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INTRODUCTION

The scientific study of human **anatomy** falls within the domain of the medical and biological disciplines. This field of study includes the investigation of the anatomical structure and form of the human body, with a focus on its functions, developmental processes, and the age-related changes that occur in individuals and their organs.

Anatomy is the scientific study of the structure of the human body, based on principles common to all living organisms. At the same time, humans differ from animals not only by a number of anatomical features, but also in **qualitative ways** due to their capacity for abstract thinking, self-awareness, and articulate speech.

Anatomy is recognized as one of the foundational disciplines in the medical and biological education system, with its curriculum typically serving as the inaugural subject in the sequence of medical education. The study of human anatomy is **closely connected** to the disciplines of histology, anthropology, physiology, genetics, and a wide array of clinical specialties, including surgery, therapy, internal medicine, and neurology.

Depending on the research methods applied, *macroscopic* (from the Greek word *makros*, meaning "large") or *normal human anatomy*, *microscopic anatomy* (from the Greek word *mikros*, meaning "small"), and *ultramicroscopic anatomy* studied with the help of special equipment (microscope, etc.) are categorized. **Histology** and **cytology**, together with *embryology*, which are part of anatomical science, have evolved into independent fields due to their specialized methods. Histology (from the Greek words *histos*, meaning "tissue", and *logos*, meaning "teaching") is the science that studies the structure and origin, development, and functions of cells and tissues. Cytology (from the Greek word *cytos*, meaning "cell") is the science of the structure and function of cells. Embryology (from the Greek word *embryon*, meaning "embryo") studies the structure and prenatal development of the organism.

The development of a specific person in ontogenesis (from the Greek word *ontos*, meaning "being, existing") is divided into several periods. Embryology studies the growth and development of a person before birth (*the prenatal period*), while *developmental anatomy* focuses on changes after birth (the postnatal period, from the Latin word *natus*, meaning "born"). During childhood, adolescence, and young adulthood, organs still grow. Age-related anatomical features are studied by the science of aging patterns, i.e., *gerontology* (from the Greek word *geron*, meaning "old man").

Anatomy studies the structure of the human body sequentially, by systems (skeletal, muscular, digestive, respiratory, etc.), which is why it is termed *systemic anatomy*. Systemic anatomy studies the structure of a healthy, "normal" person, whose tissues and organs are unaltered by disease or developmental abnormalities and function normally. At the same time, the normal indicators for a person (weight, height, body shape, structural features, etc.), individual variability of the shape and structure of the human body are determined by hereditary factors, as well as the influence of the external environment. There are different variations in human structure (from the Latin word *variatio*, meaning "change"), which are considered deviations from the most commonly observed norm.

The objectives of anatomy are to study the structure of the human body by systems (systemic approach) and consider the spatial relationships between organs (topographic approach).

Marked congenital deviations from the norm are called anomalies (from the Greek word *anomalia*, meaning “irregularity”). Those affecting appearance are referred to as **deformities**. *Teratology* (from the Greek word *teratos*, meaning “monster”) studies deformities.

Modern anatomy is referred to as **functional anatomy**, as it studies the structure of the human body and individual organs in relation to their functions.

Each person has individual structural features. Systemic (normal) anatomy describes the variations in the structure of the body of a healthy person, the most common forms (**Fig. 1**). Based on body proportions, three primary physique types are identified: **dolichomorphic** (from the Greek word dolichos, “long”) — narrow, elongated bodies and limbs (asthenic type); **brachymorphic** (*brachys*, “short”) — shorter, broader bodies and limbs (hypersthenic type), and **mesomorphic** (*mesos*, “average”) — intermediate or balanced body type (normosthenic type), often considered closest to the “ideal” human physique.

Since humans live not only in a biological environment but also in society, **they** are influenced by social and community factors. In this regard, anatomy studies a person considering the influence of their social environment, as well as working and living conditions on them.

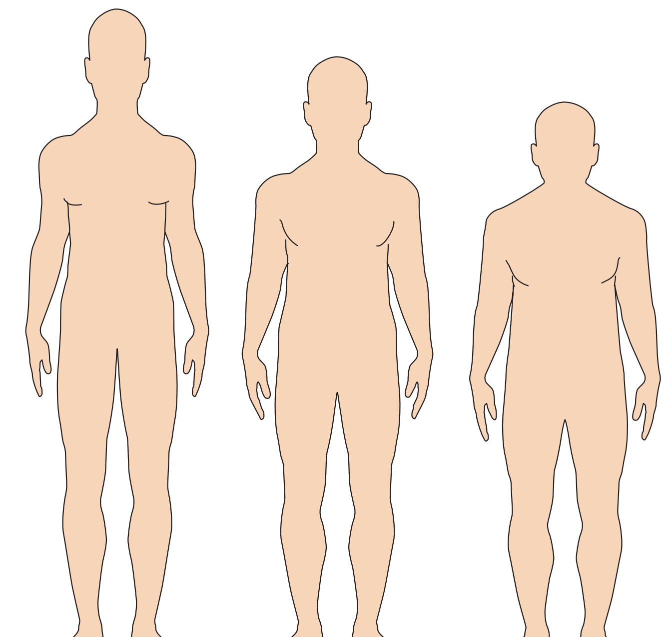

Fig. 1. Human body types: A — dolichomorphic body type; B — mesomorphic body type; C — brachymorphic body type

The characteristics typical of each individual person are taken into account; anatomy has an individual approach. At the same time, anatomy strives to find out the causes that influence the human body and determine its structure (causal approach). By examining each organ (analytical approach), anatomy studies the entire organism. Anatomy is not only an analytical science but also a synthetic one.

In anatomy, special Russian and Latin terms are used to designate areas of the body, organs, and their parts. The list of these terms is called *anatomical nomenclature* (*Nomina Anatomica*). To designate tissues, cells, and their structure, *histological nomenclature* (*Nomina Histologica*) is used, and to designate embryonic structures, *embryological nomenclature* (*Nomina Embriologica*) is used.

BRIEF HISTORY OF DEVELOPMENT OF ANATOMY

Some brief anatomical data appeared in prehistoric times. Early human hunters were already aware of the location of vital organs (heart, liver, etc.). Some information about the heart, lungs, and other organs of the human body is presented in the ancient Chinese book *Nei Jing* (from the 11th to 7th centuries BC). The Hindu book *Ayurveda* (*The Knowledge of Life*, from the 9th to 3rd centuries BC) mentions muscles, bones, blood vessels, and nerves. In ancient Egypt, the practice of ritual embalming contributed significantly to anatomical understanding. Of particular interest is the Ebers Papyrus, which records the anatomical and medical knowledge of the ancient Egyptians.

Hippocrates was one of the famous ancient Greek doctors and anatomists (c. from 460 to 377 BC). He introduced the theory of four body types, described some bones of the calvaria, vertebrae, ribs, internal and other organs, and was interested in the development of the embryo.

Aristotle (from 384 to 322 BC) outlined many facts about the structure of living organisms that he exposed to dissection; he described tendons and nerves, bones, and cartilage. Aristotle introduced the term “aorta” (from the Greek words *aer*, meaning “air”, and *tereo*, meaning “contain”). He studied the structure of the human embryo, noted the general similarities between humans and animals, and introduced the term “anthropology”.

Herophilus (born in c. 304 BC) and Erasistratus (from 300 to 250 BC) were the first in ancient Greece to perform dissections of human cadavers. Herophilus (Alexandrian school) described some cranial nerves, the membranes of the brain, the duodenum (which he also named), the eyeball, the lymphatic vessels of the mesentery, and the prostate gland. Erasistratus (School of Knidos) studied the structure of the heart, its valves and tendon threads, the aortic arch, pulmonary arteries, vena cava and its valves. He introduced the terms “artery” and “parenchyma”.

The outstanding physician of the ancient world, Claudius Galen of Pergamon (131–201 BC) described a number of cranial nerves, nerves in muscles, some blood vessels, the periosteum, and many ligaments. Galen studied anatomy by dissecting animals (pigs, dogs, sheep, monkeys, lions) and erroneously assumed that the human body was structured in the same way. Galen’s works remained the main sources of anatomical and medical knowledge for 14 centuries.

In the period from 5th to 10th centuries, the culture of the peoples of the East developed successfully. However, to religious prohibitions against dissection, anatomy was studied using books by Hippocrates, Aristotle, and Galen, which were also translated into Arabic. Prominent scholars also included Al-Razi (Rhazes, 850–923), the founder of the Baghdad hospital and the medical school at it, and Ibn Abbas (born in 997), who critically questioned the absolute authority of classical authors.

The famous scientist and physician of the East, Abu Ali ibn Sina (Avicenna, 980–1037), authored “The Canon of Medicine”, in which he presented numerous pieces of information on anatomy and physiology, consistent with the ideas of Galen.

“The Canon” was first published in Latin in the 12th century and was reprinted more than 30 times. In one of the chapters of “The Canon” a general description of the structure and functions of the human body, as well as information about bones, joints, muscles, the structure of the cranium, teeth, and cranial nerves is provided.

At the beginning of the second millennium, the first medical schools began to emerge in Europe. One of the earliest was the Salerno School in Italy near Naples, where it was permitted to dissect human corpses once every 5 years. In 1238, Emperor Frederick II permitted the dissection of 1 corpse every 5 years, and by 1240, made dissection a mandatory part of anatomy education.

In the 12th–14th centuries, the first universities appeared in Europe, and medical faculties were opened in some of them.

In 1326, Mondino de Liuzzi (1270–1326) authored an anatomy textbook based on the dissection of two female cadavers. In the 14th–15th centuries, universities were given the right to dissect 1–2 human corpses per year. In the 14th–15th centuries, anatomy began to be taught at the universities of Montpellier, Venice, Vienna, Bologna, Paris, Tübingen, and other cities. In 1594, the first anatomical theatre (educational institution) in Europe was built in Padua.

Michael Servetus (1511–1553) provided the description of pulmonary circulation and the movement of blood from the right ventricle to the left atrium.

Leonardo da Vinci (1452–1519) and Andreas Vesalius (1514–1564) made particularly significant contributions to anatomy. The artist, mathematician, and engineer Leonardo da Vinci dissected 30 corpses, made about 800 very precise and original drawings of bones, muscles, and other organs, as well as described them. He studied and classified muscles and attempted to explain their function in terms of the laws of mechanics.

In 1543, A. Vesalius, studying organs and corpses, published the work *De humani corporis fabrica libri septem*, or “On the Fabric of the Human Body in Seven Books”, in which he scientifically described the structure of human organs and systems, pointed out the mistakes of many anatomists and challenged numerous Galenic errors. Vesalius’s main merit was that he created a truly systemic human anatomy, which had not previously existed.

The students and followers of A Vesalius in the 16th–18th centuries made many anatomical discoveries and corrections of previously made errors. G. Falloppio (1523–1562) was the first to carefully describe the structure of many bones, muscles, female genital organs, and organs of hearing and vision in his work “Anatomical Observations”. B. Eustachi (1510–1574) described the adrenal glands, the structure of teeth, kidneys, the organ of hearing, and veins in his work “Guide to Anatomy”, as well as studied comparative anatomy. H. Fabricius (1533–1619) studied the structure of the esophagus, larynx, eye, and other organs. He described the venous valves and suggested that they facilitate the flow of blood to the heart and prevent its backflow. H. Fabricius authored the works “On the Formation of the Fetus (1600)”, “On the Valves of the Veins (1603)”, etc.

Dutch physician and anatomist F. Ruysch (1638–1731) improved the method of embalming corpses and assembled a collection of anatomical preparations, which Peter the Great acquired for the famous Kunstkamera.

In the 16th–19th centuries, a functional direction emerged and successfully developed in anatomy. In 1628, the English scientist W. Harvey (1578–1657) in the book "An Anatomical Disquisition on the Motion of the Heart&Blood in Animals" provided evidence that the blood moves in a closed circle. In 1751, Caspar Friedrich Wolff, in his work "Inquiries into the Origin of Animals", **was among the first to articulate the concept** that "all life comes from the egg". In 1628, Gaspare Aselli (1581–1626) published a book describing the lymphatic (lacteal) vessels of the mesentery.

M. Malpighi (1628–1694) was the author of "Anatomical Observations on the Lung" (1661), in which he first described the pulmonary alveoli and capillaries. He was the first to study and describe the microscopic structure of the kidneys, spleen, skin, and other organs.

Thanks to the improvement of the microscope by Antonie van Leeuwenhoek (1632–1723), it became possible to study the fine structure of organs and tissues. He discovered **blood cells, sperm cells**, and many other cells. His book "Secrets of Nature", published in 1699, served as a prelude to the study of the microcosm.

Research by M. Malpighi, A. Leeuwenhoek, and other scientists laid the foundation for microscopic anatomy. In 1685, Govert Bidloo (1649–1713) in his book "Anatomy of Humane Bodies" provided the proof that nerve trunks consist of numerous nerve fibers. The Dutch physician Regnier de Graaf (1641–1673) discovered follicles in the ovary. His compatriot Bernhard Albinus (1697–1770) described the anatomy of the bones and muscles of the human body, the lacteal (lymphatic) vessels, and the azygos vein. Albrecht von Haller (1708–1777) published "Anatomical Images", "Anatomical Library", and "Elements of the Physiology of the Human Body", in which he developed morphometric methods and was the first to conduct a thorough morphometry of the growing embryo. Italian scientist Paolo Mascagni (1755–1815) published "Iconography and History of the Lymphatic Vessels of the Human Body". The founder of comparative anatomy was Georges Cuvier (1769–1832) who created the theory of groups of animals based on the structure of the nervous system.

The work of Marie François Bichat (1771–1802), "General Anatomy Applied to Physiology and Medicine", in which the concepts of tissues, organs, and systems was first presented, played a major role in the development of anatomy and microscopic anatomy. M.F. Bichat thus laid the foundation for histology. He divided organs into plant and animal, and the nervous system into vegetative and animal.

In the 19th century, anatomy transformed from a descriptive science into a synthetic and functional one. Czech scientist Jan Purkinje (1787–1869) described the nucleus of the cell, various other cell types including nerve cells, and several glands, as well as introduced the concept of "protoplasm".

The German scientist Theodor Schwann (1810–1882) created the cell theory and in 1839 published the book "Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants". In the book, the proofs are provided that all tissues consist of cells; plant and animal cells are similar to each other; the activity of organisms is the sum of the vital activity of individual cells.

The further development of the cell theory is attributed to R. Virchow (1821–1902), who demonstrated that cells arise through reproduction: "every cell originates from another cell", each cell functions as an independent unit.

Charles Darwin's (1809–1882) Theory of Evolution, to which the books "On the Origin of Species by Means of Natural Selection" (1859) and "The Descent of Man, and Selection in Relation to Sex" (1871) were dedicated, gave rise to a new science — anthropology.

However, neither Ch. Darwin nor his followers observed the transformation of one species of living being into another, either under natural conditions or in an experiment.

In the second half of the 19th century, Gregor Mendel (1822–1884) discovered the laws of heredity. August Weismann (1834–1914) predicted the existence of carriers of heredity — chromosomes — and suggested a linear arrangement of units of heredity in chromosomes. Édouard Van Beneden (1846–1910), Theodor Boveri (1862–1915) and Oscar Hertwig (1849–1922) described meiosis. Walther Flemming (1843–1905), simultaneously with the Kyiv histologist P.I. Peremeshko (1833–1893) described mitosis. At the beginning of the 20th century, Thomas Morgan (1866–1945) proved the linear arrangement of genes in chromosomes.

At the end of the 19th century (in 1895), Wilhelm Conrad Roentgen (1845–1923) discovered X-rays, marking the beginning of a new field in anatomy — **radiographic anatomy**, or the study of the living body through X-ray imaging.

In the 20th century, significant advancements were made in the field of anatomy, particularly in the realm of functional anatomy, histology, and cytology. A notable development was the method pioneered by Camillo Golgi (1843–1926) for staining tissues using silver salts. This method enabled the study of the fine structure of the nervous system, the architecture of neurons, their interconnections, and nervous tissue in its entirety. Building upon these findings, Santiago Ramón y Cajal (1852–1934) employed the Golgi method to obtain new data, make the groundbreaking discovery of the dynamic polarization of neurons, and provide a comprehensive description of the **neuronal cytoarchitecture** across different brain regions.

English scientist John Langley (1852–1925) presented a general structural organization of the autonomic nervous system and identified the parasympatheticdivision alongside the sympathetic one. Constantin von Monakow (1853–1930) and Paul Flechsig (1847–1929) made a detailed study of the anatomy of the brain. Charles Sherrington (1857–1952) investigated the structure and functions of the spinal cord, brainstem, and synapses, as well as formulated general principles of functioning of the central nervous system. Otto Loewi (1873–1961) discovered the neurotransmitters of the parasympathetic (acetylcholine) and sympathetic (adrenaline) nervous systems.

Walter Hess (1881–1973) discovered and studied the hypothalamic centers and their connection to internal organs and proved the coordinating role of the hypothalamus in the activity of organs.

Alfred Benninghoff (1890–1953) introduced the concept of functional systems into morphology. Wilhelm Roux (1850–1924) proposed the concept of functional structures and studied the causes and conditions of morphogenesis. Wilhelm His (1863–1934), Ludwig Aschoff (1866–1942), Sir Arthur Keith (1866–1955), Martin Flack (1882–1931), and Sunao Tawara (1873–1952) developed the theory of the cardiac conduction system.

The advances in cytology in the 20th century are associated with the development of fundamentally new research methods in morphology. In the 1930s, Albert Claude (1899–1983) developed a method for isolating cellular organelles, discovered ribosomes, and established that cellular respiration and oxidative phosphorylation processes with the formation of ATP (adenosine triphosphoric acid) occur in mitochondria. In the mid-1940s, an electron microscope was used for the first time to study cells, and the endoplasmic reticulum was discovered.

George Palade (1912–2008) was the first to describe the ultrastructure of mitochondria, endoplasmic reticulum, ribosomes, and the Golgi complex, as well as developed experimental methods for studying protein synthesis in a living cell. He described the pathways of protein synthesis and enzyme secretion in the cell, proposed and supported the theory of intracellular substance transport, and studied the synthesis of cellular and subcellular membranes.

DEVELOPMENT OF DOMESTIC ANATOMY

In the first millennium AD, the anatomical works of Ancient Greek and Roman scientists and physicians began to spread into neighboring regions — including Russia,Georgia, Armenia, Azerbaijan, and Central Asia — where they influenced the writings of Avicenna ("The Canon of Medicine") and other researchers. In the 10th–11th centuries, Isa-ur-Rigi (Azerbaijan) in the book "Tibb" ("Medicine") provided information on anatomy. Doctor Omar Osman-oglu, despite the prohibitions of Islamic law, conducted human dissections to study anatomy. Georgian scientists also made significant contributions to anatomical science. In the 11th–12th centuries, Armenian doctors were well acquainted with advancements in anatomical knowledge.

Some anatomical knowledge regarding organ structure can be found in ancient Russian manuscripts dating from the 10th to 13th centuries. Most of the anatomical data were taken from the works of Galen. In Russia, anatomical data appear in the "Church Constitution" (10th century), "Svyatoslav's Miscellanies" (11th century), and "The Russkaya Pravda" (11th–12th centuries). In the 15th–16th centuries, books appeared in Russia containing theoretical questions of medicine with brief information on anatomy, in particular on physique ("Aristotle's Gate", "The Secret of the Secret"). The names of many parts of the body were mentioned in various medical and herbal books translated into Russian from Latin and Greek. Anatomy, as part of the study of medicine (*physick*), was taught using the poorly adapted textbook "Aristotelian Problems". The first doctors — who studied anatomy from the "skeleton", surgery, and other subjects — graduated from the Moscow Medical School in 1658. That same year the philologist Epiphanius Slavinetsky (died in 1675) translated from Latin into Russian "Epitome" by A. Vesalius, intended for university students as a textbook on anatomy.

In the 17th–18th centuries, a number of universities were established on the territory of the Russian Empire where human anatomy was taught: in 1632 in Tartu, in 1617 in Vilnius, in 1775 in Jelgava, in 1775 in Grodno.

During the reign of Peter I, several medical schools were established in Russia. One such school opened in Moscow in 1707 at the Moscow hospital. In 1733, medical schools were founded in St. Petersburg and Kronstadt, and in 1758 in Barnaul. Anatomy was taught using a handwritten textbook by N. Bidloo (1670–1735) titled "Anatomy", as well as the first Russian anatomical atlas, created in 1744 by M.I. Shein (1712–1762). In 1757, he translated L. Heister's "Abridged Anatomy" into Russian. His translation of anatomical terms into Russian laid the foundation for the creation of Russian anatomical terminology.

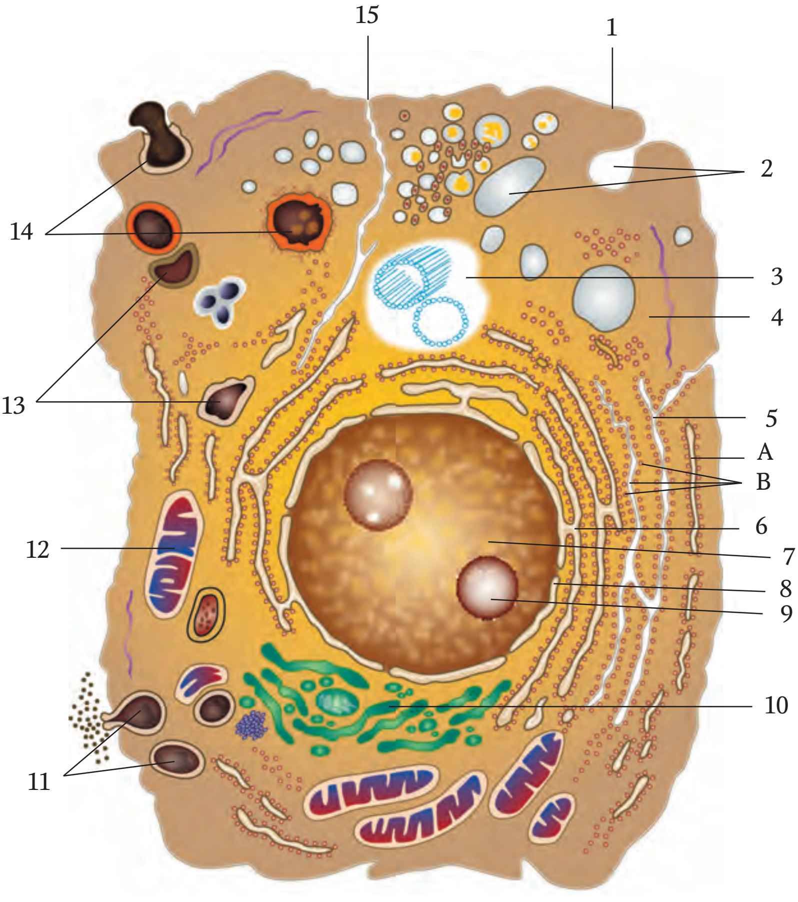

Fig. 5. Ultramicroscopic structure of a cell. Scheme: 1 — plasma (cytoplasmic) membrane; 2 — pinocytotic vesicles; 3 — centrosome (cell center; cytocenter); 4 — hyaloplasm; 5 — endoplasmic reticulum: A — endoplasmic reticulum membrane. B — ribosomes; 6 — connection of perinuclear space with cavities of endoplasmic reticulum; 7 — nucleus; 8 — nuclear pores; 9 — nucleolus; 10 — internal reticular apparatus (Golgi complex); 11 — secretory vacuoles; 12 — mitochondria; 13 — lysosomes; 14 — successive stages of phagocytosis; 15 — junction of cell membrane (plasmalemma) with membranes of endoplasmic reticulum

with each other, forming an occluding zone (zonula occludens) that is impermeable to molecules. When *zonula occludens* is formed, a localized adhesion zone known as a desmosome (common between epithelial cells) is formed in a limited area.

The gap intercellular junctions (nexuses) are 2–3 μm long. In such junctions, the plasma membrane of neighboring cells is located at a distance of 2–3 μm. Ions and small molecules easily penetrate through such junctions.

Microvilli are found on the surfaces of many cells and increase their surface area. The length of a *microvillus* is about 1–2 μm, and the diameter is up to 0.1 μm. In leukocytes, connective tissue cells, and epithelial cells of the small intestine, microvilli form the so-called *brush border*. Due to the presence of active microfilaments, microvilli can exhibit mobility. The framework of each microvillus is formed by a bundle of approximately 40 microfilaments.

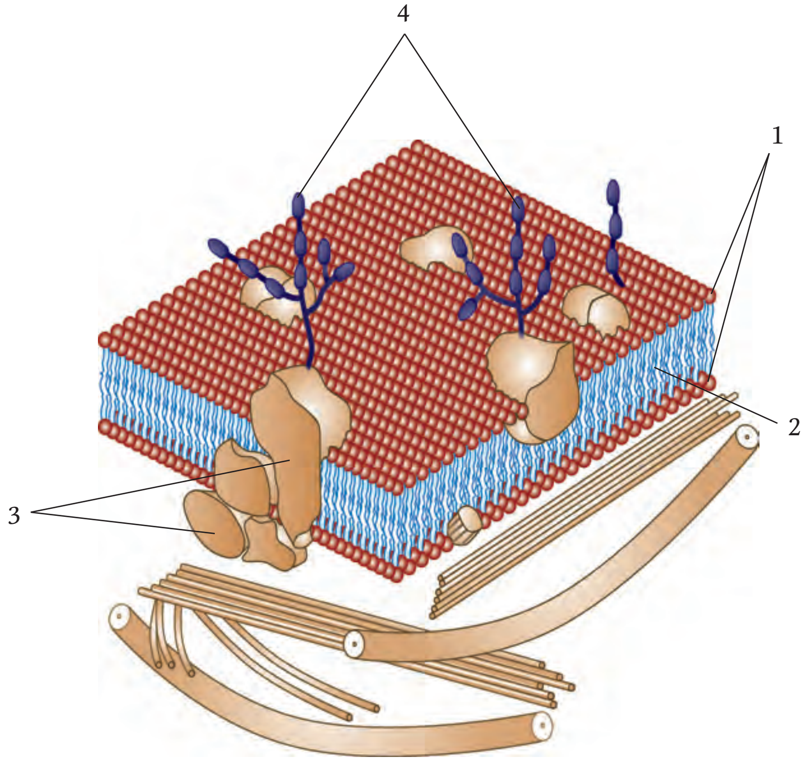

Fig. 6. Structure of the cytoplasmic membrane (plasmalemma): 1 — lipids; 2 — hydrophobic zone of lipid molecules; 3 — protein molecules; 4 — glycocalyx polysaccharides

Cilia and **flagella** (specialized purpose organelles) participate in movement processes and are outgrowths of the cytoplasm. *Cilia,* or *kinetocilia* (singular: cilium or kinetocilium), perform motor functions; their movements are pendulum- or wave-like movements. The cilia of the surface epithelium of the upper respiratory tract, ductus deferentes, and fallopian tubes are each up to 5–15 μm long and have a diameter of 0.15–0.25 μm. In the center of the cilium, there is an *axial filament* formed by peripheral double microtubules. *Flagella* are similar in structure to cilia; they perform coordinated oscillatory movements.

Hyaloplasm (*hyaloplasma*) is a homogeneous substance of complex composition, occupying about 55% of the volume of the cell cytoplasm. It contains proteins, polysaccharides, nucleic acids, enzymes, organelles, and cytoplasmic inclusions.

Organellae are essential microcomponents of cells that perform primary functions. A distinction is made between membrane and non-membrane organelles. *Membrane organelles* are separated from the hyaloplasm by membranes. Membrane organelles include the endoplasmic reticulum, the internal reticular apparatus, mitochondria, lysosomes, and peroxisomes. *The endoplasmic reticulum* (*reticulum endoplasmicum*) consists of numerous plates, tubes, cisterns of rounded or flattened shapes, and sacs. A distinction is made between *granular* (*rough*) and *non-granular* (*smooth*, *agranular*) *endoplasmic reticulum*. The outer side of the rough endoplasmic reticulum, unlike the smooth one, is covered with numerous ribosomes. The rough