes of nerve cells that have not lost their connection with the body of the nerve cell after damage.

After the nerve is cut or torn, the nerve processes that have lost their connection with the body of the neuron, thin in many places and break up into fragments, and after 10 days are destroyed and phagocytic macrophages and Schwann cells. In this regard, Schwann cells accumulate a lot of myelin in their cytoplasm, and from the fifth day after damage, they pass to mitotic division.

If you cut the nerve, i.e., the processes of nerve cells, first observed degeneration of peripheral nerve processes, and lost contact with the body of the neuron, followed by regeneration processes of nerve cells associated with the body.

Primary irritation consists of (Figure 91):

1) In increasing the volume of the neuron's body.
2) There is chromatolysis-the basophilic substance disappears.
3) Eccentric displacement of the nucleus in the neuron.

Retrograde changes are:

1) Swelling of the axial cylinder.
2) Fragmentation of the axial cylinder.
3) Disintegration of the myelin sheath.
4) Phagocytosis by microglia cells of decayed myelin.

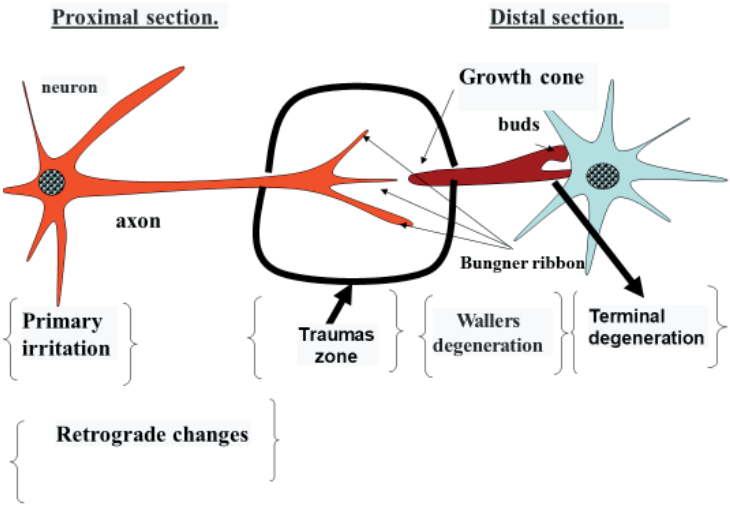

Figure 91. Regeneration of the nerve

Damage zone:

1) Phagocytosis by microglia of the decayed site.

2) Formation of connective tissue scar-Bungner tapes.

3) The appearance of the cone is actually the regeneration of the nerve fiber.

The growth rate is 1–4 mm/day. Conditions for growth-convergence of processes.

Waller's degeneration:

1) Swelling of the axial cylinder.

2) The appearance of bloating on it.

3) Disintegration of the axial cylinder into fragments.

4) Phagocytosis-activation of microglia cells.

5) Disappearance of the myelin sheath,

6) As a result of resorption of its glia cells.

Terminal degeneration:

1) Increasing the number of neurofibrils.

2) Swelling of the axolemma.

3) Wrinkling of the endings.

Schwann cells, multiplying, form capsules around the remnants of the myelin fiber, in which myelin is absorbed. After resorption of myelin, the capsules disappear, and the Schwann cells form a flat, thin cell layer called the Büngner ribbon on the site of the former nerve fiber. These strands of Schwann cells begin to grow towards the nerve processes associated with the body, making their way through the connective tissue scar that has arisen at the site of the defect.

Nerve ending

All nerve fibers end in terminal devices, which are called nerve endings. According to the functional value of the nerve endings are divided into 3 groups:

1) sensitive (receptors);

2) interneuron synapses;

3) effector (effectors).

Sensitive nerve endings-receptors are the end devices of dendrites of sensitive neurons.

Two groups of receptors are distinguished by their location:

1) exteroreceptors-perceive irritation from the external environment;

2) interoreceptors-perceive irritation from internal organs.

According to perception, the following types of receptors are distinguished: mechanoreceptors, baroreceptors, thermoreceptors, chemoreceptors.

Free nerve endings consist of terminal branches of the axial cylinder and are not accompanied by neuroglia cells (oligodendroglia).

Non-free nerve endings contain an axial cylinder and neuroglia cells (oligodendroglia).

They can be covered with a connective tissue capsule, and then they are called encapsulated.

Non-free nerve endings that do not have a connective tissue capsule are called non-encapsulated.

Free nerve endings

These endings are characteristic of the epithelium. Myelin nerve fibers, approaching the epithelium, lose myelin, and the axial cylinders penetrate the epithelium and break up into terminal branches. In the epidermis there are special sensory cells tactile cells of Merkel. The receptor terminals approach these cells and connect to them (Figure 92).

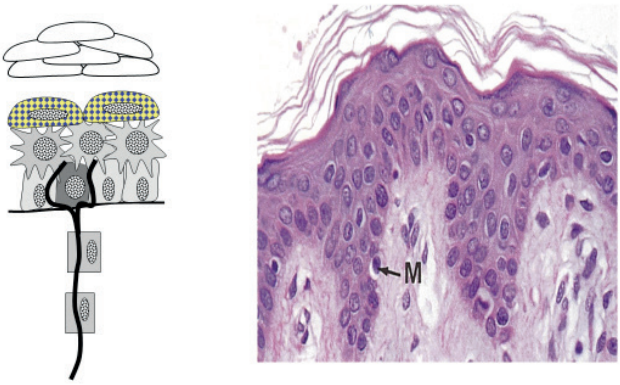

Figure 92. Merkels cell

Non-free encapsulated nerve endings

They consist of branches of the axial cylinder and neurolemmocytes. On the outside, these receptors are covered with a connective tissue capsule. The connective tissue capsule consists mainly of fibroblasts and collagen fibers. Non-free encapsulated sensitive nerve endings located in connective tissue include Meissner's tactile corpuscles, Vater-Pacini lamellar corpuscles, Golgi-Mazzoni bulbous corpuscles, Krause's end flasks, Ruffini's corpuscles, and Dogel's genital corpuscles.

Non-free encapsulated receptors of skeletal muscle tissue include neuromuscular spindles (Figure 93).

Meissner's tactile bodies are located in the papillary layer of the dermis of the skin (Figure 94). The dendrite of a sensitive neuron, devoid of myelin sheath, branches in the body in the form of a flat spiral. In the plane of this spiral are located oligodendrogliocytes, closely surrounding the dendrites and forming together with it an internal glial flask. The outer flask is formed by a connective tissue capsule.

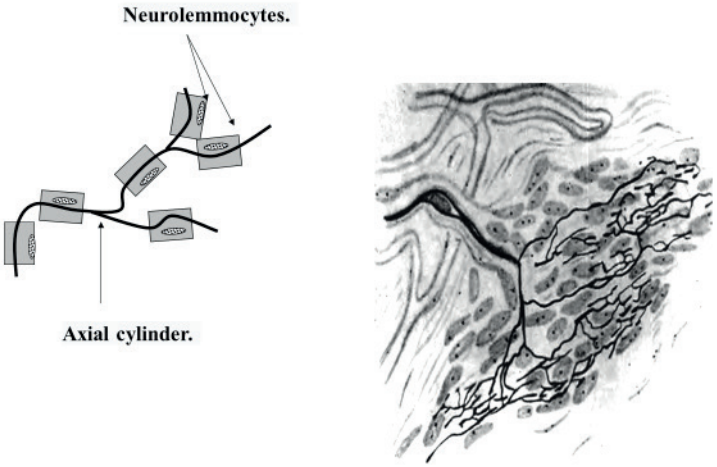

Figure 93. Non-free non-encapsulated nerve endings

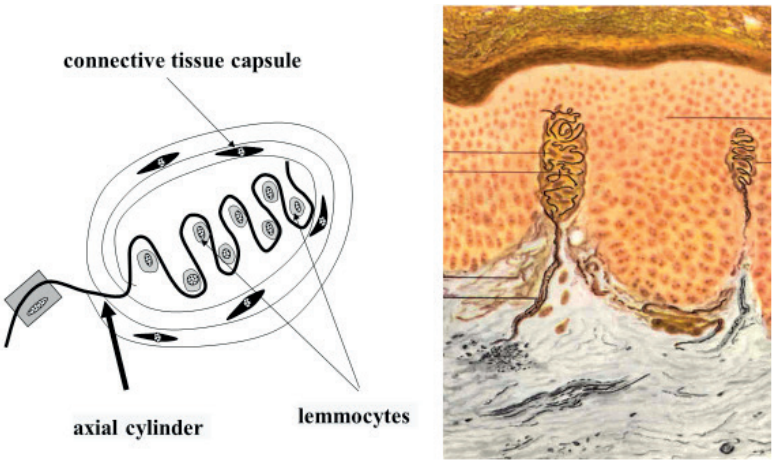

Figure 94. Structure of the Meissner's body

Skeletal muscle receptors is neuromuscular spindles

These are proprioreceptors that signal the degree of relaxation or stretching of the surrounding muscle fibers. They lie on the fibers of skeletal muscle tissue. These fibers are called intrafusal. They consist of several skeletal muscle fibers covered with a connective tissue capsule. Intrafusal fibers have myofibrils only at the ends, which are reduced. The receptor part of the intrafusal muscle fiber is the Central, non-convergent part. There are 2 types of intrafusal fibers: 1) nuclear-marsupial and 2) nuclear-chain type.

The nuclear-marsupial type contains many nuclei in the Central Equatorial expanded part. This thickening is called the Equatorial zone. The nuclear-chain type contains in the Central part of the nucleus, located in a chain along the entire receptor part.

Two types of afferent fibers – primary and secondary fibers-are suitable for intrafusal muscle fibers (Figure 95).

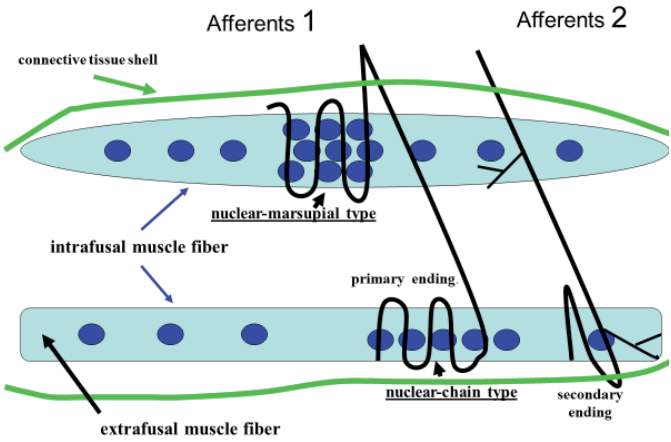

Figure 95. Interneuron synapses

Primary fibers-ringspiral endings in the form of a spiral entwine nuclear-marsupial and nuclear-chain types of intrafusal fibers and neuroglial cells located there.

Secondary fibers-cluster-like endings in the form of a "rosette" entwine only the nuclear-chain type of intrafusal fibers and lemmocytes located there.

Ringspiral endings respond to changes in the length of the muscle fiber and the speed of this change. When the muscle is relaxed or stretched, the length of the intrafusal fibers also increases.

The cluster-like endings respond only to changes in the length of the muscle fiber

Nerve cells contact other neurons by their processes

Places of such contacts are called synapses. Interneuron synapses are divided into axodendritic, axosomatic, and axoaxonal synapses (Figure 96).

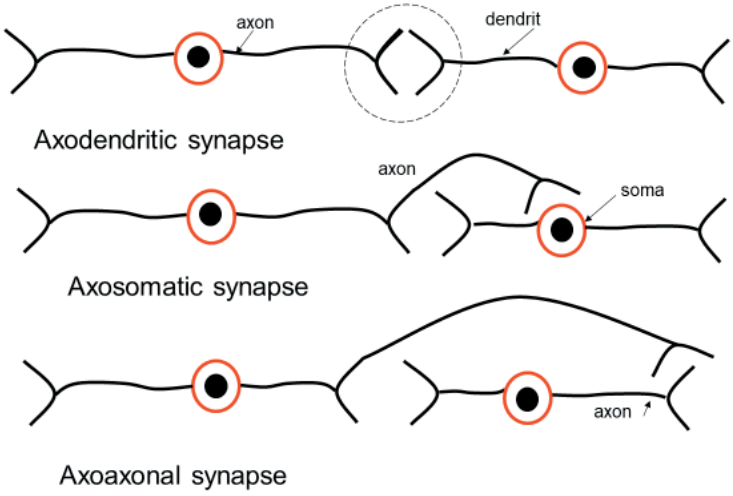

Figure 96. Types of synapses

Despite the variety of forms of synapses, there are common features in their structure. The end sections of axons and dendrites in the synapse region do not have a myelin sheath and are expanded. This part of the axon contains numerous mitochondria and synaptic vesicles.

If the axon of one neuron contacts the dendrite of another neuron, these synapses are called axodendritic.

If the axon of one neuron contacts the body of another neuron, that synapse is called axosomatic.

If the axon of one neuron contacts the axon of another neuron, such a synapse is called axoaxonal. The latter inhibit the transmission of the pulse.

There are synapses with chemical and electrical transmission.

Structure of the synapse

In the synapses axolemma is called the presynaptic membrane. And in contact with her dendrolimi is called the postsynaptic membrane. There is a gap of 10–50 nm between the presynaptic and postsynaptic membranes, called the synaptic cleft (Figure 97).

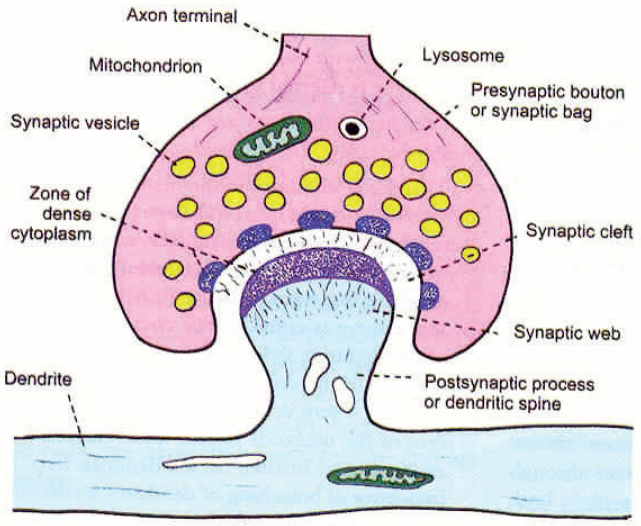

Figure 97. Structure of the synapse

Chemical synapses transmit an impulse with the help of special biologically active substances-neurotransmitters located in synaptic vesicles. The shape and content of synaptic vesicles are related to the function of the synapse. Acetylcholine and norepinephrine are the most common mediators, but there are many others. Electrical synapses in the mammalian nervous system are relatively rare.

Effector nerve endings

There are 2 types-motor and secretory.

Motor or motor nerve endings are synaptic connections between the axon of a motor neuron and striated muscle fibers. They are called neuromuscular (axomuscular) synapses or motor plaques.

An axomuscular synapse consists of a terminal branch of the axon of a motor neuron and a specialized section of muscle fiber. The axon of the motor neuron, approaching the striated muscle fiber, loses its myelin sheath and branches, sinking into the muscle fiber.

The axolemma is somewhat thickened and is a presynaptic membrane. The muscle fiber membrane (sarcolemma) is a postsynaptic membrane that forms numerous folds that pass into the T-system.

The presynaptic and postsynaptic membranes are separated by a synaptic cleft about 50 nm wide.

The axon cytoplasm in the synaptic contact area is extremely rich in mitochondria and synaptic vesicles.

Sarcoplasm of the striated muscle fiber in the area of synaptic contact does not have a typical transverse striation and is characterized by an abundance of mitochondria, a cluster of nuclei.

Diagram of the ultramicroscopic structure of the nerve endings from the textbook.

Secretory nerve endings

These are synaptic connections between axons of a motor neuron and secretory cells. The axon of the motor neuron forms flask-like terminal extensions. Secretory endings of effector neurons are represented by axons that make synaptic contact with glandular cells (Figure 98).

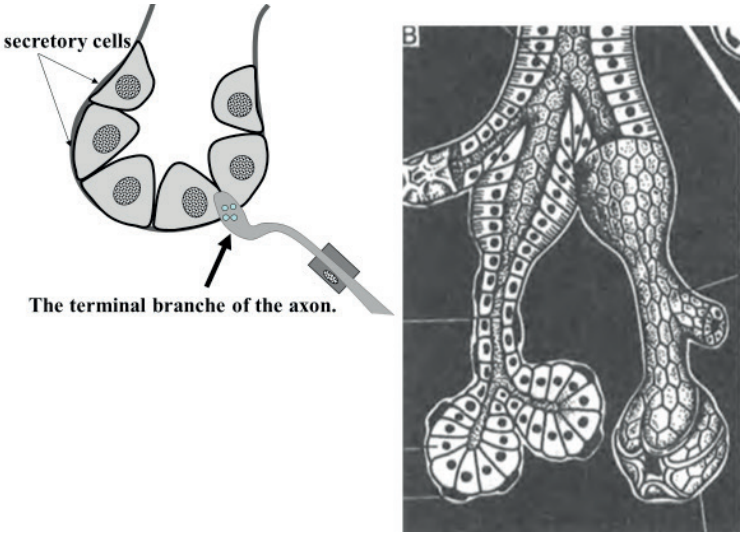

Figure 98. Secretory nerve endings

The terminal branches of the axon either come close to the secretory cell, or are deeply pressed into it. The axolemma and cytolemm of the secretory cell form, respectively, presynaptic and postsynaptic membranes separated by a narrow synaptic gap.

The concept of reflex arcs

Reflex arc-a chain of neurons connected to each other by synapses and providing a nerve impulse from the receptor of a sensitive neuron to the efferent end in the working organ.

The structure of nerve cells and synaptic contacts contributes to the fact that nerve impulses are distributed along certain paths, which are called reflex arcs.

The reflex arc is the path that nerve impulses travel from the receptor to the Executive organ. The reflex arc consists of at least two nerve cells: one of which is sensitive, and the other is effector.

Stimuli are perceived by dendrites, go to the body of a sensitive neuron and are transmitted from the body to the dendrite of another effector nerve cell along the axon of the latter to the Executive organ.

The simplest reflex arc consists of two neurons – the sensory and motor.

In the vast majority of cases, insertion or Association neurons are involved between sensory and motor neurons.

The reflex arc can be more complex depending on how many associative neurons are located between the sensitive and effector neurons.

In higher animals, reflex arcs usually consist of many neurons.

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