Вельмишановні колеги-анатоми, завідувачі профільних кафедр
медичних закладів вищої освіти України, лікарі, студенти й просто читачі!

Пропонуємо до Вашої уваги друге, виправлене і відредаговане українськомовне та англійськомовне видання тритомного підручника «Анатомія людини» за редакцією проф. В. Г. Ковешнікова, створеного у співавторстві із сімнадцятьма провідними професорами-анатомами України. Вчитайтесь у ці імена: В. Г. Ковешніков (Луганськ), І. І. Бобрик (Київ), М. А. Волошин (Запоріжжя), А. С. Головацький (Ужгород), І. І. Ільїн (Одеса), Г. С. Кірьякулов (Донецьк), В. О. Козлов (Дніпро), Ю. П. Костиленко (Полтава), В. І. Лузін (Луганськ), В. М. Лупір (Харків), Б. Г. Макар (Чернівці), В. С. Пикалюк (Сімферополь – Луцьк), О. Ю. Роменський (Вінниця), В. З. Сікора (Суми), Я. І. Федонюк (Тернопіль), В. Г. Черкасов (Київ), Б. В. Шутка (Івано-Франківськ). Це географія усієї університетської України, ареопаг Ваших учителів. П'ятнадцять років тому, з 2005 по 2009 рік, кожен новий том підручника, що з'являвся у світ, ставав своєрідним навчальним бестселером серед студентів та викладачів-анатомів. Їх читали, обговорювали, дискутували, закуповували десятками і сотнями в університетські бібліотеки, а ще тисячі примірників поповнили власні науково-медичні бібліотеки студентів-медиків, лікарів, викладачів. Упродовж наступного десятиріччя саме цей підручник був найзатребуванішим із фундаментальних навчальних видань медичного спрямування. До 2014 року видавництво в Луганську щорічно друкувало і поширювало все нові наклади підручника трьома мовами, забезпечуючи собі безбідне існування й не виплачуючи при цьому жодної копійки гонорару авторам. Але час і обставини корегують життєву дорогу і долю як людей, так і книг. Пішов у вічність головний редактор, натхненник і організатор унікального фундаментального підручника – лауреат Державної премії, заслужений діяч науки і техніки України професор-анатом Володимир Георгійович Ковешніков. Анатомічний світ утратив дванадцятьох професорів – співавторів підручника. Зникла з мапи наукових видавництв назва «Шико» з Луганською адресою. На вимогу часу підручник оцифрували й запустили в електронний обіг. Щоправда, доступ до ресурсу можливий тільки за солідний гонорар, і зробили це після смерті головного редактора, не питаючи згоди авторів підручника.

На зміну випускникам-медикам в університети приходять нові покоління першокурсників. І виявилося, що запит на «анатомічний тритомник В. Г. Ковешнікова» не зник, не зменшився, не нівелювався. Та й життєве кредо, принципи академічної доброчесності, щемливе почуття вдячності Учителю спонукало нас, учнів Професора, які мали честь працювати разом зі співавторами підручника, в черговий раз вичитати сторінки трьох томів, виправити деякі огріхи й запропонувати медичній спільноті друге видання тритомного підручника з анатомії, яке стане своєрідною пролонгацією життєвого циклу людської пам'яті, посильною даниною шани, поваги, вдячності Учителю та Колегам.

Учні та послідовники професора Володимира Георгієвича Ковешнікова
проф. Віталій Сікора, проф. Василь Пикалюк,
сини Олександр та Георгій Ковешнікови

Dear colleagues-anatomists, heads of profile departments
of medical schools of Ukraine, doctors, students and just readers!

We bring to your attention the second corrected and edited version in Ukrainian and English of the three-volume textbook "Human Anatomy" edited by Prof. V. H. Koveshnikov, co-authored by 17 leading professors-anatomists of Ukraine. Read attentively these names: V. H. Koveshnikov (Luhansk), I. I. Bobryk (Kyiv), M. A. Voloshyn (Zaporizhzhia), A. S. Holovatskyi (Uzhhorod), I. I. Iliin (Odesa), H. S. Kiriakulov (Donetsk), V. O. Kozlov (Dnipro), Yu. P. Kostylenko (Poltava), V. I. Luzin (Luhansk), V. M. Lupir (Kharkiv), B. H. Makar (Chernivtsi), V. S. Pykaliuk (Simferopol – Lutsk), O. Yu. Romenskyi (Vinnytsia), V. Z. Sikora (Sumy), Ya. I. Fedoniuk (Ternopil), V. H. Cherkasov (Kyiv), B. V. Shutka (Ivano-Frankivsk). This is the geography of the entire university Ukraine, the Areopagus of Your teachers. Fifteen years ago, from 2005 to 2009, each new volume of the textbook that appeared in the world became a kind of educational bestseller among students and teachers of anatomy. They were read, discussed, debated, purchased by the dozens and hundreds in university libraries, and thousands more copies were added to their own scientific and medical libraries of medical students, doctors and teachers. Over the next decade, this textbook was the most sought after of the fundamental educational publications in the medical field. Until 2014, the publishing house in Luhansk annually printed and distributed new editions of the textbook in three languages, and earned a reasonable living without paying a penny of royalties to the authors. But time and circumstances correct the way of life and destiny of both people and books. Volodymyr Koveshnikov, the editor-in-chief, inspirer and organizer of a unique fundamental textbook, winner of the State Prize, Honored Worker of Science and Technology of Ukraine, anatomist, passed away. The anatomical world lost twelve professors – coauthors of the textbook. The name "Shyko" with the address of Luhansk disappeared from the map of scientific publishing houses. At the request of time, the textbook was digitized and launched into electronic rotation. However, access to the resource is possible only for a hefty fee, and they did so after the death of the editor-in-chief, without asking the consent of the authors of the textbook.

New generations of freshmen are replacing medical graduates at universities. And it turned out that the demand for "anatomical three-volume by V. H. Koveshnikov" did not disappear, did not decrease, did not level. And life credo, principles of academic integrity, a sharp sense of gratitude to the Teacher prompted us, students of the Professor, who had the honor to work with coauthors of the textbook, once again read the pages of three volumes, correct some flaws and offer the medical community a second edition of the three-volume textbook which will be a kind of prolongation of the life cycle of human memory, a possible tribute to honor, respect, gratitude to the Teacher and Colleagues.

Students and followers of the Professor Volodymyr Heorhiiovych Koveshnikov,
Professor Vitalii Sikora, Professor Vasyl Pykaliuk,
Sons Oleksandr and Heorhii Koveshnikov.

PREFACE

This textbook presents the material on human anatomy according to the current educational program for medical universities.

In addition to providing general anatomical information, each part of the textbook includes material on the development, variations, and anomalies of organs and systems. The textbook also emphasizes clinical applications of the presented information. We paid particular attention to the substantiation of general principles in the study of anatomy: the correlation between the structure and function, the integrity of the organism, and the unity of the organism with its external environment. Each unit ends with practice questions, which allow students to self-evaluate their progress.

In preparing this textbook, we have been guided by the pedagogical expertise of many Ukrainian scientists-anatomists who became the coauthors of this work (Bobryk I. I., Kyiv; Voloshyn M. A., Zaporizhzhia; Holovatskyi A. S., Uzhhorod; Iliin I. I., Odesa; Kiriakulov H. S., Donetsk; Koveshnikov V. H., Luhansk: Kozlov V. O., Dnipro; Luzin V. I., Luhansk; Lupir V. M., Kharkiv; Pykaliuk V. S., Simferopol; Romenskyi O. Yu., Vinnytsia; Sikora V. Z., Sumy; Fedoniuk Ya. I., Ternopil; Cherkasov V. H., Kyiv; Shutka B. V., Ivano-Frankivsk). All coauthors followed a uniform representational style depicting a modern scientific state of the subject in a given unit of the textbook.

In the textbook, we used new anatomical nomenclature, which was approved by the International Federal Committee (SaõPaulo, 1997). Ukrainian equivalents of the terms are presented in accordance with the book "International Anatomical Nomenclature" edited by Professor I. I. Bobryk and Professor V. H. Koveshnikov (Kyiv, 2001).

Illustrations were borrowed from the manuals and textbooks accompanied by the authors' additions and revisions. The majority of the drawings are made from the drugs and are original.

The organization of the material on human anatomy into units corresponds to the curriculum of the credit transfer educational system.

I wish to acknowledge and express my appreciation to N. H. Mykula, N. P. Mishchenko, V. V. Mavrych and O. S. Bolhova for their help in preparing this textbook for publication. Apart from this I'm truly greatful to Mrs. Larysa Sankova and Ms. Eugenie Bekova, who made the English translation of the book.

Comments, suggestions, and critique aimed to improve this textbook are welcomed by the authors and will be taken into consideration in further editions.

Professor V. H. Koveshnikov

SHORTENINGS KEY

a.	– arteria	– artery
aa.	– arterie	– arteries
art.	– articulation	– joint
artt.	– articulations	– joints
for.	– foramen	– opening
forr.	– foramina	– openings
lam.	– lamina	– plate
lamm.	– laminae	– plates
lig.	– ligamentum	– ligament
ligg.	– ligamenta	– ligaments
m.	– musculus	– muscle
mm.	– musculi	– muscles
n.	– nervus	– nerve
nn.	– nervi	– nerves
r.	– ramus	– branch
rr.	– rami	– branches
sul.	– sulcus	– sulcus
sull.	– sulci	– sulci
sut.	– sutura	– sutura
sutt.	– suturae	– suturae
v.	– vena	– vein
vv.	– venae	– veins

INTRODUCTION

HUMAN ANATOMY, ITS ROLE AND PLACE AMONG OTHER BIOLOGICAL AND MEDICAL DISCIPLINES

Human anatomy is the science, which studies the form and structure of the human body. The science of anatomy is based on the study of the structure of the body as a whole, inseparable from its surrounding environment.

The term "anatomy" is derived from the most ancient and major technique used by the anatomists of the past and present. The Greek word **anatemno** means to dissect, to separate. For a long time, dissection (separation) persisted as the only technique for studying the structure of the human body. Hence the word **anatomia** (from Greek) – the art of dissecting dead body. Clearly, modern anatomy utilizes a full arsenal of the state-of-the-art medical and biological techniques for the study of human body. However, dissection remains an irreplaceable method for teaching anatomy.

Analysis and synthesis. In order to study human body, it is necessary to dissect, separate, detach, and isolate an organ and examine its structure. By the dissection method, we perform the analysis separating the body into simple, discrete components. However, the analysis must be followed by the synthesis because individual tissues, organs, and systems are not isolated. Tissues, organs, and systems represent a complex system, in which all components are interconnected and interrelated. This system is a whole organism, which is unified with its surrounding environment.

Some students, who perform the analysis and study separate human organs, may consider anatomy a difficult and boring science, because the anatomy requires memorization of numerous terms both in Ukrainian and Latin. However, specific terminology is the foundation of any science, without which it is impossible to comprehend the subject. The study of anatomical terminology creates a solid foundation for further learning of medical terminology, because the majority of medical terms are heavily based on the anatomical structures.

One who studies anatomy will find satisfaction in this subject only when the time of synthesis and generalization comes, when disjointed facts combine into a single body of knowledge. Only then, it becomes possible to comprehend the beauty of anatomy, the rationality and wisdom of nature, which created the most complex living organisms, with human beings at the apogee of this creation.

The necessity of the study of phylogeny and ontogeny. In the study of human body, the researchers and students should always yearn to explain not only how the organism is built but also why it is built that way. Two questions – "how?" and "why?" should always emerge during the study of anatomy. The first question can almost always be answered with certainty by the anatomy. At the same time, the "arsenal" of anatomy is quite insufficient to answer the question "why". In order to do so, the anatomists must research the organism in the process of its historical and individual development, that is study the phylogeny and ontogeny of animal organisms.

The connection between the anatomy and sciences, which study phylogeny. The phylogenesis[1] is the process of the historical development of the animals, the history of their development. The anatomists utilize the data gathered from anatomy, paleontology, and anthropology with the purpose of researching the course of phylogeny.

The comparative anatomy studies organisms of different animals and compares their structure. It is possible to identify common and opposite traits in the structure of organs in different animals and trace their changes using the comparative method. For example, by studying the heart anatomy in fishes, amphibians, reptiles, birds, and mammals, we can clearly imagine a process of gradual evolution of this organ and understand the reasons, which determined the increase in its structural complexity. We can also answer such questions: why four-chamber heart developed and why the separation of arterial and venous blood took place. There is a reason why the comparative anatomy is often called the philosophy of the anatomy – the data provided by this science help in understanding the reasons of the historical determination of the structure of organs, systems, and entire organism.

In order to study phylogeny, anatomists utilize data provided by the paleontology[2] – the study of fossilized forms of extinct animals and humans. The branch of this science, which studies human fossils, is called paleoanthropology.

Anatomy is closely related to the anthropology[3] – the science about human in the broad sense. Unlike anatomy, which studies humans as a common group, anthropology studies human variety. Anthropology looks at the population ethnic groups, studies racial differences and influences of social factors on the organism. Anthropogenesis is one of the branches of anthropology, which studies the origin and historical development of humans. The study of anthropogenesis allows us to clearly comprehend the place of humans in the animal kingdom and retrace the evolution of humans as a species. Anthropology studies the role of work and other factors, which shaped humans as they are, which helps in understanding of numerous anatomical characteristic features.

The relationship between anatomy and sciences, which study ontogeny. The process of development of this individual from the moment of its conception until death is called ontogenesis[4]. In other words, this is the process of individual development of the organism. The ontogenesis is divided into two stages, which differ considerably from one another – intrauterine and extrauterine. The intrauterine period encompasses the period of ontogenesis from conception until birth (prenatal[5] period). The extrauterine (postnatal[6]) period continues after birth until death.

The science, which studies early stages of the intrauterine period, is called embryology[7]. In order to understand the characteristic features of the organ structure in adults, we

[1] – **phylon** (from Greek) – a genus, genesis (from Greek) – origin
[2] – **palaios** (from Greek) – ancient, logos (from Greek) – science
[3] – **anthropos** (from Greek) – human
[4] – **ontos** (from Greek) – characteristics
[5] – **natus** (from Greek) – born; from nascor (from Greek) – being born
[6] – **post** (from Latin) – behind
[7] – **embrion** (from Greek) – embryo

must study the formation of the organ from its simple components to more complex structures. Therefore, modern anatomy is quite closely related to embryology and widely uses data provided by this science.

After birth, significant changes take place in the structure of the organism, which are called the age-related changes. The branch of anatomy, which studies age-related characteristics, is called the age anatomy. The most considerable changes occur during the first months and years of a child's life. Therefore, data provided by the age anatomy have great clinical importance in pediatrics. In elderly, senile changes take place. These changes are studied by the gerontology[1].

Anatomy and histology. These sciences study the structure of the human body using different approaches. Anatomy studies structures visible to the naked eye, hence, it is called the macroscopic anatomy. With the appearance of the microscope, a large field of study of the organism emerged – microscopic anatomy. Subsequently, the microscopic anatomy became incorporated into a broader field of science – histology, which studies microscopic structure of tissues, groups of cells, and other formations, which become visible under the light and electronic microscopes.

Morphology[2]. This term encompasses sciences, which study the form and structure of living organisms. This term was first suggested by the prominent German poet and scientist Goethe, who is known for his anatomical research. The spectrum of morphological sciences includes human anatomy, comparative anatomy, histology, cytology, and embryology.

Anatomy, physiology, and medicine. Anatomy is inextricably associated with physiology, which studies functions of the organs, systems, and the organism as a whole. The fact that structure and function (form and content) determine each other is one of the most important principles of dialectics. Kyiv Professor A. P. Valter wrote: "Anatomy united with physiology is the queen of medicine".

In the broad sense, anatomy and physiology yield the science of biology. Therefore, anatomy is a part of biology. In other words, it is a biological science.

Moreover, anatomy is one of the most fundamental branches of medicine. Competence in normal anatomy provides ground for learning pathological anatomy, diagnosing diseases, assigning treatment, and performing surgeries. It is impossible to become a physician without the expertise in anatomy. "A doctor, who doesn't know anatomy, is a greater bane for the patient than the disease itself" (V. G. Koveshnikov).

"The anatomy tree". Concluding this overview of anatomy relations with other sciences, it is handy to compare anatomy with the tree, whose roots grow deep into the theoretical sciences – comparative anatomy, paleontology, anthropology, and embryology. Bringing together anatomical facts and data provided by these sciences, we are able to understand the reasons, which determined the structure of the organism and purposefully study the structure of the human body.

---

[1] – **geron** (from Greek) – old

[2] – **morphe** (from Greek) – a form

The branches of the "anatomy tree" represent practical medicine – surgery, therapy, obstetrics, pediatrics, and other medical disciplines. Only relying on the knowledge of the structure of the human body, it is possible to master medical sciences. Severing the roots of this tree would throw the anatomy back into the times of Andreas Vesalius in XV–XVI century and turn this subject into an assemblage of discrete facts difficult for studying.

SPECIALIZED BRANCHES OF ANATOMY

In the field of anatomy it is possible to distinguish various branches, which conform to a specific educational or practical purpose.

Systematic anatomy examines the structure of the body, system by system, methodically outlining the skeleton, bones, articulations, muscular, digestive, respiratory, and other systems of the body. It is recommended to begin the study of anatomy from the study of the systematic anatomy.

Topographical (surgical) anatomy studies spatial relationships of organs and tissues in different regions of the body. This branch of anatomy was developed in response to the demands of surgical practice.

Age anatomy focuses on the study of age-related characteristic features of the body structure, which is important in pediatrics.

Plastic anatomy studies the external form and proportions of the body as well as organs, which determine the shape of the body. Expertise in plastic anatomy is required in antropometrics as well as in art, graphics, and sculpture.

The goal of the **sports anatomy** is to study the anatomic characteristics of the body for the purposes of sports medicine. This branch of anatomy studies the anatomic basis of movements and changes, which take place during physical exercise.

THE CONCEPT OF NORMALITY AND ANOMALY

Normal and pathological anatomy. Human anatomy studies the normal structure of a healthy organism, hence its name – normal human anatomy. Unlike normal human anatomy, pathological anatomy studies structural changes in the organism affected by a disease.

What is the normality? It was mentioned above that anatomy performs a generalized study of the human body. However, every person has certain individual characteristic features, determined by the genetic and environmental factors. The uttermost forms of these individual characteristics are so different from one another that it becomes extremely difficult to define the concept of 'normality'. Fluctuations within the limits of normality make it impossible to draw a solid line between the normality and pathology. A structure can be considered normal if it is a quality common to all humans as a species and if it permits optimal functioning of the organism.

Individual variability in the organ structure within the limits of normality should be considered a variation of the norm.

Anomalies. Significant deviations from the species norm that occur during the development process are called anomalies. The anatomists gathered an immense body of knowledge concerning the anomalies in different organs and systems. Curiously, some anomalies resemble the structures of human predecessors providing evidence of a genetic link between humans and other animals. Such anomalies, for example, include the increase in the number of coccygeal vertebrae leading to the tail formation in humans. Some anomalies observed in animals somewhat precede the normal course of development and point out further directions of human evolution.

Birth defects. Many anomalies are not noticeable and do not cause any significant dysfunctions in the organism. Other anomalies lead to serious structural and functional impairments. Such anomalies are called birth defects. Birth defects that have external manifestations are called deformities.

Birth defects and deformities which studies deformities, is called teratology[1].

The identification of birth defects is of great importance in medical practice, because surgical means of birth defect correction are considerably expanding in recent years.

THE METHODS OF STUDYING ANATOMY

Contemporary anatomy has a large arsenal of research methods at its disposal, including techniques used on cadavers or living beings.

Dissection – did not lose its leading position among other methods even today. In the process of dissection, the investigator dissects tissue with the scalpel, separates organs, and prepares anatomical specimens. There is no need to emphasize the importance of working on the cadaver specimens, because students must maximally utilize those, sometimes modest, opportunities, which the department provides for dissection today.

Injection. Anatomists often use the injection technique to study blood vessels, lymph vessels, and hollow organs. This method makes use of injecting contrast polymerizing dyes followed by the dissection, X-ray visualization, or preparation of corrosion or translucent specimens.

Injection-corrosion casting method. After the injection of a hollow organ with polymerizing medium, the specimen is immersed in the solutions of strong acids, which destroy (corrode) the tissues. As a result, the investigator obtains a cast of the hollow organ, which was injected (vessels, bronchi, etc.).

Elucidating method is based on preparation of transparent specimens by dehydrating and immersing tissue in special solutions, which soak into the specimen. Consequently, the light reflection index of the specimen and surrounding fluid become equal. This method allows examination of stained ossification centers, injected blood and lymph vessels as well as other organs.

Dissection of frozen cadavers. This method was proposed by M. I. Pyrohov. Sections can be performed in different planes. Moreover, relative locations of tissues and organs are preserved in frozen specimen, which provides a possibility to study their topography.

[1] – **teras, teratos** (from Greek) – crippled, deformed.

Macro-microscopic method. At the beginning of the last century, Kharkiv anatomist V. P. Vorobyov pointed out that the field, which occupies position between the macroscopic anatomy on one side and microscopic anatomy on the other side remains poorly examined. He developed a dissection and examination technique under the magnifying glass (small magnification), which filled the gap in the anatomical knowledge.

Radiography. Anatomists widely use the method of radiography, which can be successfully performed both on cadavers and living humans. This examination method gave birth to a new branch of anatomy called radioanatomy.

The greatest advantage of this method is the possibility to study organs of living humans – skeleton, joints, vessels, and hollow organs. Presently, various harmless contrast media are used in clinic. They are injected into the blood and lymph vessels in order to obtain X-ray images of vessels in living humans (angiography method).

Computed tomography (CT). Recently, new methods of computed tomography have been developed, which produce high resolution X-ray images of not only bones but internal organs as well. In CT, the computer detects the slightest differences in the attenuation of X-rays by different soft tissues and creates a CT image base on this information.

A significant role in clinic is attributed to the ultrasound examination, which gives possibility to study the anatomy and function of various internal organs in healthy subjects and individuals suffering from a disease.

ANATOMICAL TERMINOLOGY

International anatomical terminology. Historically it was predetermined that anatomists must use Greek and Latin terms to define certain anatomical structures. The first international standardization of anatomical terminology took place in Basel (Switzerland), where in 1895 the IX Congress of Anatomical Committee approved the Basel Nomina Anatomica (BNA). In 1955, in Paris, at the VI International Congress of Anatomists, new international Parisiana Nomina Anatomica (PNA) was accepted, which after several additions and revisions was acting until the year of 1997. In this year, in Saõ Paulo (Brazil), new international anatomical nomenclature (S-PNA) was adopted, which is gradually being implemented in all the countries of the world. Based on the international anatomical nomenclature, every country develops and approves for wide use (not only for teaching anatomy) the national anatomical nomenclature.

Principles of anatomical nomenclature. In order to describe positions of parts and organs in the human body, it is assumed to be in its vertical posture with the hands down and palms facing forward. The anterior, lateral, and posterior surfaces of the body are distinguished in this position.

The root of the anatomical term is most commonly represented by the name of the organ, from which the names of its parts, surfaces, and other characteristic feature are given.

Some anatomical terms are vestiges of long forgotten misconceptions, for example, **arteria** (**aer** – *air*, **tereo** – *to carry*) means the vessel, which carries air. According to the new nomenclature (S-PNA), each term possesses a nine-digit identification code.

For a long time, anatomical structures were named after the scientists who first described them. It is hard sometimes to establish precedence, and consequently in different countries the same structures were called differently. Therefore, it was agreed to stop using terms derived from the names of scientists (eponyms), except those cases when the name provides the root for the clinical term. However, in the new international nomenclature at the end of the list of surnames of scientists who first described these or those anatomical structures is given in alphabetical order. They can be identified by the identification code, which is placed in front of the name.

AXES AND PLANES, WHICH RUN THROUGH THE HUMAN BODY

In order to study the spatial relations of organs and parts of the body, anatomists use universally accepted axes and planes, which are drawn through the body (Fig. 1).

The vertical axis passes through the body from top to bottom. The sagittal (**sagitta** – *an arrow*) axis is directed from the front to the back. The frontal (**frons** – *forehead*) axis runs from right to left or left to right.

The median (**medianus** – *middle*) plane divides the body into right and left symmetrical halves. Those organs, which lie closer to this plane, are called medial (**medialis** – *positioned at the midline*), whereas those located farther away from the midline are named lateral (**lateralis** – positioned at the side). Planes, which run parallel to the median plane, are called sagittal planes.

The frontal plane corresponds to the plane of the forehead. Passing through the body, this plane divides it into anterior and posterior halves. On the torso, the anterior surface is called ventral (**venter** – *belly*), whereas posterior is named – dorsal (**dorsum** – *back*). Organs, which reside closer to the anterior surface, are defined as anterior or ventral. Organs, which lie closer to the posterior surface, are called dorsal, or posterior.

The horizontal plane lies at right angles to the previous planes, i.e. horizontally, and divides the body into the superior and inferior halves. Organs, which reside above the horizontal plane, are called superior, or cranial (**cranium** – *skull*), whereas organs, which lie below this plane, are dubbed inferior, or caudal (**cauda** – *tail*).

Upper portions of the limbs, which lie closer to the torso, are called proximal (**proximalis** – *near the trunk*). Lower portions of the limbs are dubbed distal (**distalis** – *away from the center of the trunk*).

Such terms as ventral, dorsal, cranial, and caudal are mainly used within the borders of the trunk. They are conveniently utilized in human anatomy when dealing with embryological or comparative anatomical terminology, because embryos and animals do not possess vertically-oriented bodies.

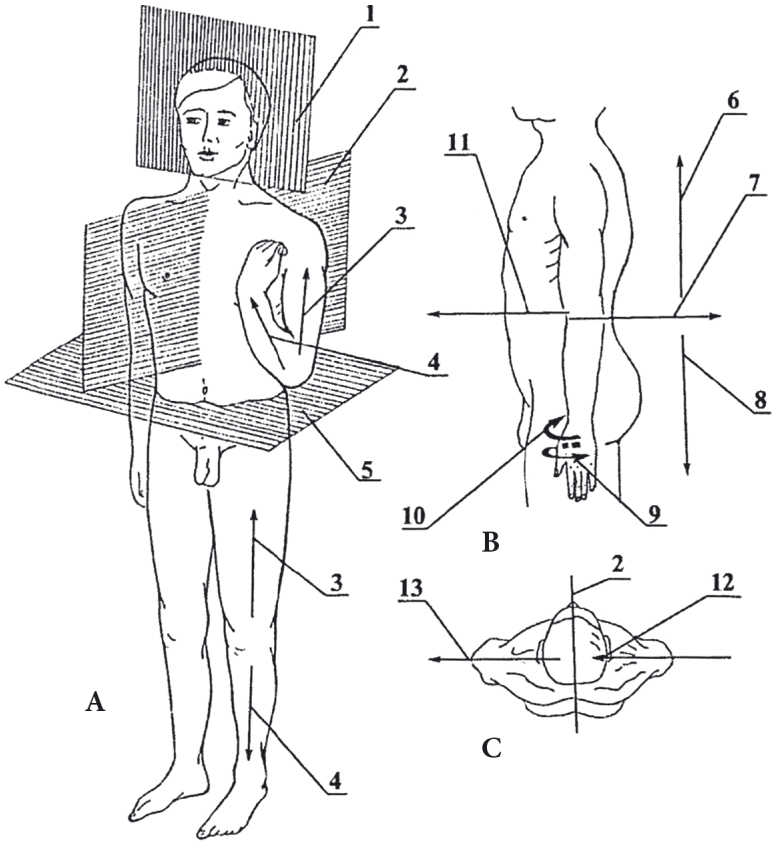

Fig. 1. The diagram of planes passing through the human body and basic anatomical terminology.
A – anterior aspect; **B** – lateral aspect; **C** – superior aspect. 1 – frontal plane; 2 – sagittal plane; 3 – proximal direction; 4 – distal direction; 5 – horizontal plane; 6 – cranial (superior) direction; 7 – dorsal (posterior) direction; 8 – caudal (inferior) direction; 9 – supination; 10 – pronation; 11 – ventral (anterior) direction; 12 – medial direction; 13 – lateral direction.

Practice questions:

1. Define anatomy as a science.
2. Explain the origin of the word "anatomy"?
3. How are such methods as analysis and synthesis used for studying anatomy?
4. Why is it essential to study the phylogeny and ontogeny?
5. Name the sciences, which study the phylogeny.
6. Name the sciences, which study the ontogeny.
7. Name the sciences, which are closely related to the anatomy.
8. What do anatomy and histology have in common and what are the differences between these two sciences?

9. What is morphology?
10. Explain the relationship between anatomy, biology, and medicine using the "tree" metaphor.
11. Name the specialized branches of anatomy.
12. What is the normality?
13. Explain the difference between the birth defect and anomaly.
14. What is the significance of studying anomalies and birth defects?
15. Name basic methods of studying anatomy.
16. Provide the names of those scientists, who developed:
    a) The method of dissecting frozen cadavers;
    b) The macro-microscopic method.
17. Name modern methods of studying anatomy on the living person.
18. When was the S-PNA adopted?
19. What are the main principles of the modern anatomical nomenclature?
20. What is the universal body posture accepted in anatomy?
21. Name the axes and planes, which are drawn through the human body.
22. Explain the following terms: medial and lateral, ventral and dorsal, cranial and caudal, proximal and distal.

FOUNDATION

GENERAL PLAN OF BODY STRUCTURE. BASIC LEVELS OF ITS STRUCTURAL ORGANIZATION

Human body consists of cells, tissues, organs, and systems of organs, which represent different levels of its structural organization. The concept of multiple levels of body organization is crucially important in medicine for proper understanding of causes, progression, and treatment of pathological processes.

Cells as elementary units of living organisms. The organism consists of structural units – cells, each of which is a self-regulating and self-reproducing system. Cells are the principle "building blocks" of all animal and plant organisms. Cells are characterized by their microscopic size, various forms, and functions.

Robert Hook was the first to discover cells in 1665. In 1838 Shleiden and Shwann formulated a universal theory of cellular structure of living organisms.

Tissues. *A tissue* (**histos seu textus**) is a complex of cells and intercellular matrix, which have a common origin, a specialized structure and function. The concept of tissues was first proposed by Bichat in 1801. He considered tissues as elementary "building blocks" of organs. He described more than twenty tissue types without the help of a microscope.

Presently, we distinguish four tissue types: 1) epithelial; 2) connective; 3) muscular; 4) nervous.

Epithelial tissues reside on the borders with the external environment and function as barriers. They also protect underlying tissues and secrete various substances. The epithelium covers the skin and lines the mucous layers of the digestive, respiratory, and urogenital tracts. Unilayered and multilayered epithelia are distinguished. According to the shape of the cells, the epithelia are divided into squamous, cuboidal, and columnar types. Furthermore, epithelial tissue gives rise to the glandular organs such as liver, pancreas, and other glands. Epithelial cells of the glands are specialized in production of various substances essential for the functioning of the organism.

Connective tissues encompass a wide group of tissues, which vary in their structure and function, but have a common origin. Connective tissues are characterized by a well-developed intercellular matrix, which provides support and connects cells within the tissue. The intercellular matrix can be quite durable (for example, in osseous tissue) withstanding considerable stress loads.

Connective tissues can be classified into the proper connective tissue (irregular and regular connective tissues), adipose tissue, cartilage, and osseous tissue. Such fluid tissues of the organism as blood and lymph, which perform trophic and protective functions, also constitute the group of connective tissues.

Muscle tissue consists of long muscle fibers, which are capable of contraction causing the movement of corresponding body parts in space. Muscles tissues are classified into striated (skeletal, or voluntary) and smooth musculature, which

undergoes involuntary contractions. There is also the striated cardiac muscle, which contracts involuntary.

Nervous tissue consists of highly specialized nerve cells, which are capable of generating and propagating nerve impulses. There are supporting cells located between the neurons, which constitute the neuroglia.

Organ. Organs are relatively independent parts of the body. They consist of several tissue types, one of which prevails and determines primary functions of the organ. Organs cannot exist outside the organism. Consequently, in order to maintain functioning of an isolated organ, it is necessary to set up its perfusion with special solutions and incubate it under certain conditions. The organism can function without certain organs (for example, without one kidney or one lung, without the spleen). However, there is a number of vital organs, which removal causes death (heart, liver, brain, and many others).

Clinical applications. When some of the vital organs are seriously injured, it is possible to transplant them from another person, or even from the cadaver and animals.

Today, kidney transplantations are quite successful. Thousands of heart transplantations have been performed, which prolonged patients' lives for 10 or more years. Transplantations of liver, pancreas, and an entire complex of organs (heart, lungs, and liver) were performed. From the standpoint of surgical technique, transplantation surgeries are well planned. However, the major obstacle in transplantation is the problem of tissue incompatibility (immune rejection). In view of that, much effort is placed into the development of artificial organs, which can be transplanted into the organism (for example, heart).

Systems of organs. Organs, which perform common function and, in general, have a common origin, constitute a system of organs. The leading role in the systemic organization is attributed to the functional principle. The following systems of organs are distinguished: skeletal system, system of bone articulations, muscular, respiratory, digestive, cardiovascular, nervous, and other systems. The systemic principle of organization gives a possibility to group structurally different organs, which ensures the achievement of a common goal. Some systems of organs come together to form an apparatus – apparatus of movement, urogenital apparatus. However, this fact does not interfere with the principle of systemic organization.

Soma and viscera. At the very beginning of the last century, famous French anatomist F. Bishat for the first time subdivided organs of the human body into those of animal living, which are defined by the term **soma** (*body*) and those of plant living – **viscera** (*internal organs*). The organs of the soma include bones, their articulations, muscles covered by the skin as well as sensory organs and nervous system. These organs are characteristic to animals only. They ensure interaction of the organism with the external environment and body movements.

Viscera include digestive, respiratory, urinary, and reproductive systems, which perform metabolic functions (digestion, respiration, excretion) and reproduction, i.e. processes, which are also possible in plants.

Without doubt, such division of organs is quite conditional. It must be viewed with caution, emphasizing the unity of somatic and visceral processes in the organism. However, such division is important in medicine, because pathological processes in the organs of soma and viscera have distinctive developmental differences. As a result, somatic diseases and visceral pathologies are distinguished in medical practice.

The **organism** (**organizio** – *creating structural order*) is a structure characterized by a set of basic life qualities, which enable it to exist in a given environment. A great variety of forms and levels of organizational complexity exists. The most advanced and complex forms of organization are evident in mammals and humans.

Different levels of organization. Now we can envision the organizational hierarchy in the human body according to the following scheme: organism – systems of organs – organs – tissues – cells. Obviously, it is possible to expand this scheme on either end, but this would put us beyond the scope of morphology into sociology and biosphere on one side, and molecular biology on the other.

What ensures the integrity of the organism? Integration of the organism into a whole is accomplished with the help of humoral and nervous regulation. The humoral regulation (**humor** – *fluid*) is older: it exists in animals, which lack nervous system. In higher animals and humans the humoral regulation is established through the integrating systems – blood and lymph as well as through the intercellular fluid.

Nervous regulation emerges during later stages of animal evolution with the development of nervous system. It is more complex providing not only integration of the organism itself but its interaction with the external environment as well. Recently, the discovery of the neurosecretion and understanding of hypothalamic and hypophyseal functions pointed out the unity of humoral and nervous types of regulation. Therefore, it is appropriate to talk about combined neuro-humoral regulation. This regulation guarantees the stability of the internal environment of the organism (homeostasis), which is the fundamental trait of any living organism.

The unity of the organism with its environment. The organism can exist only in certain environmental conditions, to which it is evolutionarily adapted. Every organism requires specific physical and chemical properties of the external environment essential for its survival. The organism establishes interaction between its external and internal environments by means of nervous system and sensory organs maintaining a constant substance exchange. In other words, the organism exists in unity with its external environment.

THE DEVELOPMENT OF THE HUMAN EMBRYO

In the process of studying anatomy we will constantly turn our attention to the data provided by embryology, because the organization of the human body can be well understood only from the standpoint of its development. For this reason we need to overview the beginning stages of human embryonic development. This material is presented here briefly, because embryology is studied in detail in the special course

offered by the Department of Histology. Embryology is one of the most important theoretical disciplines in the scope of medical education.

Fertilization and cleavage. The development of a new organism begins when nuclei of male and female gametes fuse. In fifteen minutes, fertilized egg (zygote) divides into two cells followed by another division signifying the beginning of the process of egg cleavage.

Morula and blastocyst. Cleavage of fertilized egg leads to the formation of a cellular mass called morula, which resembles the mulberry. Soon, a cavity forms within this mass of cells, and the embryo resembles a sac filled with fluid. This developmental stage is called the blastocyst. By the end of the first week, cells, which make up the walls of the blastocyst begin to differentiate. They are divided into the embryoblast and trophoblast. The embyo develops from the embryoblast, whereas the trophoblast serves for its nourishment. On the sixth or seventh day of embryonic development, the embryo passes through the fallopian tube and implants into the mucous lining of the uterus. The trophoblast produces the chorion, which together with the mucous lining of the uterus forms the placenta.

Gastrulation. On the ninth week, two single-layered sacs are formed in the embryoblast – amnion and yolk sac, which lie in close proximity to one another. The embryo itself lies where two sacs contact each other. At this stage, the embryo consists of two layers, one formed by the cells of the amnion (ectoderm), while the other derived from by the cells of the yolk sac (endoderm). The process of sac formation and development of a double-layered embryo is called gastrulation.

Embryonic layers. By the end of the second week, the third layer is formed between the ectoderm and endoderm named mesoderm. These three cellular layers are called embryonic layers. Embryonic layers are the first organized cellular groups, which considerably differ from one another. Afterward, each of these layers gives rise to organs and systems of organs. The formation of the ectoderm, endoderm, and mesoderm signals the beginning of cellular specialization in the embryo.

The formation of the embryonic layers occurs not only in vertebrates but also in invertebrates. This fact was brilliantly described by O. O. Kovalevsky (1840–1901), which allowed him to develop a general theory of the development of embryonic layers as well as demonstrate the relationship between the invertebrates and vertebrates.

Each of the three embryonic layers gives rise to different structures.

The following structures develop from the ectoderm: 1) skin epithelium and its derivatives – sweat glands, sebaceous glands, mammary glands, hair, and nails; 2) nervous system – spinal cord and brain, peripheral nerves and perceptive layers of sensory organs.

Mesoderm gives rise to the following structures: 1) skeleton and its articulations – bones, joints, cartilages, connective tissue; 2) muscles; 3) urogenital system; 4) cardiovascular system.

Endoderm produces: 1) epithelium of the digestive and respiratory tracts; 2) digestive glands – liver, pancreas and glands of the respiratory system.

Formation of the complex of axial primordia. Within the intermediate embryonic layer on the third week, a cellular stretch is formed – the notochord (**chorda dorsalis**), which runs along the body of the embryo. The cells of the ectoderm intensely divide along the midline and produce the neural plate, which gives rise to the neural groove and, later, neural tube, which represents the primordium of the nervous system. Afterward, the transverse folding of the embryo results in the inclusion of the endoderm within the embryo forming the foregut. In this folding process, the mesoderm expands ventrally and forms lateral plates, which split into two layers surrounding the gut. The primitive body cavity (coelom) is formed between two layers of mesoderm. On the border of dorsal and ventral mesoderm, the primordia of kidney appear (nephrotomes).

Therefore, the first structures to appear in the embryo are the notochord, the neural tube, and the primary gut. On both sides from the neural tube and notochord, dorsal mesoderm begins to expand and divide into segments.

Segmentation of the mesoderm. The dorsal mesoderm of the embryo gives rise to the greater portion of the body mass (soma). Therefore, it proliferates most intensely. From the sixteenth day of embryonic development, segmentation of the mesoderm takes place. Every subsequent day two or three segments are formed.

Since these segments produce somatic organs, they are called the somites. Until the 35th day, their maximum number is formed – 43–44 somites.

Differentiation of somites into skerotome, myotome, and dermatome. The cellular mass of the somites continually proliferates. They begin to specialize and differentiate giving rise to different organs. Three areas are distinguished in the somites, which differ from one another – sklerotome, myotome, and dermatome.

Sklerotome (**skleros** – *hard*) is the portion of the mesoderm, which concentrates around the notochord and neural tube. Afterward, the sklerotome gives rise to the skeleton – bone and cartilage.

Myotome is located in the middle (dorso-medial) part of the somite. Its cells differentiate into the muscle fibers, which form skeletal muscles.

Dermatome lies directly next to the ectoderm. This most lateral portion of the somite fuses with the ectoderm and forms the connective tissue of the skin (dermis).

Branchial arches. The differentiation of organs in the head region is complex. The first sign of their formation is rapid growth of the neural tube, which produces cerebral vesicles and, later, the brain. On the ventral surface of the head, there is a depression (stomatodeum). The stomatodeum is bounded by a number of projections separated by grooves. These structures are homologous to the branchial arches and gills of lower vertebrates. In human embryo, six branchial arches form, but only four of them develop. They are separated by branchial pouches.

Each branchial arch is composed of mesoderm, covered on the outside by the ectoderm, and lined on the side of the pharynx by the endoderm.

The first two branchial arches are called visceral arches. They give rise to the bones of the viscerocranium.

Organogenesis. After the formation of embryonic layers between the 4th and 8th week of intrauterine life, tissues and organs of the embryo develop (organogenesis). Heart, brain, digestive tract, lungs, and other organs appear. The anlages of the limbs appear on the 5th or 6th week. During the second month of intrauterine development, the embryo takes on the human form. Beginning with the third month of intrauterine life, the embryo is called fetus.

THE PLACE OF HOMO SAPIENS IN NATURE

All living organisms are grouped into the Plant and Animal Kingdoms. Animals, in turn, are subdivided into two large groups – Invertebrates and Vertebrates.

Phylum Chordata. All vertebrates, including lancelets (which lack a backbone), compose the Phylum of Chordates, characterized by having a notochord in the embryonic state. *Chordates* are divided into two subphyla.

Subphylum A. Acraniates (Acrania) are represented by the lancelets, which have a chord but lack the skull.

Subphylum B. Craniates, or Vertebrates (Vertebrata) possess skulls and vertebral columns. In the embryonic period of all vertebrates *the dorsal chord* **(chorda dorsalis)** develops.

Classes of Vertebrates. Vertebrates comprise six classes of animals, which differ in the complexity of their organization.

1. Cyclostomes (Cyclostomata), or Agnatha, are represented by hagfishes and lampreys, which have no true jaws or paired limbs.

2. Fishes (Pisces) comprise the following subclasses: Chondrichthyes, Chondrostei, and Osteichthyes. Chondrichthyes or cartilaginous fishes, include sharks and rays, which possess a cartilaginous skeleton and lack osseous tissue. Chondrostei are represented by biluga, sevruga, and sturgeons, which possess both cartilaginous and osseous skeleton. The skeleton of Osteichthyes, or bony fishes, consists of osseous tissue. Osteichtyes is the most numerous group within this class.

3. Amphibians (Amphibia) include both tailed (salamanders) and tailless representatives (frogs). Adult forms possess lung respiration, while larvae breathe through gills.

4. Reptiles (Reptilia) – turtles, lizards, snakes, and crocodiles. They also have lung respiration. Their skin is covered with scales.

5. Birds (Aves) are characterized by modified forelimbs, which turned into wings. Their skin is covered with feathers. Birds can maintain constant body temperature.

6. Mammals (Mammalia) represent the most highly organized group of vertebrate animals, which includes three subclasses: egg-laying mammals, marsupials, and placental animals. The last subclass comprises Insectivora, Chiroptera, Rodentia, Carnivora, Artiodactyla, Perissodactyla, Proboscidea, Cetacea, and Primates.

Order Primates (Primates). Humans belong to the order of primates (**primarius** – the first), which is subdivided into the suborder of non-tarsier prosimians and the

CONTENT