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ANATOMY OF BONE SYSTEM

АНАТОМИЯ КОСТНОЙ СИСТЕМЫ

The manual for medical students

Учебное пособие для медицинских вузов
(специальность «Лечебное дело»)

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Данное пособие является английской версией учебника профессора И. В. Гайворонского «Нормальная анатомия человека», который был издан в России 9 раз и одобрен Министерством образования Российской Федерации.

Структура пособия соответствует современным стандартам медицинского образования в России и важнейшим Европейским стандартам. Английская и латинская терминология приведены в соответствии с Международной Анатомической Номенклатурой.

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LIST OF ABBREVIATIONS

A., a.	— arteria
Aa., aa.	— arteriae
Art., art.,	— articulatio
Artt., artt.,	— articulationes
For., for.	— foramen
Gl., gl.	— glandula
Gll., gll.	— glandulae
Lig., lig.	— ligamentum
Ligg., ligg.	— ligamenta
M., m.	— musculus
Mm., mm.	— musculi
N., n.	— nervus
Nn., nn.	— nervi
R., r.	— ramus
Rr., rr.	— rami
S., s.	— sulcus
V., v.	— vena
Vv., vv.	— venae

PREFACE

Creation of the manual «Anatomy of Bone System» in English meets the requirements of modern Russian medicine and education. Nowadays, many English-speaking oversea students study in Medical Universities of Russia. Besides, many Russian school leavers have a good command of English, so they will be able to use this manual by taking into consideration the fact that many Russian medical specialists work abroad after graduating from the universities or take part in different international conferences and symposiums.

The English version of the manual is based on the Russian manual by professor I. V. Gaivoronskiy «Normal Human Anatomy» which has been published in Russia 9 times and is approved by the Ministry of education of Russia.

This manual introduces the main principles of the Russian Anatomy School, such as: detailed study of the general aspects and items of Anatomy including the development of organs and anomalies of the development. If we compare theoretical approaches to Anatomy in Russia and in other countries, we will see that our approach is based on the system descriptions of organs, i.e. we describe separately the Skeletal system, Articulations, Muscular system etc. Moreover, we use Latin terminology in describing the structure of organs, and discuss clinicoanatomical and functional problems. As for foreign manuals, many of them describe Anatomical systems in accordance with the regional and topographical principles.

The structure of our manual meets the requirements of modern standards of medical education in Russia which, in their turn, correspond to the major European standards. After each chapter, we give test questions and clinicoanatomical problems. The English and Latin terminology is given in accordance with the International Anatomical Nomenclature.

The authers srongly believe that the manual will allow future doctors to form the morphological foundation for the further study of theoretical and clinical disciplines. We also hope that it will be of great help to Anatomy teachers.

ПРЕДИСЛОВИЕ

Создание учебного пособия «Остеология» на английском языке является требованием современной системы медицинского образования в России. В настоящее время в медицинских университетах нашей страны обучаются студенты из различных регионов дальнего зарубежья. Кроме того, многие выпускники российских школ хорошо владеют английским языком, поэтому они так же смогут пользоваться данным пособием, принимая во внимание, что зачастую русские специалисты в медицине после окончания университета уезжают работать за рубеж или принимают участие в различных международных конференциях и симпозиумах.

Английская версия пособия базируется на учебнике профессора И. В. Гайворонского «Нормальная анатомия человека», который был издан в России 9 раз и имеет гриф Министерства образования Российской Федерации.

Данное пособие познакомит читателей с главными принципами Русской Анатомической Школы, которые заключаются в подробном изучении общих вопросов, в том числе развития органов и аномалий развития. В России преподавание анатомии ведется с функционально-клинических позиций и основано на описании органов по системам, т. е. отдельно изучается опорно-двигательная система, артросиндесмология, миология и другие системы. Также при описании строения органов акцентируется внимание на латинской терминологии. Что касается зарубежных руководств по анатомии человека, многие из них основываются на регионально-топографическом принципе без использования латинской терминологии.

Структура данного пособия соответствует современным стандартам медицинского образования в России, которые, в свою очередь, соответствуют важнейшим Европейским стандартам. После каждой главы мы приводим контрольные вопросы и ситуационные клинические задачи. Английская и латинская терминология приведена в соответствии с Международной анатомической номенклатурой.

Авторы выражают уверенность, что данное пособие позволит будущим докторам сформировать морфологический фундамент для последующего изучения теоретических и клинических дисциплин. Мы также надеемся, что оно принесет определенную пользу и преподавателям анатомии человека.

1. GENERAL OSTEOLOGY

Osteology is the part of anatomy which studies bones. It is quite difficult to determine the exact number of bones, because their number changes with age. During life, more than 800 individual bony elements develop, 270 of them appear in the prenatal period, other ones appear after birth. The majority of individual bony elements fuse with each other, therefore the skeleton in an adult person contains only 206 bones (fig. 1.1). Apart from permanent bones, there may be inconstant (sesamoid) bones in mature age, their appearance is caused by specific features of the body structure and function.

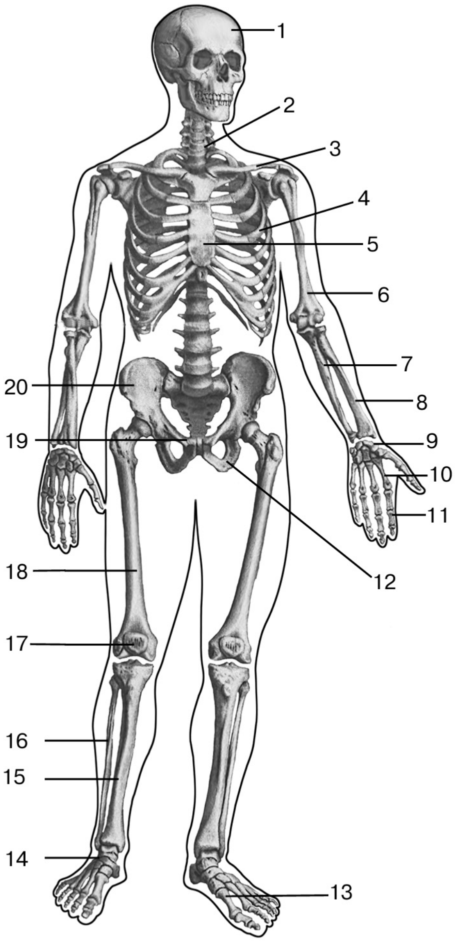

Fig. 1.1. Human skeleton (frontal aspect):

1 — skull (cranium); 2 — vertebral column (columna vertebrale); 3 — clavicle (clavicula); 4 — IV rib (costa IV); 5 — sternum (sternum); 6 — humerus (humerus); 7 — ulna (ulna); 8 — radius (radius); 9 — carpal bones (ossa carpi); 10 — metacarpal bones (ossa metacarpi); 11 — phalanges of hand (ossa digitorum manus); 12 — ischium (os ischium); 13 — metatarsal bones (ossa metatarsi); 14 — tarsal bones (ossa tarsi); 15 — tibia (tibia); 16 — fibula (fibula); 17 — patella (patella); 18 — femur (femur); 19 — pubis (os pubis); 20 — ilium (os ilium)

The bones, together with their joints, form the skeleton of the human body. It serves as a place for start and attachment of muscles, provides protection of visceral organs and also carries out the form-building and some other major functions.

1.1. Bone as an Organ

Bone, *os*, is an organ, which is a component of the musculoskeletal system. It has a typical form and structure, specific architectonics of vessels and nerves, it is constructed mainly from osseous tissue covered with periosteum on the outside; *periosteum* containing inside bone marrow, *medulla osseum*.

Each bone has a certain shape, size and location in the human body. The conditions of bone development and functional loads which bones are subjected to in ontogenesis influence the morphogenesis of bones. Each bone has a certain number of blood supply sources (arteries), which have specific extra- and intraorganic architectonics. Nervous structures of bones also have such features.

The bone is coated with periosteum on the outside, except the surfaces and places where articular cartilages are locted, and where muscles, tendons and ligaments are attached to the bone. The periosteum separates the bone from its surrounding tissues. It is a thin sheath of dense connective tissue which contains blood and lymphatic vessels and nerves. The nerves penetrate into the bone tissue from the periosteum.

The periosteum, *periosteum*, plays a major role in bone growth at thickness and in its nutrition. The osseous tissue is formed in the inner osteogenic layer of the periosteum. A bone lacking periosteum becomes inviable and necrotizes. The periosteum has a rich nerve supply, therefore it is very sensitive. During surgical operations, doctors try to maximally preserve the periosteum because of its very important role in reparative processes.

Almost all bones (except for most of the skull bones) have articular surfaces for junction with other bones. The articular surfaces are covered not with periosteum, but with articular cartilage, *cartilago articularis.* The articular cartilage has a specific, non-uniform structure: its superficial layer resembles a hyaline cartilage, the deep layer is fibrous.

The majority of bones have bone marrow inside — in spaces between lamellae of the spongy bone or in the medullary cavity, *cavitas medullaris*. The medullary cavity is covered inside with a specific sheath which is termed endosteum — *endosteum*. The endosteum, as well as the periosteum, plays a great role in metabolic processes in bones.

Bones of fetuses and newborns contain only red (haematogenic) bone marrow, *medulla ossea rubra*. It is a homogenous red color mass, rich in reticulate tissue, blood corpuscles and blood vessels. The total amount of red bone marrow is about 1500 cm^3. In an adult, red bone marrow is partially substituted with yellow bone marrow*, medulla osseum flava*, which is mainly composed of adipose cells. Red bone marrow is substituted with yellow bone marrow only within medullar cavities.

1.2. Classification of Bones

It should be noted that there is no comprehensive classification of bones so far. For this purpose, various criteria are used in most of manuals on anatomy. At the same time, the principles of development and external structure features are often missed. Such feature as the structure of bones has an important clinical value. It determines the level of bone durability and specifications for treatment of injuries. In terms of phylogenesis, taking into consideration the existence of acranial and cranial organisms during the evolution, it is appropriate to divide bones into two groups: 1) bones of trunk and limbs; 2) skull bones. These bones differ from each other not only in their development but also in their structure.

According to the form and structure, four types of trunk and limb bones are distinguished: tubular, flat, volumetric and mixed bones.

Tubular bones have a cavity inside. They may be divided into long (humeral, forearm bones, femoral, leg bones, clavicle) and short (carpals, metatarsals, phalanges) bones.

In long tubular bones, one size prevails over other sizes. The middle part — diaphysis, *diaphysis*, (or body, *corpus*) of such bone has a cylindrical or triangular shape and consists of compact tissue, *substantia compacta*. Within the diaphysis, the medullary cavity is located. The bone ends — epiphyses, *epiphyses*, — are somewhat thickened. Their surfaces intended for joining with adjacent bones are covered with articular cartilage. On the inside, the epiphysises consist of spongy bone — *substantia spongiosa*, and on the outside there is a thin layer of compact bone — *substantia compacta*. Long tubular bones form the proximal and middle parts of the limb skeleton and play the role of leverages actuated by muscles. Short tubular bones form the distal parts of the limb skeleton and also consist of the middle part — the corpus and two ends called basis and caput.

Flat bones mainly consist of homogenous mass of spongy bone covered outside with a thin layer of compact bone. In flat bones, two sizes (width and length) prevail over 1.3.

thickness. Such bones form the walls of cavities enclosing important organs, or represent extensive surfaces for attachment of muscles. Here belong the pelvic bones, sternum, scapulae and ribs.

Volumetric bones have the same structure, as the flat bones, i.e. they consist of a thin layer of compact bone outside and spongy bone inside. By shape, they resemble a cube with all dimensions roughly the same. Such bones are the carpal and tarsal bones. These bones are situated on the border between the middle and distal parts of the limbs, where not only high durability, but also high mobility is necessary.

Mixed bones are specific and complicated in shape. In their composition there are structural elements of volumetric and flat bones (vertebrae, sacrum, coccyx). Spongy tissue is contained in the bodies of these bones, and their other parts are mainly formed of compact bone. Such bones possess specific durability at continious loads.

Skull bones are classified by their location, development and structure.

According to location, they are divided into neurocranium bones and viscerocranium bones. According to development*:* into primary (endesmal), secondary (enchondral) and also mixed bones. The bones of the calvaria and viscerocranium are primary; the bones of the skull base are secondary; the occipital, sphenoidal and temporal bones are mixed; for example, the pyramid of the temporal bone and its mastoid part are secondary, but the squamous and tympanic parts of this bone are primary.

The skull bones have a very complicated external shape, thus it is appropriate to take their structure into consideration. *According to the structure,* it is possible to distinguish three types of the skull bones: 1) bones having diploë in their composition — diploic bones (parietal, occipital, frontal bones, mandible); 2) bones containing air cavities — pneumatized bones (temporal, sphenoid, ethmoid, frontal bones and maxilla); 3) bones built mainly from compact tissue — compact bones (lacrimal, zygomatic, palatine, nasal bones, inferior nasal concha, vomer, hyoid bone)The diploic substance is like spongy tissue, but its spaces between the osteal trabeculae are significantly smaller in diameter and have rounded shape.

1.3. Internal Structure of Bones

The internal structure of bones essentially differs in a fetus and in a newborn child. Therefore two types of osseous tissue are distinguished — reticulofibrous and lamellar. The reticulofibrous bone tissue is the basis of the embrional human skeleton. Its bony matrix is not arranged structurally, the bundles of collagen fibers are located in different directions, and they are directly connected with connective tissue surrounding the bone.

After birth, reticulofibrous tissue is replaced with lamellar tissue formed of osteal lamellae 4,5—11 mkm thick. There are osteal cells (osteocytes) in the smallest cavities (lacunae) between osteal lamellae. Collagen fibers in the bone lamellae are strictly arranged parallelly to their surfaces. They lose connection with the connective tissue surrounding the bone. They are connected with the periosteum only due to perforating (Sharpey`s) fibers running from the periosteum to the superficial layers of the bone. The lamellar bone is much more solid than the reticulofibrous bone. Substitution of one osseous tissue with another is caused by the influence of functional loads on the skeleton.

On the section of a macerated bone (bone deprived of soft tissues), it is possible to see two types of the osseous tissue: compact and spongy. The compact bone, *substantia compacta*, is a solid bony mass located on the exterior of the bone. The osteal lamellae of the compact bone are very close to each other. The compact tissue coats the epiphyses of

tubular and flat bones as a thin sheath. The diaphyses of tubular bones entirely consist of compact bone.

Spongy bone, *substantia spongiosa*, is formed by loosely located osteal lamellae. In the spaces between them there is red bone marrow. Spongy tissue forms epiphyses of tubular bones, bodies of vertebrae, ribs, sternum, pelvic bones and some hand and foot bones. Only the superficial cortical layer of such bones is comprised of the compact tissue. The spongy tissue of the skull bones has significantly smaller regularly shaped spaces in comparison with the trunk and limb bones. It has a specific name — diploë.

The structural and functional unit of the bone is osteon or Haversian system. It is possible to see osteons on thin sections or on histological preparations. The osteon is formed of concentrically arranged osteal (Haversian) lamellae which surround the Haversian canal in the form of cylinders of various sizes nested into each other. The Haversian canal contains blood vessels and nerves. The majority of osteons are oriented parallelly to the axis of the bone joining with each other in many points. The number of osteons is individual for each bone. For example, in the femoral bone this number is 1,8 per 1 mm^2. Meanwhile, the share of the Haversian canal is 0,2—0,3 mm^2. Between the osteons there are insert or intermediate lamellae which run in all directions. The intermediate lamellae are the remnants of destroyed old osteons. Processes of new formation and destruction of osteons continuously occur in bones.

There is a layer of internal circumferential lamellae, *lamina circumferentialis interna* in tubular bones on the border with the medullary cavity. They are permeated with numerous canals widening to spaces. Several layers of general (or external) circumferential lamellae, *lamina circumferentialis externa*, surround the bone on the outside. The perforating canals (Volcmann`s canals) containing blood vessels with the same name pass through them.

There are three types of osteal lamellae in the diaphyses of tubular bones: Haversian, intermediate and general (external and internal). The lamellae lie close to each other, they are located parallelly to the axis of the bone and form quite a thick layer of only compact bone. It is 1,5—5 mm thick. Thus the diahysis of a long tubular bone is a hollow cylinder with walls formed of compact bone. The cavity of this cylinder is termed medullary canal. The latter is connected with spaces of the spongy tissue in the epiphyses of the bone. The Haversian lamellae form the basic mass of compact bone, thus making up osteons. The intermediate lamellae fill in the gaps between osteons. External and internal general (circumferential) lamellae form the most outer and the most inner layers of the compact bone, being located parallelly to the bone surface under the periosteum and endosteum respectively.

The epyphises of tubular bones consist of spongy tissue which is also formed of osteal lamellae. In structure, spongy bone may have large and small spaces. There are red bone marrow and vessels in these spaces. Compact bone covers epiphyses only on the outside with a comparatively thin layer. Flat and volumetric bones have a similar structure. Lamellae of spongy substance are strictly arranged in each bone. Their direction coincides with that of the maximum compression and stretching forces. The environment of each bone

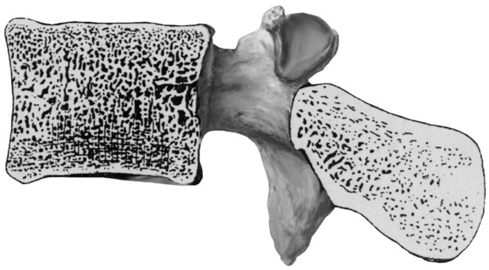

Fig. 1.2. Orientation of trabeculae in the vertebral body (saggital section)

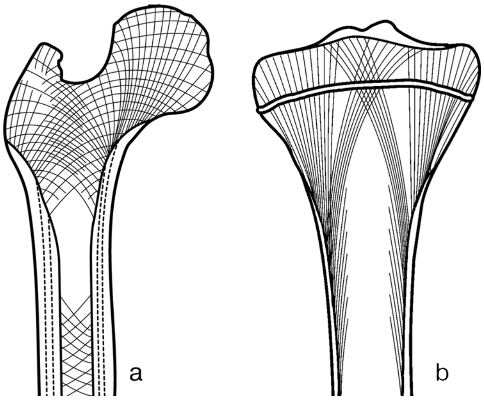

Fig. 1.3. Orientation of trabeculae in proximal epiphyses of tubular bones: a — in femur; b — in tibia

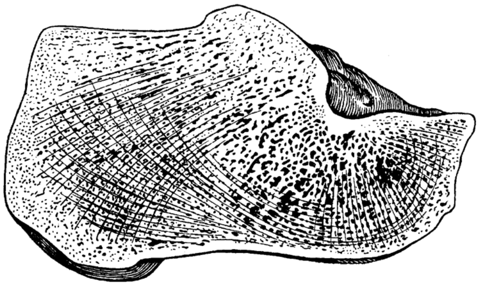

Fig. 1.4. Orientaton of trabeculae in calcaneus

determines its structure. Trabeculae form an integral system in several adjacent bones, which characterizes the trabeculae's architectonics. Such structure of bones preconditions their maximum solidity. In vertebrae, the stretching and compression forces are perpendicular to the superior and inferior surfaces of the vertebral bodies. This corresponds to the fact that the trabeculae have mainly vertical direction in spongy substance (fig. 1.2). In the proximal epiphysis of the femoral bone there are arch-shaped systems of trabeculae which transfer pressure from the surface of the bone head to the walls of the diaphysis. Besides, there are trabeculae transfering the traction force of muscles attached to the greater trochanter (fig. 1.3).

Trabeculae running in the radial direction are typical of the calcaneus. They distribute loads equally over the surface of the calcaneal tuberosity which serves as a foot support (fig. 1.4).

Compact bone is formed in places of the highest concentration of force trajectories. It is clearly visible on the section of the femoral, tibial and calcaneal bones where the compact tissue is thickened in the areas of crossing between force lines and the bone surface. Thus we can say that compact bone is the result of compression of spongy bone, and vice versa, it is possible to consider spongy bone as sparse compact bone. It should be noted that if static and dynamic conditions are changed (increase or decrease in functional loads), the spongy bone architectonics changes too, a part of trabeculae disappear, or new systems of osteal trabeculae develop. The spongy bone structure changes in a special visible manner after fractures.

1.4. External Structure of Bones

While describing the external structure of bones, we should pay attention to the surfaces, *facies*, of the bones, which may be flat, concave or convex, smooth or rough. Articular surfaces *facies articularis*, involved in formation of joints, are the most smoothly polished ones. In some bones the end is rounded, forming a head — *caput*; at the same time, the end of other bones has concavity, called articular fossa, or *fossa articularis*. The head may be separated from the bone body with a constricted part — neck, *collum*. If the articular end is extensive but slightly curved surface, it is termed condyle, *condilus*. The processes located near the condyle are named epicondyles, *epicondyli,* they serve for attachment of tendons and ligaments (they may also be called apophyses).

The following surfaces are distinguished in bones (depending on theirlocation in the human body): internal or external, medial or lateral etc. The surfaces are separated by

borders, *margo*. The borders, in turn, are known as superior or inferior, medial or lateral etc. They may be smooth or serrated, blunt or sharp, sometimes they have notches, *incisurae*, of different sizes.

On the surfaces of bones, there may be such formations as: processes, eminences, depressions, openings etc. (bone process, *processus*; elevation, eminence, *eminentia;* large rounded elevation or tuberosity, *tuberositas*; hillock, tuber; bulge, protuberance, *protuberantia*; tubercle, *tuberculum*; sharp process — spine, *spina;* crest, *crista*; hollow in the bone, *fossa*; pit, *foveola*; groove, *sulcus*, opening, *foramen*; canal, *canalis;* small canal, *canaliculus*; fissure, *fissura;* cavity, *cavitas*).

1.5 Chemical Composition of Bone and its Properties

The chemical composition of a bone depends on the condition of the bone under examination, its age and individual characteristics. In a grown-up, a fresh bone which is not treated contains: water — 50 %; fat — 16 %; other organic substances — 12 % and inorganic substances — 22 %. A dehydrated and defatted bone contains approximately two-thirds of inorganic substances and one third of organic substances.

The inorganic substances are mainly represented by calcium salts in the form of submicroscopic crystals of hydroxyapatite. The microscopic examination shows that the axes of crystals are oriented parallelly to osteal fibers. The crystals of hydroxyapatite form mineral fibers.

The organic substance of the bone is called ossein. This protein is the type of collagen. It forms the basic substance of the bone. Ossein is contained in osteal cells — osteocytes. There are osteal fibers containing protein — collagen — in the intercellular matrix of the bone. When bones are boiled, the proteins (collagen and ossein) form glutinous mass. It should be noted that the bony matrix contains mineral fibers, apart from collagen ones. The interlacement of organic and inorganic fibers determines the specific features of osseous tissue: durability and elasticity.

If a bone is treated by acid (decalcification), the mineral salts are removed. Such bone, containing only organic substance keeps its shape in all details, but becomes much more flexible and elastic. If the organic substance is removed from the bone through burning, the elasticity is lost. Such bone is very fragile.

The proportion of organic and inorganic substances in bones primarily depends on age, and it may change under the influence of various reasons (climatic conditions, nutrition, diseases). Thus in children, bones contain much less mineral (inorganic) substances, therefore they are more flexible and less solid. In elderly persons, vise versa, the amount of organic substances decreases. In such age, bones become more fragile and susceptible to fractures.

1.6. Mechanical Properties of Bones

The bone is a solid object, and its main properties are durability and elasticity. Durability is the ability to resist to the external destroying force. It depends on the macro- and microscopic structure, and on the osseous tissue composition. As for the macroscopic structure, each bone has its specific form which enables withstanding the maximal strain in a certain part of the skeleton.

The internal structure of the bone is also complicated. As already stated, the osteon is a hollow cylinder tube the walls of which are built of numerous lamellae. It is known that in architectural constructions, hollow (tubular) columns have greater durability per

a unit of mass as compared to solid columns. Therefore, the osteon-based structure of the bone itself predetermines a high level of its durability. Groups of osteal lamellae, being arranged along the axes of maximal strains,form osteal trabeculae of spongy bone and terminal lamellae of compact bone. It should be noted that osteal trabeculae are arch-shaped in places of maximal strains. As well as tubular systems, arch-shaped systems are most durable. The arch principle in the structure of spongy bone trabeculae is typical of the proximal epiphysis of the femur, as well as of the calcaneus spongy tissue etc.

The bone composition significantly influences its durability. Decalcification causes a considerable decrease in the level of compression, tension and torsion strength . As a result, it is easy to bend, compress and twist the bone. If the calcium content increases, the bone becomes fragile.

Bone durability in a healthy adult is higher than the durability of some construction materials — it is like a cast iron. The first examinations of bone durability were conducted in XIX century. According to Lesgaft`s researches, the human bone withstood tensile strain of 5500 N/cm^2, compressive strain — 7787 N/cm^2. The tibia withstood compressive strain of 1650 N/cm^2, whichis comparable to the weight of more than 20 men. These data show a high level of reserve capabilities of bones against various strains. Changes in the tubular structure of a bone (both macro- and microscopic) reduces its mechanical durability. For example, the tubular structure of bones is disrupted after fracture healing, and the durability of such bones significantly decreases.

Elasticity is the ability to regain the initial shape after cessation of an external impact. Bone elasticity is equal to that of hard tree species. Like durability, it depends on the macro- and misroscopic structure and the chemical composition of the bone.

Thus, the mechanical properties of bones — durability and elasticity — are predetermined by the optimal combination of organic and inorganic substances contained in them.

1.7. Functions of Skeleton

1. The bones serve as support for soft tissues (muscles, ligaments, fasciae, visceral organs).

2. Most of bones are leverages which are moved by attached muscles. According to these two functions, the skeleton may be considered to be the passive part of the musculoskeletal system.

3. The human skeleton is an antigravitational structure which counteracts the force of gravity. It prevents any changes in the body shape under the impact of gravitation pressing the human body to the ground.

4. Protective function: the skull, trunk and pelvis bones prevent any potential damage to the vital organs, major vessels and nerve trunks. For example, the skull encloses the brain, organs of vision, hearing and equilibrium. In the vertebral canal there is the spinal cord. The chest protects the heart, lungs, major vessels and nerve trunks. The pelvic bones protect the rectum, urinary bladder and internal genital organs against injuries.

5. Hematopoietic function: most bones contain red bone marrow which is the hematopoietic organ, as well asthe immune system organ . The bones protect the red bone marrow against damages, and provide favorable conditions for its trophism and for maturation of blood elements.

6. Involvement in mineral metabolism: bones deposit numerous chemical elements, predominantly calcium and phosphorus salts.

According to V. S. Speransky, the human skeleton is a perfect dynamic structure adapted to the motor function and human way of life; it is responsive to various changes which occur both in the body itself and in the environment.

1.8. Development of Bones

The osseous tissue appears in the human embryo in the middle of the second month of fetal development, when all other tissues have been already formed. The development of bones may proceed in two ways: on the basis of connective tissue and on the basis of cartilage. It should be noted that connective tissue never turns directly into cartilaginous tissue or osseous tissue. Osseous tissue is capable of developing by the way of growth along the surface of connective tissue or cartilage (appositional bone growth), or it develops to replace a resorbed cartilage.

Bones developing on the basis of connective tissue are termed primary. They are calvarial bones, and viscerocranial bones. Ossification of the primary bones is termed endesmal. It occurs in the following way: within the anlage of connective tissue, an ossification centre, *punctum ossificationis* (*centrum ossificationis*), appears and then expands into the depth and across the surface. From the ossification centre, osteal trabeculae start to form along the radii. They are interconnected with bone rods. In these spaces between the rods there are red bone marrow and blood vessels. In most of primary (membrane) bones, not one but several ossification centres are formed. They gradually grow and merge with each other. Eventually, only the most superficial layer of the initial connective tissue stratum remains unchanged. Then this layer turns into the periosteum.

Bones developing on the basis of cartilages are termed secondary. They pass through connective, cartilaginous and, in the last turn, osseous stages. Secondary bones are the skull base bones, trunk bones and bones of extremities. Let`s study the development of a secondary bone on the example of the long tubular bone. By the end of the second month of the fetal period, the cartilaginous anlage appears; it resembles a definite bone by shape. The cartilaginous anlage is covered by perichondrium. In the area of the future diaphysis of the bone, the perichondrium transforms into the periosteum. Lime salts are accumulated in the cartilaginous tissue under the periosteum, and cartilaginous cells die away. The osteal cells — osteoblasts — come from the periosteum to replace the dead cells. They start to produce an organic matrix of osseous tissue which endures calcification. The osteoblasts enclosed in the intercellular substance transform into osteosytes. Thus, the osteal cylinder termed periosteal or perichondral bone is formed in the diaphysis area. This stage of ossification of secondary bones is termed perichondral. Subsequently, new bone layers overgrow from the periosteum. Bone lamellae evolve, i.e. Haversian systems (osteons) start to develop around the vessels growing from the periosteum. The vessels sprouting from the periosteum are directed to the midst of the cartilaginous anlage. The cartilage located in the center of the diaphysis accumulates lime salts, dissolves and is substituted by spongy bone. This process is termed enchondral ossification of the diaphysis. The medullary canal is absent at first. It is formed in the process of transformation of spongy tissue of the enchondral bone inside the diaphysis and during red bone marrow development inside it.

In the epiphyses, ossification starts later, some bones are ossified even after the birth. Ossification begins from the ossification centre which appears within the cartilaginous anlage of the epiphysis. Such ossification process is called enchondral. It occurs in the following way: firstly, from the periosteum, blood vessels sprout into depth of the cartilage along the radii. In the midst of the epiphysis, the cartilage accumulates lime salts,

dissolves and is substituted by osseous tissue. Later, the periosteal (perichondral) bone develops from the periosteum along the edge of the cartilaginous anlage of the epiphysis. The periosteal bone is comprised by a thin layer of compact tissue. The perichondral lamina is absent only in the areas of future articular surfaces — a quite thick layer of cartilage remains there. The cartilaginous layer also remains between the epiphysis and diaphysis — this is a metaepiphysial cartilage. It is the area of bone growth in length, and it disappears (transforms into osseous tissue) only after bone growth stops.

In long tubular bones, individual ossification centres appear in each epiphysis. Fusion of the epiphyses with the diaphysis usually occurs after birth. For example, in the tibia, the lower epiphysis merges with the diaphysis by the age of about 22 years, and the upper epiphysis — by 24 years. Short tubular bones normally have the ossification centre only in one epiphysis, the other epiphysis is ossified from the diaphysis. Some tubular bones have several ossification centres in their epiphysis at the same time. For example, in the upper epiphysis of the humerus, three centers appear; in the lower epiphysis of the humerus — there are four centers.

Volumetric bones are ossified like the epiphyses of long tubular bones i.e. enchondral ossification precedes periostal ossification. In flat bones, this process occurs vice versa, i.e. periostal ossification precedes ehchondral ossification.

It should be noted that, besides the main ossification centres, additional ossification centres may exist. They appear much later than the main centres. With the coming puberty, metaepiphysial cartilages become thinner and are replaced with osseous tissue. In the skeleton, synostoses start to develop. The distal epiphysis of the humerus and the epiphyses of the metacarpals are the first to fuse with their diaphyses. Formation of the synostoses comes to an end by about 24–25 years. Bone growth terminates when all the main and additional centers merge into one solid mass, i.e. when the cartilaginous layers separating the bone parts from each other disappear.

Significant individual differences in ossification rates are observed. The process of skeleton ossification in a child may be accelerated or decelerated; it depends on the genetic, hormonal and environmental factors. The term «osteal age» is used to assess the process of skeleton development in children. It is determined according to the number of ossification centres in bones and according to the time of their fusion. To evaluate ossification, roentgenography of the hand is made, because the age dynamics of ossification centre appearance and formation of synostosis are very clearly manifested in this part of the body. Ossification centres in carpal bones appear in the following periods:

— at birth, carpal bones are cartilaginous;
— ossification points emerge in the capitate and hamate bones during the first year of life;
— in the triquetral bone — during the third year of life;
— in the lunate bone — during the fourth year of life;
— in the scaphoid bone — during the fifth year of life;
— in the trapezium and trapezoid bones — during the sixth-seventh years of life;
— in the pisiform bone — in the tenth-fourteenth years of life.

Ossifcation of free parts of limbs is given in fig. 1.5.

V.S. Speransky distinguishes the following characteristic features in the ossification process :

1) ossification starts earlier in the connective tissue than in the cartilage;
2) ossification of the skeleton occurs in the cranial-caudal direction;
3) skull ossification spreads from the viscerocranium to the neurocranium;
4) in the free parts of extremities, ossification occurs from the proximal regions to the distal areas.

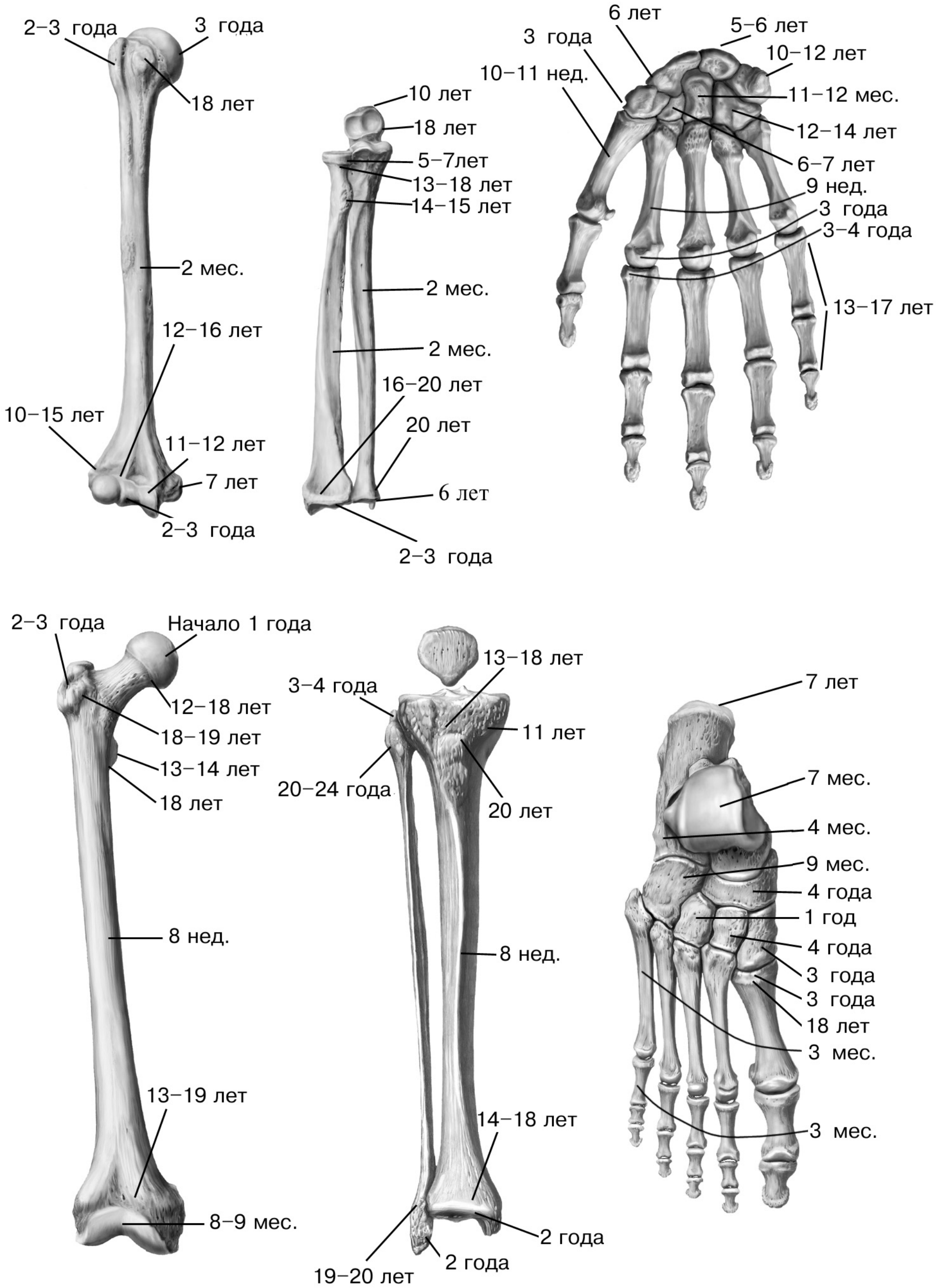

Fig. 1.5. Periods of ossification of free parts of extremities in males (Alexina L.A., 1985, 1998)

Osteal age does not always coincide with the passport age. In some children, the ossification process terminates 1–2 years earlier than it happens normally, in others — 1–2 years later. Starting from the age of 9 years, sexual differences of ossification can be distinguished clearly — in girls this process occurs more rapidly.

Body growth in girls terminates mainly at the age of about 16–17 years, in boys — at about 17–18 years. After this age, body growth in length is no more than 2 %.

In old age, bone rarefication termed osteoporosis occurs in different parts of the skeleton. In tubular bones, osseous tissue dissolves inside the diaphysis, as a result, the medullary cavity becomes wider.

At the same time, calcium salts are accumulated, and osseous tissue is developed on the outer surface of the bone, under the periosteum. Quite often, in places of attachment of ligaments and tendons, bony outgrowths called osteophytes develop. They also emerge along the edges of articular surfaces. In elderly persons, bone durability considerably decreases, and even minor injuries may cause fractures.

Skeleton ageing is characterized by individual changeability. In some persons, ageing symptoms appear as early as at the age of 35–40 years, in other persons — only after 70. Skeleton ageing symptoms are more manifested in women than in men. But this process significantly depends on the complex of factors: genetic, climatic, hormonal, alimentary (nutritive), functional, ecological etc.

1.9. Anomalies of Bone Development

1. Osteomalacia — disorder of calcification of newly formed osseous tissue which is caused by deficiency in calcium or vitamin D.
2. Osteoporosis — disorder of formation of the bony matrix during the skeleton formation (insufficient compensation of resorbed bone tissue). It occurs in elderly and old age and is caused by exessive resorption of osseous tissue.
3. Ectopic osteogenesis — ossification of soft tissues in abnormal places (in walls of arteries, kidneys etc.)

TEST QUESTIONS

1. What function does the skeleton carry out?
2. Name the types and functions of the bone marrow.
3. List the principles of the bone classification.
4. Give the characteristic of the primary and secondary bones.
5. What organic and inorganic substances are included into the composition of the bone (in what ratio)?
6. What connective tissue structure covers the bone from outside? What is its function?
7. What is the structural unit of osseous tissue? Name the types of osteocytes.

CLINICOANATOMICAL PROBLEM

During the surgical operation in a 10-year-old patient the metaepiphysial cartilage which separates the head of humerus from the body of humerus, was radically removed. What is the prognosis?

2. SKELETON OF TRUNK

The skeleton of trunk consists of the vertebral column, or backbone, *columna vertebralis*, and the thorax, *cavea thoracis (thorax)*.

The vertebral column in an adult person consists of 24 individual vertebrae, sacrum and coccyx. There are the cervical vertebrae (7), thoracic (12) and lumbar ones (5) distinguished in the vertebral column. The sacrum consists of five fused sacral vertebrae. The coccyx consists of 3–5 fused coccygeal vertebrae. The thorax consists of 12 pairs of ribs with corresponding thoracic vertebrae and the sternum.

2.1 General Vertebral Features

The vertebra, *vertebra*, is comprised of the vertebral body, *corpus vertebrae*, anteriorly, the vertebral arch, *arcus vertebrae*, posteriorly and vertebral processes, *processus vertebrae*. The vertebral body is anterior and supporting part of the vertebra. The arch is located behind the vertebral body. The vertebral arch is attached to the body with the help of two pedicles of vertebral arch, *pediculi arcus vertebrae*, thus bounding the vertebral foramen, *foramen vertebrale* (fig. 2.1).

The foramina of all vertebrae form the vertebral canal, *canalis vertebralis*, enclosing the spinal cord. Openings for blood vessels named nutrient foramina, *foramina nutricia*, are visible on the surface of the vertebral body.

Seven processes project from the vertebral arch. An unpaired spinous process, *processus spinosus*, projects dorsally along the median line. The paired transverse processes, *processus transversus*, project on the right and on the left in the frontal plane. The paired superior and inferior articular processes, *processus articularis superior et processus articularis inferior*, project up and down from the arch. The bases of the articular processes bound the superior and inferior vertebral notches, *incisura vertebralis superior et inci-*

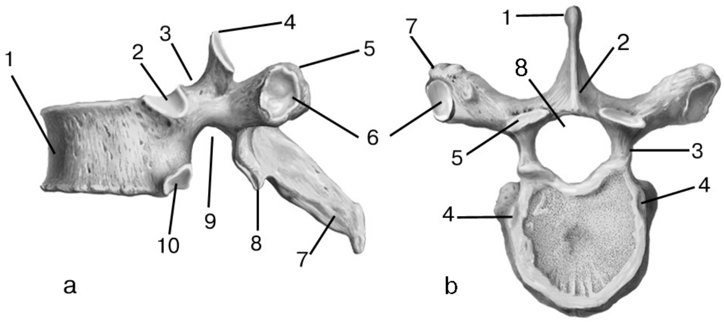

Fig. 2.1. Thoracic vertebra:

a – lateral aspect: 1 — vertebral body (*corpus vertebrae*); 2 — superior costal demi-facet (*fovea costalis superior*); 3 — superior vertebral notch (*incisura vertebralis superior*); 4 — superior articular process (*processus articularis superior*); 5 — transverse process (*processus transversus*); 6 — transverse costal facet (*fovea costalis processus transversi*); 7 — spinous process (*processus spinosus*); 8 — inferior articular process (*processus articularis inferior*); 9 — inferior vertebral notch (*incisura vertebralis inferior*); 10 — inferior costal demi-facet (*fovea costalis inferior*)

b — superior aspect: 1 — spinous process (*processus spinosus*); 2 — vertebral arch (*arcus vertebrae*); 3 — pedicles of vertebral arch (*pediculi arcus vertebrae*); 4 — superior costal demi-facet (*fovea costalis superior*); 5 — superior articular process (*processus articularis superior*); 6 — transverse costal facet (*fovea costalis processus transversi*); 7 — transverse process (*processus transversus*)

sura vertebralis inferior. The inferior notches are deeper than the superior ones. When the vertebrae are articulated with each other, the inferior and superior notches form an intervertebral foramen, *foramen intervertebrale*, on the right and on the left. The intervertebral foramina transmit spinal nerves and blood vessels.

2.2. Cervical Vertebrae

The cervical vertebrae, vertebrae cervicales (C_I–C_{VII}), form the upper (cervical) part of the vertebral column. Two upper cervical vertebrae of seven significantly differ from other ones, therefore, they are termed atypical vertebrae. We will study them later. The other five vertebrae are structured according to the general principle: their bodies are relatively small, have an ellipsoid form, the vertebral foramen is large and triangular.

The distinctive feature of all cervical vertebrae is the presence of transverse foramina, *foramen transversarium*, in the transverse processes. They are formed as a result of the fusion of the transverse processes and the rudiments of the cervical ribs. The vertebral artery and vein pass through these foramina.

The groove for spinal nerve, *sulcus nervi spinalis*, passes along the superior surface of the transverse prosesses of the III–VII cervical vertebrae. These processes end with two tubercles — anterior and posterior, *tuberculum anterius et tuberculum posterius*. The anterior tubercle of the VI vertebra is more developed than the anterior tubercles of other cervical vertebrae. It is termed carotid tubercle, *tuberculum caroticum*, because the carotid artery can be compressed to it during hemorrhage.

The spinous processes are short and directed downwards, and their ends are bifurcated. The spinous process of the VII cervical vertebra is the longest, and its end is thickened. This vertebra is called prominent, *vertebra prominens*, because the apex of its spinous process is clearly palpated in a living person.

The articular processes of the cervical vertebrae are short and located obliquely between the frontal and horizontal planes. Meanwhile, the superior articular processes are directed backwards and slightly upwards, the inferior articular processes are directed forwards and slightly downwards (fig. 2.2).

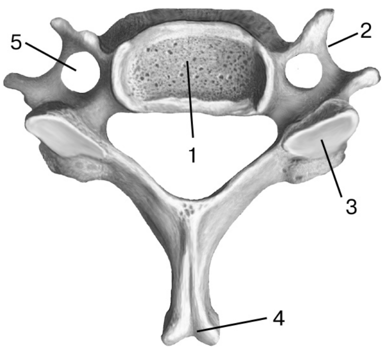

Fig. 2.2. Typical cervical vertebra (superior aspect):

1 — vertebral body (*corpus vertebrae*); 2 — transverse process (*processus transversus*); 3 — superior articular process (*processus articularis superior*); 4 — spinous process (*processus spinosus*); 5 — transverse foramen (*foramen transversarium*)

The shape of the first two cervical vertebrae is influenced by their close location to the skull. They are involved in head turning. Therefore, they are termed «rotational vertebrae».

The I cervical vertebra is called the atlas, *atlas* (C_I). It differs from the general structure of individual vertebrae: it has no body no notches and no spinous or articular processes (fig. 2.3).

The atlas has an anterior arch, *arcus anterior atlantis*, instead of the body. Its anterior surface has an anterior tubercle, *tuberculum anterius;* on its posterior surface there is a small articular facet, *fovea dentis*, with which the II cervical vertebra is joined.

The lateral masses of atlas, *massae laterales atlantis,* are located on the both sides. Each of them bears an ellipsoid, concave superior articular surface, *facies articularis superioris*, joining with the corresponding occipital condyle. The inferior ar-

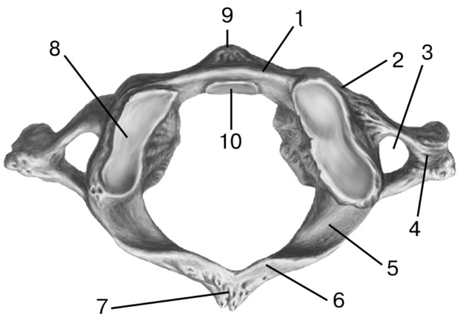

Fig. 2.3. I cervical vertebra (atlas) (superior aspect):

1 — anterior arch of atlas (*arcus anterior atlantis*); 2 — lateral mass (*massa lateralis*); 3 — transverse foramen (*foramen transversarium*); 4 — transverse process (*processus transversus*); 5 — groove for vertebral artery (*sulcus arteriae vertebralis*); 6 — posterior arch of atlas (*arcus posterior atlantis*); 7 — posterior tubercle (*tuberculum posterius*); 8 — superior articular surface (*facies articulars superior*); 9 — anterior tubercle (*tuberculum anterius*); 10 — facet for dens (*fovea dentis*)

ticular surfaces, *facies articulares inferiores*, form round, slightly concave articulate areas connected with the II cervical vertebra.

The posterior arch of the atlas, *arcus posterior atlantis*, corresponds to the arch of a typical vertebra. There is a reduced spinous process in the form of a small posterior tubercle, *tuberculum posterius*, on the back surface of the posterior arch. The groove for vertebral artery, *sulcus arteriae vertebralis*, passes on the superior surface of the posterior arch behind the lateral mass.

The vertebral foramen, *foramen vertebrale*, is bounded with arches and lateral masses. It is much larger than the vertebral foramina of other vertebrae, and only its posterior part corresponds to them. In its anterior part narrowed on the sides with the lateral masses, the dens of the II cervical vertebra is located. The transverse process, *processus transversus*, is perforated by the transverse foramen, *foramen transversarium*, for the passage of blood vessels like transverse processes of the other cervical vertebrae. The ends of the transverse processes are slightly thickened. They have no anterior and posterior tubercles and no the groove for spinal nerve.

The II cervical vertebra is termed the axis, *axis* (C_{II}). Its distinctive feature is the presence of a dental process or dens, *dens axis*, projecting vertically from the superior surface of its body. The dens is the body of the atlas relocated during the development (fig. 2.4).

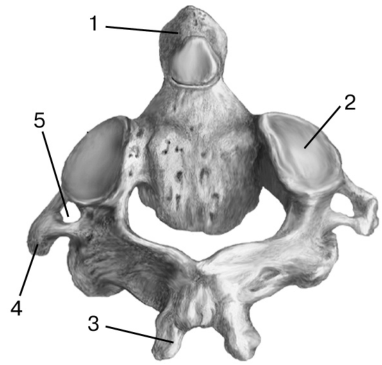

Fig. 2.4. II cervical vertebra (axis) (posterior aspect):

1 — dens (*dens*); 2 — superior articular facet (*facies articularis superioris*); 3 — spinous process (*processus spinosus*); 4 — transverse process (*processus transversus*); 5 — transverse foramen (*foramen transversarium*)

The dens plays the role of a pivot, around which the atlas together with the skull rotates to the right and to the left. The dens of the II cervical vertebra is cylindrical, it has an apex, *apex dentis*, and articular facets on its anterior and poste-

rior sides. The anterior articular facet, *facies articularis anterior*, articulates with *fovea dentis* of the anterior arch of the atlas; the posterior articular facet, *facies articularis posterior*, joins with the transverse ligament of the atlas. The axis has no superior articular processes. Instead of them there are slightly convex superior articular facets, *facies articulares superiores*, are on the sides of the dens. These facets articulate with the inferior articular surfaces on the lateral masses of the atlas. The ends of the transverse processes of the axis are slightly thickened like the ends of the I vertebra; there is the *foramen transversarium* at the base of each transverse process. The groove for spinal nerve is absent.

2.3. Thoracic Vertebrae

The thoracic vertebrae, *vertebrae thoracicae* (Th_I–Th_{XII}), are much bigger than the cervical vertebrae (fig. 2.1). The height and transverse size of the thoracic vertebrae bodies gradually increase from the I to XII vertebra. The distinctive feature of the thoracic vertebrae is the presence of the articular facets or demi-facets for articulation with ribs. These facets are located on the lateral sides of the bodies and on the transverse processes.

Most vertebrae have two demi-facets. They are directly in front of the pedicle of the vertebral arch: one — at superior edge, the other — at inferior edge. They are called the superior costal facet and inferior costal facet, respectively, *fovea costalis superior et fovea costalis inferior*. Each such facet (demi-facet to be more precise) of one vertebra, together with the nearest demi-facet of the adjacent vertebra, form an articular area for articulation with the head of the rib. An exception is the I vertebra: it has a complete facet to articulate with the I rib, and a demi-facet to articulate with the II rib. The X vertebra has only the superior demi-facet for articulation with the X rib. The XI and XII vertebrae have one complete facet for articulation with the corresponding ribs.

The articular processes of the thoracic vertebrae are located in the frontal plane. The articular surfaces of superior articular processes are directed backwards, the articular surfaces of the inferior articular processes are directed forwards. The transverse processes are directed laterally and backwards; their length increases from the I to the IX vertebra but then they become shorter. The ends of the transverse processes are thickened. They have a transverse costal facet, *fovea costalis processus transversi*, for articulation with the tubercle of the rib. The XI and XII vertebrae do not have such facet.

The spinous processes of the thoracic vertebrae are longer than the spinous processes of the cervical vertebrae; they are tilted downwards and lie on each other like tiles.

2.4. Lumbar Vertebrae

The distinctive feature of the lumbar vertebra, *vertebrae lumbales* (L_I–L_V), is a bean-shaped massive body. The transverse size of the body is wider than the anteroposterior size. The height and width of the body gradually increases from the I to the V vertebrae. The vertebral foramen is large and triangular with rounded angles. The articular processes are well developed, their articular surfaces are located in the sagittal plane: the articular surfaces of the superior processes are directed medially, the articular surfaces of the inferior processes are directed laterally (fig. 2.5).

The superior articular process may have a rudimental tubercle named mammillary process, *processus mamillaris*. The lumbar vertebra` s transverse processes are formed by fusion of rudimental ribs with the transverse processes of the vertebra. They are located in the frontal plane, their ends are tilted backwards. Often the accessory process, *proces-*

sus accessorius, may be present at the base of the transverse process. The spinous processes are short and flat, their ends are thickened; they are located almost at the same level with the vertebral body and directed backwards.

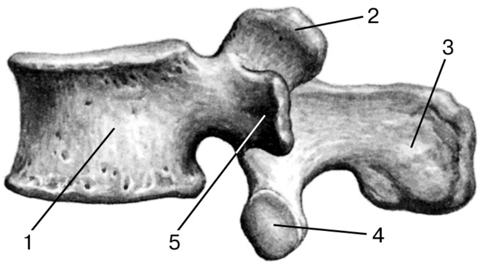

Fig. 2.5. Lumbar vertebra (lateral aspect):

1 — vertebral body (*corpus vertebrae*); 2 — superior articular process (*processus articularis superior*); 3 — spinous process (*processus spinosus*); 4 — inferior articular process (*processus articularis inferior*); 5 — transverse process (*processus transversus*)

2.5. Sacrum

The sacrum, *os sacrum* (S_I–S_V), consists of five sacral vertebrae, *vertebrae sacrales*, which fuse to form a single bone in adults. Two parts and two surfaces are distinguished in the sacrum: the upper wide part, which is the base of the sacrum, *basis ossis sacri*; the lower part, which is the apex of the sacrum, *apex ossis sacri*; the anterior (concave) surface, which is the pelvic surface, *facies pelvica*; the posterior surface (convex, rough), which is the dorsal surface, *facies dorsalis* (fig. 2.6).

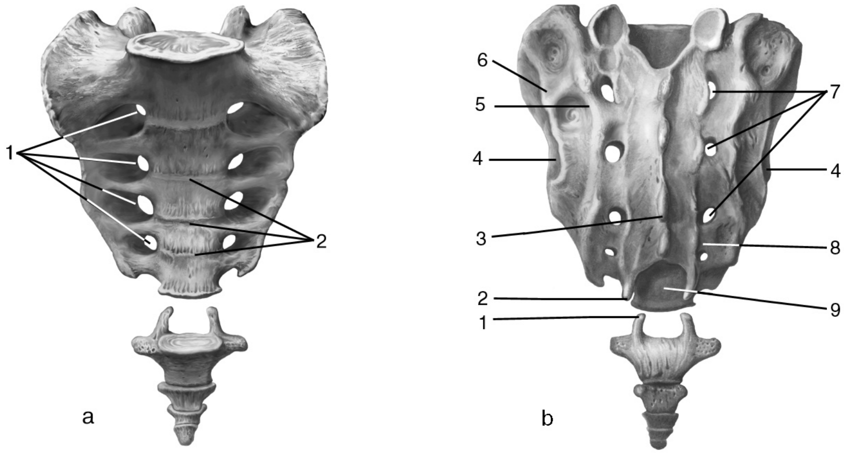

Fig. 2.6. Sacrum and coccyx:

a — anterior aspect: 1 — anterior sacral foramina (*foramina sacralia anteriora*); 2 — transverse lines (*lineae transversae*)

b — posterior aspect: 3 — coccygeal horn (*cornu coccygeum*); 4 — sacral horn (*cornu sacrale*); 5 — median sacral crest (*crista sacralis mediana*); 6 — auricular surface (*facies auricularis*); 7 — lateral sacral crest (*crista sacralis lateralis*); 8 — sacral tuberosity (*tuberositas ossis sacri*); 9 — posterior sacral foramina (*foramina sacralia posteriora*); 10 – intermediate sacral crest (*crista sacralis intermedia*); 11 — sacral hiatus (hiatus sacralis)

Fig. 2.7.Sagittal section of sacrum:
1 — sacral canal (*canalis sacralis*), 2 — base of sacrum (*basis ossis sacri*); 3 — sacral horn (*cornu sacrale*)

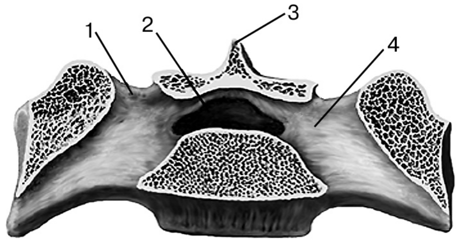

Fig. 2.8. Horizontal section of sacrum:
1 — posterior sacral foramen (*foramen sacrale posterius*); 2 — sacral canal (*canalis sacralis*); 3 — median sacral crest (*crista sacralis mediana*); 4 — intervertebral foramen (*foramen intervertebrale*)

The superior articular processes, *processus articulares superiores*, project from the base of the sacrum; they articulate with the inferior articular processes of the V lumbar vertebra. The place of the junction of the sacrum with the body of the V lumbar vertebra bulges forwards, and is known as the sacral promontory, *promontorium*.

Four transverse lines, *lineae transversae*, running horizontally, are visible on the pelvic surface of the sacrum. They are the traces of the fusion of the sacral vertebral bodies. The anterior sacral foramina, *foramina sacralia anteriora*, open on the right and left ends of these lines.

There are five longitudinal crests on the dorsal surface of the sacrum. The unpaired median sacral crest, *crista sacralis mediana*, is formed by the fusion of the spinous processes. There is the paired intermediate sacral crest, *crista sacralis intermedia*, on each side of it. The intermediate sacral crest represents fused articular processes of the sacral vertebrae. There are the posterior intermediate foramina, *foramina sacralia posteriora*, near the intermediate crests. The paired lateral sacral crest, *crista sacralis lateralis*, lies laterally to these foramina. It is the trace of the fusion of the transverse processes and rudimental ribs. The paired lateral parts, *partes laterales*, with the auricular surfaces, *facies auriculares*, are located outside the posterior sacral foramina. They articulate with the auricular surfaces of the pelvic bone. There is the sacral tuberosity, *tuberositas ossis sacri*, behind the auricular surfaces. It is connected by ligaments with the tuberosity of the pelvic bone. In the process of the fusion of the sacral vertebrae into a single bone, the vertebral foramina form the sacral canal, *canalis caralis* (fig. 2.7). It terminates with the sacral hiatus, *hiatus sacralis*. The sacral horns, *cornua sacralia*, are on both sides of the hiatus. They are rudiments of the inferior articular processes. The anterior and posterior sacral foramina are connected with the sacral canal by the intervertebral foramina, *foramina intervertebralia* (fig. 2.8).

2.6. Coccyx

The coccyx, *os coccygis* (Co_I–Co_{III-V}), consists of 3–5 rudimental vertebrae in adults. Only the I vertebra has rudiments of superior articular processes named coccygeal horns, *cornua coccygea*, besides the body. The coccygeal horns are connected with the sacral horns by ligaments. The I vertebra also has lateral projections which are rudiments of transverse processes. The other vertebrae are round-shaped and small, they have no arch and no processes.

2.7. Anomalies and Developmental Defects of Vertebrae

Anomalies and developmental defects may be classified according to the following criteria:

I. Vertebral size anomalies:

1. Microspondylia — reduction in size of one or more vertebrae.
2. Brachyspondylia — reduction in width of one or more vertebrae.
3. Platyspondylia — flattening of some vertebrae which get a truncated cone shape.
4. Macrospondylia — increase in size of some vertebrae.

II. Slit-like Defects of Vertebrae:

1. Splitting of vertebral bodies (anterior splitspine, spina bifida anterior) — a slit-like defect of the vertebral body located more often in the sagittal plane.
2. Splitting of the vertebral arch (posterior split spine, spina bifida posterior) — a slit-like defect of the vertebral arch (near a spinous process or on its place).
3. Spondylolysis — in this case, the vertebral body is not fused with the pedicles of the vertebral arch: this anomaly may be observed either on one or on both sides, it happens most often in the V lumbar vertebra or in the I sacral vertebra; in case of bilateral spondylolysis, the posterior part of the arch with the inferior articular processes are separated from the pedicles of the arch with the superior articular processes.
4. Spondylolisthesis — displacement of the body of the upper vertebra frontwards (very seldom — backwards relative to the lower vertebra. Most often it occurs after compressive fracture of a vertebral body when the vertebra becomes wedge-shaped.
5. Rachischisis — in this case the vertebral body is not fused with the pedicles of the vertebral arch, and the vertebral arch is splitted.

III. Development anomalies of individual vertebrae:

1. Assimilation of the atlas:

— atlanto-occipital assimilation (occipitalization) — partial or complete fusion of the I cervical vertebra with the occipital bone: two-sided (symmetric) or one-sided (asymmetric);

— atlantoaxial assimilation — partial or complete fusion of the I and II vertebrae.

2. Manifestation of the atlas (formation of the occipital vertebra — proatlas) –inclusion of the atlas particles into the occipital bone which is manifested in the presence of anomalous bony prominences in the circle of the great (occipital) foramen.

3. Kimmerle`s anomaly — transformation of the vertebral artery groove on the atlas into the canal as a result of formation of a bony outgrowth above this groove.

4. Development anomalies of the II cervical vertebra:

— agenesia (absence) of the dens;

— the dens and the body of the II cervical vertebra are not fused together.

5. Thoracolisation of the cervical vertebrae — formation of cervical ribs (most often from the VII cervical vertebra).

6. Sacralisation — fusion of the V lumbar vertebra with the I sacral vertebra: there are 4 vertebrae in the lumbar part of the vertebral column; the sacrum consists of 6 vertebrae.

7. Lumbarisation — the I sacral vertebra and the II sacral vertebra are not fused together: there are 6 vertebrae in the lumbar part of the vertebral column; the sacrum consists of 4 vertebrae.

8. Segmented sacrum — in this case, the sacral vertebrae are not fused into a single bone. This is not anomaly in children, because the presence of cartilaginous tissue between vertebral bodies is normal for this age.

9. Splitting of the sacral canal, *spina bifida sacralis*: partial or complete.

10. Anomalies of the coccygeal vertebrae:

— different number of coccygeal vertebrae (1 to 5);

— different variations of fusion of the coccygeal vertebrae together or with the sacrum.

2.8. Ribs

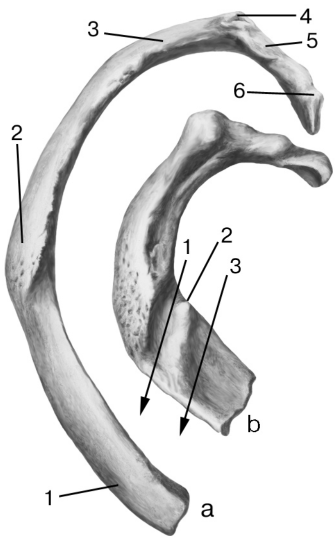

Fig. 2.9. Ribs:

a — II right rib: 1 — anterior end (*extremitas anterior*); 2 — shaft (*corpus costae*); 3 — posterior end (*extremitas posterior*); 4 — costal tubercle (*tuberculum costae*); 5 — neck of rib (*collum costae*); 6 — head of rib (*caput costae*)

b — I right rib: 1 — groove for subclavian artery (*sulcus arteriae subclaviae*); 2 — scalene tubercle (*tuberculum musculi scaleni anteroris*); 3 — groove for subclavian vein (*sulcus venae subclaviae*)

The ribs, *costae*, (12 pairs) join symmetrically in pairs to the thoracic vertebrae. Each rib consists of the posterior bony part and anterior cartilaginous part. The bony part is longer than the cartilaginous part, *cartilago costalis*. The upper seven ribs (I–VII) are attached anteriorly to the sternum by their cartilaginous parts. These ribs are called the true ribs, *costae verae*. The VIII–X ribs are named false, *costae spuriae*, because they are attached to each other and to the seventh rib by means of their costal cartilages. The cartilaginous parts of the XI and XII ribs are short, they have no anterior attachment and they end in the abdominal musculature. These ribs are called floating ribs, *costae fluctuantes*.

Each rib is a narrow long plate, curved along the edge or along the surface (fig. 2.9).

The posterior end of each rib has a head, *caput costae*. Such heads of the ribs from II to X articulate with the bodies of two adjacent thoracic vertebrae. Thus the ribs from II to X have the crest of rib head, *crista capitis costae*, which divides the articular facet of the head into two demi-facets for two adjacent vertebral bodies. The I, XI and XII ribs have no such crest, that is why the heads of these ribs articulate with the complete fovea on the bodies of the corresponding vertebrae. The posterior part of the rib is constricted behind the head, forming the neck of rib, *collum costae*, which continues into the longest part of the rib named the body (shaft) of rib, *corpus costae*. There is the tubercle of rib, *tuberculum costae*, at the

junction of the neck with the shaft. The tubercles of the 10 upper ribs are divided into two prominent parts: the first part is the articular part of the rib tubercle, *facies articularis tuberculi costae*, it lies medially and more inferiorly and joins with the transverse process of the corresponding thoracic vertebra; and the second art is non-articular part of the rib tubercle, *eminentia tuberculi costae*, it lies more laterally and superiorly and serves for attachment of ligaments. There are no articular parts on the tubercles of the XI and XII ribs, and tubercles may also be absent because these ribs are not joined with the transverse processes of the corresponding vertebrae.

The bodies of the II–XII ribs have internal and external surfaces, superior and inferior borders. Each of these ribs is slightly twisted around a longitudinal axis and is bent forwards at the tubercle. The place of this bend is named the costal angle, *angulus costae*. The costal groove, *sulcus costae*, runs on the internal surface of the shaft along its inferior border. The intercostal vessels and nerves pass along this groove. The anterior end of the rib has a pit with rough surface which serves for joining with the costal cartilage.

The I rib, *costa prima*, differs from the other ribs — it has inferior and superior surfaces, medial and lateral borders. On its superior surface there is a scalene tubercle, *tuberculum musculi scaleni anterioris*, for insertion of the anterior scalene muscle. The groove for subclavian artery, *sulcus arteriae subclaviae*, passes behind this tubercle. The groove for subclavian vein, *sulcus venae subclaviae*, is in front of this tubercle.

2.9. Anomalies and Defects in Development of Ribs

I. Anomalies in Number of Ribs:

1. Aplasia of rib — absence of any rib: partial or full; one- or two-sided.

2. Hypoplasia of ribs — defect of rib development in which the anterior ends of ribs are underdeveloped; the missing part of the rib is replaced with connective tissue;

3. Additional rib (may be symmetrical or asymmetrical). We often observe:

— cervical rib — an elongated transverse process of the VII vertebra (more seldom– from the VI cervical vertebra);

— thoracic rib (thirteenth) — an elongated transverse process of the I lumbar vertebra.

II. Rib shape anomalies:

1. Widening of a rib — a shovel-shaped rib.

2. Split rib (Luschka`s bifurcated rib) — splitting of the anterior end of the rib in the form of a bident fork.

3. Perforated rib — presence of slits and openings in the bony part of the rib.

4. Intergrowth of ribs — presence of bony bridges between adjacent ribs.

2.10. Sternum

The sternum, *sternum*, is a flat bone which is located almost in the frontal plane. It consists of three individual parts joined with each other by means of cartilage tissue. The upper part is the manubrium of sternum, *manubrium sterni*; the middle part is the body of sternum, *corpus sterni*; the lower part is the xiphoid process, *processus xiphoideus*. Usually in adults these three parts are fused into a single bone (fig. 2.10). The sternal angle, *angulus sterni*, is formed at the place of articulation between the manubrium and the body.

The manubrium is the thickest part of the sternum. There are three notches on its superior edge: the jugular notch, *incisura jugularis*, is in the center; the clavicular notches, *incisurae claviculares*, are on lateral sides; they serve for articulation of the clavicles with the sternum. A rough depression called the notch of the I rib, *incisura costalis I*, is located below the clavicular notches on the lateral edge; the cartilage of the I rib is attached to this notch. Half of the notch of the II rib, *incisura costalis II*, is at the lower edge of the manubrium. It is complemented by the other half of this notch located on the lateral edge of the body of sternum near its connection with the manubrium.

There are notches for articulation with the costal cartilages of the III-VII ribs, *incisurae costales*, on each side of the sternum`s body. The notch for the VII rib is on the boundary between the body and the xiphoid process.

The xiphoid process is much narrower and thinner than the body, and it is variable in shape. Usually it is sharpened downwards sometimes, it is bifurcated or has a through hole.

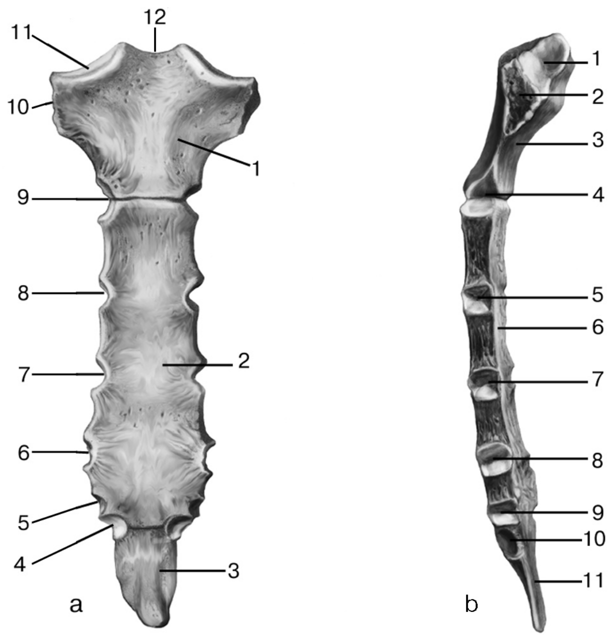

Fig. 2.10. Sternum:

a — anterior aspect: 1 — manubrum of sternum (*manubrium sterni*); 2 — body of sternum (*corpus sterni*); 3 — xiphoid process (*processus xiphodeus*); 4—10 — costal notches (*incisurae costales*); 11 — clavicular notch (*incisura clavicularis*); 12 — jugular notch (*incisura jugularis*)

b — lateral aspect: 1 — clavicular notch (*incisura clavicularis*); 2, 4, 5, 7, 8, 9, 10 — costal notches (*incisurae costales*); 3 — manubrium of sternum (*manubrium sterni*); 6 — body of sternum (*corpus sterni*); 11 — xiphoid process (*processus xiphodeus*)

2.11. Anomalies and Defects of Sternum Development

1. Aplasia of the sternum (asternia) — absence of the distal part of the sternum or absence of the manubrium. In this case, the ribs of opposite sizes fused with each other by their anterior ends.

2. Segmented sternum — in this case, cartilages between bony parts of the sternum are not ossified for a long time. As a result, the sternum body consists of several pieces.

3. Deformation of the sternum — elongated, oval or square-shaped sternum; the sternal angle is very prominent.

4. Splitting of the sternum — resence of a longitudinal slit located along the median line. This defect may be so considerable that the heart, covered only by soft tissues, bulges through the slit.

5. Axiphoidia — absence of the xiphoid process.

6. Splitting of the xiphoid process — it may be bifurcated, or it may have a small opening.

TEST QUESTIONS

1. What parts of the vertebral column do you know?
2. What are the parts of a typical vertebra?
3. What are the distinctive features of the cervical vertebrae?
4. What are the distinctive features of the thoracic vertebrae?
5. What are the differences between the I, X, XI, XII vertebrae and others?
6. What are the distinctive features of the lumbar vertebrae?
7. What is the function of articular processes?
8. What is the function of dens?
9. What is the function of the articular facets of the atlas and axis?
10. Why do the atlas and axis have specific structure? Describe them.
11. Describe the sacrum.
12. Describe the coccyx.
13. What types of ribs do you know?
14. Name the parts of ribs.
15. What is the function of heads of ribs and costal tubercle?
16. What specific features have the I, X, XI, XII ribs?
17. How will you differentiate the right and the left ribs?
18. How will you count the ribs and intercostal spaces at the person?
19. What are the parts of the sternum?
20. What are the notches of the sternum? What is their function?

CLINICOANATOMICAL PROBLEMS

During the X-ray examination of an adult man the defect of the posterior arch of the atlas is found. What should the doctor think of first?

What vessels may be damaged in case of combined fracture of the clavicle and first rib?

During the X-ray examination a longitudinal slit on the body of sternum is found. What conclusion should the doctor make?

3. SKELETON OF HEAD — SKULL

3.1. General Cranial Features

The skeleton of head — skull, *cranium*, carries the important functions in the organism. It contains the brain and the sense organs and protects them. The skull bones participate in formation of the skeleton of the beginning of the digestive and respiratory systems (fig. 3.1). The neurocranium, *neurocranium* and the viscerocranium, *viscerocranium*, are distinguished in the skull.

The anterior part of the neurocranium is called the forehead, and it is narrower than the posterior part; the latter is called the occiput. The cranial cavity, *cavitas cranii*, is the continuation of the vertebral canal and it looks like the widened termination of the vertebral canal. It encloses the brain with its meninges and vessels. The cranial cavity is connected with the vertebral canal by means of the foramen magnum, *foramen magnum.*

The neurocranium is divided into the base of the skull, *basis cranii*, and the vault of the skull (skullcap, calvaria), *calvaria.* The calvaria is smooth and uniformly rounded. Anteriorly it is formed by the squamous part of the frontal bone, the right and left parietal bones, the squamous parts of the temporal and occipital bones. The frontal and occipital bones are also form the skull base. There is the foramen magnum, *foramen magnum*, in the occipital bone. The sphenoid bone is in front of the occipital bone; the

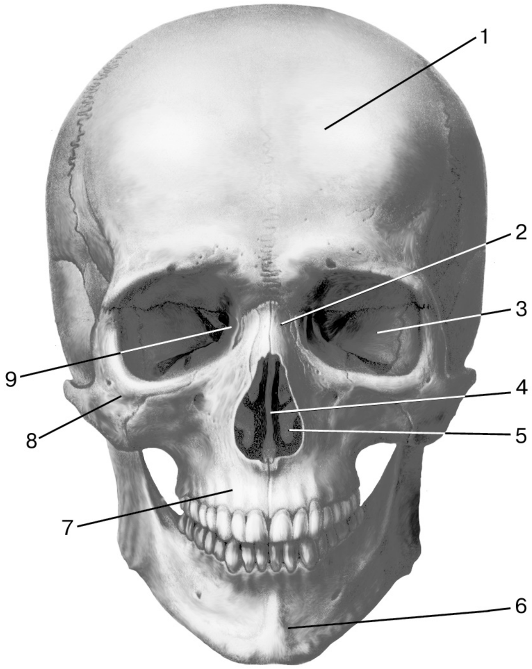

Fig. 3.1. Skull of adult person (anterior aspect):

1 — frontal bone (*os frontale*); 2 — nasal bone (*os nasale*); 3 –sphenoid bone (*os sphenodale*); 4 — nasal septum (*septum nasi osseum*); 5 — inferior nasal concha (*concha nasalis inferior*); 6 — mandible (*mandibula*); 7 — maxilla (*maxilla*); 8 — zygomatic bone (*os zygomaticum*); 9 — lacrimal bone (*os lacrimale*)

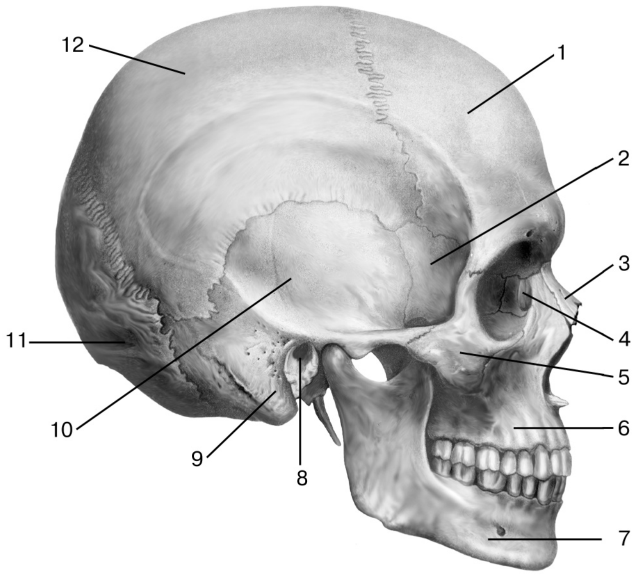

Fig. 3.2. Skull of adult person (lateral aspect):

1 — frontal bone (*os frontale*); 2 — sphenoid bone (*os sphenodale*); 3 — nasal bone (*os nasale*); 4 — lacrimal bone (*os lacrimale*); 5 — zygomatic bone (*os zygomaticum*); 6 — maxilla (*maxilla*); 7 — mandible (*mandibula*); 8 — external acoustic porus (*porus acusticus externus*); 9 — mastoid process (*processus mastoideus*); 10 — temporal bone (*os temporale*); 11 — occipital bone (*os occipitale*); 12 — parietal bone (*os parietale*)

ethmoid bone is between the occipital and frontal bones. The paired temporal bone is between the occipital and sphenoid bones on both sides.

The viscerocranium is located anteriorly and inferiorly to the neurocranium (fig. 3.2). The mandible and maxilla with teeth form the main part of the viscerocranium. Other bones of the viscerocranium are more delicate and fragile, they complement the skeleton of face on different sides.

In examination of the skull, we note large paired cavities named orbits, *orbitae*. A little below them there is a piriform aperture, *apertura piriformis*, leading into the bony nasal cavity, *cavitas` nasalis ossea*.

The relief of the face is significantly defined by the zygomatic bones which adjoin the maxillae on the outside. The zygomatic bone takes part in formation of the orbits` inferior and lateral walls. The protruding part of the viscerocranium is bounded on the top by the nasal bones. On the whole skull it is hard to see some bones because they are shielded by other bones.

According to the origin the hyoid bone, *os hyoideum*, also belongs to the skull bones; it is not very big and arch-shaped, it is located under the root of the tongue. It is joined with the skull by ligaments. The larynx is fixed to the hyoid bone.

To sum everything up in review of the head skeleton, it should be focused again that the neurocranium consists of the following bones: 1) occipital, *os occipitale*; 2) sphenoid, *os sphenoidale*; 3) frontal, *os frontale*; 4) ethmoid, *os ethmoidale*; 5) parietal, *os parietale*; 6) temporal, *os temporale*. The parietal and temporal bones are paired, the other ones are unpaired.

The viscerocranium consists of: 1) maxilla, *maxilla*; 2) palatine bone, *os palatinum*; 3) zygomatic bone, *os zygomaticum*; 4) nasal bone, *os nasale*; 5) lacrimal bone, *os lacrimale*; 6) inferior nasal concha, *concha nasalis inferior*; 7) vomer, *vomer*; 8) mandible, *mandibula*; 9) hyoid bone, *os hyoideum*. The vomer, mandible and hyoid bone are unpaired, the other ones are paired.

Three paired auditory ossicles — malleus, incus and stapes, *malleus*, *incus et stapes*, — also belong to the viscerocranium; they are part of the auditory apparatus and are located in the tympanic cavity of the temporal bone. They will be described together with the structure of the middle ear.

3.2. Principles of structure of skull bones

The skullcap bones develop endesmally, i.e. directly from connective tissue and are similar in the structure. These bones are structured by the external and internal plates of compact bone separated by the layer of spongy bone called diploë, *diploe*. The compact bone plates are different in thickness. The external plate is thicker, its relief is caused by attachment of muscles, ligaments and epicranial aponeurosis which form tubercles, lines, fossae, etc., on the bones. The internal plate is thin, that is why the anatomists of the past called it glassy. The relief of the internal plate is an imprint of the adjoining structures of the brain. Small depressions resembling fingerprints — impressions of cerebral gyri (or digitate impressions), *impressiones gyrorum seu digitatae*, alternate with cerebral ridges, *juga cerebralia*; the first ones correspond to the cerebral gyri, the second ones — to the cerebral sulci. Narrow arterial grooves, *sulci arteriosi*, branched like a tree, can be found on the lateral sides of the skull base; the arteries pass in them. Do not confuse the arterial grooves with the broad, flat venous grooves, *sulci venosi*, which are mainly present in the posterior part of the skull base. In certain places the venous grooves have small trough holes called emissary, *emissaria*. The emissary veins which take the venous blood out, pass trough them. There are irregular pits called granular foveolae, *foveolae granulares*, on the inner surface of the skull (mainly on the skullcap, closer to the midline). Occasionally, they are rather deep and located in groups. Meningeal venous plexuses are contained in them.

3.3. Bones of neurocranium

Frontal Bone

The frontal bone, *os frontale* (fig. 3.3), is unpaired, it closes the cranial cavity anteriorly, being part of both the skullcap and skull base. It participates in formation of the temporal fossa, nasal cavity and orbit. It consists of three parts: squamos part (squama), *squama frontalis*, orbital, *partes orbitales*, and nasal, *pars nasalis*, parts. The orbital part makes almost the right angle with the squamous part.

The squamous part, *squama frontalis*, forms the convex part of the forehead, occupying approximately one third of the skull cap. Its internal surface, *facies interna*, is directed to the brain and is concave; the external surface, *facies externa*, is convex. The latter is separated from the orbital parts by the paired supra-orbital margin, *margo supraorbitalis*, which laterally continues into the zygomatic process, *processus zygomaticus*.

Closer to the medial end of the supra-orbital margin there is a small supraorbital notch, *incisura supraorbitalis* (occasionally, it is turned into a supra-orbital foramen, *foramen supraorbitale*). More medially to it there is the frontal notch, *incisura frontalis*.

Vessels and nerves pass through these structures. Superior to the zygomatic process there is the temporal line, *linea temporalis*, which is the upper border of the temporal surface, *facies temporalis*. Above the medial half of the supra-orbital margin there is a roller-like elevation termed superciliary arch, *arcus superciliaris*, and above it there is the frontal tuber, *tuber frontale*. The area known as glabella, *glabella*, is between the right and left superciliary arches.

On the internal surface along the midline there is the groove for superior sagittal sinus, *sulcus sinus sagittalis superioris*. The edges of this groove converge inferiorly and form the unpaired frontal crest, *crista frontalis*. The foramen caecum, *foramen caecum*, is located at the lower end of this crest. Besides, the internal surface of the squama has arterial grooves, granular foveolae and digitate impressions (near the inferior border). The major portion of the serrated margin of the squamous part joins to the parietal bones, while the lesser inferior portion of it joins to the greater wing of the sphenoid bone. The internal surface of the squamous part gradually continues into the orbital parts, *partes orbitales*.

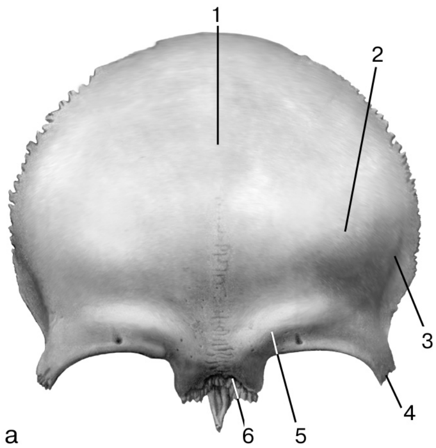

Fig. 3.3. Frontal bone (external surface):
1 — squamous part (*squama frontalis*); 2 — frontal tuber (*tuber frontale*); 3 — temporal line (*linea temporalis*); 4 — zygomatic process (*processus zygomaticus*); 5 — superciliar arch (*arcus superciliaris*); 6 — nasal part (*pars nasalis*)

The orbital parts, *partes orbitales*, are trapezoidal plates. They form part of the anterior cranial fossa and of the orbit`s superior wall. The medial sharp border of the orbital part is located sagittally, the posterior border joins to the anterior border of the sphenoid`s lesser wings. The digitate impressions, *impressiones digitatae*, and cerebral ridges, *juga cerebralia*, are pronounced on the cerebral surface, *facies cerebralis*, of the orbital parts. The orbital surface, *facies orbitalis*, of the orbital part is smooth; it forms the superior wall of the orbit. There is a shallow fossa for lacrimal gland, *fossa glandulae lacrimalis*, in the region of the zygomatic process. Medially to the supraorbital notch there is a slight depression named trochlear fovea, *fovea trochlearis*. An inconstant formation termed trochlear spine, *spina trochlearis*, is in the region of the trochlear fovea (it is the place for attachment of the tendon of the eyeball`s superior oblique muscle). The ethmoidal notch, *incisura ethmoidalis*, is between the orbital parts; it is filled with the ethmoid bone.

The nasal part, *pars nasalis*, joins with the nasal bones and with the frontal processes of the maxillae. In the posterior portion of the nasal part there are depressions called ethmoidal foveolae, *foveolae ethmoidales*; they cover the superior ethmoidal cells. Along the midline of the nasal part a sharp nasal spine, *spina nasalis*, protrudes; it takes part in formation of the nasal septum. There are openings of frontal sinuses, *aperturae sinus frontalis*, to the right and to the left from the nasal spine. The frontal sinus, *sinus frontalis*, is within the frontal bone, it is paired and varies in shape and size (pneumatization) in adults. The septum of the frontal sinus, *septum sinuum frontalium*, located sagittally divides the right and left sinuses. Quite often, the right and left sinuses are non-symmetrical or absolutely absent.

The frontal bone is primary in its development, i.e. it passes through two stages of development and is formed on the basis of connective tissue.

Variations of Frontal Bone Development:

— the frontal bone may consist of two parts; in this case, the frontal (or metopic) suture, *sutura metopica frontalis*, remains between them (10 % of cases);

— the size of the frontal sinus is variable; very seldom the sinus is absent;

— there may be the foramen caecum, *foramen caecum*, behind the frontal crest (in most cases, it is located at the junction of the frontal and ethmoid bones).

Occipital Bone

The occipital bone, *os occipitale* (fig. 3.4), forms the posterior part of the neurocranium. Mainly it forms the skull base, partially it forms the skull cap. This bone joins with the parietal, temporal and sphenoid bones. The occipital bone consists of four parts. Anteriorly is the basilar part, *pars basilaris*, posteriorly is the squamous part (squama), *squama occipitalis*, (the biggest part), and on the lateral sides are the lateral parts (paired), *partes laterales*. The distinctive feature of the occipital bone is the presence of the foramen magnum, *foramen magnum*, which connects the cranial cavity with the vertebral canal.

The basilar part, *pars basilaris*, (or body, *corpus*) of the occipital bone is gradually thickened anteriorly, and it terminates with rough surface which is connected by cartilage with the body of the sphenoid bone until the age of 18–20. After this age the both bones fuse together. The superior surface of the basilar part, together with the sphenoid`s body, forms the clivus, *clivus*. The inferior surface of the basilar part is directed outwardly, it is uneven and has a small pharyngeal tubercle, *tuberculum pharyngeum*, in the middle. The vault of pharynx is attached to this tubercle. The lateral rough borders of the basilar part join with the pyramids of the temporal bones by cartilage.

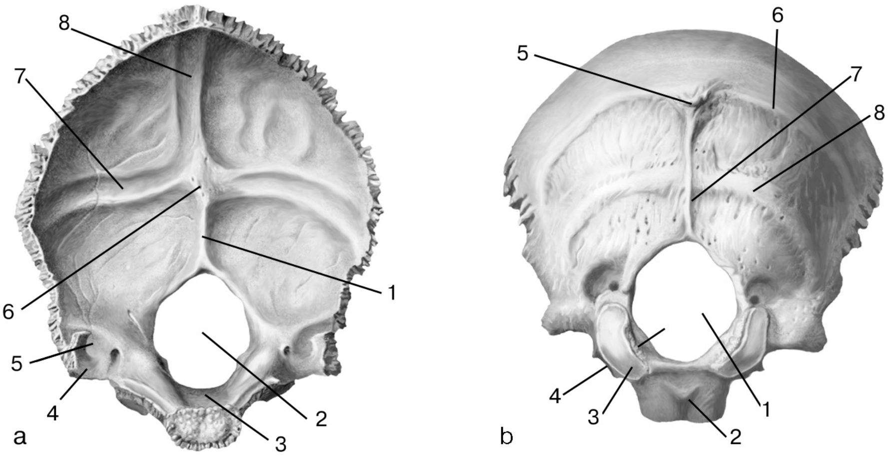

Fig. 3.4. Occpital bone:

a — internal surface: 1 — internal occipital crest (*crista occipitalis interna*); 2 — foramen magnum (*foramen magnum*); 3 — clivus (*clivus*); 4 — jugular notch (*incisura jugularis*); 5 — groove for sigmoid sinus (*sulcus sinus sigmoidei*); 6 — internal occipital protuberance (*protuberantia occipitalis interna*); 7 — groove for transverse sinus (*sucus sinus transversi*); 8 — groove for superior sagittal sinus (*sulcus sinus sagittalis superioris*)

b — external surface: 1 — foramen magnum (*foramen magnum*); 2 — pharyngeal tubercle (*tuberculum pharyngeum*); 3 — occipital condyle (*condylus occptalis*); 4 — hypoglossal canal (*canalis nervi hypoglossi*); 5 — external occipital protuberance (*protuberantia occipitalis externa*); 6 — superior nuchal line (*linea nuchalis superior*); 7 — external occipital crest (*crista occipitalis externa*); 8 — inferior nuchal line (*linea nuchalis inferior*)

The lateral parts, *partes laterales*, bound the foramen magnum, *foramen magnum*, from the anterior and lateral sides and gradually continue into the squamous part. On their inferior surface there are the occipital condyles, *condyli occipitales*, which bear the convex ellipsoid articular surfaces to articulate with the superior articular surfaces of the atlas. The condylar fossa, *fossa condylaris*, is behind each condyle. On the bottom of this fossa the inconstant condylar canal, *canalis condylaris*, opens; the emissary vein passes through it. Above the midst of the occipital condyle the short hypoglossal canal, *canalis n. hypoglossi*, containing the hypoglossal nerve (the XII pair of cranial nerves), perforates the occipital bone. On the lateral border of each lateral part there is the jugular notch, *incisura jugularis*, which forms the jugular foramen, *foramen jugulare*, together with the jugular fossa of the temporal bone. The jugular foramen contains the internal jugular vein and the IX, X, XI pairs of cranial nerves. Posteriorly the jugular notch is bounded by the upward prominent jugular process, *processus jugularis.* Near it on the internal surface of the lateral part there is a rather wide groove for sigmoid sinus, *sulcus sinus sigmoidei.* The small jugular tubercle, *tuberculum jugulare*, is above the internal opening of the hypoglossal canal.

The squamous part, *squama occipitalis*, is like a wide plate with concave internal and convex external surfaces.

On the internal (cerebral) surface of the squama there is a cruciform eminence, *eminentia cruciformis*, which delineates four fossae — two superior and two inferior ones. The posterior parts of the cerebral hemispheres adjoin the superior fossae, and the cerebellar hemispheres adjoin the inferior ones. The center of the cruciform eminence forms a small internal occipital protuberance, *protuberantia occipitalis interna*. The internal occipital crest, *crista occipitalis interna*, descends from it, reaching the foramen magnum. The groove for superior sagittal sinus, *sulcus sinus sagittalis superioris*, ascends from the internal occipital protuberance, the groove for transverse sinus, *sulcus sinus transversi*, extends to the right and to the left from it. In most of cases, the groove for superior sagittal sinus continues into the groove for the right transverse sinus. The lambdoid (superior) border of the squamous part is serrated: it joins to the parietal bones.

There is an external occipital protuberance, *protuberantia occipitalis externa*, in the center of the squamous part`s external surface. The external occipital crest, *crista occipitalis externa*, descends from the protuberance to the edge of the foramen magnum along the midline. The rough superior nuchal line, *linea nuchalis superior*, extends horizontally from the external occipital protuberance to the right and to the left. The inferior nuchal line, *linea nuchalis inferior*, is below and parallel to the superior nuchal line. Above the superior nuchal line the highest nuchal line, *linea nuchalis superior*, may exist.

According to development, the occipital bone is mixed: the basilar part, lateral parts and the inferior portion of squamous part are formed on the basis of cartilage and pass through three stages of development (secondary bone); the superior portion of the squamous part is formed on the basis of connective tissue and passes through two stages of development (primary bone).

Variations of occipital bone development:

— superior portion of the squamous part is separated (entirely or partially) from other parts of the bone by a transverse suture; as a result the interparietal bone (Inca Bone) is formed;

— assimilation or manifestation of atlas (see «Anomalies of Vertebrae Development»);

— significant increase in size of the external occipital protuberance;

— presence of the third occipital condyle, which is located at the anterior edge of the foramen magnum; at a result, an additional joint may be formed between the occipital bone and the anterior arch of the atlas.

Ethmoid Bone

The ethmoid bone, *os ethmoidale* (fig. 3.5), has a form of an irregular cube. It is located between the facial bones, thus it is hard to see this bone on the whole skull. It consists of thin plates of compact bone separated by small air cells; due to their presence the ethmoid bone is very lightweight.

The ethmoid bone consists of three parts: the ethmoidal labyrinths, *labyrinthi ethmoidales*, the horizontally located cribriform plate, *lamina cribrosa*, and the vertically located perpendicular plate, *lamina perpendicularis*.

The ethmoidal labyrinth, *labyrinthus ethmoidalis*, is a paired formation consisting of thin flat laminae which join with each other forming cavities of various sizes named ethmoidal cells, *cellulae ethmoidales*. They are connected with the nasal cavity. The labyrinths have a solid wall called the orbital plate, *lamina orbitalis*, on the lateral side.

The anterior, middle and posterior cells, *cellulae ethmoidales anteriores*, *mediae et posteriores*, are distinguished. There are two thin curved plates named the superior and middle nasal conchae on the medial surface of each labyrinth. The superior nasal concha, *concha nasalis superior*, is not big; the middle nasal concha, *concha nasalis media*, is longer and is located under the superior nasal concha. Occasionally, the supreme nasal concha, *concha nasalis suprema*, develops above the superior nasal concha.

On the anterior end of the middle nasal concha there is a curved downwards uncinate process, *processus uncinatus*, which joins to the ethmoid process of the inferior nasal concha. The ethmoidal bulla, *bulla ethmoidalis*, which is the biggest cell of the ethmoid, projects behind the uncinate process. The semilunar hiatus, *hiatus semilunaris*, is in front

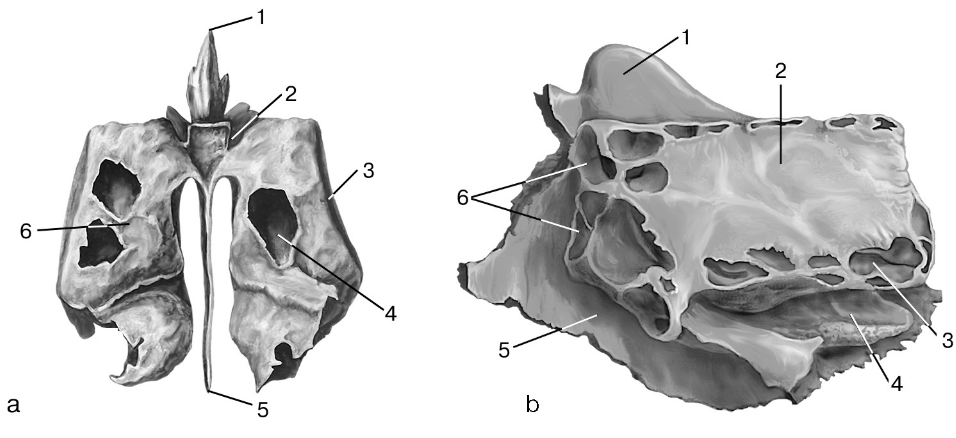

Fig. 3.5. Ethmoid bone:

a — posterior aspect: 1 — crista galli (*crista galli*); 2 — cribriform plate (*lamina cribrosa*); 3 — orbital plate (*lamina orbitalis*); 4 — posterior ethmoidal cells (*cellulae ethmoidales posteriores*); 5 — perpendicular plate (*lamina perpendicularis*); 6 — ethmoidal labyrinth (*labyrinthus ethmoidalis*)

b — left side: 1 — crista galli (*crista galli*); 2 — orbital plate (*lamina orbitalis*); 3 — posterior ethmoidal cells (*cellulae ethmoidales posteriores*); 4 — middle nasal concha (*concha nasalis media*); 5 — perpendicular plate (*lamina perpendicularis*); 6 — anterior ethmoidal cells (*cellulae athmoidales anteriores*)

of the ethmoidal bulla. This hiatus, together with the adjacent bones (the inferior nasal concha and maxilla), form the ethmoidal infundibulum, *infundibulum ethmoidale*, which connects the frontal sinus with the middle nasal meatus.

The cribriform plate, *lamina cribrosa*, is quadrangular, it is located in the ethmoidal notch of the frontal bone. It forms the portion of the neurocranium`s anterior part and participates in formation of the nasal cavity`s superior wall. Above the cribriform plate there is the crista galli, *crista galli*. It becomes higher and thicker anteriorly and terminates with two processes termed the alae of crista galli, *alae cristae galli*. The alae of crista galli, together with the frontal bone, bound the foramen caecum, *foramen caecum* (sometimes, the foramen caecum is entirely located in the frontal bone). On the sides of the crista galli there are numerous cribriform foramina, *foramina cribrosa*, through which the olfactory nerves, *nn. olfactorii*, penetrate from the nasal cavity into the cranial cavity.

The perpendicular plate, *lamina perpendicularis*, forms the part of the bony nasal septum. Its free edges join with the nasal bones, vomer, sphenoidal crest and also with the cartilaginous nasal septum.

According to development, the ethmoid bone is secondary: it passes trough three development stages and is formed on the basis of cartilage.

Variations of ethmoid bone development :

— variability in location and attachment of the uncinate process;
— variability in the form and size of the ethmoidal cells;
— presence of the supreme nasal concha.

Sphenoid Bone

The sphenoid bone, *os sphenoidale* (fig. 3.6), lies in the middle of the skull base. It articulates with all bones of the skull and participates in formation of the major part of cavities and fossae of the skull. It has a complicated shape, consists of the body and three pairs of processes. The pterygoid processes are directed downwards, the greater and lesser wings protrude laterally to the right and to the left. The lesser wings are separated from the greater wings by the superior orbital fissure, *fissura orbitalis superior*, which transmit the III, IV and VI pairs of cranial nerves and the first branch of the V pair which pass into the orbit from the cranial cavity.

The body of sphenoid bone, *corpus ossis sphenoidalis*, looks like an irregular cube. Six surfaces are distinguished in the body: superior, posterior, inferior, anterior and two lateral ones. The superior surface is directed to the cranial cavity. The posterior surface joins with the occipital bone. The inferior and anterior surfaces continue one into another and they are directed to the nasal cavity. The greater and lesser wings are attached to the lateral surfaces. The body of sphenoid bone is connected with the anterior surface of the occipital bone`s body by cartilage in the young age and by osseous tissue subsequently. The superior surface of the sphenoid bone body has a peculiar shape, known as sella turcica, *sella turcica* (fig. 3.7). In its center there is the hypophisial fossa, *fossa hypophysialis*. The brain appendage –hypophisis — is placed in this fossa. Posteriorly the hypophisial fossa is bounded by a high crest termed dorsum sellae, *dorsum sellae*, and anteriorly — by the tuberculum sellae, *tuberculum sellae*. The angles of the dorsum sellae form the posterior clinoid processes, *processus clinoidei posteriores*.

In front of the tuberculum sellae there is the transverse prechiasmatic sulcus, *sulcus prechiasmaticus*; it accomodates the decussation of optic nerves. The lateral surfaces of the sphenoid`s body are almost completely occupied by the greater and lesser wings

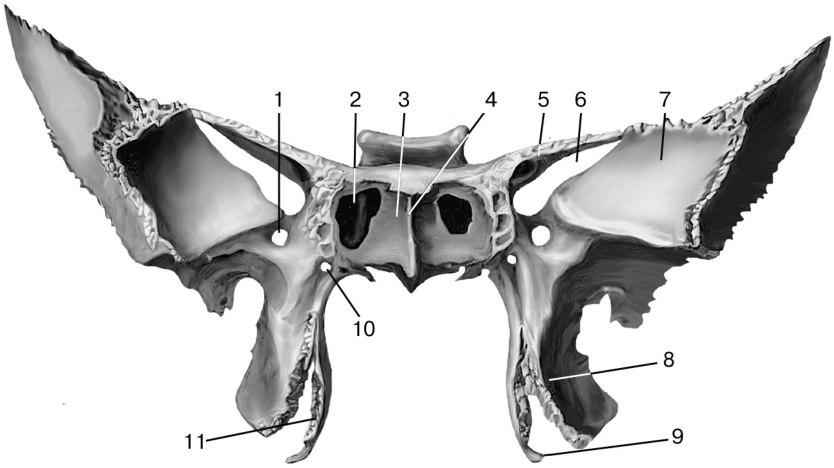

Fig. 3.6. Sphenoid bone (anterior aspect):

1 — foramen rotundum (*foramen rotundum*); 2 — opening of sphenoidal sinus (*apertura sinus sphenodalis*); 3 — sphenodal concha (*concha sphenodalis*); 4 — sphenoidal crest (*crista sphenodalis*); 5 — lesser wing (*ala minor*); 6 — superior orbital fissure (*fissura orbitalis superior*); 7 — greater wing (*ala major*); 8 — lateral plate of pterygoid process (*lamina lateralis processus pterygodei*); 9 — pterygoid hamulus (*hamulus pterygoideus*); 10 — pterygoid canal (*canalis pterygoideus*); 11 — medial plate of pterygoid process (*lamina medalis processus pterygodei*)

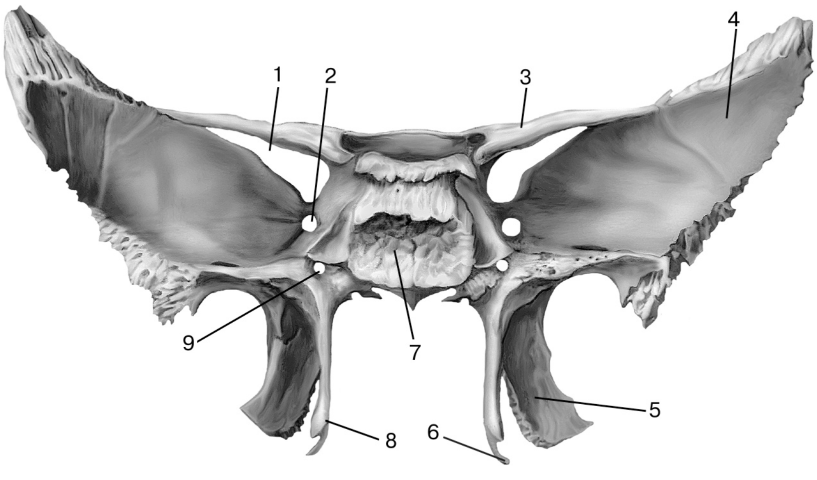

Fig. 3.7. Sphenoid bone (posterior aspect):

1 — superior orbital fissure (*fissura orbtalis superior*); 2 — foramen rotundum (*foramen rotundum*); 3 — lesser wing (*ala minor*); 4 — greater wing (*ala major*); 5 — lateral plate of pterygoid process (*lamina lateralis processus pterygodei*); 6 — pterygoid hamulus (*hamulus pterygoideus*); 7 — body (*corpus*); 8 — medial plate of pterygoid process (*lamina medialis processus pterygodei*); 9 — pterygoid canal (*canalis pterygoideus*)

protruding from them. The carotid sulcus, *sulcus caroticus*, is at the base of the dorsum sellae. It is bounded by the sharp crest from the lateral side and accomodates the internal carotid artery.

The anterior surface of the body is directed to the nasal cavity. Along its midline there is the sphenoidal crest, *crista sphenoidalis*, which continues to the spenoidal rostrum, *rostrum sphenoidale*, on the inferior surface of the body. The sphenoidal conchae, *conchae sphenoidales*, are on both sides of the crest. The superior edge of each sphenoidal concha bounds the paired opening of the sphenoidal sinus, *apertura sinus sphenoidalis*, leading into the sphenoidal sinus, *sinus sphenoidalis*. Almost always, the right and left sphenoidal sinuses are separated from each other by the septum of sphenoidal sinuses, *septum sinuum sphenoidalium*, which often deviates from the median plane to one or another side.

The lesser wing, *ala minor*, protrudes from the body with two roots, which enclose the optic canal, *canalis opticus*. The superior surface of the wing is directed to the cranial cavity, the inferior surface is directed to the orbit. The anterior serrated margin joins with the frontal bone, the posterior smooth margin freely protrudes into the cranial cavity forming prominences named the anterior clinoid processes, *processus clinoidei anteriores*.

The greater wing, *ala major*, starts with a wide base from the lateral surface of the body; there are three openings in the base: the foramen rotundum, *foramen rotundum*, the foramen ovale, *foramen ovale*, and the foramen spinosum, *foramen spinosum*. The second and third branches of the V pair of cranial nerves (*n. trigeminus*) leave the cranial cavity trough the foramen ovale and foramen spinosum respectively, the middle meningeal artery passes trough the foramen spinosum.

The greater wing has five surfaces. The cerebral surface, *facies cerebralis*, is concave and is directed to the cranial cavity. The digitate impressions, *impressiones digitatae*, which alternate with the cerebral ridges, *juga cerebralia*, are visible on this surface. The orbital surface, *facies orbitalis*, is a quadrangular smooth area and is directed forwards and medially; it is a part of the lateral wall of the orbit. The temporal surface, *facies temporalis*, is extensive and is located almost vertically; it is a part of the temporal surface. Inferiorly the temporal surface is separated from the infratemporal surface, *facies infratemporalis*, by the infratemporal crest, *crista infratemporalis*. The infratemporal surface is located horizontally and it forms one of the infratemporal fossa`s walls. The maxillary surface, *facies maxillaris*, is directed to the side of the maxillary tuberosity.

The posterior margin of the greater wing is serrated, it is termed the squamous margin, *margo squamosus*, and it is connected with the squamous part of the temporal bone. The anterior — zygomatic margin, *margo zygomaticus*, — is significantly shorter than the posterior margin; it articulates with the zygomatic bone and separates the temporal surface from the orbital one. The superior margin is divided into two parts: the anterior part, which is named the frontal margin, *margo frontalis*, and posterior part, which is named the parietal margin, *margo parietalis*. The frontal margin joins with the frontal bone, and the parietal margin joins with the parietal bone.

The pterygoid process, *processus pterygoideus*, is paired, it projects vertically and downwards from the body starting from the beginning of the greater wings (fig. 3.6, 3.7). The base of each process is perforated by the pterygoid canal, *canalis pterygoideus*, which passes horizontally. The pterygoid process consists of two plates: medial and lateral, *lamina medialis et lamina lateralis*. Anteriorly these plates are fused together, but posteriorly they diverge and bound the pterygoid fossa, *fossa pterygoidea*, — below, and the scaphoid fossa, *fossa scaphoidea*, — above. Inferiorly the medial plate terminates with a process which is curved like a hook that is named the pterygoid hamulus, *hamulus*

pterygoideus. The greater palatine groove, *sulcus palatinus major*, runs along the anterior edge of the pterygoid process. The medial surface of the pterygoid process is directed to the nasal cavity, and the lateral surface is directed to the infratemporal fossa.

According to development, the sphenoid is a mixed bone: the medial plate of the pterygoid process (except the pterygoid hamulus), the lateral part of the greater wing and the sphenoidal conchae pass through two stages of development and are formed on the basis of connective tissue (the primary bones), other parts pass through three stages of development and are formed on the base of cartilage.

Anomalies and variations of sphenoid bone development:

— the anterior and posterior halves of the sphenoid body may be not fused with each other; as a result, the narrow canal named the craniopharyngeal canal, *canalis cranio-pharyngeus*, is formed in the center of the sella turcica;

— the foramen ovale and foramen spinosum can merge into one single opening.

Parietal Bone

The parietal bone, *os parietale*, (fig. 3.8) is paired, participates in formation of the skullcap and resembles a curved quadrangular plate by shape. It has four borders, four angles and also the external and internal surfaces.

Three borders are serrated, the fourth one (inferior) is sharp. The superior sagittal border, *margo sagittalis*, is connected with the same border of the opposite parietal bone along the midline. The anterior border — frontal, *margo frontalis*, — is connected with the squamous part of the frontal bone; it converges with the sagittal border forming a right angle. The occipital border, *margo occipitalis*, forms with the sagittal border an obtuse angle and joins with the squamous part of the occipital bone. The anterior part of the squamosal border, *margo squamosus*, is covered by the sphenoid`s greater wing, and the middle part is covered by the squamous part of the temporal bone. The posterior part of the squamous border joins with the mastoid part of the temporal bone.

The following angles are distinguished in the parietal bone: the frontal angle, *angulus frontalis*, is anterosuperior; the occipital angle, *angulus occipitalis*, is posterosuperior; the shenoidal angle, *angulus sphenoidalis*, is anteroinferior; the mastoid angle, *angulus mastoideus*, is posteroinferior.

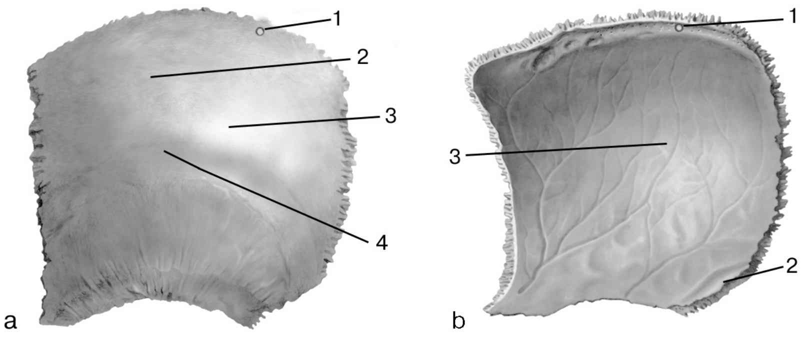

Fig. 3.8. Parietal bone:

a — external surface: 1 — parietal foramen (*foramen parietale*); 2 — external surface (*facies externa*); 3 — parietal tuber (*tuber parietale*); 4 — superior temporal line (*linea temporalis superior*)

b — internal surface: 1 — groove for superior sagittal sinus (*sulcus sinus sagittals superioris*); 2 — groove for sigmoid sinus (*sulcus sinus sigmoidei*); 3 — internal surface (*facies interna*)

There is a broad prominence named the parietal tuber, *tuber parietale*, on the external convex surface. A rough inferior temporal line, *linea temporalis inferior*, runs parallelly to the inferior border, and above it there is a superior temporal line, *linea temporalis superior*.

The internal surface, *facies interna*, is concave. The arterial grooves, digitate impressions, *impressiones digitatae*, cerebral ridges, *juga cerebralia*, and granular foveolae, *foveolae granulares*, are pronounced on this surface. The clearest arterial groove is the groove for middle meningeal artery, *sulcus arteriae meningeae mediae*. Besides, on the internal surface there are two grooves corresponding to the venous sinuses of the dura mater of the brain. The first groove runs along the superior border and, together with the same groove of the opposite parietal bone, they form the groove for superior sagittal sinus, *sulcus sinus sagittalis superioris*. The second groove named the groove for sigmoid sinus, *sulcus sinus sigmoidei*, is in the region of the mastoid angle. There is the parietal foramen, *foramen parietale*, near the sagittal border closer to the occipital angle. The emissary vein passes trough it.

According to development, the parietal bone is primary i.e. passes trough two stages of development and is formed on the basis of connective tissue.

Variations of parietal bone development:

— presence of the superior and inferior halves of the parietal bone;
— significant manifestation of the parietal tuber.

Temporal Bone

The temporal bone, *os temporale* (fig. 3.9), is paired and located between the occipital and sphenoid bones. The temporal bone forms the part of the skull base and skull cap, it participates in formation of the temporomandibular joint and articulates with the zygomatic bone. It contains the organs of hearing and balance (the vestibulocochlear organ); very important vessels and nerves pass through the temporal bone. It is the most complicated bone. It consists of four parts: petrous, *pars petrosa*; tympanic, *pars tympanica*; mastoid, *pars mastoidea*, and squamous, *pars squamosa seu squama*.

The petrous part, *pars petrosa*, has a shape of a trihedral pyramid that is why it is also called pyramid, *pyramis* (fig. 3.10). The pyramid has three surfaces, three borders, the base and the apex. The anterior and posterior surfaces are directed to the cranial cavity, and the inferior surface is directed outwards. From the three borders (anterior, posterior and superior), only the superior border is directed to the cranial cavity. The anterior border, *margo anterior*, is on the lateral side of the apex. The base of the pyramid, *basis partis petrosae*, is fused with the mastoid and squamous parts, and it is covered with the tympanic part.

The apex of the petrous part, *apex partis petrosae*, is directed forwards and medially. The internal opening of the carotid canal, *apertura interna canalis carotici*, and the musculotubal canal, *canalis musculotubarius*, open here.

The anterior surface, *facies anterior*, is separated from the squamous part by the petrosquamous fissure, *fissura petrosquamosa*. There is the trigeminal impression, *impressio trigeminalis*, at the apex of the pyramid; the trigeminal ganglion lies here. Behind the trigeminal impression and laterally from it there are two small openings named the hiatus for greater petrosal nerve and the hiatus for lesser petrosal nerve, *hiatus canalis nervi petrosi majoris et hiatus canalis nervi petrosi minoris*. They continue into the grooves called the groove for greater petrosal nerve and the groove for lesser petrosal nerve, *sulcus nervi petrosi majoris et sulcus nervi petrosi minoris*. In the midst of the anterior surface there is

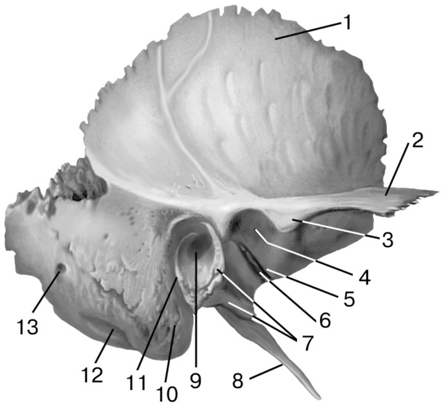

Fig. 3.9. Right temporal bone (lateral aspect):

1 — squamous part (*pars squamosa*); 2 — zygomatic process (*processus zygomaticus*); 3 — articular tubercle (*tuberculum articulare*); 4 — mandibular fossa (*fossa mandibularis*); 5 — petrosquamous fissure (*fissura petrosquamosa*); 6 — petrotympanic fissure (*fissura petrotympanica*); 7 — tympanic part (*pars tympanica*); 8 — styloid process (*processus styloideus*); 9 — external acoustic porus (*porus acusticus externus*); 10 — mastoid process (*processus mastoideus*); 11 — tympanomastoid fissure (*fissura tympanomastoidea*); 12 — mastoid notch (*incisura mastoidea*); 13 — mastoid foramen (*foramen mastoideum*)

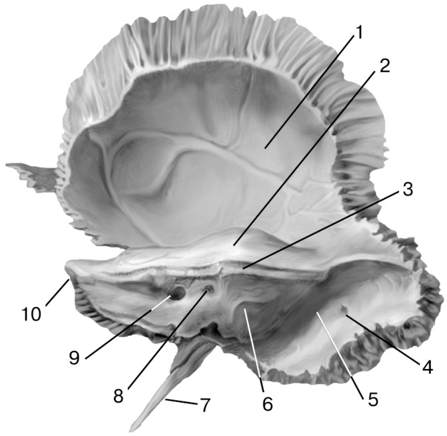

Fig. 3.10. Right temporal bone (medial aspect):

1 — cerebral surface (*facies cerebralis*); 2 — arcuate eminence (*eminentia arcuata*); 3 — groove for superior petrosal sinus (*sulcus sinus petrosi superioris*); 4 — mastoid foramen (*foramen mastoideum*); 5 — groove for sigmoid sinus (*sulcus sinus sigmoidei*); 6 — opening of vestibular canaliculus (*apertura canaliculi vestibuli*); 7 — styloid process (*processus styloideus*); 8 — subarcuate fossa (*fossa subarcuata*); 9 — external acoustic porus (*porus acusticus externus*); 10 — apex of petrosal part (*apex partis petrosae*)

an arcuate eminence, *eminentia arcuata*, which corresponds to the anterior semicircular canal of the inner ear located inside the pyramid. The part of the anterior surface between *eminentia arcuata* and *fissura petrosquamosa* is called the tegmen tympani, *tegmen tympani*. The anterior surface is separated from the posterior surface by the superior border, *margo superior*; a slight groove for superior petrosal sinus, *sulcus sinus petrosi superioris*, passes along this border.

On the posterior surface, *facies posterior*, there is a rather big internal acoustic opening, *porus acusticus internus*, which leads into the short internal acoustic meatus, *meatus acusticus internus*. The facial nerve, *n. facialis* (VII pair), enters this meatus, and the vestibulocohlear nerve, *n. vestibulocochlearis* (VIII pair) runs out of it. A subarcuate fossa, *fossa subarcuata*, is located above *porus acusticus internus* and laterally from it. The process of the dura mater enters this fossa. Below the subarcuate fossa and laterally from it we can see a small fissure named the opening of vestibular canaliculus, *apertura canaliculi vestibuli*. It is the external opening of vestibular canaliculus, *canaliculus vestibuli,* which serves for drain of endolymph from the inner ear to the endolymphatic sac located on the posterior surface of the pyramid in the splitting of the dura mater.

The groove for inferior petrosal sinus, *sulcus sinus petrosi inferioris*, runs along the posterior border, *margo posterior*, closer to the apex of the pyramid. At the lateral end of this groove there is an opening of the cochlear canaliculus, *apertura canaliculi cochleae*. It is the external opening of the cochlear canaliculus, *canaliculus cochleae,* which serves

for drain of perilymph from the inner ear to the subarachnoid space. The posterior border separates the posterior and inferior surfaces from each other.

On the rough inferior surface, *facies inferior*, closer to the base we can find a rather big jugular fossa, *fossa jugularis* (fig. 3.11). In front of it there is an external opening of carotid canal, *apertura externa canalis carotici*, having a round

shape and big size, leading into the carotid canal, *canalis caroticus*, which contains the internal carotid artery.

The petrosal fossula, *fossula petrosa*, is in the crest separating the external opening of carotid canal from the jugular fossa; this fossula is so small, that it is hard to notice it. On the bottom of the petrosal fossula the inferior opening of tympanic canaliculus, *apertura inferior canaliculi tympanici*, is located. Behind *fossa jugularis* and laterally from it there is a stylomastoid foramen, *foramen stylomastoideum*. It has such name because it is located between the styloid, *processus styloideus*, and mastoid, *processus mastoideus*, processes.

The tympanic part, *pars tympanica*, is a slightly concave plate, which is closely connected with the other parts of the temporal bone and which forms the wall of the bony part of the external acoustic meatus. The tympanic part bounds the external acoustic opening, *porus acusticus externus*, anteriorly, inferiorly and posteriorly. The external acoustic opening leads into the external acoustic meatus, *meatus acusticus externus*. The latter opens into the tympanic cavity, *cavitas tympani*. The tympanic part is separated from the mastoid part by the tympanomastoid fissure, *fissura tympanomastoidea*, and from the squamous part — by the tympanosquamous fissure, *fissura tympanosquamosa*. The piece of the petrous part, *pars petrosa*, wedges into this fissure and divides the almost whole fissure into the petrosquamous fissure, *fissura petrosquamosa*, and the petrotympanic fissure, *fissura petrotympanica*. The branch of the facial nerve — the chorda tympani, *chorda tympani*, — runs from the tympanic cavity trough the petrotympanic fissure.

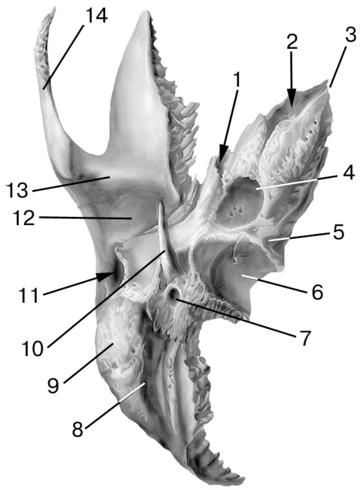

Fig. 3.11. Right temporal bone (inferior aspect):

1 — musculotubal canal (*canalis musculotubarius*); 2 — internal opening of carotid canal (*apertura interna canalis carotici*); 3 — apex of petrosal part (*apex parties petrosae*); 4 — external opening of carotid canal (*apertura externa canalis carotici*); 5 — opening of cochlear canaliculus (*apertura canaliculi cochleae*); 6 — jugular fossa (*fossa jugularis*); 7 — stylomastoid foramen (*foramen stylomastoideum*); 8 — mastoid notch (*incisura mastoidea*); 9 — mastoid process (*processus mastoideus*); 10 — styloid process (*processus stylodeus*); 11 — external acoustic porus (*porus acusticus externus*); 12 — mandibular fossa (*fossa mandibularis*); 13 — articular tubercle (*tuberculum articulare*); 14 — zygomatic process (*processus zygomaticus*)

The mastoid part, *pars mastoidea*, occupies the largest part of the temporal bone`s external surface, and it is located posteriorly from the external acoustic meatus. Its basis is the mastoid process, *processus mastoideus*. The squamous and mastoid parts are separated from each other by the parietal notch, *incisura parietalis*; the mastoid angle of the parietal bone enters into this notch. Posteriorly from the mastoid part there is the squamous part of the occipital bone. The external surface of the mastoid process is rough because of attachment of the muscles. Medially from the mastoid process a deep mastoid notch, *incisura mastoidea*, is visible. The occipital groove, *sulcus arteriae occipitalis*, is between the mastoid notch and the edge of the mastoid part. Quite often, we can see the mastoid foramen, *foramen mastoideum*, on the

posterior surface of the mastoid process. As usual, the mastoid foramen opens into the groove for sigmoid sinus, *sulcus sinus sigmoidei*, and it serves for passage of the emissary vein.

The mastoid cells, *cellulae mastoideae*, can be seen on the sections of the mastoid process. Anteriorly the osseous septa, which separate the mastoid cells from each other disappear, and, as a result, quite a large cavity known as the mastoid antrum, *antrum mastoideum*, is formed. The mastoid antrum is connected with the tympanic cavity.

The squamous part, *pars squamosa* (*squama temporalis*), is a semicircular vertical plate, which is almost entirely included into the skull cap. Its free border is sharp, it covers the corresponding parts of the parietal bone and the greater wing of sphenoid bone. Inferiorly the squamous part joins with the pyramid and mastoid part and also with the border of the tympanic part. Two surfaces are distinguished in the squamous part: internal — cerebral, *facies cerebralis*, and external — temporal, *facies temporalis*.

There are digitate impressions, cerebral ridges and also arterial grooves on the cerebral surface. The temporal surface is smooth. It takes part in formation of the temporal fossa. The zygomatic process, *processus zygomaticus*, protrudes from the temporal surface upwards and forwards to articulate with the zygomatic bone. At the beginning of the zygomatic process there is a mandibular fossa, *fossa mandibularis*, which serves for articulation with the mandible. The articular tubercle, *tuberculum articulare*, is in front of the mandibular fossa.

The canals of temporal bone

The pyramid of temporal bone is perforated with the canals which mainly contain vessels and nerves.

The carotid canal, *canalis caroticus*, starts with the external opening of the carotid canal on the inferior surface of the pyramid of temporal bone. Within the pyramid, the canal makes a turn approximately at a right angle, then it runs to the apex of the pyramid, and there it ends with the internal opening of carotid canal. The internal carotid artery passes through this canal. In the wall of the carotid canal, near its external opening, there are two small openings. They continue into the thin carotycotympanic canaliculi, *canaliculi caroticotympanici*, running into the tympanic cavity.

The facial nerve canal, *canalis nervi facialis*, starts on the bottom of the internal acoustic meatus and is directed perpendicularly to the axis of the pyramid. It makes a turn backwards and laterally at a right angle near the hiatus for greater petrosal nerve, *hiatus canalis nervi petrosi majoris*. This first turn is called the geniculum of facial nerve canal, *geniculum canalis nervi facialis*. Topographically, the location of the horizontal part of the carotid canal corresponds to the border between the tegmen tympani and the labyrinthine wall of the tympanic cavity. At the posterior wall of the tympanic cavity, the carotid canal makes a turn with a change of the horizontal direction to the vertical direction; and it ends with the stylomastoid foramen on the inferior surface of the pyramid. The two branches start from the carotid canal; they can be considered as the canals.

The greater petrosal nerve canal, *canalis nervi petrosi majoris*, starts from the facial nerve canal in the region of its geniculum and ends with a fissure termed the hiatus for greater petrosal nerve, *hiatus canalis nervi petrosi majoris*, on the anterior surface of the pyramid of temporal bone.

The canaliculus of chorda tympani, *canaliculus chordae tympani*, starts from the facial nerve canal immediately before its exit from the pyramid. It passes trough the tympanic cavity and opens into the petrotympanic fissure, *fissura petrotympanica*.

The musculotubal canal, *canalis musculotubarius*, is located in the place where the pyramid joins with the squamous part of the temporal bone. It consists of two parts — semicanals: lower — the canal for auditory tube, *semicanalis tubae auditivae*, and upper — the canal for tensor tympani, *semicanalis musculi tensoris tympani*. The first canal is the part of the auditory tube which connects the tympanic cavity with the nasopharynx. The second canal contains the tensor tympani. These canals are separated by the thin osseous plate named the septum of the musculotubal canal, *septum canalis musculotubarii*.

The tympanic canaliculus, *canaliculus tympanicus*, is very narrow. It starts in the petrosal fossula (in the crest which separates the external opening of the carotid canal from the jugular fossa) and terminates with the hiatus for lesser petrosal nerve, *hiatus canalis nervi petrosi minoris*, on the anterior surface of the pyramid.

The mastoid canaliculus, *canaliculus mastoideus*, starts with the small opening in the anterior part of the jugular fossa, runs to the tympanomastoid fissura, and ends with the opening of mastoid canaliculus, *foramen canaliculi mastoidei*, in this fissure.

According to development, the temporal bone is mixed: the mastoid and petrous part*s* pass through three stages of development and are formed on the basis of cartilage (secondary); the squamous and tympanic parts pass through two stages of development and are formed on the basis of connective tissue (primary).

The canals of the temporal bone (except the musculotubal canal) serve for passage of vessels and nerves.

Variations of temporal bone development:

— the jugular notch can be divided into two parts by the interjugular process; if the occipital bone has this process, the double jugular foramen may be formed;

— the styloid process is not fused with the temporal bone; it may be absent; it can be enlarged and even can reach the hyoid bone, especially, in case of stylohyoid ligament synostosis.

3.4. Bones of viscerocranium (facial bones)

Maxilla

The maxilla, *maxilla* (fig. 3.12), occupies the significant part of the viscerocranium. It participates in formation of the walls of the nasal cavity, orbits, oral cavity and the infratemporal and pterygopalatine fossae. The maxilla consists of the body and four processes: frontal, *processus frontalis*; zygomatic, *processus zygomaticus*; alveolar, *processus alveolaris*, and palatine, *processus palatinus*, processes.

The body of maxilla, *corpus maxillae*, has a rather big cavity called the maxillary sinus, *sinus maxillaris* (Highmore` s antrum, *sinus Highmori*). Four surfaces are distinguished on the body: anterior, *facies anterior*; infratemporal, *facies infratemporalis*; orbital, *facies orbitalis*, and nasal, *facies nasalis*, surfaces.

The anterior (facial) surface, *facies anterior*, is separated from the infratemporal surface by the zygomatic process, and from the orbital surface — by the infra-orbital margin, *margo infraorbitalis*. Below it there is an infra-orbital foramen, *foramen infraorbitale*, for passage of nerve and vessels. A depression termed canine fossa, *fossa canina*, is on the anterior surface. The medial border is between the anterior and nasal surfaces, it is concave because of the nasal notch, *incisura nasalis*. The nasal notches of the right and left maxillae take part in formation of the piriform aperture, *apertura piriformis*.

The infratemporal surface is convex due to the maxillary tuberosity, *tuber maxillae*, that is directed backwards. On the maxillary tuberosity there are several small open-

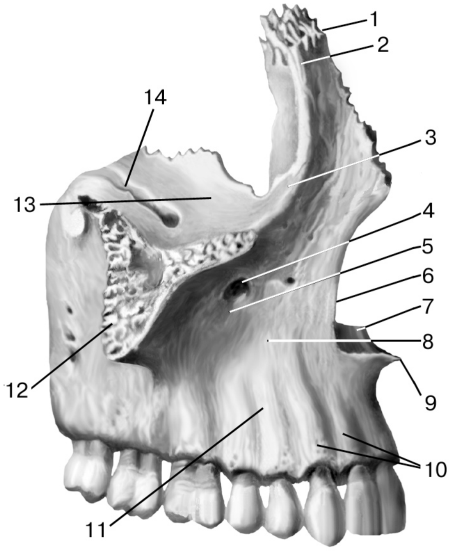

Fig. 3.12. Right maxilla (lateral aspect):

1 — frontal process (*processus frontalis*); 2 — anterior lacrimal crest (*crista lacrimalis anterior*); 3 — infraorbital margin (*margo infraorbitalis*); 4 — infraorbital foramen (*foramen infraorbitale*); 5 — canine fossa (*fossa canina*); 6 — nasal notch (*incisura nasalis*); 7 — palatine process (*processus palatinus*); 8 — anterior surface (*facies anterior*); 9 — anterior nasal spine (*spina nasalis anterior*); 10 — alveolar yokes (*juga alveolaria*); 11 — alveolar process (*processus alveolaris*); 12 — zygomatic process (*processus zygomaticus*); 13 — orbital surface (*facies orbitalis*); 14 — infraorbital groove (*sulcus infraorbitalis*)

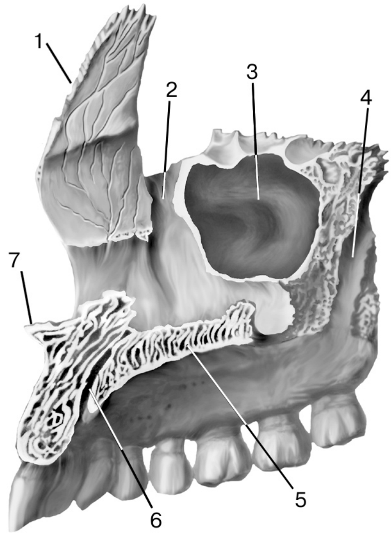

Fig. 3.13. Right maxilla (medial aspect):

1 — frontal process (*processus frontalis*); 2 — lacrimal groove (*sulcus lacrimalis*); 3 — maxillary hiatus (*hiatus maxillaris*); 4 — greater palatine groove (*sulcus palatinus major*); 5 — palatine process (*processus palatinus*); 6 — incisive canal (*canalis incisivus*); 7 — anterior nasal spine (*spina nasalis anterior*)

ings named the alveolar foramina, *foramina alveolaria*, through which vessels and nerves reach the superior molar teeth. Not a very big greater palatine groove, *sulcus palatinus major*, passes in the area of the medial edge of the maxillary tuberosity.

The orbital surface is a smooth triangular area, which forms a part of the orbit`s inferior wall. Its medial edge joins to the lacrimal bone and to the orbital plate of the ethmoid bone. Its anterior edge ajoins the anterior surface of the maxilla. The infaorbital groove, *sulcus infraorbitalis*, starts in the region of the posterior edge; anteriorly it continues into the infraorbital canal, *canalis infraorbitalis*, which opens with the infraorbital foramen on the anterior surface of the maxilla. The alveolar canals, *canales alveolares*, containing the vessels and nerves, run from the infraorbital canal to the anterior superior teeth.

The nasal surface takes part in formation of the nasal cavity`s lateral wall. On this surface we can see a big irregular-shaped opening termed the maxillary hiatus, *hiatus maxillaris*, which leads into the Highmore`s antrum (fig. 3.13). On the whole skull the maxillary hiatus is partially covered with the palatine and ethmoid bones and also by the inferior nasal concha. The lacrimal groove, *sulcus lacrimalis*, descends between the edge of the maxillary sinus and the posterior edge of the frontal process. In front of the lacrimal groove there is a conchal crest, *crista conchalis*, to which the anterior end of the inferior nasal concha is attached.

The frontal process, *processus frontalis*, rises vertically from the angle where the anterior, nasal and orbital surfaces of the maxilla`s body converge. The superior end of the frontal process reaches the nasal part of the frontal bone. Along the anterior surface of the frontal process, the anterior lacrimal crest, *crista lacrimalis anterior*, descends. It continues into the infra-orbital margin which bounds the lacrimal groove together with the posterior part of the frontal process. On the medial surface of the frontal process there is an ethmoidal crest, *crista ethmoidalis*, which is the place for additional fixation of the middle nasal concha. The ethmoidal crest is parallel to the conchal crest.

The zygomatic process, *processus zygomaticus*, starts from the place where the orbital, anterior and infratemporal surfaces of the maxilla`s body are connected. It is wide and short and has a serrated surface to articulate with the zygomatic bone.

The alveolar process, *processus alveolaris*, is the continuation of the maxilla`s body and is located below it. The free inferior edge of this process forms an alveolar arch, *arcus alveolaris*, which has pits named the dental alveoli, *alveoli dentales*, containing the roots of teeth. The dental alveoli are separated from each other by the interalveolar septa, *septa interalveolaria*. There are alveolar yokes, *juga alveolaria*, corresponding to the each individual alveola on the external surface of the alveolar process.

The palatine process, *processus palatinus*, has a shape of a horizontal plate. It starts from the nasal surface of the body at the place, where the body continues into the alveolar process. When the right and left palatine processes join with each other, they form the anterior part of the bony (hard) palate. The posterior edges of the palatine processes join with the horizontal plates of the palatine bones.

When the palatine processes of both maxillae join with each other, the incisive canal, *canalis incisivus*, is formed in the anterior part of these processes behind the anterior teeth.

According to development, the maxilla is primary: it passes trough two stages of development and is formed on the basis of connective tissue.

Variations of maxilla development:

— variability of the maxillary sinus in size and shape;

— underdevelopment of the palatine process; combination of underdevelopment of the palatine process with a defect in the horizontal plate of the palatine bone is known as cleft palate, *faux lupina seu palatum fissum*.

— variable number and shape of dental alveoli;

— presence of an additional incisive bone in the area of the incisive foramen.

Palatine Bone

The palatine bone, *os palatinum* (fig. 3.14), takes part in formation of the nasal cavity, oral cavity, orbit and pterygopalatine fossa. It consists of two plates, which are connected with each other at a right angle.

The horizontal plate, *lamina horizontalis*, is quadrangular; its anterior edge joins with the posterior edge of the maxilla`s palatine process. The horizontal plates of the right and left palatine bones participate in formation of the hard palate.

The perpendicular plate, *lamina perpendicularis*, is narrower and longer than the horizontal one. It has nasal and maxillary surfaces, *facies nasalis et facies maxillaris*. The nasal surface is the part of the nasal cavity`s lateral wall. The greater palatine groove, *sulcus palatinus major*, runs along the posterior edge of the perpendicular plate; it participates in formation of the greater palatine canal. Two crests can be seen on the nasal surface: the conchal crest, *crista conchalis*, to which the inferior nasal concha is attached, and the ethmoidal crest, *crista ethmoidalis*, to which the middle nasal concha is attached.

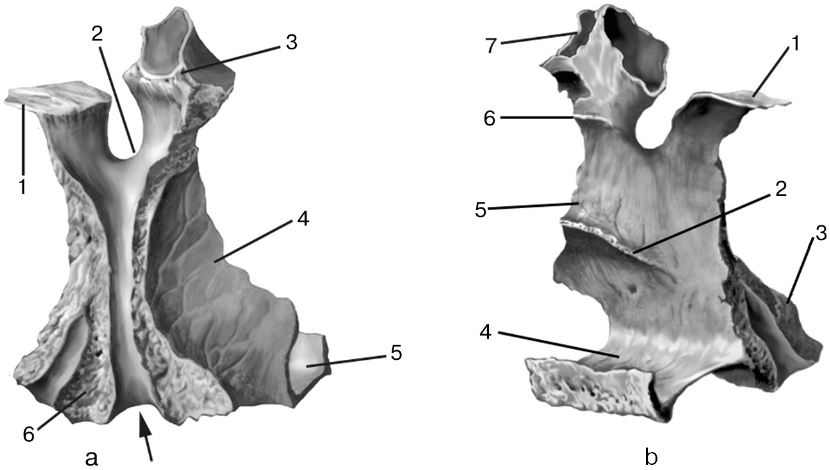

Fig. 3.14. Right palatine bone:

a — external aspect: 1 — sphenoidal process (*processus sphenoidalis*); 2 — sphenopalatine notch (*incisura sphenopalatina*); 3 — orbital process (*processus orbitalis*); 4 — perpendicular plate (*lamina perpendicularis*); 5 — horizontal plate (*lamina horizontalis*); 6 — pyramidal process (*processus pyramidalis*)

b — internal aspect: 1 — sphenoidal process (*processus sphenoidalis*); 2 — conchal crest (*crista conchalis*); 3 — pyramidal process (*processus pyramidalis*); 4 — horizontal plate (*lamina horizontalis*); 5 — perpendicular plate (*lamina perpendicularis*); 6 — ethmoidal crest (*crista ethmoidalis*); 7 — orbital process (*processus orbitalis*)

The palatine bone has three processes: pyramidal, orbital and sphenoidal processes.

The pyramidal process, *processus pyramidalis*, descends slightly laterally from the junction of the perpendicular and horizontal plates. It enters between two plates of the sphenoid`s pterygoid process. Two other processes of the palatine bone project from the superior edge of the perpendicular plate. The orbital process, *processus orbitalis*, is in front of the sphenoidal process and is directed laterally. It joins with the orbital surface of the maxilla and takes part in formation of the orbit`s inferior wall. The sphenoidal process, *processus sphenoidalis*, adjoins the inferior surface of the sphenoid`s body. The sphenopalatine notch, *incisura sphenopalatina*, is between the orbital and sphenoidal processes. When the palatine bone joins with the sphenoid bone, this notch forms an opening called the sphenopalatine foramen, *foramen sphenopalatinum*.

According to development, the palatine bone is primary: it passes through two stages of development and is formed on the basis of connective tissue.

Variations of palatine bone development:

— variable shape and size of the palatine bone, especially of its processes;

— underdevelopment of the horizontal plate (formation of cleft palate).

Zygomatic Bone

The zygomatic bone, *os zygomaticum* (fig. 3.15), connects the maxilla with the temporal bone, thus forming the zygomatic arch, *arcus zygomaticus*. The zygomatic bone forms part of the walls of the orbit, temporal and infratemporal fossae; it plays a great role in strong connection between the viscerocranium and the neurocranium. In the horizontal direction it connects the maxilla with the temporal bone; and in the vertical direction it connects the frontal bone with the sphenoid bone. Therefore, the zygomatic bone is composed of two plates: buccal and orbital.

These plates are connected at an angle; its acute edge forms the major part of the infra-orbital margin, *margo infraorbitalis*. The buccal surface is quadrangular and much bigger than the orbital one. It has two surfaces: lateral, *facies lateralis*, directed forwards and laterally, and temporal, *facies temporalis*, directed to the side of the temporal and infratemporal fossae. There is the marginal tubercle, *tuberculum marginale*, in the anteroinferior part of the lateral surface. The orbital plate has concave orbital surface, *facies orbitalis*, and forms a part of the orbit`s inferior and lateral walls. On this surface there is a small zygomaticoorbital foramen, *foramen zygomaticoorbitale*; it leads into the canal which is bifurcated within the zygomatic bone. This canal opens with the zygomaticofacial foramen, *foramen zygomaticofaciale*, on the lateral surface of the zygomatic bone, and with the zygomaticotemporal foramen, *foramen zygomaticotemporale*, on the temporal surface.

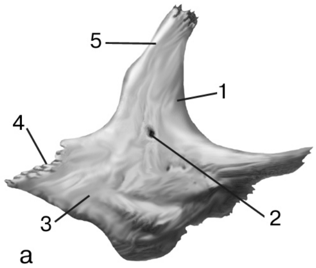

Fig. 3.15. Zygomatic bone:

1 — infraorbital surface (*facies infraorbitalis*); 2 — zygomaticofacial foramen (*foramen zygomaticofaciale*); 3 — lateral surface (*facies lateralis*); 4 — temporal process (*processus temporalis*); 5 — frontal process (*processus frontalis*)

The zygomatic bone has two processes: temporal, *processus temporalis*, which is connected with the zygomatic process of the temporal bone, and frontal, *processus frontalis*, which reaches the zygomatic process of the frontal bone; the posterior edge of the frontal process adjoins the sphenoid`s greater wing. Also the wide serrated surface of the zygomatic bone is connected with the zygomatic process of the maxilla.

According to development, the zygomatic bone is primary: it passes through two stages of development and is formed on the basis of connective tissue.

Variations of zygomatic bone development:

— the bone can be divided into two parts by the horizontal suture;

— variable number of canals which pass within the bone (some of them may be absent or change their location);

— rudimentary development of the bone; in this case, the zygomatic arch is not closed, i.e. the zygomatic bone is not articulated with the temporal bone.

Nasal Bone

The nasal bone, *os nasale* (fig. 3.16), is paired, it takes part in formation of the dorsum of nose. Its medial edge joins with the same bone of opposite side. The nasal bone is a quadrangular plate. Its lateral edge is connected with the frontal process of the maxilla, its superior edge is connected with the nasal part of the frontal bone. Its inferior edge, together with the nasal notch of the maxilla, bound the piriform aperture. The nasal bone is perforated by the nasal foramen, *foramen nasale*, which serves for passage of vessels.

According to development, the nasal bone is primary: it passes through two stages of development and is formed on the basis of connective tissue.

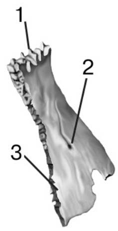

Fig.3.16. Nasal bone:

1 — superior margin (*margo superior*); 2 — nasal foramen (*foramen nasale*); 3 — lateral margin (*margo lateralis*)

Variations of nasal bone development:

— variable shape and size of the bone;

— absence of the bone: in this case, the nasal bone is

replaced by the frontal process of the maxilla and by the nasal part of the frontal bone;
— right and left nasal bones may fuse into a single nasal bone.

Lacrimal Bone

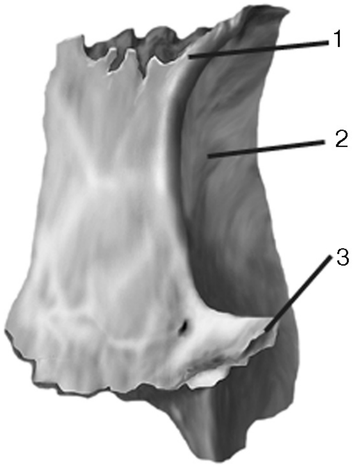

Fig. 3.17.Lacrimal bone:

1 — posterior lacrimal crest (*crista lacrimalis posterior*); 2 — lacrimal groove (*sulcus lacrimalis*); 3 — lacrimal hamulus (*hamulus lacrimalis*)

The lacrimal bone, *os lacrimale*, is quadrangular, and it is the smallest of all bones of the skull (fig. 3.17). Anteriorly it ajoins the frontal process of the maxilla, posteriorly — the orbital plate of the palatine bone, superiorly — the orbital part of the frontal bone, and inferiorly — the orbital surface of the maxilla. Its medial surface covers a part of the ethmoidal cells, and the lateral surface is directed to the orbit. The posterior lacrimal crest, *crista lacrimalis posterior*, runs vertically along the lateral surface and inferiorly it ends with the lacrimal hamulus, *hamulus lacrimalis*. In front of the crest there is the lacrimal groove, *sulcus lacrimalis*. The latter, together with the lacrimal groove of the maxilla, forms the fossa for lacrimal sac, *fossa sacci lacrimalis*, which continues into the nasolacrimal canal, *canalis nasolacrimalis*.

According to development, the lacrimal bone is primary: it passes through two stages of development and is formed on the basis of connective tissue.

Variations of lacrimal bone development:

— variable shape and size of the bone;
— absence of the bone: it is replaced by the orbital plate of the ethmoid bone or by the frontal process of the maxilla.

Inferior Nasal Concha

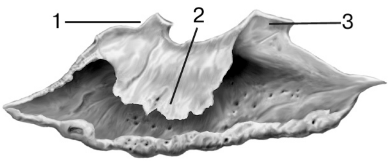

Fig. 3.18. Inferior nasal concha:

1 — ethmoidal process (*processus ethmoidalis*); 2 — maxillary process (*processus maxillaris*); 3 — lacrimal process (*processus lacrimalis*)

The inferior nasal concha, *concha nasalis inferior* (fig. 3.18) is an individual bone; it looks like an elongated plate. Its medial surface is convex and the lateral one is concave. Its superior edge is attached to the palatine bone and to the conchal crest of the maxilla.

The inferior nasal concha has three processes: the lacrimal process, *processus lacrimalis*, which is directed upwards and reaches the inferior edge of the lacrimal bone; the maxillary process, *processus maxillaris*, which is directed downwards and partially closes the maxillary hiatus; the ethmoidal process, *processus ethmoidalis*, which is connected with the uncinate process of the ethmoid bone.

According to development, the inferior nasal concha is secondary; it passes through three stages of development and is formed on the basis of cartilage.

Variations of development of inferior nasal concha:

— variable shape and size of the bone;
— variable shape and size of the bone's processes.

Vomer

The vomer, *vomer* (fig. 3.19), is an unpaired thin quadrangular plate which participates in formation of the nasal septum. The superior edge of the vomer diverges into two wings called the alae of vomer, *alae vomeris*, which adjoin the inferior surface of the sphenoid bone body and embrace the sphenoidal rostrum. The posterior surface of the vomer is free; it divides the posterior nasal aperture into the right and left choanae. The inferior edge of the vomer joins with the nasal crest of the maxilla and the palatine bone. The anterior edge is the longest, it is connected with the perpendicular plate of the ethmoid bone superiorly, and with the cartilage of the nasal septum inferiorly.

According to development, the vomer is a primary bone: it passes through two stages of development and is formed on the basis of connective tissue.

Variations of vomer development: it can deviate to the right or to the left.

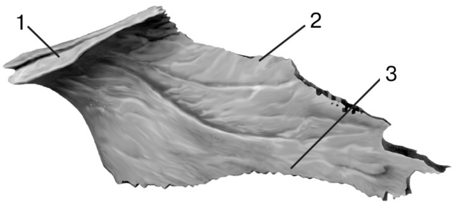

Fig. 3.19. Vomer:
1 — alae of vomer (*alae vomeris*); 2 — anterior margin (*margo anterior*); 3 — inferior margin (*margo inferior*)

Mandible

The mandible, *mandibula* (fig. 3.20, 3.21), is a big unpaired bone. It articulates with both temporal bones forming the paired temporomandibular joints. It consists of the body and two rami.

The body of mandible, *corpus mandibulae*, is like a horseshoe; it has the internal and external surfaces and also two edges. The inferior edge is rounded; it is the base of mandible, *basis mandibulae*. The superior edge forms the alveolar arch, *arcus alveolaris*. Here we can see depressions named dental alveoli, *alveoli dentales*, for 16 teeth; the dental alveoli are separated from each other by the interalveolar septa, *septa interalveolaria*.

In the middle of the external surface between the right and left halves there is the mental protuberance, *protuberantia mentalis*, which gradually widens downwards and terminates with the paired mental tubercle, *tuberculum mentale*. On the right and on the left sides behind the mental tubercle at the level of the second premolar tooth there is the mental foramen, *foramen mentale*, which transmits the mental vessels and nerve.

The mental spine, *spina mentalis*, protrudes from the internal surface on the curved place of the body. On the sides of the mental spine, closer to the dental alveoli there is a paired depression named the sublingual fossa, *fovea sublingualis*, for the sublingual gland. A shallow digastric fossa, *fossa digastrica*, is located at the inferior edge of the body on both sides of the midline. On the internal surface there is the mylohyoid line, *linea mylohyoidea*, to which the mylohyoid muscle is attached. Under this line at the level

of the molar teeth the submandibular fossa, *fovea submandibularis*, can be found. The submandibular gland lies in this fossa.

The rami of mandible, *rami mandibulae,* ascend from the body at an obtuse angle. They have the external and internal surfaces and also the anterior and posterior edges. The angle of mandible, *angulus mandibulae*, is formed at the junction of the posterior edge of the ramus and the base of the body. On the external surface of the angle the masseteric tuberosity, *tuberositas masseterica*, is clearly visible; on the internal surface there is the pterygoid tuberosity, *tuberositas pterygoidea*. On the internal surface of the ramus there is the mandibular foramen, *foramen mandibulae*, which is bounded by the lingula of mandible, *lingula mandibulae*, from the medial side. This foramen leads into the mandibular canal, *canalis mandibulae*, which perforates almost the whole body of mandible and ends with the mental foramen. Superiorly the ramus of mandible terminates with the coronoid and condylar (articular) processes; these processes are separated by the mandibular notch, *incisura mandibulae.*

The coronoid process, *processus coronoideus*, has a sharpened apex. The buccinator crest, *crista buccinatoria*, extends on the internal side from the base of the coronoid process to the last molar tooth.

The condylar process, *processus condylaris*, terminates with the head of mandible, *caput mandibulae*, which is a continuation of the mandible`s neck, *collum mandibulae*. The pterygoid fovea, *fovea pterygoidea*, can be seen on the anterior surface of the neck; the lateral pterygoid muscle is attached here.

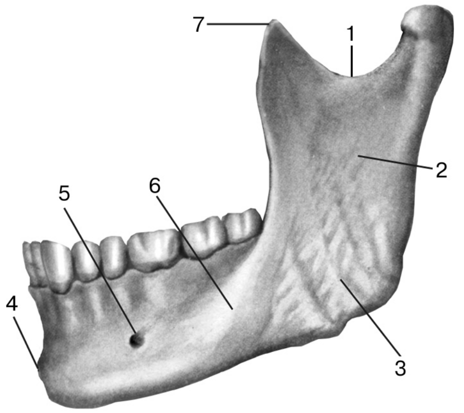

Fig. 3.20 Mandible (external aspect):

1 — mandibular notch (*incisura mandibulae*); 2 — mandibular ramus (*ramus mandbulae*); 3 — masseteric tuberosity (*tuberositas masseterica*); 4 — mental protuberance (*protuberantia mentalis*); 5 — mental foramen (*foramen mentale*); 6 — body of mandible (*corpus mandibulae*); 7 — coronoid process (*processus coronoideus*)

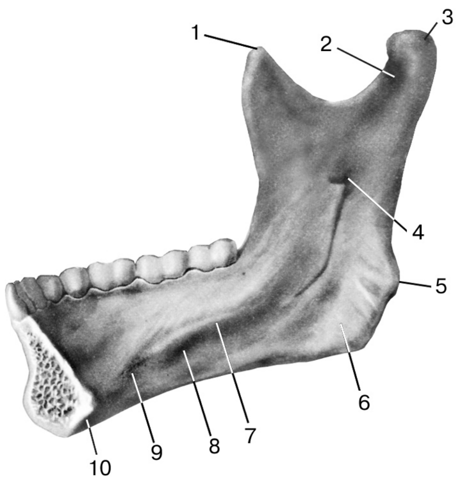

Fig. 3.21. Mandible (internal aspect)

1 — coronoid process (*processus coronoideus*); 2 — pterygoid fovea (*fovea pterygoidea*); 3 — condylar process (*processus condylaris*); 4 — mandibular foramen (*foramen mandibulae*); 5 — mandibular angle (*angulus mandibulae*); 6 — pterygoid tuberosity (*tuberositas pterygoidea*); 7 — mylohyoid line (*linea mylohyoidea*); 8 — submandbular fossa (*fossa submandibularis*); 9 — sublingual fossa (*fossa sublingualis*); 10 — digastric fossa (*fossa digastrica*)

According to development, the mandible is mixed: the coronoid and condylar processes are developed on the basis of cartilage (secondary); the other parts are developed on the basis of connective tissue (primary).

Variations of mandible development:

— significant decrease of the mandible in size (micrognathia);

— significant increase of the mandible in size and its protrusion forwards (prognathia);

— variable size and shape of the angle of mandible;

— doubling of the mandibular canal, mandibular foramen and mental foramen.

Hyoid Bone

The hyoid bone, *os hyoideum* (fig. 3.22), is connected with the skull not directly, but by means of ligaments and muscles. It is located in the region of the neck, between the superior edge of the thyroid cartilage and the mandible. This bone looks like a horseshoe. It has the body which protrudes forwards, and two pairs of horns. The greater horns, *cornua majora*, are thinner than the body, and they are directed upwards and backwards. The lesser horns, *cornua minora*, are connected with the superior edge of the body. They are shorter than the greater ones, their free ends are directed upwards, backwards and laterally.

According development, the hyoid bone is secondary: it passes through three stages in its development and is formed on the basis of cartilage.

Variations of hyoid bone development: the hyoid bone (especially its horns) is variable in shape and size.

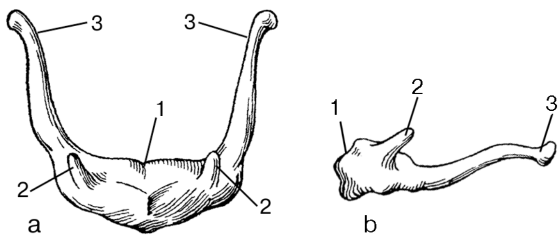

Fig. 3.22. Hyoid bone: a — superior aspect; b — lateral aspect

1 — body (*copus*); 2 — lesser horns (*cornua minora*); 3 — greater wings (*cornua majora*)

3.5. Skull as a whole

Structures, which are absent in individual bones, appear, when the bones of the neurocranium and viscerocranium are connected with each other to make up a whole skull. The whole skull may be examined from five aspects: from the top (*norma superior*) — the calvaria; from the base (*norma inferior*) — the skull base; from the front (*norma facialis*) — the viscerocranium; from the back (*norma occipitalis*) — the occipital part of the neurocranium, and from the sides (*norma lateralis*) — a number of depressions (fossae). The main formations of the neurocranium are: the calvaria, external base, internal base; the main formations of the viscerocranium are: the orbit, nasal cavity, oral cavity, temporal fossa, infratemporal fossa and pterygopalatine fossa.

3.5.1. Neurocranium

It is accepted to delimit the vault (skullcap, calvaria), *calvaria*, from the base, *basis*, with a conventional border. This border starts behind the external occipital protuberance, extends along the superior nuchal line to the base of the mastoid process, then it continues along the superior edge of the external acoustic opening, along the beginning of the temporal bone`s zygomatic process and the infratemporal crest of the sphenoid`s greater wing. Then it rises along the connection of the sphenoid`s greater wing with the zygomatic bone to the zygomatic process of the frontal bone, and it extends along the supraorbital margin and reaches the nasofrontal suture. This marked border permits to define which bones are included into the calvaria entirely or partially.

The calvaria, *calvaria*, is made from the squamous part of the frontal bone, the temporal surfaces of the sphenoid`s greater wings, parietal bones, the squamous parts of both temporal bones and occipital bone (fig. 3.2). These bones are connected with each other by means of sutures which have different shape. The coronal suture, *sutura coronalis*, (placed in frontal plane) is between the frontal and parietal bones. The lambdoid suture, *sutura lambdoidea*, is between the occipital and parietal bones; it looks like the Greek letter lambda. At the junction of both parietals there is the sagittal suture, *sutura sagittalis*. It joins with the coronoid suture at a right angle and with the lambdoid suture at an obtuse angle. The paired squamous suture, *sutura squamosa*, is to the right and to the left from the sagittal suture; it is formed between the greater wing of sphenoid bone, the squamous and mastoid parts of the temporal bone below, and the squamous part of the frontal bone and the inferior edge of the parietal bone above.

The calvaria has internal and external surfaces. The external surface is smooth; here we can see only a paired rough line named the temporal line, *linea temporalis*, which continues into the inferior temporal line, *linea temporalis inferior*, of the parietal bone. Both temporal lines separate the external surface into three parts: median (unpaired) and two lateral ones.

The lateral part of the calvaria gradually continues into the temporal fossa, *fossa temporalis*, which is separated from the skull base by the zygomatic process of the temporal bone and by the infratemporal crest of the sphenoid`s greater wing. The temporal fossa is bounded by the zygomatic arch laterally, by the temporal surface of the zygomatic bone, the zygomatic process of maxilla and the frontal process of the zygomatic bone anteriorly, by the temporal surface of the sphenoid`s greater wing and the squamous part of the temporal bone medially. The lateral part of the calvaria and the temporal fossa are filled with the temporal muscle.

Tubera frontalia, *arcus superciliares*, *glabella* and *tubera parietalia* also belong to the anatomical structures of the external surface of the calvaria.

The internal surface of the calvaria is concave. Along its midline there is the groove for superior sagittal sinus, *sulcus sinus sagittalis superioris*, which ends with the frontal crest, *crista frontalis*, anteriorly. The arterial grooves, *sulci arteriosi*, are pronounced in the lateral parts of the internal surface of the calvaria. The granular foveolae, *foveolae granulares*, the digitate impressions, *impressiones digitatae*, and the cerebral ridges, *juga cerebralia*, can be seen along the sagittal suture. There is no definite border between the calvaria and skull base on the internal surface. Just posteriorly it is marked with the groove for transverse sinus, *sulcus sinus transversi*, and with the internal occipital protuberance, *protuberantia occipitalis interna*.

Base of Skull. The external base of skull, *basis cranii externa* (fig. 3.23), and the internal base of skull, *basis cranii interna*, are distinguished (fig. 3.24).

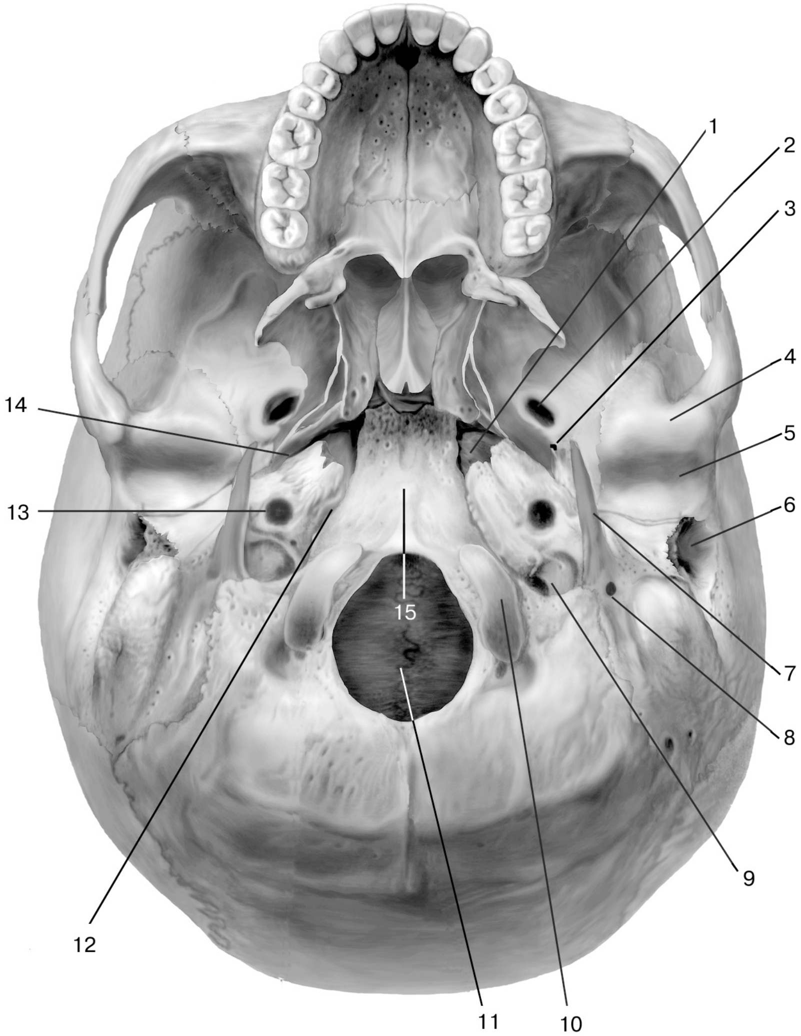

Fig. 3.23. External base of skull:

1 — foramen lacerum (*foramen lacerum*); 2 — foramen ovale (*foramen ovale*); 3 — foramen spinosum (*foramen spinosum*); 4 — articular tubercle (*tuberculum artculare*); 5 — mandibular fossa (*fossa mandibularis*); 6 — external acoustic porus (*porus acusticus externus*); 7 — styloid process (*processus styloideus*); 8 — stylomastoid foramen (*foramen stylomastoideum*); 9 — jugular foramen (*foramen jugulare*); 10 — occpital condyle (*condylus occipitalis*); 11 — foramen magnum (*foramen magnum*); 12 — petrooccipital fissure (*fissura petrooccpitalis*); 13 — external opening of carotid canal (*apertura externa canalis carotici*); 14 — sphenopetrous fissure (*fissura sphenopetrosa*); 15 — pharyngeal tubercle (*tuberculum pharyngeum*)

The external base is shielded by the facial bones on the front side. The other part of the external base, which is visible for examination, is formed by the sphenoid (the part of its body and of the greater wings and also the pterygoid processes), and by the temporal bones (the pyramid, mastoid and tympanic parts and also the inferior portion of the squamous part).

The external surface has an uneven relief because of the presence of openings, processes and grooves. Some openings of the skull base perforate bones, other ones are formed between individual bones, where the bones join together. In the center of the external base`s posterior part there is the foramen magnum, *foramen magnum*, on the sides of which the occipital condyles, *condyli occipitals*, are located. Behind each condyle we can see the condylar fossa, *fossa condylaris*, with an inconstant condylar canal, *canalis condylaris*. The hypoglossal canal, *canalis nervi hypoglossi*, passes through the base of the condyle. The external occipital crest, *crista occipitalis externa*, ascends from the edge of the foramen magnum along the squamous part of the occipital bone. The inferior and superior nuchal lines, *lineae nuchales inferior et superior*, extend from this crest to the right and to the left. The basilar part of the occipital bone with the pharyngeal tubercle in its center lies in front of the foramen magnum. In front of the basilar part there are the body and pterygoid processes of the sphenoid bone; these processes bound the choanae of the nasal cavity on the lateral sides.

Laterally, on the right and on the left from the basilar and lateral parts of the occipital bone there are pyramids of the temporal bone. We can see the external opening of carotid canal, the jugular fossa and styloid process on the inferior surface of the pyramid; and the stylomastoid foramen between the styloid and mastoid processes.

The pyramid of the temporal bone adjoins the tympanic part which bounds the external acoustic opening and the external acoustic meatus. The tympanomastoid fissure, *fissura tympanomastoidea*, is located posteriorly, between the tympanic and mastoid parts. On the mastoid part, besides the mastoid process, we can see the mastoid notch, occipital groove and inconstant mastoid foramen.

The tympanosquamous fissure, *fissura tympanosquamosa*, is between the tympanic and squamous parts. It is divided by the piece of the petrous part into two fissures: petrosquamous and petrotympanic. On the squamous part of the temporal bone at the base of the zygomatic process there is the mandibular fossa and in front of it — the articular tubercle.

The sphenoid`s lesser wing wedges between the pyramid and squamous part of the temporal bone. It is perforated by the foramen spinosum, *foramen spinosum*. Medially from the foramen spinosum and in front of it there is the foramen ovale. The pterygoid fossa, *fossa pterygoidea*, is between the plates of the pterygoid process. The pterygoid canal, *canalis pterygoideus*, opens at the base of the pterygoid process.

The foramen lacerum, *foramen lacerum*, is formed at the junction of the pyramid`s apex, the sphenoid`s body and the basilar part of the occipital bone; it has an irregular shape and serrated edges. The internal opening of carotid canal, the musculotubal and pterygoid canals open into the foramen lacerum.

The jugular foramen, *foramen jugulare*, is formed between the jugular fossa of the temporal bone`s pyramid and the jugular notch of the occipital bone; the internal jugular vein, glossopharyngeal (IX pair), vagus (X pair) and accessory (XI pair) nerves pass trough the jugular foramen.

The pyramid of the temporal bone is separated from the occipital bone by the petrooccipital fissure, *fissura petrooccipitalis*, and from the sphenoid`s greater wing — by the sphenopetrosal fissure, *fissura sphenopetrosa*.

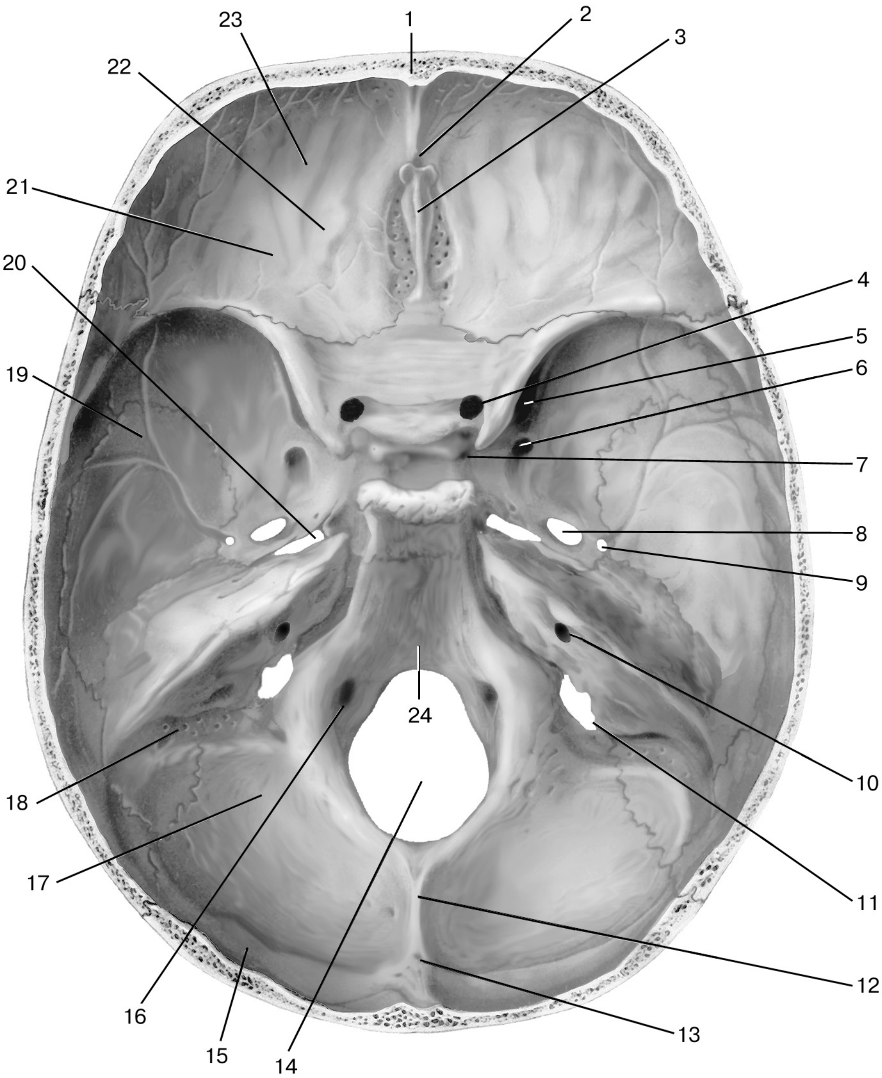

Fig. 3.24. Internal base of skull:

1 — frontal crest (*crista frontalis*); 2 — foramen caecum (*foramen caecum*); 3 — crista galli (*crista galli*); 4 — optic canal (*canalis opticus*); 5 — superior orbital fissure (*fissura orbitalis superior*); 6 — foramen rotundum (*foramen rotundum*); 7 — carotid sulcus (*sulcus caroticus*); 8 — foramen ovale (*foramen ovale*); 9 — foramen spinosum (*foramen spinosum*); 10 — internal acoustic porus (*porus acusticus internus*); 11 — jugular foramen (*foramen jugulare)*; 12 — internal occipital crest (*crista occipitalis interna*); 13 — internal occipital protuberance (*protuberantia occipitalis interna*); 14 — foramen magnum (*foramen magnum*); 15 — groove for transverse sinus (*sulcus sinus transversi*); 16 — hypoglossal canal (*canalis nervi hypoglossi*); 17 — posterior cranial fossa (*fossa cranii posterior*); 18 — groove for sigmoid sinus (*sulcus sinus sigmoidei*); 19 — medial cranial fossa (*fossa cranii media*); 20 — foramen lacerum (*foramen lacerum*); 21 — anterior cranial fossa (*fossa cranii anterior*); 22 — digitate impressions (*impressiones dgitatae*); 23 — orbital part of frontal bone (*pars orbitalis ossis frontalis*); 24 — clivus (*clivus*)

The openings of the external base of skull transmit the vessels and nerves.

The internal base of skull corresponds to the relief of the brain`s inferior surface. It is divided into the anterior, middle and posterior cranial fossae.

The anterior cranial fossa, *fossa cranii anterior*, is separated from the middle cranial fossa by the posterior edge of the sphenoid`s lesser wings, the anterior clinoid processes and by the tuberculum sellae. It contains the frontal lobes of the cerebral hemispheres. The anterior cranial fossa is formed by the orbital parts of frontal bone, the cribriform plate of ethmoid bone, and also by the sphenoid`s lesser wings. It is connected with the nasal cavity trough the openings of the crimriform plate. The crista galli rises in the middle of the cribriform plate, in front of the crista galli there are the foramen caecum and frontal crest. The anterior cranial fossa is connected with the orbits through the optic canals. The prechiasmatic sulcus, *sulcus prechiasmaticus*, is located transversely between the openings of the optic canals.

The openings of the anterior cranial fossa serve for passage of vessels and nerves.

The middle cranial fossa, *fossa cranii media*, is separated from the posterior cranial fossa by the superior borders of the temporal bone`s pyramids and sphenoid`s dorsum sellae. It is composed of the sphenoid`s body and greater wings, the anterior surface of pyramids, and the squamous part of both temporal bones. The middle cranial fossa consists of the unpaired central part, which corresponds to the sella turcica, and also the right and left lateral parts. In the central part there is a depression known as the hypophisial fossa, *fossa hypophysialis*. The carotid sulcus, *sulcus caroticus*, is clearly visible on the lateral surface of the sphenoid`s body. Near the apex of the temporal bone`s pyramid, we can see the foramen lacerum shielded by cartilage. Between the greater and lesser wings of the sphenoid bone and its body there is a superior orbital fissure, *fissura orbitalis superior*, traversed by the vessels and nerves, which pass into the orbit. The foramen rotundum is behind and little below the superior orbital fissure; the maxillary nerve (the branch of the trigeminal nerve) passes through the foramen rotundum. Near it there is the *foramen ovale*, which transmit the mandibular nerve (the branch of the trigeminal nerve). The foramen spinosum is near the posterior edge of the sphenoid`s greater wing, it contains the middle meningeal artery.

The trigeminal impression is located on the anterior surface of the temporal bone`s pyramid, very close to its apex. Laterally from the trigeminal impression and behind it we can see the hiatuses and grooves for greater and lesser petrosal nerves, the arcuate eminence and tegmen tympani.

The openings of the middle cranial fossa serve for passage of vessels and nerves.

The posterior cranial fossa, *fossa cranii posterior*, is deeper than the middle and the anterior cranial fossae. It is mainly formed by the occipital bone. Besides, it is composed of the pyramids` posterior surfaces and mastoid parts of temporal bones, the posterior part of the sphenoid`s body and the mastoid angle of the parietal bone.

In the center of the posterior cranial fossa there is the foramen magnum, and in front of it, we can see the clivus which is formed by fusion of the sphenoid and occipital bones. The medulla oblongata and pons lie on the clivus. The internal occipital crest ascends from the posterior semicircle of the foramen magnum to the cruciform eminence, *eminentia cruciformis*. The groove for transverse sinus, *sulcus sinus transversi*, extends to the right and to the left from the cruciform eminence, and it continues into the groove for sigmoid sinus, *sulcus sinus sigmoidei*. The latter runs on the internal surface of the parietal bone`s mastoid angle and of the temporal bone`s mastoid part. The groove for sigmoid sinus reaches the jugular notch of the occipital bone and ends in the region of the jugular foramen.

Medially from the jugular foramen there is an opening of the hypoglossal canal, *canalis nervi hypoglossi*, which contains the hypoglossal nerve (XII pair). The internal acoustic opening, *porus acusticus internus*, is on the posterior surface of the pyramids. The internal acoustic opening leads into the internal acoustic meatus. The facial nerve canal, containing the facial nerve (VII pair) starts in its depth. The vestibulocochlear nerve (VIII pair) passes from the internal acoustic meatus into the posterior cranial fossa.

The openings of the posterior cranial fossa serve for passage of vessels and nerves.

3.5.2. Viscerocranium

The viscerocranium may be examined from two aspects: from the front side (*norma facialis*) and from the lateral sides (*norma lateralis*). In the examination of *norma facialis* we study the walls and communications of the orbit, the nasal and oral cavities; in the examination of *norma lateralis* we study the pterygopalatine and infratemporal fossae.

Orbit

The orbit, *orbita* (рис. 3.25), is a paired cavity resembling a tetrahedral pyramid in shape; its base is directed forwards, and its apex is directed backwards and medially. The base of this pyramid is the orbital opening, *aditus orbitalis*. The optic canal pierces the apex of the orbit.

The orbit contains the eyeball, associated muscles, lacrimal gland and other structures which belong to the auxiliary apparatus of the visual organ. The orbital opening is bounded by: the supraorbital margin of the frontal bone from above; the infraorbital margin of the maxilla and partially the zygomatic bone below; the frontal process of the maxilla and the nasal part of the frontal bone medially; the zygomatic bone and the zygomatic process of the frontal bone laterally. Four walls are distinguished in the orbit: superior, medial, lateral and inferior.

The superior wall, *paries superior*, is smooth, slightly concave, it lies almost horizontally. It is formed by the orbital part of the frontal bone to which the sphenoidal lesser wing adjoins posteriorly. In the lateral region of the superior wall of the orbit there is a shallow fossa for the lacrimal gland, *fossa glandulae lacrimalis.* At the medial edge of the superior wall closer to the frontal notch we can find a slight pit named the trochlear fovea, *fovea trochlearis.* Sometimes, near this fossa, the small trochlear spine, *spina trochlearis*, protrudes. The cartilaginous trochlea of the eyeball`s superior oblique muscle is attached to the trochlear spine. On the supraorbital margin there is the supraorbital notch, *incisura supraorbitalis*, which occasionally transforms into the supraorbital foramen. The vessels and nerves pass here.

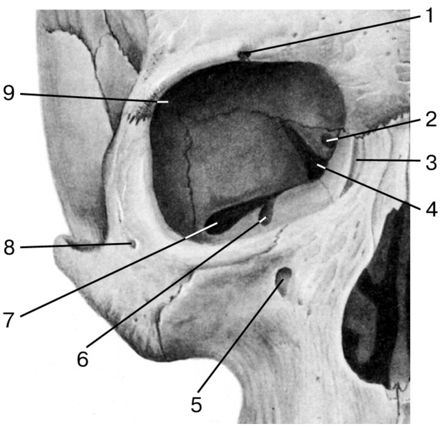

Fig. 3.25. Orbit:

1 — supraorbital notch (*incisura supraorbitalis*); 2 — optic canal (*canalis opticus*); 3 — fossa for lacrimal sac (*fossa sacci lacrimalis*); 4 — superior orbital fissure (*fissura orbitalis superior*); 5 — infraorbital foramen (*foramen infraorbitale*); 6 — infraorbital groove (*sulcus infraorbitalis*); 7 — inferior orbital fissure (*fissura orbitalis inferior*); 8 — zygomaticofacial foramen (*foramen zygomaticofaciale*); 9 — fossa for lacrimal gland (*fossa glandulae lacrimalis*)

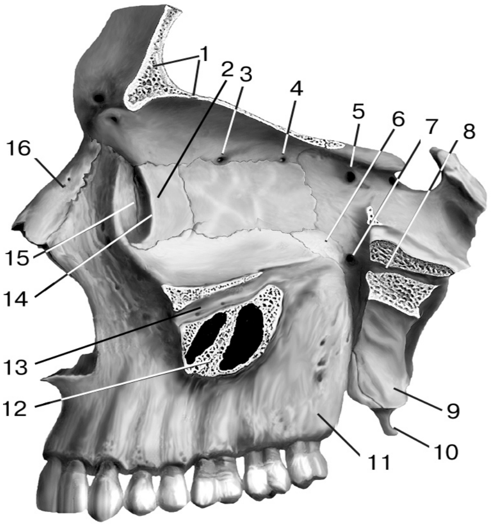

Fig. 3.26. Medial wall of orbit:

1 – frontal bone (*os frontale*); 2 – lacrimal bone (*os lacrimale*); 3 – anterior ethmoidal foramen (*foramen ethmoidale anterius*); 4 – posterior ethmoidal foramen (*foramen ethmoidale posterius*); 5 – optic canal (*canalis opticus*); 6 – orbital process of palatine bone (*processus orbtalis ossis palatini*); 7 – sphenopalatine foramen (*foramen sphenopalatinum*); 8 – pterygoid canal (*canalis pterygoideus*); 9 – medial plate of pterygoid process (*lamina medialis processus pterygoidei*); 10 – pterygoid hamulus (*hamulus pterygoideus*); 11 – maxillary tuber (*tuber maxillae*); 12 – zygomatic process of maxilla (*processus zygomaticus maxillae*); 13 – infraorbital canal (*canalis infraorbitalis*); 14 – posterior lacrimal crest (*crista lacrimalis posterior*); 15 – fossa for lacrimal sac (*fossa sacci lacrimalis*); 16 – nasal bone (*os nasale*)

The medial wall, *paries medialis*, is located sagittally (fig. 3.26). It is formed front to back by the frontal process of the maxilla, the lacrimal bone, the ethmoid`s orbital plate, the sphenoid`s body (posteriorly) and the most medial portion of the frontal bone`s orbital part (superiorly). In the anterior part of this wall there is the fossa for lacrimal sac, *fossa sacci lacrimalis*, which is bounded by the anterior and posterior lacrimal crests. This fossa continues downwards into the nasolacrimal canal, *canalis nasolacrimalis*, which opens into the nasal cavity directly into the inferior nasal meatus.

The walls of the nasolacrimal canal are formed by the lacrimal groove of the maxilla, the lacrimal bone and the lacrimal process of the inferior nasal concha. In the suture between the ethmoid`s orbital plate and the frontal bone there are two ethmoidal foramina – anterior, *foramen ethmoidale anterius*, and posterior, *foramen ethmoidale posterius*. The ethmoidal vessels and nerves leave the orbit to reach the cells of the ethmoidal labyrinth through these foramina.

The inferior wall, *paries inferior*, is mainly formed by the orbital surface of the maxillary body. The orbital process of the palatine bone joins with it posteriorly, and the zygomatic bone joins with it anteriorly. In the inferior wall of the orbit there is an infraorbital groove which continues into the infraorbital canal, *canalis infraorbitalis*. The latter opens with the infraorbital foramen, *foramen infraorbitale*, on the anterior surface of the maxilla.

The lateral wall, *paries lateralis*, is formed by the orbital surfaces of the sphenoidal greater wing, the frontal process of the zygomatic bone and also by the zygomatic process of the frontal bone. This wall is located obliquely and it is separated from the superior and inferior walls of the orbit by fissures. Between the lateral and inferior walls there is an inferior orbital fissure, *fissura orbitalis inferior*. On one side it is bounded by the posterior edge of the maxilla`s orbital surface and by the palatine bone`s orbital process; on the other side, it is bounded by the inferior edge of the orbital surface of the sphenoid`s greater wing. The inferior orbital fissure connects the orbit with the infratemporal and pterygopalatine fossae.

Between the lateral and superior walls of the orbit there is the superior orbital fissure, *fissura orbitalis superior*, which connects the orbit with the middle cranial fossa. On the lateral wall of the orbit we can see the small zygomaticoorbital foramen, *foramen zygomaticoorbitale*. It leads into the canal which opens with the zygomaticofacial fora-

men, *foramen zygomaticofaciale*, on the facial surface of the zygomatic bone and with the zygomaticotemporal foramen, *foramen zygomaticotemporale*, on its temporal surface.

The openings and fissures of the orbit transmit the vessels and nerves.

Bony Nasal Cavity

The nasal cavity, *cavitas nasi*, occupies the central position in the viscerocranium; it is surrounded by cavities from all sides: superiorly — by the cranial cavity, (the anterior cranial fossa), inferiorly — by the oral cavity, laterally — by the orbits and maxillary sinuses. The nasal cavity is divided into two halves by the bony nasal septum, *septum nasi osseum*, located sagittaly (fig. 3.27).

The piriform aperture is bounded by the nasal notches of the maxillae and by the inferior edges of the nasal bones. Inferiorly along the midline the anterior nasal spine, *spina nasalis anterior*, protrudes forwards.

Posteriorly the nasal cavity is connected with the nasopharinx by the paired openings — the right and left choanae, *choanae*. The choana is bounded laterally by the medial plate of the pterygoid process, medially — by the vomer, superiorly — by the sphenoid`s body, inferiorly — by the horizontal plate of the palatine bone (fig. 3.23).

The nasal cavity has four walls: the superior wall, inferior wall and two lateral walls and it also has the nasal septum.

The superior wall is formed (front to back) by the nasal bones, the frontal bone`s nasal part, the ethmoid`s cribriform plate, and by the sphenoid`s body.

The inferior wall is composed of the maxillae`s palatine processes and by the palatine bone`s horizontal plates. These bones form the nasal crest, *crista nasalis*, along the midline. At the anterior end of the nasal crest there is an opening that leads into the incisive canal, *canalis incisivus*.

The lateral wall (fig. 3.28) has the most complicated structure. It is formed by six bones: the maxilla (the nasal surface of its body and the frontal process, *facies nasalis et processus frontalis maxillae*); the lacrimal bone, *os lacrimale*; the ethmoidal labyrinth, *labyrinthus ethmoidalis*; the palatine bone (the perpendicular plate, *lamina perpendicularis*), the sphenoid bone (the medial plate of the pterygoid process, *lamina medialis processus pterygoidei*) and the inferior nasal concha, *concha nasalis inferior*. On the lateral wall of the nasal cavity there are three nasal conchae located one under another. The superior nasal concha, *concha nasalis superior*, and the middle nasal concha, *concha nasalis media*, are the parts of the ethmoidal labyrinth; the inferior nasal concha, *concha nasalis inferior*, is

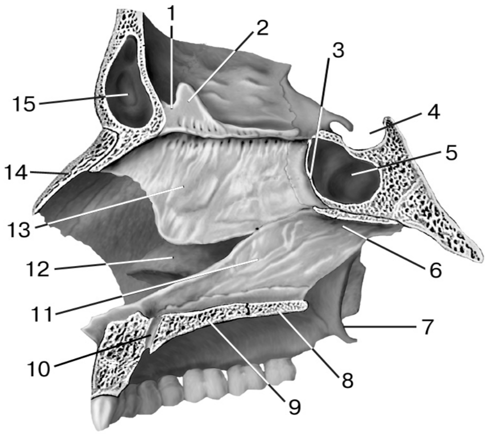

Fig. 3.27. Bony nasal septum (left side):

1 — foramen caecum (*foramen caecum*); 2 — crista galli (*crista galli*); 3 — sphenoidal crest (*crista sphenoidalis*); 4 — hypophisial fossa (*fossa hypophisialis*); 5 — sphenoidal sinus (*sinus sphenoidalis*); 6 — ala of vomer (*ala vomeris*); 7 — pterygoid process (*processus pterygoideus*); 8 — horizontal plate of palatine bone (*lamina horizontalis ossis palatini*); 9 — palatine process of maxilla (*processus palatinus maxillae*); 10 — incisive canal (*canalis incisivus*); 11 — vomer (*vomer*); 12 — inferior nasal concha (*concha nasalis inferior*); 13 — perpendicular plate of ethmoid bone (*lamina perpendicularis ossis ethmoidalis*); 14 — nasal bone (*os nasale*); 15 — frontal sinus (*sinus frontalis*)

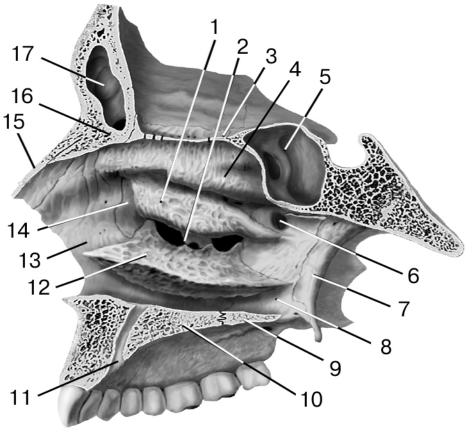

Fig. 3.28. Lateral wall of nasal cavity:

1 — medial nasal concha (*concha nasalis media*); 2 — maxillary hiatus (*hiatus maxillaris*); 3 — cribriform plate (*lamina cribrosa*); 4 — superior nasal concha (*concha nasalis superior*); 5 — sphenoidal sinus (*sinus sphenoidalis*); 6 — sphenopalatine foramen (*foramen sphenopalatinum*); 7 — medial plate of pterygoid process (*lamina medialis processus pterygoidei*); 8 — perpendicular plate of palatine bone (*lamina perpendcularis ossis palatni*); 9 — horizontal plate of palatine bone (*lamina horizontalis ossis palatni*); 10 — palatine process of maxilla (*processus palatinus maxillae*); 11 — incisive canal (*canalis incisivus*); 12 — inferior nasal concha (*concha nasalis inferior*); 13 — frontal process of maxilla (*processus frontalis maxillae*); 14 — lacrimal bone (*os lacrimale*); 15 — nasal bone (*os nasale*); 16 — nasal part of frontal bone (*pars nasalis ossis frontalis*); 17 — frontal sinus (*sinus frontalis*)

an individual bone. Due to the presence of the nasal conchae the lateral part of the nasal cavity is divided into three nasal meatuses: superior, middle and inferior meatuses.

The superior nasal meatus, *meatus nasi superior*, is bounded by the superior nasal concha above and by the middle nasal concha below. This nasal meatus is the shortest of all nasal meatuses, it is poorly developed and it is located in the posterior part of the nasal cavity. The posterior ethmoidal cells and the opening of the sphenoidal sinus, *apertura sinus sphenoidalis*, open into the superior nasal meatus.

The middle nasal meatus, *meatus nasi medius*, is between the middle and inferior nasal conchae. It is longer and wider than the superior nasal meatus. The anterior and middle ethmoidal cells, *cellulae ethmoidales anteriores et medii*, the opening of frontal sinus, *apertura sinus frontalis*, and Highmore`s antrum by means of the maxillary hiatus, *hiatus maxillaris*, open here. The sphenopalatine foramen, *foramen sphenopalatinum*, which is located behind the middle nasal concha, connects the middle nasal meatus with the pterygopalatine fossa.

The inferior nasal meatus, *meatus nasi inferior*, is the space between the inferior nasal concha and the inferior wall of the nasal cavity; it is the longest and widest. The nasolacrimal canal, *canalis nasolacrimalis*, which starts in the orbit, opens into the anterior part of the inferior nasal meatus. This canal contains the nasolacrimal duct, *ductus nasolacrimalis*.

The bony nasal septum mainly consists of the vomer and the ethmoid`s perpendicular plate. The latter adjoins the sphenoidal crest. The vomer is attached to the nasal crests of the maxillae and to the sphenoidal rostrum. The septum rarely matches the median plane, usually it deviates to one or another side. Anteriorly the cartilage joins with the nasal septum that is why in the macerated skull, the piriform aperture is not divided.

Between the nasal septum medially and the nasal conchae laterally, the narrow fissure located in the sagittal plane, is formed; it is the common nasal meatus, *meatus nasi communis*. The anterior parts of the oral and nasal cavities are connected with each other by the incisive canal, which is located along the midline and contains vessels and nerves. The common nasal meatus communicates with the anterior cranial fossa by the openings in the ethmoid`s cribriform plate.

The openings of the nasal cavity serve for passage of vessels and nerves.

Bony Frame of Oral Cavity

The oral cavity, *cavitas oris*, has bony walls only on the front and lateral sides and above. On the front and lateral sides, it is bounded by the teeth, alveolar processes of the maxillae, by the alveolar arch, body and rami of the mandible. The superior wall is formed by the bony (hard) palate, *palatum osseum*.

The hard palate is composed of the palatine processes of the maxillae and of the horizontal plates of the palatine bones. From the front and lateral sides, the hard palate is bounded by the alveolar processes of the maxillae which together form the alveolar arch (fig. 3.23).

The hard palate is a plate slightly curved upwards; along its midline there is a median palatine suture, *sutura palatina mediana*. The transverse palatine suture, *sutura palatina transversa*, is located perpendicularly to it, between the palatine processes of the maxillae and the horizontal plates of the palatine bones.

At the anterior end of the median palatine suture there is an unpaired incisive foramen leading to the incisive canal. In the horizontal plate of the palatine bone, near its posterior edge on each side, we can see a greater palatine foramen leading into the greater palatine canal, and 2—3 lesser palatine foramina; the greater and lesser palatine foramina connect the oral cavity with the pterygopalatine fossa.

The openings in the bony palate serve for passage of vessels and nerves.

Temporal Fossa

The temporal fossa, *fossa temporalis*, is located on the lateral surface of the neurocranium (fig. 3.2). This surface of the skull within the limits of the temporal fossa is called the temporal plane, *planum temporale.* The temporal fossa has medial, anterior and lateral walls. The medial wall is formed by the parietal and frontal bones, by the squamous part of the temporal bone and by the greater wing of the sphenoid. The anterior wall is composed of the temporal surface of the zygomatic bone and the zygomatic process of the frontal bone. The lateral wall is formed by the zygomatic arch. The temporal fossa continues downwards into the infratemporal fossa. The border between these two fossae is the infratemporal crest, *crista infratemporalis.*

In the temporal fossa there is the temporal muscle, *m. temporalis*, and also the vessels and nerves.

Infratemporal Fossa

On the border between the viscerocranium and neurocranium, behind the maxilla there is an infratemporal fossa, *fossa infratemporalis* (fig. 3.23). It is separated from the temporal fossa located above by the infratemporal crest of the greater wing of the sphenoid. Its superior wall is formed by the temporal bone and by the greater wing of the sphenoid. The medial wall is formed by the lateral plate of the sphenoid`s pterygoid process, the anterior wall is formed by the maxillary tuberosity and partially by the zygomatic bone, the lateral wall is formed by the zygomatic arch and by the ramus of mandible.

Anteriorly the infratemporal fossa is connected with the orbit by means of the inferior orbital fissure, and medially it continues into the pterygopalatine fossa through the pterygomaxillary fissure, *fissura pterygomaxillaris.*

The infratemporal fossa contains the medial and lateral pterygoid muscles, *mm. pterygoidei medialis et lateralis*, fatty tissue and vessels and nerves.

Pterygopalatine fossa

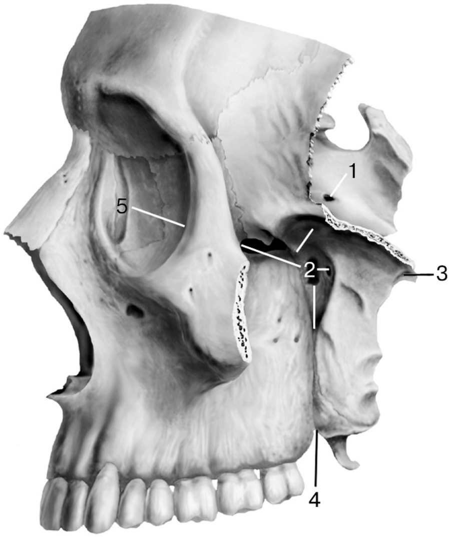

Fig. 3.29. Pterygopalatine fossa:

1 — foramen rotundum (*foramen rotundum*); 2 — sphenopalatine foramen (*foramen sphenopalatinum*); 3 — pterygoid canal (*canalis pterygoideus*); 4 — greater palatine canal (*canalis palatinus major*); 5 — inferior orbital fissure (*fissura orbitalis inferior*)

The pterygopalatine fossa, *fossa pterygopalatina* (fig. 3.29), has three walls: anterior, posterior and medial. The anterior wall is formed by the maxillary tuberosity, *tuber maxillae*; the posterior wall — by the sphenoid`s pterygoid process, *processus pterygoideus ossis sphenoidalis*; the medial wall — by the palatine bone`s perpendicular plate, *lamina perpendicularis ossis palatini*. From the lateral side the pterygopalatine fossa has no bony wall and it opens into the infratemporal fossa.

The pterygopalatine fossa gradually narrows downwards and continues into the greater paltine canal, *canalis palatinus major*. From above this canal has the same walls as the pterygopalatine fossa and from below it is bounded by the maxilla and palatine bone. The pterygopalatine fossa has six communications with the adjacent cavities and fossae:

1) with the orbit — trough the inferior orbital fissure, *fissura orbitalis inferior*;

2) with the nasal cavity — by means the sphenopalatine foramen, *foramen sphenopalatinum;*

3) with the oral cavity — through the greater palatine canal, *canalis palatinus major;*

4) with the middle cranial fossa — by means of foramen rotundum, *foramen rotundum;*

5) with the external base of the skull — trough the pterygoid canal, *canalis pterygoideus.*

6) with the infratemporal fossa — through the pterygomaxillary fissure, *fissura pterygomaxillaris.*

The openings of the pterygopalatine fossa serve for passage of vessels and nerves.

Skull shapes

Specific criteria are used for description of the skull shape features (cranial indexes). To calculate them, certain dimensions of the skull are made.

To define the length of the neurocranium (longitudinal size), we measure the distance between the glabella and the most protruding part of the occipital bone (usually it is the external occipital protuberance). The breadth of the skull (transverse size) is the distance between the most distant points of the parietal tubers. The height of the neurocranium is measured between the anterior margin of the foramen magnum and the crossing point of the coronal suture with the sagittal suture. The following variations of skull forms are distinguished:

1. According to the ratio of the maximum breadth to the maximum length of the skull (the cranial index in the horizontal plane):

— dolichocrania (long, narrow skull) — the skull with a cranial index below 75 %;
— mesocrania (moderate skull) — the skull with a cranial index 75–80 %,
— brachycrania (short, wide skull) — the skull with a cranial index higher than 80 %.

2. According to the ratio of the maximum height to the maximum length of the skull (the cranial index in the vertical plane):
— hypsicrania (high skull) — the skull with a the cranial index 75 % and more;
— orthocrania (moderate skull) — the skull with a cranial index from 70 to 75 %;
— platycrania (flat, low skull) — the skull with a cranial index below 70 %.

To define the height of the viscerocranium, we measure the distance from the nasofrontal suture to the inferior edge of the chin along the midline. The width of the viscerocranium is the distance between the most distant points of the zygomatic arches. Such cranial index as the ratio between the height of the viscerocranium to its width allows to distinguish broad-faced skulls (cranial index below 84 %), long-faced skulls (cranial index over 88 %) and moderate-faced skulls (cranial index from 84 to 88 %).

3.7 Skull of newborns

The skull of a newborn has some essential features in comparison with the skull of an adult person; this fact should be considered in clinical practice.

1. The most specific feature of the newborn skull is the presence of fontanelles (fig. 3.30). The fontanelles, *fonticuli*, are areas of connective tissue between the bones of the calvaria.

There are 6 fontanelles in a newborn skull. The biggest fontanelle is the anterior (or frontal, major) one, *fonticulus anterior* (*frontalis, major*), which is located between the frontal and parietal bones. It overgrows at the beginning of the second year of life. The posterior fontanelle (or occipital, minor), *fonticulus posterior* (*occipitalis*, *minor*), is located between the occipital and parietal bones. It closes completely during the second month of life. The lateral fontanelles -sphenoidal and mastoid — are paired and they are not felt during palpation. The sphenoidal fontanelle, *fonticulus sphenoidalis*, is located in the region of the sphenoidal angle of the parietal bone; the mastoid fontanelle, *fonticulus mastoideus*, is located in the region of the mastoid angle of the parietal bone. The lateral fontanelles close during the second week of life.

2. The newborn skull is dolichocranial.

3. The number of skull bones in a newborn is greater than in an adult person, because the components of the majority of skull bones have not fused with each other yet.

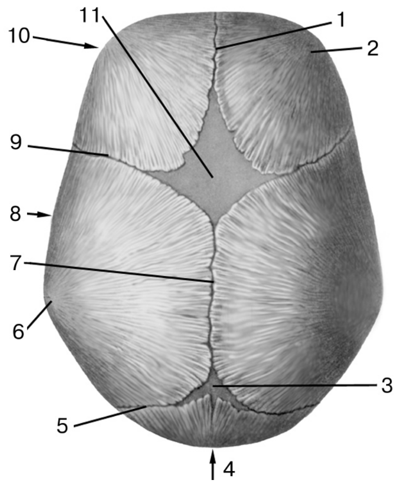

Fig. 3.30. Skull of newborn (superior aspect):
1 — frontal suture (*sutura frontalis*); 2 — frontal tuber (*tuber frontale*); 3 — posterior fontanelle (*fonticulus posterior*); 4 — occipital bone (*os occipitale*); 5 — lambdoid suture (*sutura lambdodea*); 6 — parietal tuber (*tuber parietale*); 7 — sagittal suture (sutura *sagittalis*); 8 — parietal bone (*os parietale*); 9 — coronal suture (*sutura coronalis*); 10 — frontal bone (*sutura frontalis*); 11 — anterior fontanelle (*fonticulus anterior*)

4. The sutures between the bones of calvaria are flat and wider. Due to this feature, the head of fetus can conform to the sizes of the woman`s lesser pelvis during a delivery: the parietal bones are displaced towards each other along the midline, and the squamous parts of the frontal and occipital bones are displaced to the parietal bones; as a result, the size of a newborn head decreses. After birth the width of the sutures significantly decreases, and during the third year of life the serrate sutures, *sutura serrata*, start to form.

5. The neurocranium is eight times larger than the viscerocranium (in adults — four times larger).

6. The bones of the skull base are connected with each other by wide layers of cartilage and connective tissue.

7. The orbital opening is wider.

8. *Norma verticalis* has a quadrangular shape due to a better development of the parital and frontal tubers.

9. The skull height is lesser due to underdevelopment of the jaws.

10. The places, where the muscles are attached to the skull bones (lines, tuberosities, processes etc.), are not developed.

11. The diploë, *diploe*, is almost absent in the skull bones.

12. The relief of the bones` cerebral surface (*impressiones digitatae, juga cerebralia*, *sulci arteriosi*) is poorly expressed.

13. The nasal cavity is relatively short and smaller in volume; rather often, this fact contributes to difficulties in nasal breathing in children.

14. The external acoustic meatus is wider and shorter, its inferior wall has openings (dehiscences). As a result, quite often otitis occures in children.

The individual skull bones also have significant defferences which are given in Table 3.1.

Table 3.1

Distinctive Features of Skull Bones of Newborns

Name of Bone	Distinctive Feature
Occipital bone, *os occipitale*	– parts of the bone fuse together through synostosis by the age of 3
Frontal bone, *os frontale*	– paired, its parts fuse through synostosis during the 2nd year of life; – absence of frontal sinus; – superciliary arches poorly developed
Parietal bone, *os parietale*	– angles of the bone are smoothed; – *tuber parietale* is stongly pronounced
Ethmoid, *os ethmoidale*	– cells in the labyrinth; – parts of the bone fuse together through synostosis during the 6th year of life
Sphenoid, *os sphenoidale*	– sphenoidal sinus is absent; – parts of the bone fuse together through synostosis during the 8th year of life
Temporal bone, *os temporale*	– parts of the bone fuse together through synostosis during the 13th year of life; – the mastoid process is poorly developed; – the external acoustic meatus is wider; – the tympanic part is poorly developed, the external acoustic opening is not closed into a bony ring; – the styloid process is an individual bony structure

Name of Bone	Distinctive Feature
Maxilla, *maxilla*	– the alveolar process is underdeveloped; – the alveolar process has no teeth; – the canine fossa is not pronounced
Mandible, *mandibula*	– the alveolar process has no teeth; – the coronoid process is not expressed; – the mental spine is absent
Nasal bone, *os nasale*	– has a relatively small size (the bony nose is undereveloped)
Vomer, *vomer*	– consists of two plates (which fuse by the age of 10—12)
Hyoid bone, *os hyoideum*	– parts of the bone fuse together through synostosis by the age of 30

3.8. Age-specific changes of skull

Three main periods in the skull development are distinguished. **The first period** (from the age of 1 to the age of 7) is characterized with an intensive growth: during the first six months, the skull volume increases almost twice, the cranial fossae become deeper. Due to growth and replacement of teeth, the height and structure of the maxilla and mandible change, and, as a result the form of the face also changes. The majority of the bones are fused together through synostosis. The sutures of the calvaria transform from flat into serrated sutures. **The second period** (from the age of 7 to the beginning of puberty) is characterized with a relative slowdown of the growth of skull bones. **The third period** (from the beginning of puberty to the age of 20—25) is characterized with more intensive growth of the viscerocranium in comparison with the neurorocranium. Formation of the air sinuses, tubers, prominences and grooves terminates.

In **mature age,** the sutures are ossified. The time of occurrence of suture oblitaration is rather individual: usually, at first the saggital and coronal sutures close. The serrate suture is the last to ossify (at about 45 years). Rarely sutures remain during the whole life.

Futher the bone thickness is gradually decreased. The skull shape changes because of tooth loss and atrophia of the alveolar processes of the maxilla and mandible.

3.9. Sexual differences of skull

The sexual differences of the human skull are insignificant, therefore sometimes it is difficult to distinguish the male and female skull. The following sexual differences of the skull (which are not always pronounced) should be noted:

1. In the male skull, the relief of its external surface (crests, lines, tubers) is more distinctive; the superciliary arches are more expressed, the external occipital protuberance is better developed.
2. In the female skull, the orbits are relatevely bigger.
3. In the male skull, the pneumatic sinuses are bigger in volume.
4. The bones of the male skull are a little bit thicker.
5. In males the mandible is more massive.
6. In males, the angle of mandible is mostly right, in women, it is mostly obtuse.
7. In males, the viscerocranium is relatively more developed, in women, the neurocranium is relatevily more developed.

TEST QUESTIONS

1. What bones form viscerocranium?
2. What bones form neurocranium?
3. What is the cranial cavity? What organs does it contain?
4. What parts of neurocranium are distinguished?
5. What bones form the calvaria?
6. What bones form the base of the skull?
7. Describe the internal structure of skull bones.
8. Describe the relief of skull bones.
9. What bones of the skull are pneumatized?

Bones of neurocranium:

10. What parts of the frontal bone are distinguished?
11. What bones join to the frontal bone?
12. What indications can help to differentiate the anterior and posterior sides of the frontal bone, its upper and lower parts, its internal and extrernal surfaces?
13. How will you determine the right position in the skull?
14 What parts of the occipital bone do you know?
15. What bones join to the occipital bone?
16. What indications can help to differentiate the anterior and posterior sides of the occipital bone, its upper and lower parts, its internal and extrernal surfaces?
17. What indications can help to determine the right position of occipital bone in the skull?
18. What parts does the ethmoid bone include?
19. What bones join to the ethmoid?
20. What indications can help to differentiate the anterior and posterior sides of the ethmoid bone and its upper and lower parts?
21. What indications can help to determine the right position of the ethmoid in the skull?
22. What parts does the sphenoid bone include?
23. What bones join to the sphenoid?
24. How will you differentiate the anterior and posterior sides of the sphenoid bone and its upper and lower parts?
25. What indications can help to determine the right position of the sphenoid bone in the skull?
26. What bones join to the parietal bone?
27. What signs can help to differentiate the margins of parietal bone?
28. What signs can help to determine the right position of the parietal bone in the skull?
29. How can you determine the right and the left parietal bone?
30. What parts of the temporal bone are distinguished?
31. What bones join to the temporal bone?
32. What organs does the temporal bone contain?
33. What signs can help to differentiate the anterior and posterior sides of the temporal bone, its upper and lower parts, its internal and external surfaces?
34. What indications can help to determine the right position of the temporal bone in the skull?
35. How can you determine the right and the left temporal bone?

36. What structures are the beginning, the end and the content of the carotid canal? Describe its way.

37. What structures are the beginning, the end and the content of the facial canal? Describe its way.

38. What are the beginning and the end of the canal for greater petrosal nerve?

39. What structures are the beginning and the end of the canal for chorda tympani?

40. What structures are the beginning, the end and the content of the musculotubal canal? Describe its way.

41. What are the beginning and the end of the tympanic canaliculus?

42. What are the beginning and the end of the mastoid canaliculus?

Bones of viscerocranium:

43. What parts of the maxilla do you know?

44. What bones join to the maxilla?

45. In formation of what cavities does the maxilla participate?

46. What signs can help to differentiate the anterior and posterior sides of the maxilla, its upper and lower parts, its medial and lateral sides?

47. What signs can help to determine the right position of the maxilla in the skull?

48. How can you determine the right and the left maxilla?

49. What parts of the palatine bone do you know?

50. What bones join to the palatine bone?

51. In formation of what cavities does the palatine bone participate?

52. What indications can help to differentiate the anterior and posterior sides of the palatine bone, its upper and lower parts, its medial and lateral sides?

53. What indications can help to determine the right position of the palatine bone in the skull?

54. What bones join to the zygomatic bone?

55. In the formation of what cavities does the zygomatic bone participate?

56. What signs can help to differentiate the anterior and posterior sides of the zygomatic bone, its upper and lower parts, its medial and lateral sides?

57. What signs can help to determine the right position of the zygomatic bone in the skull?

58. What bones join to the nasal bone?

59. What structure does the nasal bone form?

60. What bones join to the lacrimal bone?

61. In the formation of what cavity does the lacrimal bone participate?

62. Where is the inferior nasal concha located?

63. What bones join to the inferior nasal concha?

64. In the formation of what structure does the inferior nasal concha participate?

65. Where is the vomer located?

66. What bones join to the vomer?

67. In the formation of what structure does the vomer participate?

68. What parts of the mandible are distinguished?

69. To what bone does the mandible join?

70. What parts of the hyoid bone do you know?

71. Where is the hyoid bone located?

72. How is the hyoid bone connected with the skull?

Skull as a whole:

73. Describe the external base of skull.
74. What bones form the anterior cranial fossa? Describe its structures.
75. What bones form the middle cranial fossa? Describe its structures.
76. What bones form the posterior cranial fossa? Describe its structures.
77. What bones form the superior wall of the orbit?
78. What bones form the inferior wall of the orbit?
79. What bones form the medial wall of the orbit?
80. What bones form the lateral wall of the orbit?
81. Describe the structures of the orbit, its openings and communications.
82. What bones form the superior wall of the nasal cavity?
83. What bones form the inferior wall of the nasal cavity?
84. What bones form the lateral wall of the nasal cavity?
85. What bones form the bony nasal septum?
86. What opening leads into the nasal cavity from the anterior side of the skull?
87. What opening leads into the nasal cavity from the posterior side of the skull?
88. Describe the communications of the nasal cavity.
89. What walls does the bony oral cavity have? What bones form these walls?
90. What bones form the walls of the temporal fossa? What does it contain?
91. What is the border between temporal and infratemporal fossae?
92. What bones form the walls of the infratemporal fossa? What does it contain?
93. What bones form the pterygopalatine fossa?
94. Describe the communications of the pterygopalatine fossa.
95. What forms of the skull do you know?
96. Describe specific features of the newborn skull.
97. What happens with the skull with age?
98. What are the sexual differences of the skull?

CLINICOANATOMICAL PROBLEMS

1. A patient complains of headache and pain in the region of the suoraorbital margin. On the X-ray picture of the skull the darkness in the region of the frontal sinus is visible. What should the doctor think of?

2. The damage of what vessel will cause immediate death in case of a penetrating bullet wound of the pyramid of temporal bone?

3. What consequences will you expect to occur in case of displacement of the canine tooth in the fracture of alveolar process of mandible at the level of canine tooth as a result of a stroke on the lower jaw from below upwards?

4. On the roentgenogram you see the darkness in the region of the ethmoidal labyrinth. Where will pus disseminate?

4. BONES OF THE UPPER LIMB

The upper limb can be divided into the shoulder girdle, *cingulum membri superioris*, and the free part of the upper limb, *membrum superioris libera*; the latter consists of three parts: proximal, middle and distal. The proximal part is named the shoulder, *brachium*; the middle part — the forearm, *antebrachium*, and the distal one — the hand, *manus*. The hand also includes three parts: the wrist, *carpus*, (located closer to the forearm); metacarpus, *metacarpus*, and the fingers of the hand, *digiti manus*. The bones of the upper limb, *ossa membri superioris*, are divided into the bones of the shoulder girdle and the bones of the free upper limb.

The bones of the shoulder girdle, *ossa cinguli membri superioris*, are the scapula and the clavicle. The scapula, *scapula*, is a flat bone which lies closely to the posterior surface of the thorax. The glenoid cavity of the scapula articulates with the head of humerus. The clavicle, *clavicula*, is a tubular bone which is located in front of the thorax. It articulates with the sternum medially and with the scapula laterally.

Bones of the free upper limb, *ossa membri superioris liberi*, are: the humerus, *humerus*; the bones of the forearm, *ossa antebrachii*, and the bones of the hand, *ossa manus*. The bones of the forearm include the radius, *radius*, located laterally in the anatomic position (on the side of the thumb), and the ulna, *ulna*, located medially. The bones of the hand are divided into three parts: the carpal bones, *ossa carpi*; the metacarpal bones, *ossa metacarpi*, and the phalanges, *ossa digitorum manus*.

4.1. Bones of shoulder girdle

Scapula

The scapula, *scapula,* (fig. 4.1) is a flat triangular bone which lies on the posterolateral side of the thorax at the level of the II–VII ribs. Three angles are distinguished in the scapula: inferior, *angulus inferior*, superior, *angulus superior*, located medially, and lateral, *angulus lateralis*. The scapula has three borders: medial border, *margo medialis*, directed to the vertebral column, lateral border, *margo lateralis*, directed to the axilla, and the shortest superior border, *margo superior*.

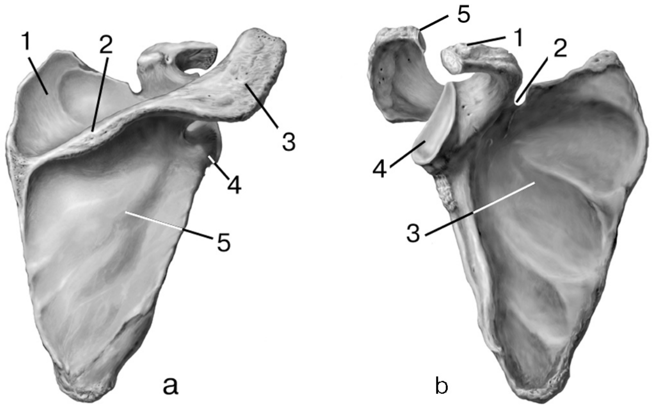

Fig. 4.1. Right scapula:

a — posterior aspect: 1 — supraspinous fossa (*fossa supraspinata*); 2 — scapular spine (*spina scapulae*); 3 — acromion (*acromion*); 4 — scapular neck (*collum scapulae*); 5 — infraspinous fossa (*fossa infraspinata*)

b — anterior aspect: 1 — coracoid process (*processus coracoideus*); 2 — scapular notch (*incisura scapulae*); 3 — subscapular fossa (*fossa subscapularis*); 4 — glenoid cavity (*cavitas glenoidalis*); 5 — clavicular facet (*facies artcularis clavicularis*)

The scapula has two surfaces — anterior and posterior. The anterior (costal) surface, *facies anterior seu costalis*, lies closely to ribs. It is slightly concave forming a shallow subscapular fossa, *fossa subscapularis*. The posterior surface, *facies posterior*, is divided by the scapular spine, *spina scapulae*, into the supraspinous (lesser) fossa, *fossa supraspinata*, and infraspinous (greater) fossa, *fossa infraspinata*. The supraspinatus and infraspinatus muscles are attached to these fossae. The lateral angle is thickened and forms a slightly concave glenoid cavity, *cavitas glenoidalis*. The supraglenoid tubercle, *tuberculum supraglenoidale*, and the infraglenoid tubercle, *tuberculum infraglenoidale*, are located immediately above and below it. The muscles originate from these tubercles. The lateral angle tapers medially forming the neck of the scapula, *collum scapulae*.

The coracoid process, *processus coracoideus*, projects above the glenoid cavity. The scapular notch, *incisura scapulae*, is located medially to it, in the area of the upper border. The scapular spine gradually increases from the medial border to the lateral angle; the end of the scapula forms the acromion, *acromion*. It hangs over the glenoid cavity. The apex of the acromion has a flat articular surface which is connected with the clavicle, *facies articularis clavicularis*.

Clavicle

The clavicle, *clavicula*, is an S-shaped tubular bone (fig. 4.2), which extends horizontally from the clavicular notch of the sternum to the acromion of the scapula. It is divided into middle part, or body, *corpus claviculae*, and two ends — sternal, *extremitas sternalis*, and acromial, *extrimitas acromialis*. The medial part of the clavicle (near the sternal end) is curved forwards, the lateral part is curved backwards.

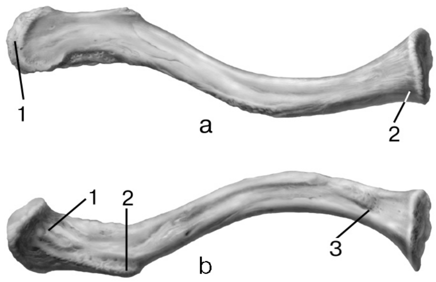

Fig. 4.2. Right clavicle:

a — superior aspect: 1 — acromial end (*extremitas acromalis*); 2 — sternal end (*extremitas sternalis*)
b — inferior aspect: 1 — trapezoid line (*linea trapezoidea*); 2 — conoid tubercle (*tuberculum conoideum*); 3 — impression for costoclavicular ligament (*impressio ligamenti costoclavicularis*)

The sternal end is thickened and has a saddle-shaped sternal facet, *facies articularis sternalis,* which articulates with the sternum. The acromial end is flattened vertically and has a flat acromial articular facet, *facies articularis acromialis*, which articulates with corresponding surface of the acromion.

The superior surface of the clavicle is smooth. There is an impression of the costoclavicular ligament, *impressio ligamenti costoclavicularis*, on the inferior surface at the sternal end. It is a trace of attachment of the ligament which connects the clavicle with the I rib. The two rough areas are clearly visible on the acromial end: the conoid tubercle, *tuberculum conoideum*, and the trapezoid line, *linea trapezoidea*. Together, they form a tuberosity of the coracoclavicular ligament, *tuberositas ligamenti coracoclavicularis*, which provides attachment for the coracoclavicular ligament.

4.2. Bones of free part of upper limb

Humerus

The humerus, *humerus*, is a typical long tubular bone (fig. 4.3). It includes the diaphysis — body (shaft), *corpus humeri*, and two thickened ends — epyphises: the upper — proximal and lower — distal ones.

The upper epyphisis has a head of the humerus, *caput humeri*. It is spherical, directed medially and slightly backwards. It is separated from two rough tubercles by a slight groove named the anatomical neck, *collum anatomicum*. The anterior tubercle is lesser, *tuberculum minus*, the lateral tubercle is greater, *tuberculum majus*; the latter one has three areas for attachment of muscles. The rough crests of the greater and lesser tubercles, *crista tuberculi majoris et crista tuberculi minoris*, descend from these tubercles to the body of the humerus. The tubercles and their crests are separated from each other by the bicipital groove, *sulcus intertubercularis*; the tendon of the long head of the biceps passes in it. A narrowed place called the surgical neck, *collum chirurgicum*, is below the tubercles; it separates the upper epiphysis from the body. Most commonly, fractures of the humerus occur in this place.

The body of the humerus, *corpus humeri*, is cylindrical in its superior part, but is trihedral in its inferior part. The posterior surface, *facies posterior*, the anteromedial surface, *facies anteromedialis*, and the anterolateral surface, *facies anterolateralis*, are distinguished in the inferior part of the body.

The deltoid tuberosity, *tuberositas deltoidea*, is above the midst of the body of humerus, distally to the crest of the greater tubercle; the deltoid muscle is attached to this tuberosity. The spiral groove (the groove for the radial nerve), *sulcus nervi radialis* (*sulcus spiralis*), passes below the deltoid tuberosity along the posterior surface of the humerus. The spiral groove starts on the medial surface of the bone, curves it at the back and terminates on the border between the middle and lower thirds of the diaphysis of the humerus at its lateral edge.

The lower epiphysis is the condyle of the humerus, *condylus humeri*; it is flattened front to back. It joins with both bones of the forearm

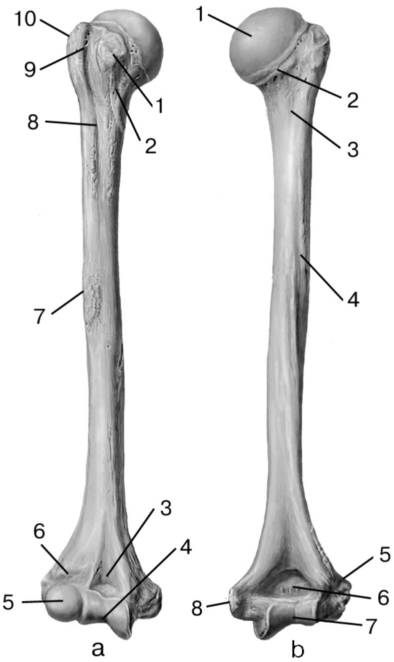

Fig. 4.3. Right humerus:

a — anterior aspect: 1 — lesser tubercle (*tuberculum minus*); 2 — crest of lesser tubercle (*crista tuberculi minoris*); 3 — coronoid fossa (*fossa coronoidea*); 4 — trochlea of humerus (*trochlea humeri*); 5 — capitulum of humerus (*capitulum humeri*); 6 — radial fossa (*fossa radialis*); 7 — deltoid tuberosity (*tuberositas deltoidea*); 8 — crest of greater tubercle (*crista tuberculi majoris*); 9 — intertubercular groove (*sulcus intertubercularis*); 10 — greater tubercle (*tuberculum majus*)

b — posterior aspect: 1 — head of humerus (*caput humeri*); 2 — anatomical neck (*collum anatomicum*); 3 — surgical neck (*collum chirurgicum*); 5 — groove for radial nerve (*sulcus nervi radialis*); 6 — olecranon fossa (*fossa olecrani*); 7 — trochlea of humerus (*trochlea humeri*); 8 — medial epicondyle (*epicondylus medialis*)

and consists of the trochlea, *trochlea humeri*, which articulates with the ulna, and the capitulum, *capitulum humeri*, which articulates with the radius.

The coronoid fossa, *fossa coronoidea*, is located anteriorly above the trochlea; when the elbow is flexed, the coronoid process of the ulna gets into the coronoid fossa. A shallow radial fossa, *fossa radialis*, is above capitulum; it matches the head of the radius. The deep olecranon fossa, *fossa olecrani*, is visible posteriorly above the trochlea. There are two elevations on the both sides of the epiphysis of the humerus: the medial epicondyle, *epicondylus medialis*, and the lateral epicondyle, *epicondylus lateralis*. The medial epicondyle is bigger than the lateral one; the groove for ulnar nerve, *sulcus nervi ulnaris*, passes along its posterior surface. Each epicondyle continues upwards into the corresponding medial or lateral supracondylar crest, *crista supracondylaris medialis et crista supracondylaris lateralis*.

Bones of forearm

The forearm consists of two bones, *ossa antebrachii*: the ulnar and the radius, *radius et* which belong to long tubular bones. These bones are curved and therefore they touch each other by their ends only. The space between the bones of forearm is called the interosseous space, *spatium interosseum antebrachii*. Each bone of the forearm consists of the diapysis (body) and the epiphyses (ends).

The proximal epiphyses of these bones have the articular surfaces which articulate with the humerus. The articular surface of the distal epiphysis of the radius articulates with the carpal bones. The major parts of the bodies of these bones are trichedral in shape. Three surfaces and three borders are distinguished on the bodies. One of these surfaces is directed backwards, *facies posterior*; the second one — forwards, *facies anterior*; the third one is directed laterally in the radius, *facies lateralis*, and medially at the ulna, *facies medialis*. One of the borders is sharp in both bones, it is named interosseous border, *margo interosseus*. It separates the anterior surface from the posterior surface and it is directed to the adjacent bone. Each bone also has the anterior and posterior borders, *margo anterior et margo posterior*. The radius and the ulna have distinctive features besides the general characteristics.

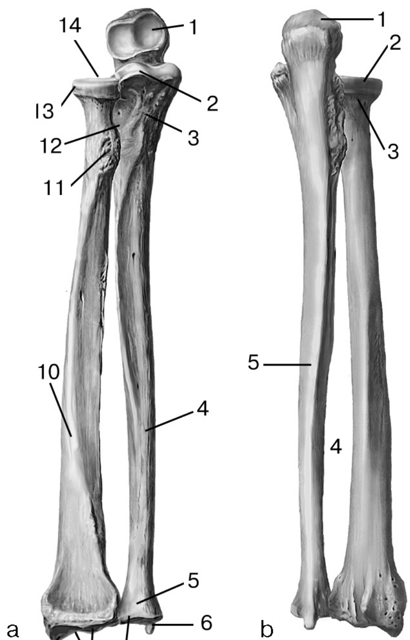

Fig. 4.4. Right ulna and radius:

a — anterior aspect: 1 — trochlear notch (*incisura trochlearis*); 2 — coronoid process (*processus coronoideus*); 3 — ulnar tuberosity (*tuberositas ulnae*); 4 — ulna (*ulna*); 5 — head of ulna (*caput ulnae*); 6 — styloid process of ulna (*processus styloideus ulnae*); 7 — articular circumference of ulna (*circumferentia articularis ulnae*); 8 — carpal articular surface (*facies artcularis carpalis*); 9 — styloid process of radius (*processus styloideus radii*); 10 — radius (*radius*); 11 — radial tuberosity (*tuberositas radii*); 12 — supinator crest (*crista m. supinatoris*); 13 — head of radius (*caput radii*); 14 — articular facet (*fovea articularis*)

b — posterior aspect: 1 — olecranon (*olecranon*); 2 — articular circumference of radius (*circumferentia articularis radii*); 3 — neck of radius (*collum radii*); 4 — interosseous space (*spatium interosseum*); 5 — ulna (*ulna*)

The ulna, *ulna*, is located medially in the anatomic position. Its upper (proximal) epiphysis articulates with *trochlea humeri* by means the the trochlear notch, *incisura trochlearis* (fig. 4.4). This notch is directed forwards and is bounded by two processes: the coronoid process, *processus coronoideus*, which is located antreiorly and inferiorly, and the olecranon, *olecranon*, which is located posteriorly and superiorly. Laterally to the coronoid process there is a shallow radial notch, *incisura radialis*, which articulates with the head of radius. The supinator crest, *crista m. supinatoris*, descends from the radial notch. The tuberosity of ulna, *tuberositas ulna,* is located below the coronoid process. There is a large nutrient foramen, *foramen nutricium*, on the anterior surface of the middle part of the body. The distal epiphysis is smaller than the proximal one, and it forms the head of ulna, *caput ulnae*. The head bears the articular circumference, *circumferentia articularis*, which articulates with the radius. The inferior surface of the head is flat. The ulnar styloid process, *processus styloideus ulnae*, projects down from the medial edge of the head.

The radius, *radius*, is located laterally. Its lower (distal) epiphysis is more massive than the upper (proximal) epiphysis (fig. 4.4). The latter has the head of radius, *caput radii*, with a shallow depression called the articular facet, *fovea articularis*, in its center. It articulates with *capitulum humeri*. The articular circumference, *circumferentia articularis*, corresponding to the radial notch (of the ulna) skirts the head. Below the head there is the neck of the radius, *collum radii*. Distally to the neck, on the anterior surface of the body, there is the radial bone tuberosity, *tuberositas radii*, which is the place of attachment of the biceps brachii. The medial side of the distal epiphysis has the ulnar notch, *incisura ulnaris*, which articulates with the head of ulna. On the lateral side of the distal epiphysis there is the radial styloid process, *processus styloideus radii*. The inferior supface of the distal epiphysis forms the concave carpal articular surface, *facies articularis carpalis*, which is divided by a prominence into two parts for the the scaphoid and lunate bones. Several grooves for tendons of the extensor muscles are visible on the posterior surface of the body of the radius.

Bones of hand

The bones of hand, *ossa manus*, are divided into the carpal bones, *ossa carpi*; the metacarpals, *ossa metacarpi*, and the phalanges of fingers, *phalanges digitorum manus* (fig. 4.5, 4.6).

1. Carpal bones. These are eight volumetric bones which are located in two rows; each row consists of four bones. In the proximal row, counting from the lateral edge there are the scaphoid bone, *os scaphoideum*, lunate bone, *os lunatum*, and triquetral bone, *os triquetrum*. The fourth bone in this row is the pisiform, *os pisiforme*, it lies on the palmar surface of the triquetrum and belongs to sesamoid bones, *ossa sesamoidea*. The distal row of carpal bones starting from the lateral edge, consists of: the trapezium, *os trapezium*, trapezoid bone, *os trapezoideum*; capitate bone, *os capitatum*, and hamate bone, *os hamatum*.

The pisiform differs from all other carpal bones by shape and location. It is the smallest, round in shape, and has only one articular surface for articulation with the palmar surface of the triquetral. The pisiform is elevated above the total level of the carpal bones therefore it can be palpated easily under the skin.

The other seven carpal bones have the following surfaces: palmar, *facies palmaris*; dorsal, *facies dorsalis*; proximal, *facies proximalis*; distal, *facies distalis*; lateral (or radial), *facies lateralis*, and medial (or ulnar), *facies medialis*. The dorsal and palmar surfaces are always rough. The distal and proximal sides have articular surfaces, and three bones of

the proximal row are turned to the forearm forming altogether something like one single ellipsoid articular head. Their distal surfaces articulate with the proximal surfaces of the four bones of the second row. The distal surfaces of these four bones are connected with the bases of the carpal bones. Almost all lateral and medial sides of the carpal bones also have articular surfaces to connect the bones with each other. The lateral sides of the scaphoid and trapezium, and the medial sides of the triquetral and pisiform, are exceptions, because they are directed to the free edge of the wrist; all these surfaces are rough.

The scaphoid bone, *os scaphoideum*, is the biggest bone of the first row bones. Its proximal surface is convex. The lateral end of the bone forms the tubercle, *tuberculum ossis scaphoidei*, which rises above other bones towards the palmar surface.

The lunate bone, *os lunatum*, is semilunar in shape. Its proximal surface is convex, the distal surface is concave and embraces together with the scaphoid the head of the capitate.

The triquetral bone, *os triquetrum*, has a small flat articular surface for articulation with the pisiform.

The pisiform bone, *os pisiforme*, has the shape of a pea. It is located within the tendon of the flexor carpi ulnaris and belongs to sesamoid bones.

The os trapezium, *os trapezium*, differs from other bones by a large saddle-like surface which articulates with the base of the I metacarpal. There is the groove which is

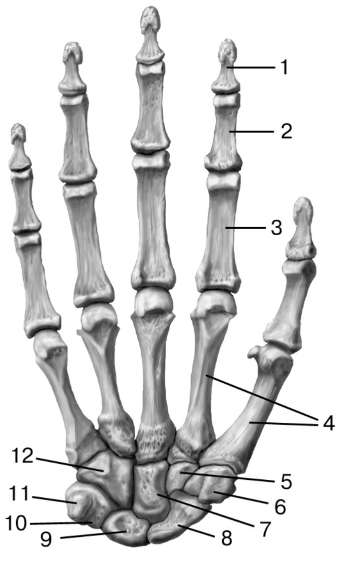

Fig. 4.5. Bones of right hand (palmar surface):
1 — distal phalanx (*phalanx distalis*); 2 — medial phalanx (*phalanx media*); 3 — proximal phalanx (*phalanx proximalis*); 4 — metacarpals (*ossa metacarpi*); 5 — trapezoid (*os trapezoideum*); 6 — trapezium (*os trapezium*); 7 — capitate (*os capitatum*); 8 — scaphoid (*os scaphoideum*); 9 — lunate (*os lunatum*); 10 — triquetrum (*os triquetrum*); 11 — pisiform (*os pisiforme*); 12 — hamate (*os hamatum*)

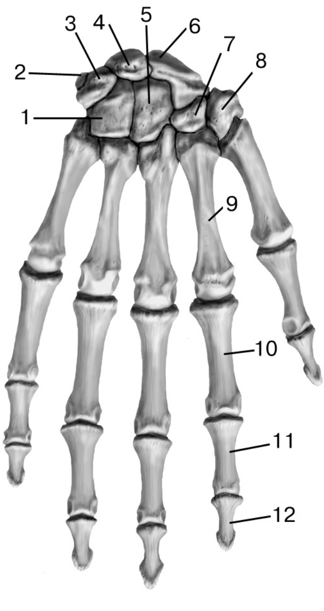

Fig. 4.6. Bones of right hand (dorsal surface):
1 — hamate (*os hamatum*); 2 — pisiform *(os pisiforme*); 3 — triquetrum (*os triquetrum*); 4 — lunate (*os lunatum*); 5 — capitate (*os capitatum*); 6 — scaphoid (*os scaphoideum*); 7 — trapezoid (*os trapezoideum*); 8 — trapezium (*os trapezium*); 9 — metacarpals (*ossa metacarpi*); 10 — proximal phalanx (*phalanx proximalis*); 11 — medial phalanx (*phalanx media*); 12 — distal phalanx (*phalanx distalis*)

bounded laterally by the tubercle of the trapezium, *tuberculum ossis trapezii,* on the palmar surface of the trapezium.

The trapezoid bone, *os trapezoideum*, is small and similar to the trapezium in shape.

The capitate bone, *os capitatum*, is the biggest of all carpal bones. The distinctive feature of this bone is the presence of a head which is placed in the depression formed by the scaphoid and lunate. The distal end of the capitate articulates with the III metacarpal bone.

The hamate bone, *os hamatum*, has a hook-shaped process, *hamulus ossis hamati*, on the palmar surface at the ulnar side.

The carpal bones don`t lie in one plane, they form an arch; the dorsal carpal surface is convex, the palmar forms a concave carpal groove, *sulcus carpi*; it is bounded by the tubercle of the scaphoid and by the tubercle of the trapezium on the radial side, and by the hook of the hamate and by the pisiform on the ulnar side.

2. The metacarpal bones, *ossa metacarpi*, are five short tubular bones; it is accepted to count them from the thumb to the little finger. Each bone is composed of the body, *corpus*; base, *basis*, and head, *caput.* The bodies of metacarpals have an irregular prismatic shape; they are thinner than the epiphyses, therefore the metacarpal interosseous spaces, *spatia interossea metacarpi*, remain between the bodies. The bases of the metacarpal bones also have irregular shape. Their proximal epiphyses are occupied with the articular surfaces to be connected with the carpal bones. The lateral surfaces of the II-V metacarpal bones facing each other, have the articular areas for articulation with each other.

The I metacarpal, *os metacarpale I*, is shorter and wider than the other ones; its head is ellipsoid, its base has a saddle surface which articulates with the trapezium. The II metacarpal, *os metacarpale II*, is the longest one. The length of the bones gradually decreases towards the V finger. The bases of the II, III and IV metacarpal bones are flat: the base of the II metacarpal is divided into two parts by the depression; the base of the III metacarpal continues into the styloid process, *processus styloideus*, on the lateral side; the base of the V metacarpal has a saddle-shaped surface and a small tubercle on the medial side. The heads of the II–V metacarpal bones have spherical shape and terminate with the convex articular surface for articulation with the proximal phalanges.

3. The phalanges. The fingers are called: the thumb, *pollex* (*digitus primus*), shoterst and thickest; the index finger, *index* (*digitus secundus*); the middle finger, *digitus medius* (*tertius*), the longest one; the ring finger, *digitus anonimus* (*quartus*) and the little finger, *digitus minimus* (*quintus*). The phalanges, *phalanges digitorum*, are short tubular bones. Each finger, except the thumb, has three phalanges: proximal, *phalanx proximalis*; middle, *phalanx media*, and distal, *phalanx distali*s. The thumb has only two phalahges — proximal and distal. The proximal phalanges (basic) are the longest, the distal phalanges (end, nail) are the shortest. All phalanges of the middle finger are longest.

Each phalanx has a base, *basis phalangis*, body, *corpus phalangis*, and head, *caput phalangi*s. The bodies of the proximal and middle phalanges are convex from the dorsal side and slightly concave from the palmar side. The heads of these phalanges have hinge articular surfaces which correspond to the middle and distal phalanges by shape. Each of these hinge surfaces is represented by two pits with the crest between them. The bases of the proximal phalanges have the shape of a fossa, corresponding to the heads of the metacarpals. The distal epiphysis of the distal phalanges is widened and forms the tuberosity of distal phalanx, *tuberositas phalangis distalis.*

TEST QUESTIONS:

1. What parts does the upper limb include?
2. What parts does the free part of upper limb include?
3. What bones form the sholder girdle?
4. What bones form the free part of upper limb?

Scapula:

5. What is the scapula according to the classification of bones?
6. What parts of the scapula serve for articulation with the humerus and clavicle?
7. What structures of the scapula serve for attachment of muscles?
8. What signs can help to differentiate the anterior and posterior surfaces of the scapula, its medial and lateral borders?
9. How can you determine the right and the left scapula?

Clavicle:

10. What is the clavicle according to the classification of bones?
11. What parts of the clavicle serve for articulation with the sternum and scapula?
12. What structures of the clavicle serve for attachment of ligaments?
13. What signs can help to differentiate superior and inferior surfaces of the clavicle, its medial and lateral ends, its anterior and posterior sides?
14. How can you determine the right and the left clavicle?

Humerus:

15. What is the humerus according to the classification of bones?
16. What parts of the humerus serve for articulation with the scapula and ulna and radius?
17. What structures of the humerus serve for attachment of muscles?
18. What indications can help to differentiate the proximal and distal epiphyses of the humerus, its medial and lateral borders, its anterior and posterior surfaces?
19. How can you determine the right and the left humerus?

Bones of forearm:

20. Which of the bones of forearm is located medially in the anatomic position?
21. What is the ulna according to the classification of bones?
22. What parts of the ulna serve for articulation with the humerus and radius?
23. What signs can help to differentiate proximal and distal epiphyses of the ulna, its medial and lateral borders, its anterior and posterior surfaces?
24. How can you determine right and left ulna?
25. What is the radius according to the classification of bones?
26. What parts of the radius serve for articulation with the humerus, ulna and carpal bones?
27. What structures of the radius serve for attachment of muscles?
28. What signs can help to differentiate the proximal and distal epiphyses of the radius, its medial and lateral borders, its anterior and posterior surfaces?
29. How can you determine the right and the left radius?

Bones of hand:

30. What are the carpals according to the classification of bones?
31. What bones of the carpus form the proximal row, how are they located in lateral to medial order?

32. What bones of the carpus form the distal row, how are they located in lateral to medial order?

33. What bones of the carpus articulate with the radius?

34. What is the carpal groove, what bones bound it?

35. What bones of the carpus articulate with metacarpal bones?

36. What are the metacarpals according to the classification of bones?

37. What parts of the metacarpal bones serve for articulation with the carpals and proximal phalanges of fingers?

38. What are the phalanges according to the classification of bones?

39. What types of phalanges do you know?

40. How many phalanges does each finger have?

41. What parts of the phalanges serve for articulation with each other and metacarpals?

42. What signs can help to differentiate the dorsal and palmar surfaces of the hand, its medial and lateral sides?

CLINICOANATOMICAL PROBLEMS

Falling down from height a patient broke the clavicle and it displaced to the side of the I rib. What vessels lying on the I rib, may be damaged?

A 45-year-old patient complains of pain in the fingers of the hand. He associates it with a trauma which he had not long ago. The X-ray examination detects no fructures but numerous osteophytes are visible. What will the doctor think of?

5. BONES OF LOWER LIMB

The lower limb is composed of the pelvic girdle, *cingulum membri inferioris*, and the free part of the lower limb, *membrum inferioris libera*. The latter consists of three parts: proximal, middle and distal. The proximal part is called the thigh, *femur*; the middle part — the leg, *crus*, and the distal part — the foot, *pes*. The foot also includes three parts: the tarsus, *tarsus*; metatarsus, *metatarsus*, and toes, *digiti pedis*. The bones of the upper limb, *ossa membri inferioris*, are divided into the bones of the pelvic girdle and the bones of free lower limb.

The bones of the pelvic girdle, *ossa cinguli membri inferioris*, are paired pelvic bone, *os coxae*, which consists of three bones connected by cartilage in children: the ilium, *os ilium*; pubis, *os pubis*, and ischium, *os ischii*. The pelvic bone articulates with the sacrum and femur.

The bones of the free lower limb, *ossa membri inferioris liberi*, are: the femur, *femur* (*os femoris*), the bones of the leg, *ossa cruris*, and the bones of the foot, *ossa pedis*. The bones of the leg include the tibia, *tibia*, located on the side of the big toe (medially), and the fibula, *fibula*, located laterally. There is the sesamoid bone named patella, *patella*, in the knee region. The tarsus is located closer to the leg, and is comprised of seven bones; two of them form the proximal row: the talus, *talu*s, and calcaneus, *calcaneus*. Four bones form the distal row, and they lie, in the medial to lateral order (from the big toe), as follows: the medial cuneiform, *os cuneiforme mediale*; the intermediate cuneiform, *os cuneiforme intermedium*; the lateral cuneiform, *os cuneiforme laterale*, and the cuboid, *os cuboideum*. The seventh bone, the navicular, *os naviculare*, has an intermediate position: between the talus posteriorly and the cuneiform anteriorly. The metatarsus consists of five short tubular bones, *ossa metatarsi* (*metatarsalia*). The bones of toes are phalanges, *phalanges*; the I toe has two phalanges, the other ones have three phalanges.

5.1. Bones of pelvic girdle

Pelvic bone

The pelvic bone, *os coxae* (fig. 5.1, 5.2), in an adult person consists of three fused bones — the ilium, *os ilium*, ischium, *os ischii*, and pubis, *os pubis*. Before the puberty, there are distinct cartilaginous borders between these bones. Further the cartilages ossify, and the borders between the bones are marked conditionally. The bodies of all three bones are connected in the region of the acetabulum, *acetabulum*, which is on the external surface of the pelvic bone.

The ilium, *os ilium* (fig. 5.1, 5.2), forms the superior widened part of the pelvic bone. It has a body, *corpus ossis ilii*, and the wing, *ala ossis ilii*. The body is the inferior thickened part of the bone which takes part in formation of the acetabulum. The wing is a superior thinner part of the ilium. On the internal surface between the body and the wing there is a distinct border in the form of a convex arch-shaped line termed the arcuate line, *linea arcuata*. The superior edge of the wing is called the iliac crest, *crista iliaca*. Three parallel rough lines extend along the crest; they are caused by attachment of the abdominal muscles. The lines are named: the external lip, *labium externum*; internal lip, *labium internum*, and intermediate line, *linea intermedia*, located between the lips. Anteriorly and posteriorly, the iliac crest terminates with projections named the anterior superior iliac spine, *spina iliaca anterior superior*, and the posterior superior iliac spine, *spina iliaca posterior superior*, correspondently. Below these spines there are the anterior inferior iliac spine, *spina iliaca anterior inferior*, and the posterior inferior iliac spine, *spina iliaca posterior inferior*, separated from each other by the notches.

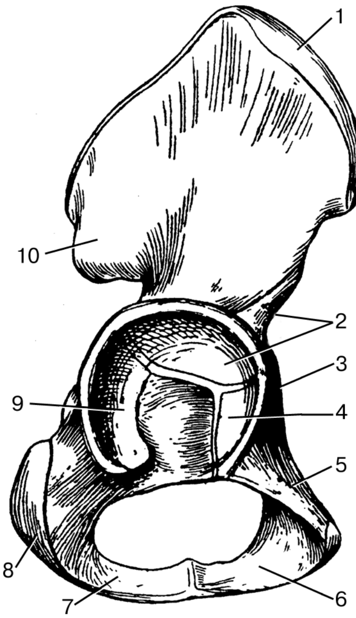

Fig. 5.1. Right pelvic bone of child (lateral aspect):

1 — iliac crest (*crista iliaca*); 2 — body of ilium (*corpus ossis ilii*); 3 — iliopubic eminence (*eminentia iliopubica*); 4 — body of pubis (*corpus ossis pubis*); 5 — superior ramus of pubis (*ramus superior ossis pubis*); 6 — inferior ramus of pubis (*ramus inferior ossis pubis*); 7 — ramus of ischium (*ramus ossis ischii*); 8 — ischial tuberosity (*tuber ischiadicum*); 9 — body of ischium (*corpus ossis ischii*); 10 — ala of ilium (*ala ossis ilii*)

The external surface of the ilium`s wing also has three rough lines caused by the origin of the muscles. The posterior gluteal line, *linea glutea posterior*, is in the posterior part of the wing and runs vertically; the inferior gluteal line, *linea glutea inferior*, short and arch-shaped, is located immediately above the acetabulum; the anterior gluteal line, *linea glutea anterior*, long, arch-shaped, is above the previous one, almost in the midst of the wing.

The internal surface of the ilium`s wing is slightly concave and is named the iliac fossa, *fossa iliaca*. Behind it there is the auricular surface, *facies auricularis,* which articulates with the sacrum. Above and behind this surface there is the iliac tuberosity, *tuberositas iliaca*, caused by attachment of strong ligaments.

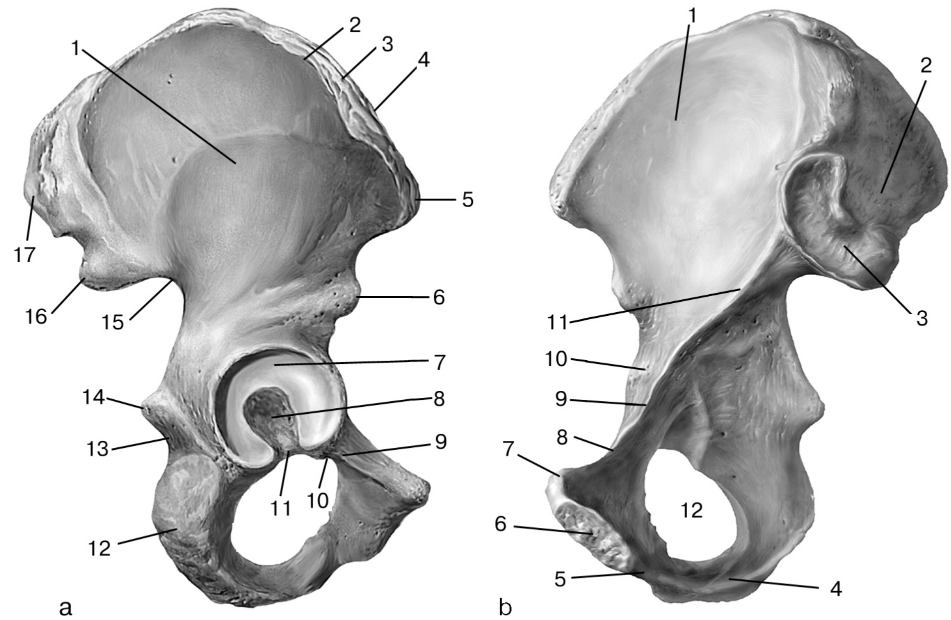

Fig. 5.2. Right pelvic bone of adult person:

a — external surface: 1 — ilium (*os ilium*); 2 — outer lip (*labium externum*); 3 — intermediate zone (*linea intermedia*); 4 — inner lip (*labium internum*); 5 — anterior superior iliac spine (*spina iliaca anterior superior*); 6 — anterior inferior iliac spine (*spina iliaca anterior inferior*); 7 — lunate surface (*facies lunata*); 8 — acetabular fossa (*fossa acetabuli*); 9 — obturator crest (*crista obturatoria*); 10 — obturator groove (*sulcus obturatorius*); 11 — acetabular notch (*incisura acetabuli*); 12 — ischial tuberosity (*tuber ischiadicum*); 13 — lesser sciatic notch (*incisura ischiadica minor*); 14 — ischial spine (*spina ischiadica*); 15 — greater sciatic notch (*incisura ischiadica major*); 16 — posterior inferior iliac spine (*spina iliaca posterior inferior*); 17 — posterior superior iliac spine (*spina iliaca posterior superior*)

b — internal surface: 1 — iliac fossa (*fossa illiaca*); 2 — iliac tuberosity (*tuberositas iliaca*); 3 — auricular surface (*facies auricularis*); 4 — ramus of ischium (*ramus ossis ischii*); 5 — inferior ramus of pubis (*ramus inferior ossis pubis*); 6 — symphysial surface (*facies symphysialis*); 7 — pubic tubercle (*tuberculum pubicum*); 8 — superior ramus of pubis (*ramus superior ossis pubis*); 9 — pecten pubis (*pecten ossis pubis*); 10 — iliopubic eminence (*eminentia iliopubica*); 11 — arcuate line (*linea arcuata*); 12 — obrurator foramen (*foramen obturatum*)

The ischium *os ischii* (fig.5.1, 5.2), has a body and ramus. The body of ischium, *corpus ossis ischii*, takes part in formation of the acetabulum. The ramus of ischium, *ramus ossis ischii*, joins with the inferior pubic ramus bounding the irregular-shaped obturator foramen, *foramen obturatum*. At the junction of the body and the ramus there is the large ischial tuberosity, *tuber ischiadicum*. Above it, a sharpened projection called the ischial spine, *spina ischiadica*, is located. The ischial spine separates two ischial notches: greater and lesser ones. The greater sciatic notch, *incisura ischiadica major*, is between the posterior inferior iliac spine and the ischial spine. The lesser sciatic notch, *incisura ischiadica minor*, is between the ischial spine and the ischial tuberosity.

The pubis, *os pubis* (fig. 5.1, 5.2), consists of the body, *corpus ossis pubis*, included into the acetabulum, and two rami, *ramus superior et ramus inferior ossis pubis*, bounding the obturator foramen. The pubic rami are connected with each other at an angle, which carries a rough oval symphysial surface, *facies symphysialis*. It participates in formation of the pubic articulation. There is an iliopubic eminence, *eminentia iliopubica*, on the internal surface

of the pelvic bone in the place of fusion between the ilium and pubis. The arcuate line of the ilium continues into the pubic crest, *pecten ossis pubis*, which terminates with the pubic tubercle, *tuberculum pubicum. Linea arcuata* together with *pecten ossis pubis* form the terminal line, *linea terminalis*, which is the border between the greater and lesser pelvis. There is a deep obturator groove, *sulcus obturatorius*, between the body of pubis and the superior pubic ramus. The obturator vessels and nerves pass along this groove.

The acetabulum, *acetabulum*, serves for articulation of the pelvic bone with the head of the femur. The two parts can be distinguished in the acetabulum: the central part named the acetabular fossa, *fossa acetabuli*, and the lunate surface, *facies lunata acetabuli*, located along the periphery of the acetabular fossa and bounded by the acetabular margin, *limbus acetabuli*, outside. There is the acetabular notch, *incisura acetabuli,* in the inferior part of the acetabulum between the ends of the lunate surface.

5.2. Bones of free part of lower limb

Femur

The femur, *femur* (*os femoris*), (fig. 5.3) has a body (shaft) and two ends (epiphyses): proximal and distal. The proximal epiphysis is composed of the spheroidal head, *caput femoris*, and the neck, *collum femoris*, which continues into the body. The head is directed medially, and its articular surface has a pit termed the fossa for ligament of head, *fovea capitis ossis femoris*; the intraarticular ligament is attached to this fovea. There are two large prominences named the greater and lesser trochanters, *trochanter major et trochanter minor*, at the junction of the neck with the body. The greater trochanter occupies the upperlateral position and has a small trochanteric fossa, *fossa trochanterica*, on the inner side. The lesser trochanter is located below and behind the greater one and medially to it. The neck of femur is separated from the body by the intertrochanteric line, *linea intertrochanterica*, anteriorly and by the intertrochanteric crest, *crista intertrochanterica,* posteriorly.

The body of femur is slightly convex forwards and is gradually widened downwards. It is smooth on the anterior and lateral surfaces. The rough line named linea aspera, *linea aspera*, passes along the bone on its posterior surface. The linea aspera consists of the lateral and medial lips, *labium laterale et labium mediale*, which diverge upwards and downwards. Near the proximal epiphysis, the medial lip continues into the pectineal line, *linea pectinea*, the lateral lip reaches the gluteal tuberisuty, *tuberositas glutea*, caused by attachment of the gluteus maximus. Near the distal epiphysis, both diverging lips bound the triangular popliteal surface, *facies poplitea.*

The distal epiphysis is comprised of the lateral and medial condyles, *condylus lateralis et condylus medialis*, separated by a depression called the intercondylar fossa, *fossa intercondylaris.* Anteriorly, the articular surfaces of both condyles merge and form the patellar surface, *facies patellaris.* Above the articular surface of each condyle, there are two elevations named the lateral and medial epicondyles, *epicondylus lateralis et epicondylus medialis.*

Patella

The patella, *patella* (fig. 5.3) is the largest sesamoid bone, its external surface is fused with the tendon of the quadriceps femoris. The superior widened part of the patella is called the base of patella, *basis patellae.* The lateral edges converge downwards and form the sharpened apex of patella, *apex patellae.* The bone has two surfaces — the external, or anterior, surface, *facies anterior*, and the internal one named articular surface, *facies articularis.* The latter is divided by the small prominence into the greater part located medially and the lesser part located laterally.

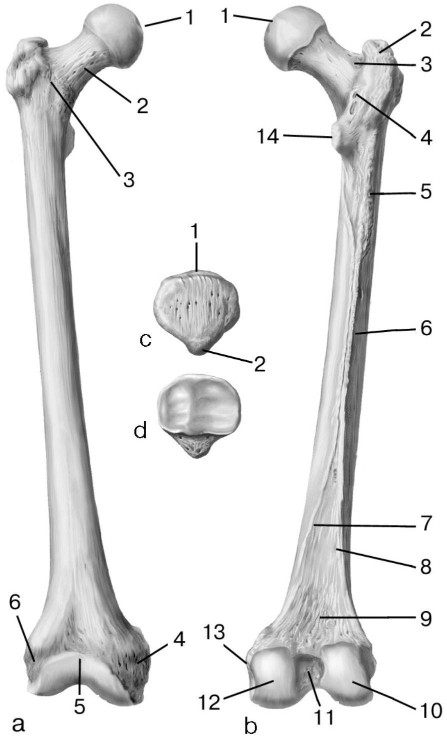

Fig. 5.3. Right femur and patella: a, b — anterior aspect; c, d — posterior aspect

a: 1 — fovea for ligament of head (*ligamentum capitis femoris*); 2 — neck of femur (*collum femoris*); 3 — intertrochanteric line (*linea intertrochanterica*); 4 — medial epicondyle (*epicondylus medialis*); 5 — patellar surface (*facies patellaris*); 6 — lateral epicondyle (*epicondylus lateralis*)

b: 1 — head of femur (*caput femoris*); 2 — greater trochanter (*trochanter major*); 3 — trochanteric fossa (*fossa trochanterica*); 4 — intertrochanteric crest (*crista intertrochanterica*); 5 — gluteal tuberosity (*tuberositas glutea*); 6 — linea aspera (*linea aspera*); 7 — medial lip (*labium mediale*); 8 — lateral lip (*labium laterale*); 9 — popliteal surface (*facies poplitea*); 10 — lateral condyle (*condylus lateralis*); 11 — intercondylar fossa (*fossa intercondylaris*); 12 — medial condyle (*condylus medalis*); 13 — medial epicondyle (*epicondylus medialis*); 14 — greater trochanter (*trochanter major*)

c: 1 — base of patella (*basis patellae*); 2 — apex of patella (*apex patellae*)

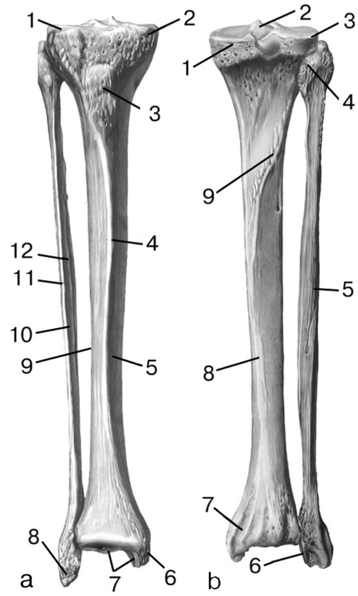

Fig. 5.4. Right tibia and fibula:

a — anterior aspect: 1 — lateral condyle (*condylus lateralis*); 2 — medial condyle (*condylus medialis*); 3 — tibial uberosity (*tuberositas tibiae*); 4 — anterior border of tibia (*margo anterior tibiae*); 5 — tibia (*tibia*); 6 — medial malleolus (*malleolus medialis*); 7 — inferior articular surface and articular facet of medial malleolus (*facies articularis inferior et facies articularis malleoli medialis*); 8 — lateral malleolus (*malleolus lateralis*); 9 — interosseous border of tibia (*margo interosseus tibiae*); 10 — fibula (*fibula*); 11 — anterior border of fibula (*margo anterior fibulae*); 12 — interosseous border of fibula (*margo interosseus fibulae*)

b — posterior aspect: 1 — medial condyle (*condylus medialis*); 2 — intercondylar eminence (*eminentia intercondylaris*); 3 — lateral condyle (*condylus lateralis*); 4 — head of fibula (*caput fibulae*); 5 — fibula (*fibula*); 6 — articular facet of lateral malleolus (*facies articularis malleoli latealis*); 7 — malleolar groove (*sulcus malleolaris*); 8 — tibia (*tibia*); 9 — soleal line (*linea m. solei*)

Bones of leg

The bones of the leg, *ossa cruris*, are long tubular; they include the tibia, *tibia*, located medially, and fibula, *fibula*, located laterally.

The tibia, *tibia* (fig. 5.4), has a body (shaft) and proximal and distal epiphyses. The proximal epiphysis is massive and is composed of two condyles — lateral and medial,

condylus lateralis et condylus medialis. The articular surface of each condyle is directed to the femur and is named the superior articular surface, *facies articularis superior*. In its center there is an intercondylar eminence, *eminentia intercondylaris*, which separates the concave articular surfaces of condyles. In front of the eminence and behind it there are the depressions called the anterior and posterior intercondylar areae, *areae intercondylares anterior et posterior*. The inferior part of the lateral condyle has a small flat fibular articular facet, *facies articularis fibularis*, for articulation with the head of fibula.

The body of tibia has three surfaces which are separated from each other by borders. The sharpest anterior border, *margo anterior*, is clearly visible under the skin; it separates the lateral surface from the medial one. The third surface, posterior, is bounded by the rounded medial border, *margo medialis*, and the sharp lateral border, *margo lateralis*. The lateral border is directed to the fibula, therefore it is called the interosseous border, *margo interosseus*. The anterior border reaches the tibial tuberosity, *tuberositas tibiae*, superiorly. The rough soleal line, *linea m. solei*, crosses the posterior surface of the tibia near the proximal epiphysis. It runs obliquely from the fibular articular facet downwards and medially, and it is the place of attachment of the soleus. The body of tibia is widened inferiorly and continues into the distal epiphysis. The latter has the inferior articular surface, *facies articularis inferior*, articulating with the talus. There is a notch on the lateral side of the distal epiphysis; it is called the fibular notch, *incisura fibularis*, because the fibula adjoins it. On the medial side of the distal epiphysis there is a prominence with the sharpened inferior part named the medial malleolus, *malleolus medialis*. It has the articular facet, *facies articularis malleoli medialis*, which merges with the inferior articular surface of the tibia.

The fibula, *fibula seu perone* (fig. 5.4), has a body (shaft), the proximal and distal epiphyses like the tibia. This bone is located laterally to the tibia and parallelly to it. The proximal epiphysis is formed by the head of the fubula, *caput fibulae*, with the sharpened apex, *apex capitis fibulae*. There is the articular facet, *facies articularis capitis fibulae,* on the internal surface of the head; it articulates with the tibia and is directed upwards and medially. The neck of the fibula, *collum fibulae*, is between the head and body.

Three borders are distinguished on the body: the anterior border, *margo anterior*, the posterior border, *margo posterior*, and the sharpest interosseous border, *margo interosseus*, located medially.

The distal epiphysis is called the lateral malleolus, *malleolus lateralis*. On its internal surface there is a smooth articular facet, *facies articularis malleoli lateralis*, which is located in the sagittal plane differently from the articular facet of the head. The malleolar fossa, *fossa malleoli lateralis*, is behind this articular facet; here are the tendons of muscles.

Bones of foot

The bones of foot, *ossa pedis*, are divided into three parts: the tarsal bones, *ossa tarsi*, which form the proximal part of the foot; the metatarsal bones, *ossa metatarsi*, which are the central part of the foot and phalanges, *phalanges digitorum pedis*, forming the distal part (fig. 5.5).

1. The tarsus consists of seven bones. It is accepted to distinguish two rows of bones in the tarsus: the proximal row which consists of two bones (the talus and calcaneus) and the distal one composed of four bones (three cuneiform and cuboid). The navicular is between these two rows. The bones of the proximal row are located one above the other: the talus, *talus*, — below, the calcaneus, *calcaneus*, — above.

The talus, *talus* (fig. 5.6), has a head, neck and body. The head of talus, *caput tali*, is directed forwards and has the spheroid navicular articular surface, *facies articularis navicularis*, for articulation with the navicular bone.

On the inferior surface of the head there is the anterior facet for calcaneus, *facies articularis calcanea anterior*, articulating with the corresponding surface of the calcaneus. The short narrowed part of the talus is named the neck, *collum tali*, it is behind the head and joins the head with the body. The body has a part which protrudes superiorly; it is called the trochlea of talus, *trochlea tali*; it has three articular facets: the superior facet, *facies superior*, which is for articulation of the talus with the tibia; two other facets are medial and lateral malleolar, *facies malleolares medialis et lateralis*. Laterally to the lateral malleolar facet there is a lateral process, *processus lateralis tali*. The posterior process, *processus posterior tali*, projects behind the trochlea. It is divided into the lateral and medial tubercles, *tuberculum laterale et tuberculum mediale*, by the groove for tendon of flexor hallucis longus, *sulcus tendinis m. flexoris hallucis longi*. The inferior surface of the body has the articular facets for articulation with the calcaneus: the anterior calcaneal facet, *facies articularis calcanea anterior*, is near the head of talus; the middle and posterior calcaneal facets, *facies articulares calcanea media et posterior*, are separated from each other by a wide groove named sulcus tali, *sulcus tali*. These facets adjoin the similar facets of the calcaneus.

The calcaneus, *calcaneus* (fig. 5.7), is the most massive bone of the foot bones. It has a body, *corpus calcanei*, which ends with the calcaneal tuberosity, *tuber calcanei*, posteriorly.

Medially to the body there is a projection named sustentaculum tali (talar shelf), *sustentaculum tali*. On the superior surface of the body there are the anterior, middle and posterior talar articular surfaces, *facies articulares talares anterior, medius et posterior*, which correspond to the facets for calcaneus of the talus. The middle talar articular surface is located on the sustentaculum tali. In front of the posterior talar articular surface there is a wide rough calcaneal sulcus, *sulcus calcanei*. The calcaneal sulcus and sulcus tali together form a depression called the tarsal sinus, *sinus tarsi*, which is opened on the lateral side of the body. *Sustentaculum tali* is on the medial side of the body. It supports the head of talus. On its inferior surface there is a groove for tendon of flexor hallucis longus, *sulcus tendinis m. flexoris hallucis longi*, which is the continuation of the groove with the same name located on the talus. A small process named the fibular trochlea, *trochlea fibularis*, is on the lateral side of the calcaneus. There is a groove for tendons of peronei muscles, *sulcus tendinis mm. peronei*, under it. The articular surface for cuboid, *facies articularis cuboidea*, is on the anterior end of the body; it is for articulation with the cuboid bone.

The navicular bone, *os naviculare* (fig. 5.5), has a concavity which is directed to the head of talus. This concavity is occupied with the articular surface for articulation with the talus. The convex side of the navicu-

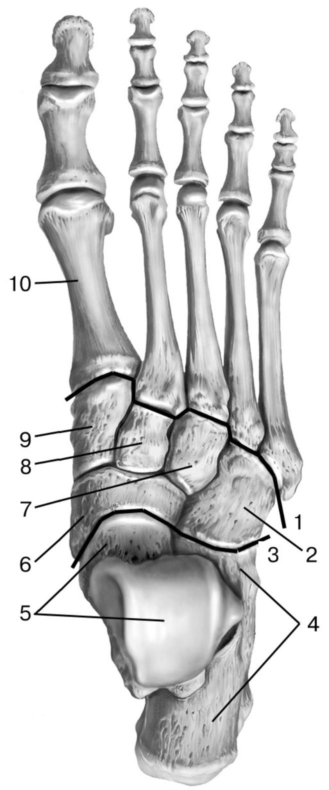

Fig. 5.5. Bones of right foot (superior aspect):

1 — line of tarsometatarsal joints; 2 — cuboid (*os cuboideum*); 3 — line of transverse joint of tarsus; 4 — calcaneus (*calcaneus*); 5 — talus (*talus*); 6 — navicular (*os naviculare*); 7 — lateral cuneiform (*os cuneiforme laterale*); 8 — intermediate cuneiform (*os cuneiforme intermedium*); 9 — medial cuneiform (*os cuneiforme mediale*); 10 — I metatarsal (*os metatarsale I*)

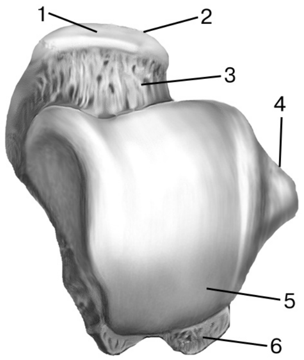

Fig. 5.6. Right talus (superior aspect):

1 — head of talus (*caput tali*); 2 — navicular articular surface (*facies articularis navicularis*); 3 — neck of talus (*collum tali*); 4 — lateral process of talus (*processus lateralis tali*); 5 — trochlea of talus (*trochlea tali*); 6 — posterior process of talus (*processus posterior tali*)

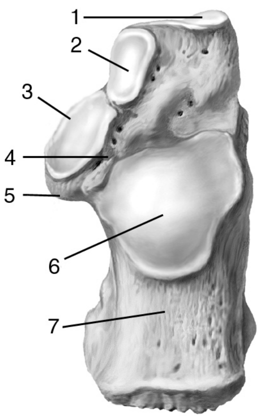

Fig. 5.7. Right calcaneus (superior aspect):

1 — articular surface for cuboid (*facies articularis cuboidea*); 2 — anterior talar articular surface (*facies articularis talaris anterior*); 3 — medial talar articular surface (*facies articularis talaris media*); 4 — calacaneal sulcus (*sulcus calcanei*); 5 — talar shelf (*sustentaculum tali*); 6 — posterior talar articular surface (*facies articularis talaris posterior*); 7 — body of calacaneus (*corpus calcanei*)

lar bone is directed to three cuneiform bones. The surface of this side is divided into three unequal articular areas that serve for articulation with the cuneiform bones. On the lateral side of the navicular bone there is an articular surface to articulate with the cuboid bone. At the medial edge there is a tuberosity of navicular, *tuberositas ossis navicularis*, to which the tendon of the tibialis posterior muscle is attached.

The cuneiform bones, *ossa cuneiformia* (fig. 5.5), are bones of the distal row of the tarsus and are located in front of the navicular. These three bones are wedge-shaped but differ from each other in size and location.

The middle cuneiform bone, *os cuneiforme mediale*, is the biggest of all cuneiforms. Its sharp end is turned to the dorsum of foot, and its widened base is turned to the sole. This bone has three articular surfaces: the posterior (concave) surface, anterior (flat) surface and the lateral one. The first surface serves for articulation with the navicular, the second surface — with the I metatarsal and the third one — with the intermediate cuneiform.

The intermediate cuneiform bone, *os cuneiforme intermedium*, is the smallest of other cuneiforms. Unlike the middle cuneiform, its base is directed to the dorsum of foot and its sharp end — to the sole. This bone has articular surfaces for articulation with adjacent bones: posteriorly — with the navicular bone, anteriorly — with the II metatarsal bone and on the lateral sides — with other cuneiform bone.

The lateral cuneiform bone, *os cuneiforme laterale*, is medium in size and has the most regular wedge shape in comparison with other cuneiforms. Its base is directed to the dorsum of foot and its sharp end — to the sole. This bone has the following articular surfaces to be connected with adjacent bones: posteriorly — with the navicular bone, anteriorly — with the III metatarsal bone, on the internal side — with the intermediate cuneiform bone and the II metatarsal bone and on the external side — with the cuboid bone.

The cuboid bone, *os cuboideum* (fig. 5.5), is in the lateral region of the foot between the calcaneus posteriorly and the IV and V metatarsals anteriorly, therefore there are two articular areas on the anterior surface of the bone and one articular area on the posterior surface. The internal surface is adjacent to the lateral cuneiform and the navicular therefore it has two articular facets for articulation with these two bones. The articular facet for the lateral cuneiform is bigger, the articular facet for the navicular is smaller and may be absent. The lateral side of the cuboid bone has no articular facets. On the plantar surface of the bone there is a tuberosity of cuboid, *tuberositas ossis cuboidei*; the groove for tendon of peroneus longus, *sulcus tendinis musculi peronei longi*, is in front of this tuberosity.

2. The metatarsal bones, *ossa metatarsi*, are five short tubular bones (fig. 5.5), that have a body, *corpus*, head, *caput*, and base, *basis*. The metatarsals are similar in shape and structure but differ from each other in size. The I metatarsal bone (located from the side of the big toe) is the shortest and the most massive. The II metatarsal bone is the longest. The heads of the metatarsal bones are narrowed in comparison with the metacarpal bones and are significantly compressed from the lateral sides. The bodies are prismatic in shape, curved in the sagittal plane and are directed with their convexities to the dorsum of the foot. The bases of the metatarsals articulate with the tarsal bones of the distal row, and they have specific articular surfaces. From the plantar side, the head of the I metatarsal is divided by the prominence into two areas which join with the sesamoid bones. The base of the I metatarsal bone has a concave surface which articulates with the middle cuneiform bone. There is a tuberosity of the first metatarsal bone, *tuberositas ossis metatarsi I*, on the plantar side of the base. The bases of the II and III metatarsals resemble a wedge the sharp end of which is directed downwards. The base of the V metatarsal bone is like a cube; it has a tuberosity of the V metatarsal bone, *tuberositas ossis metatarsi V*, to which the tendon of the peroneus brevis is attached.

3. Phalanges. The skeleton of toes (fig. 5.5) is similar to the skeleton of the fingers, i.e. it consists of phalanges, *phalanges digitorum pedis*; the number, shape and names of these phalanges are the same as in the hand (the I toe, *hallux*, also has only two phalanges). The phalanges of the I toe are thicker and bigger than in other toes. The shortest phalanges are in the IV and V toes. Rather often, the middle and distal (nail) phalanges of the V toe are fused together. The body of the proximal phalanges is significantly thinner than the body of the middle and distal phalanges and it is cylindrical.

There are sesamoid bones in the foot just as in the hand. They are located in the region of the metatarsophalangeal joints of the I and V toes and also in the region of the interphalangeal joint of the I toe. Besides these sesamoid bones, inconstant sesamoid bones are observed in the tendons of the peroneus longus and tibialis posterior.

TEST QUESTIONS

1. What parts does the lower limb include?
2. What parts does the free part of lower limb include?
3. What bones form the pelvic girdle?
4. What bones form the free part of lower limb?

Pelvic bone:

5. What is the pelvic bone according to the classification of bones?
6. What parts of the pelvic bones serve for articulation with each other, with sacrum and femur?
7. What parts can be distinguished in the pelvic bone?
8. What structures of the pelvic bone serve for attachment of muscles and ligaments?
9. What signs can help to differentiate internal and external surfaces of the pelvic bone, its anterior and posterior sides?
10. How can you determine the right and the left pelvic bone?

Femur:

11. What is the femur according to the classification of bones?
12. What parts of the femur serve for articulation with the pelvic bone and tibia and fibula?
13. What structures of the femur serve for attachment of muscles and ligaments?

14. What signs can help to differentiate the proximal and distal epiphyses of the femur, its medial and lateral borders, its anterior and posterior surfaces?
15. How can you determine the right and the left femur?

Patella:

16. What is the patella according to the classification of bones?
17. Describe the location of the patella.

Bones of leg:

18. Which of the bones of the leg is located medially in the anatomic position?
19. What is the tibia according to the classification of bones?
20. What parts of the tibia serve for articulation with the femur, fibula and talus?
21. What structures of the femur serve for attachment of muscles and ligaments?
22. What signs can help to differentiate the proximal and distal epiphyses of the tibia, its medial and lateral borders, its anterior and posterior surfaces?
23. How can you determine the right and the left tibia?
24. What is the fibula according to the classification of bones?
25. What parts of the fibula serve for articulation with the tibia?
26. What signs can help to differentiate proximal and distal epiphyses of the fibula, its medial and lateral borders, its anterior and posterior surfaces?
27. How can you determine right and left fibula?

Bones of foot:

28. What are the tarsal bones according to the classification of bones?
29. What bones form the proximal row of tarsus?
30. What bones form the distal row of tarsus?
31. What bone of the tarsus articulates with the tibia?
32. With what bones does the talus articulate?
33. What parts of the calcaneus serve for articulation with the talus and cuboid?
34. What structures of the calacaneus serve for the passage of muscles?
35. What is the function of the sustentaculum tali?
36. What bones form the tarsal sinus?
37. With what bones does the navicular articulate?
38. With what bones does each of cuneiforms articulate?
39. With what bones does the cuboid articulate?
40. What are the metatarsals according to the classification of bones?
41. With what bones does each of metatrasals articulate?
42. What parts of metatarsals articulate with the tarsus and with phalanges of fingers?
43. What are the palanges according to the classification of bones?
44. What types of phalanges are distinguished in the foot?
45. How many phalanges does each toe have?
46. What parts of the phalanges serve for articulation with each other and metatarsals?
47. What signs can help to differentiate the dorsal and plantar surfaces of the foot, its medial and lateral sides?

CLINICOANATOMICAL PROBLEMS

1. A 10-year-old patient was hospitalized after a car accident with the diagnosis of the fracture of pelvic bones. The X-ray picture revealed the lightness in the region of the acetabulum between the bodies of ilium and ischium. Can we be sure in such diagnosis?
2. As a result of tuberculosis process, the ligament of head of femur was destroyed. What complications may occur if surgical operation is not made in due time?