A.K. Usovich, T.A.Ostrovskaya

Human Anatomy

Part I.

Introduction of anatomy & Skeletal System

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Reviewed by:
V.P. Deykalo – M.D., Ph.D., D.Sc., Professor of the Department of Traumatology & Orthopaedy Vitebsk State Medical University
P.M. Tpyasuchov – M.D., Ph.D., D.Sc., Professor of the Department of Human Anatomy Vitebsk State Medical University
K.B. Boloboshko – M.D., Ph.D., Docent of the Department of Traumatology & Orthopaedy Vitebsk State Medical University

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Preface

Anatomy is the first stage of the basic science that medical students have to study. Study of human anatomy starts from study of skeletal system and can be only by using preparation in the museum and laboratory class.

In this book you can get good knowledge about skeletal system of human being, methods which we used to study structure of human body. Under this topic (Skeletal System) you can get enough information about anatomy of all bones and their clinical value.

The illustrations & pictures have been done by a young artist, my son Alexei Usovich. He used preparations from the museum of department of human anatomy Vitebsk State Medical University. The Translation from Russian into English was made by my assistant T.A.Ostrovskaya & my friend translator A.V. Skrashschuk.

I take this opportunity to thank all collegues for the help in preparing this book. I'll be very thankful for this.

Alexander K. Usovich – M.D., Ph.D., D.Sc.,
Head of the Department of Human Anatomy
Vitebsk State Medical University

INTRODUCTION

Human anatomy is the science about form, structure, origin and development of the human organism.

Anatomy studies exterior forms of a human body and its parts, separate organs, their general and microscopic structure as well as the main stages of human development in the course of evolution and structural features of the organs in various age periods.

Anatomy is part of the continuum of human knowledge. Descriptive anatomy, so called because it was restricted to a description of the body's structures, studied the body's form without regard to its function and made no attempt to disclose the laws governing its development.

The human species, in addition, is the product of prolonged evolution and displays features resembling those of the lower animal forms. Anatomy, therefore, studies not only the structure of the modern adult human being, but investigates the human organism in its historical development.

The development of the human genus in relation to the evolutionary process is called ***phylogenesis*** (Gk *phylon* – genus, *genesis* – development) and uses the data of ***comparative anatomy***, which compares the structures of various animals and man. In addition to comparative anatomy, which is a descriptive science, phylogenesis takes into account the principles of evolutionary morphology. Evolutionary morphology studies the dynamic forces of evolution and the structural changes an organism undergoes in its adaptation to given conditions in the environment.

The process of the development of the individual organism throughout life is ***ontogenesis*** (Gk *onthos* – being). It is devided into 2 periods: prenatal, or uterine, or embryonal period, and postnatal (L *post* - after, *natus* - birth), or extrauterine, or postembryonal period. The data of ***embryology*** (Gk *embryo* – grow) and ***age anatomy*** are used in the study of ontogenesis. The last period of ontogenesis, ageing, is the subject of ***gerontology*** (Gk *geron, gerontos* – old man), the study of the ageing process. Individual and sexual differences in the shape, structure, and position of the body and its organs as well as the topographic relationships of the organs are also taken into account.

The formation and development of the human being in relation to the development of society is the subject of ***anthropology*** (Gk *anthropos* – human being).

The ***systematic anatomy*** examines the structure of the human body according to systems (bone system, muscle system, nervous system, etc.).

The ***topographic*** or ***regional anatomy*** studies the spatial relationships of the organs in the different body regions. Since topographic anatomy has direct, practical significance for clinical work, particularly in surgical practice, it is also called *surgical anatomy*. The ***plastic, relief anatomy*** studies only the external form and proportions of the body and serves for artists and sculptors.

The ***dynamic*** or ***sport anatomy*** studies not only the structure of the apparatus but its dynamics.

Anatomy that studies the normal healthy organism is called ***normal anatomy***, as distinct from ***pathological***, or *morbid, anatomy,* which is concerned with the study of the sick organism and the morbid changes in its organs.

All these branches of anatomical science are different aspects of a *single human anatomy*.

THE PRINCIPLES OF ANATOMICAL INVESTIGATIONS

Modern anatomy is based on the following three **main principles of construction of organisms**:

1. The principle of integrity of an organism.
2. The principle of conformity of structure and function.
3. The principle of unity of an organism and the environment.

The **organism** is not simply the sum of separate organs, tissues and cells. The organism is a system of elements dynamically interrelated and interacting among them which constantly influence each other. Moreover, the organism as a whole and its particular parts is also influenced by environmental factors (external factors). Therefore in order to study profoundly the structure of biological objects including the man, it is necessary to use the following **basic (directions) approaches**:

- the **evolutional anatomic approach** – studying the regularities of a structure of an organism, developed under influence of internal and external factors throughout evolution of the species and the fauna on the whole;
- the **functional anatomic approach** – studying the structure of an organism and its particular parts and organs in dynamics of their functioning;
- the **age anatomic (ontogenetic) approach** – studying the features of a structure of the organism which is taking place at a certain stage of its individual development;
- the **applied (practical) approach** (or a principle of unity of theory and practice) - studying anatomy not separately, but for the purposes of applied medicine and physical training.

METHODS OF ANATOMICAL STUDY

There are two groups of methods of anatomical study: examination of a cadaver, and examination of a living human being.

Examination of a cadaver

The work of the anatomist starts with preservation (embalming). Anatomists have long sought a technique for the preservation of soft tissue, producing durable, dry and handable speciment.

In 1893 Bloom has opened **Formalinum**, which one is the basis of mud formulations of an embalming.

The main methods of anatomical research is the **dissection, dissecting** (Gk *anatemno* - to make dissecting, to dissect), and **observation**, inspection of the shape of a body, separate organ or group of organs.

Injection method – when tubular systems (vessels, ducts, and so forth) are injected with various coloured substances.

Corrosion method – after filling of studied cavities of indurating weight with the subsequent chemical dissolution of ambient tissues is possible to see the true shape of a cavity, in which one weight ran in.

The best representation about spatial relationship of organs and ambient tissues gives a **method of a clarification** - decolorization of tissues of an organ, at which one injected organs are visible. Thus the spatial relationship of organs is saved.

N. I. Pirogoff's method (frozen corpse saw up) - when previously frozen corpse cut up on laminas of given depth.

Method of plastination (polymer embalming) - replacement of water and lipids of tissues of an organism by transparent, or coloured polymers.

The external shape of organs cannot be separated from their internal structure. Anatomy is related closely to *histology*, the science of tissues, particularly to the branch of histology known as *microscopic anatomy*. Microscopic (Gk *mikros* small, *skopein* - to watch) anatomy and macroscopic, or gross, anatomy (Gk *markos* - large) are in essence a single science divided into two branches according to examination technique. Because of the specific character of the examination methods (microscope), the vast amount of material to be examined, and the specific patterns governing the development of tissues, cells, and extracellular substance, however, *histology* (Gk *histos* tissue) and *cytology*, the science of the cell (Gk *kytos* cell), are considered independent branches of science.

Examination of a living human being

Anthropometry methods - various measurements of the body (weight, length, etc.).

Physician methods, which includes palpation, percussion, auscultation.

X-ray methods:

- **X-rays radiography** are used for making X-ray photographs,

- **X-rays radioscopy** for visualization on a special screen.

- **Computer tomography (CT)** – is a technique which uses x-ray and depends on the differences in absorption by different tissues. Once a series of transverse section has been made and the results recorded in digital form. It is possible to combine these in the computer and to construct images in different plane if required. CT produces an image of all the organs in a single plane of body tissue, much like sections of a frozen cadaver prepared according to the method developed by N. I. Pirogoff.

- **Magnetic Resonance Imaging (MRI)** is non invasive way that is with out entering the body or breaking the skin. The scanner is able to excite proton of hydrogen atoms in such a way that they transmit radio signals. The signals are then read by a computer and converted in to a very detailed image

- **Ultrasonic tomography** (an echography, sonography, ultrasound) is grounded on analysis of the maps of frames, tissues, organs and systems of an organism. Ultrasound is sound waves with a frequency 3,5 – 7,5 m.g. The method consists of passing an ultrasound transmitter and recorder over the skin and showing the computerized reflection on a cathode ray tube.

- **Endoscopy examination** of the hollow organs through the natural body orifices (Gk *endon – within*).

THE ORGANISM AND ITS COMPONENTS

The **organism** is the highest form of unity of protein bodies capable of exchanging substances with the environment and of growing and multiplying. The organism is a historically formed, integral, continuously changing system with a specific structure and developmental pattern.

The organism is built of separate individual structures, i.e. organs, tissues, and tissue components united into a whole.

Modern anatomy is based on the following three **main principles of construction of organisms**:

1. The principle of integrity of an organism.
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ORGANS, SYSTEMS AND APPARATUS OF ORGANS

The organism is built of separate individual structures, i.e. organs, tissues, and tissue components united into a whole.

Organ (Gk *organon* tool, instrument) is the part of the human body that serves as an instrument for the adaptation of the organism to the environment. The organs form as the result of a long-term process of the selection of useful adaptations of the organism to certain conditions of nutrition, reproduction, and protection, the selection and strengthening of such adaptations from generation to generation, and at the same time the dropping out of least adapted organisms. An organ is the body's natural instrument.

Some functions cannot be accomplished by only one organ. That is why a complex of organs, systems, forms. For instance, a limb cannot be bent at a joint by the action of one muscle, a flexor, another muscle, an extensor, is needed. The complex of all muscles make up the muscular system.

The system of organs is a collection of homogeneous organs marked by a common structure, function, and development. It is a morphological and functional assemblage of organs, i.e. organs which have a common plan of structure and a common origin and which are connected with each other anatomically and topographically.

The bone system, for instance, is a set of bones with common structure, function, and development. The same applies to the muscular, vascular or nervous system.

Some organs and systems of organs differing in structure and development may be united for the performance of a common function. Such functional collections of heterogeneous organs are called an **apparatus.** The apparatus of movement, for instance, includes the bone system, the articulations of bones, and the muscular system.

The scheme of the organism's structure can be marked out: *the organism—the system of organs—the organ—the morpho-functional unit of the organ—the tissue—the tissue elements.*

It should be emphasized, however, that the different organs and systems are so closely related that it is impossible to isolate one system from another in the organism from the anatomical or from the functional standpoint. But for the convenience of studying the vast factual material and because the structure of the integral organism cannot be thoroughly understood at once, anatomy is traditionally studied according to systems. A definite branch of anatomy corresponds to each system: the study of the bone system (osteology), the articulations of bones (arthrosyndesmology), the muscular system (myology), the viscera (splanchnology), the cardiovascular system (angiology), the nervous system (neurology), the sensory organs (aesthesiology), and the endocrine glands (endocrinology).

THE BASIS FOR SCIENTIFIC ANATOMICAL TERMINOLOGY

Unified anatomical terms having a leading role in studying and description of any anatomical structure may become the basis for communication of specialists of different fields of medicine in any country.

That's why a lesson devoted to the basis of *Nomina Anatomica* is introduced into the curriculum in Anatomy.

Nomina Anatomica was established in ancient Rome and Greece as early as B.C. period. The founders of medicine itself and medical terminology were a Greek physician Hippocrates, the father of medicine, and C.Galen who lived and worked in Rome but wrote in the Greek language. Celsus, a Rome scientist, made his contribution to the development of medicine and medical terminology.

The greatest scientists of the Renaissance and the New Age used Latin in their works: Erasmus of Rotterdam, T.Moor, the Italians – A.Vesalius, anatomist, M.Malpigui, biologist and anatomist, and an English physician W.Harwey who discovered blood circulation and some other outstanding philosophers and naturalists.

Even in the XVIII century many scientists continued to use Latin in their works. C. Linney, the greatest Swedish botanist who classified the fauna, wrote in Latin his works known worldwide.

The prominent Russian scientist M.V.Lomonosov, a great Russian surgeon N.I.Pirogov, an outstanding Russian physician M.Ya.Mudrov and the brothers Shumlianski and others had a good command of Latin and Greek-Latin scientific terminology.

Nomina Anatomica of the XX century was enriched with the terms formed on the basis of the Latin and the Greek languages.

A new anatomical nomenclature, the Paris Nomina Anatomica, was approved by the Sixth International Congress of Anatomists held in Paris in 1955. This textbook, therefore, uses the terms of the Paris Nomina Anatomica (PNA) with amendments and additions approved by the Federative Committee on Anatomical Terminology in 1998. Some terms from the old Basle Nomina Anatomica, from which the names of diseases were derived and which became firmly established in clinical literature, are preserved. They are given in the text next to the new terms, followed by the letter s. (i.e. *seu* or) and by the abbreviation for the Basle Nomina Anatomica (BNA). For example: axis s. epistropheus (BNA). This means that axis is a new term from the Paris classification, while epistropheus is the old Basle term. Some of the terms are given in abbreviated form: art.—articulatio (joint); lig.—ligamentum (ligament), a.—arteria (artery), aa.—arteriae (arteries); v.—vena (vein), vv.—venae (veins); n.—nervus (nerve), nn.—nervi (nerves); m.—musculus (muscle), mm.—musculi (muscles).

Some Characteristics of Latin Medical Terms

Three branches are distinguished in Medical Terminology:

1) anatomo-hystological,
2) clinical,
3) pharmaceutical.

Latin is used in *Nomina Anatomica*. The names of the organs, other notions, with a little exception, have Latin origin. Clinical terminology has the Greek basis. Greek words are used for naming pathological processes in human organs, methods of diagnostics and treatment. Even in pharmaceutical terminology both Latin and Greek words are used.

Latin Alphabet

Latin is used in all branches of medical terminology; the terms are read according to the rules of Latin phonetics.

There are 24 letters in Latin alphabet.

Aa [a]	pronounced approximately as english [a]: anterior [antεrier] – front
Bb [bε]	pronounced as english [b]: tuber [tubεr] – a tuber
c [tsε]	pronounced 1) before a, o, u, before all consonants and at the and of the words as the sound [k]: caput [kaput] – a head; corpus [korpus] – a body; sulcus [sulkus] – a fissure, slight depression. 2) before e, i, y, before the diphthongs ae, oe is pronounced [ts]: facies [fatsiεs] – surfase; incisura [intsizura] – notch.
Dd [dε]	as english [d]: dexter [dεkstεr] – right
Ee [ε]	pronounced as english [ε]: medius [mεdius] – middle.
Ff [εf]	pronounced as english [f]: foramen [foramεn] – opening; hole.
Gg [gε]	sagittalis [sagitalis] – sagital
Hh [ga]	homo [gomo] – a man.
Ii [i], Jj [i]	major [major] – great.
Kk [ka]	skeleton [skεleten] – skeleton.
Ll	lateralis [lateralis] – lateral.
Mm, Nn, Oo, Pp	pronounced as english sound
Qq [ku]	squama [skvame] – sqwama.
Rr [εr]	pars [pars] – part.
Ss [εs]	as english sound [s]: os [os] – a bone; processus [protsεssus] – a process. in the middle of the nord between vowels as [z]: incisura [intsizura] – notch, emargination.
Tt [tε]	tuberositas [tubεrozitas] – tuberosity, eminence. Letter combination ti is pronounced as [tsi]: artticulatio [artikulatsio] – joint.
Uu [u]	trunccus [trunkus] – trunk.
Vv [vε]	verticalis [vεrtikalis] – vertical.
Xx [iks]	is named double consonent and is pronounced approximately as [ks]: extremitas [εkstrεmites] – an end, cervix [tserviks] – neck, collum.
Yy (ipsilon (igrek) [i]	greek is pronounced as [i], is used only in the words of the greek origin: diaphysis [diafizis] – diaphys, middle part of tubular bones.

Zz (zεte)- [z]	horizontalis [gorizontalis] – horizontal.
	Diphthongs
ae [ε] oe [ε]	diaeta [diεte] – diet. oesophagus [εzofagus] – gullet
	Digraphs
ch [h]	synchondrosis [sinhodrozis] – connection of two bones with the help of cartilaginous tissue.
ph [f]	metaphysis [mεtafizis] – a part of the diaphysis of tubular bone.
th [t]	thorax [thoraks] – chest.
rh [r]	rhomboideus [romboideus] – rhomboid (al).

A subject such as anatomy, with its accept on description, necessarily requires a very large number of names for structure and processes. For effective communication such words should be as simple as possible and used with unfailing precision.

Unified anatomical terms having a leading role in studying and description of any anatomical structure may become the basis for communication of specialists of different fields of medicine in any country.

A person beginning to study anatomy is struck first of all by the copious terminology that must be firmly understood and completely mastered by every student and physician. These terms usually designate spatial relations, the shape or size of various organs, and so forth.

In mathematics and physical geography, certain initial points and planes are accepted from which distances are measured to establish spatial relations. In anatomy as well, there are generally accepted designations of perpendicular planes by means of which the position of organs or their parts in space is determined exactly.

Three such planes are of primary importance: sagittal, frontal, and horizontal. It should be borne in mind that the planes are related to an erect human body.

Planes:

1. A **sagittal** plane is any vertical anteroposterior plane parallel to and including the median plane.

   This is a vertical plane by means of which we divide the body mentally (for example, a fixed, frozen cadaver) with an arrow (L *sagitta* arrow) piercing it from front to back and with an arrow along the length of the body. The sagittal plane that passes through the middle of the body and divides it into two symmetrical, right and left, parts is called the **median** plane (L *medius* middle).

2. A **coronal** or **frontal** plane is any vertical side-to-side plane at right angles to the sagittal plane. This plane is parallel to the forehead (L *frons* forehead). The frontal plane divides the body into the front and back parts.

3. A **transverse** or **horizontal** plane is any plane at right angles to 1 and 2, at right angles to the long axis of the body or limb; in accordance with its name passes horizontally. It divides the body into the upper and lower halves.

4. A **cross-section** is a section at right angles to the long axis of the organ and structure.

5. An **oblique** plane may lie at any other angle.

The positions of the different points or lines in these planes are designated as follows: those located nearer to the median plane are called **medial** *(medialis)* (L *medius* middle); those located further from the median plane are designated **lateral** *(lateralis)* (L *lotus* side). Points and lines found on a front to back plane are designated as follows: those located nearer to the front surface of the body are called **anterior or ventral** *(ventralis)* (L *venter* belly); those nearer to the back are known as **posterior or dorsal** *(dorsalis)*. The following points and lines are distinguished in the vertical plane: those nearer to the **upper** end of the body are called **upper, superior, or cranial** *(cranialis)* (Gk *kranion* skull); those nearer to the lower end are referred to as **lower, inferior or caudal** *(caudalis)* (L *cauda* tail).

Terms of relationship

1. Anterior or in front = nearer the front surface of the body.
2. Posterior or behind = nearer the black surface of the body.
3. Superior or above = nearer the crown of the head.
4. Inferior or below = nearer the soles of the feet.
5. Medial = nearer the median plane of the body.
6. Lateral = farther from the median plane of the body.

Terms of comparison

1. Proximal (L *proximus* nearest) = near the trunk and is synonymous with superior;
2. Distal (L *distare* to be distant)= farther from the trunk and is synonymous with inferior;
3. The anterior surface of the hand is generally called the palmar (or volar) surface, and the inferior surface of the foot is called the palmar surface. The opposite surface are called the dorsum of the hand and foot.

The terms proximal and distal are used in reference to the parts of the limbs. *Proximal* (L *proximus* nearest) is applied to parts nearer to the point of origin of the limb from the trunk; *distal*, in contrast, is a term applied to parts farthest from the trunk (L *distare* to be distant). On the upper limb, for instance, the elbow is proximal in comparison to the fingers, while the latter are distal in relation to the elbow.

Other terms:

Inside, inferior or **internal** and **outside, exterior** or **external** are served:

1) for bony cavities, such as the pelvic, thoracic, cranial, and orbital:
2) for hollow organs, such as the heart, mouth, bladder, and intestine.

The terms **external** *(externus)* and **internal** *(internus)* are used mainly to designate positions in relation to the body cavities and whole organs, either outward or inward; the terms **superficial** *(super ficialis)* and **deep** *(profundus)* are used for organs located "less deep" or "more deep" in relation to the surface of the body or organ. Superficial and deep denote nearness to and remoteness from the skin surface irrespective of whether of the front, side, or back. These two may be applied to organs, such as the liver and lung.

The commonly used terms for size are **great** *(magnus)*; **small** *(parvus)*; **greater** *(major)*; **lesser** *(minor)*. The last two terms, major and minor, are used to designate the comparative size of two related or identical structures, e.g. tuberculum majus and minus on the humerus. The term magnus (great) does not imply the presence of another identical but smaller structure. For instance, nervus auricularis magnus, the great auricular nerve, is called so because of its thick trunk; there is no nervus auricularis parvus.

The shapes of the various structures, particularly in osteology, have many designations whose meaning is best mastered during study of these structures.

The human body is made up of the **head** *(caput)*, **neck** *(collum)*, **trunk** *(truncus)*, and two pairs of **limbs, or extremities,** the **upper** *(membra* s. *extremitates* [BNA] *superiores)* and **lower** *(membra* s. *extremitates* [BNA] *inferiores)*. The following parts are distinguished in the head: the **forehead** *(frons)*; the **highest point of the skull** *(vertex)*; the **back of the head** *(occiput)*; the **temples** *(tempera)* and the **face** *(facies)*. The trunk consists of the **chest** *(thorax)*, the **abdomen** *(abdomen)* and the **back** *(dorsum)*. The following linest are drawn for orientation on the chest surface: **midline** *(linea mediana anterior)*; **sternal line** *(linea sternalis)* stretching along the sternal border; **mamillary line** *(linea mamillaris* s. *medioclavicularis)* passing through the nipple or themiddle of the clavicle; **parasternal line** *(linea parasternalis)* passing midway between the sternal and mamillary lines; **anterior, middle,** and **posterior axillary lines** *(lineae axillarea anterior, media* and *posterior)*, the first and last passing through the anterior and posterior folds of the axilla, respectively, and the middle line passing through the point midway between these folds; **scapular line** *(linea scapularis)* passing through the inferior angle of the scapula.

The abdomen is divided by two horizontal lines, one drawn between the ends of the 10th ribs and the other between both the anterior superior iliac spines, into three parts, one located above another: the **upper part of the abdomen** *(epigastrium)*, the **middle part** *(mesogastrium)* and the **lower part** *(hypogastrium)*. Each of these three parts of the abdomen is subdivided by two vertical lines into three secondary regions: the epigastrium is divided into a **middle epigastric region** *(regio epigastrica)* and two **lateral regions, the right and left hypochondrium** *(regiones hypochondriacae dextra* and *sinistra)*. The middle abdomen is divided in the same manner into a **medial um-**

bilical region *(regio umbilicalis)* and two **lateral, right and left lumbar regions** *(regiones abdominales laterales, dextra* and *sinistra).* Finally, the hypogastrium is divided into the **pubic region** *(regio pubica)* and two **lateral, right and left inguinal regions** *(regiones inguinales, dextra* and *sinistra).* The upper limb is divided into the arm *(brachium),* the **forearm** *(antebrachium)* and the **hand** *(manus);* the **palm** *(palma manus),* the **back** *(dorsum manus)* and the **fingers** *(digiti manus)* are distinguished in the hand. The lower limb, in turn, is divided into the following parts: the **thigh** *(femur),* the leg *(crus, cruris),* and the **foot** *(pes),* in which the **sole** *(planta),* the **dorsum of foot** *(dorsum pedis),* and the **toes** *(digiti pedis)* are distinguished.

The human body is regarded as standing erect, the eyes looking forward to the horizon, the arms by the sides, and the palms of the hand and the toes directed forward; this is the anatomical position.

THE PASSIVE PART OF THE SUPPORTING (WEIGHT-BEARING) AND LOCOMOTOR APPARATUS

BONES; SKELETAL SYSTEM
(OSTEOLOGY, OSTEOLOGIA)

The **bones** form the bony **skeleton,** and with the joints, they represent the passive locomotor system which is controlled by the active locomotor apparatus, the musculature. The different shapes of bones are dependent on their function and their position in the body.

A bone of a living creature is itself a living thing. It has blood vessels, lymph vessels, and nerves. It grows and is subject to disease. When fractured it heals itself, and even if the fracture is not set perfectly, its internal structure undergoes compensatory remodeling in order to withstand strains and stresses as it did before. Unnecessary bone is resorbed. For example, the bones of a paralyzed limb atrophy (become thinner and weaker) from disuse. Conversely, when bones have increased weight to support, they hypertrophy (become thicker and stronger).

PROPERTIES OF BONE

Bones have an organic framework of fibrous tissue and cells, among which inorganic salts—notably, calcium phosphate—are deposited in a characteristic fashion. The fibrous tissue gives the bones resilience and toughness; the salts give them hardness and rigidity and make them opaque to X-rays. One-third is organic; two-thirds are inorganic.

Physical Properties

By submerging a bone in a mineral acid, the salts are removed, but the organic material remains and still displays in detail the shape of the untreated bone. Such a specimen is flexible.

The organic material of a buried bone is removed by bacterial action (i.e., decomposition), and only the salts remain. Being more brittle than porcelain, the bone will crumble and fracture easily. But bones that have lain buried in a limestone cave become petrified (i.e., calcium carbonate replaces the organic material) and, so, they endure; so do those that are mineralized through lying in soils containing iron, lead, or zinc, etc.

Function of Bones

In addition to being (1) the rigid supporting framework of the body, bones serve as (2) levers for muscles; (3) they afford protection to certain viscera (e.g., brain and spinal cord, heart and lungs, liver and bladder); (4) they contain marrow, which is the factory for blood cells; and (5) they are the storehouses of calcium and phosphorus, essential for many functions, e.g., muscle contraction.

Structure

Macroscopically two differently constructed portions can be distinguished. A rather *dense compact* or *cortical bone* (1) is generally observed on the surface. Within the short and flat bones and in the epiphyses and metaphyses of the long bones, there is a *sponge-like meshwork* (2) formed of individual bony trabeculae, cancellous or spongy bone, 'substantia spongiosa'. Between the meshes is the bone marrow or medulla. In the flat bones of the skull, the compact material is called the *external* (3) and *internal* (4) *laminae* and in between them is the *diploe* (5), corresponding to the spongy bone.

The structure of a dried bone seen on section is shown in Figure 1.

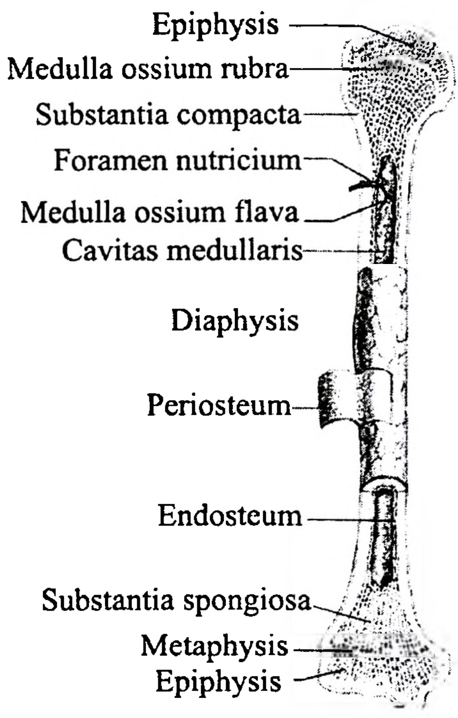

Fig. 1. Structure of bone

Macroscopically, there are 2 forms of bony tissue: (1) spongy (or "cancellous") and (2) compact (or dense) (Fig. 2).

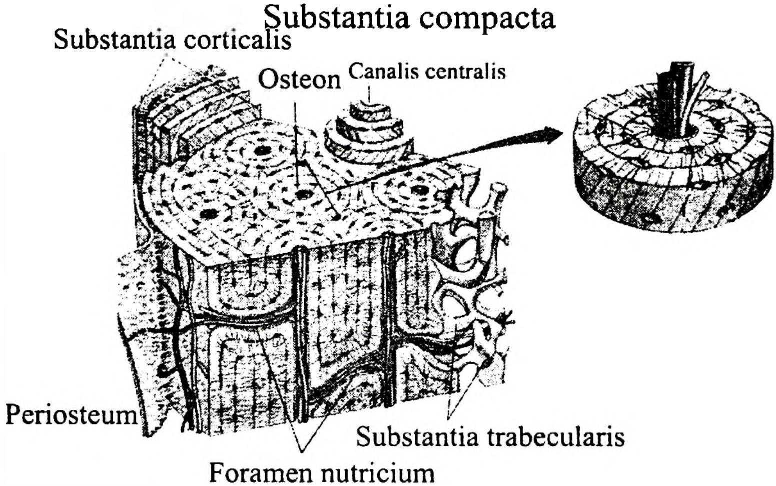

Fig. 2. Structure of the compact bone tissue.

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All bones have a complete outer casing of compact bone; the interior is filled with spongy or cancellous bone except when replaced by a medullary cavity or an air sinus (see below). In a long bone, such as the humerus, the compact bone is thickest near the middle of the shaft, and it becomes progressively thinner as the bone expands towards its articular ends, these being covered with a thin shell of compact bone. Conversely, spongy bone fills the expanded ends and extends for a variable distance along the shaft but leaves a tubular space, the medullary cavity. The lamellae or plates of the spongework are arranged in lines of pressure and of tension, and in an X-ray photograph, the pressure lines are seen to pass across joints from bone to bone.

Osseous tissue consists of bone cells, *osteocytes, interstitial substance, collagen fibrils, a cement substance* and certain *mineral salts*. The interstitial substance and collagenous fibrils form the intercellular substance, *osteoid*. The fibrils belong to the organic part and the salts to the inorganic component of the bone. The most important salts are calcium phosphate, calcium carbonate and magnesium phosphate. In addition there are compounds of calcium, potassium and sodium with chlorine and fluorine.

The salts determine the hardness and stability of bone. Therefore, decalcified bone becomes pliable. A too low calcium content may result from lack of vitamins or hormonal disturbances. Vitamin deficiency may be due, for instance, to absence of UV irradiation on the body, with consequent failure to convert pro-vitamins to vitamin D. Inadequate calcification leads to softening of bone, e. g., in rickets.

The stability of bone is determined not only by its inorganic but also by its organic components. If there is inadequate organic material, the elasticity of the bone is lost. Bones then cannot resist stress and become brittle. The organic constituents may be destroyed artificially by incineration.

The structure and arrangement of osteons depends upon the stresses on the bones and changes in stress result in a reconstruction of the osteons. Remodelling of osteons is also macroscopi-cally observable. Particular notice should be taken, for example, of the *trajectories* within the femur since they are formed in response to the stresses exerted on it.

Bone receives its nutrients from the periosteum and the bone marrow via the nutrient foramina.

The periosteum covers all parts of the bone which are not joint surfaces. It consists of a *fibrous layer* and an *osteogenetic layer* forming the cambium layer. It contains many blood and lymph vessels and nerves. The latter account for the pain felt after a blow to a bone. Larger blood vessels in the outer layer send numerous capillaries to the inner cell-rich layer. This is the site of the osteoblasts, which build up bone. After fractures, formation of new bone starts in the periosteum.

Blood vessels and nerves reach the bone through nutrient foramina. Some bones have canals which also serve for the passage of vessels, usually only veins, which are known as emissary veins. They are found, for example, in the vault of the skull.

Bone formation is due to the *osteoblasts* which are specialized mesenchymal cells. Osteoblasts secrete an intercellular substance, the *osteoid*, which consists initially of soft ground substance and collagen fibers. Osteoblasts develop into *osteocytes*, the definitive bone cells. At the same time mul-tinucleated *osteoclasts* develop, cells connected with resorbing and remodelling bone.

CLASSIFICATION OF BONES

The bones of the body may be classified developmentally, or according to shape.

Developmentally

They may be classified according to whether they developed (1) in cartilage, or (2) in membrane.

Intramembranous ossification (primary bones), *osteogenesis membranacea* is the development of bone from connective tissue. The latter contains many mesenchymal cells which develop via osteoblasts into osteocytes. At the same time osteoclasts develop and collagen fibers also appear. The original bone is fibrous and it is subsequently remodelled into lamellar bone. The skull cap, the facial bones and the clavicles develop as membranous bones.

Preformed cartilaginous skeletal parts are necessary for **chondral ossification (secondary bones),** *osteogenesis cartilaginea* when they become replaced by bone. Growth is possible only as long as cartilage still remains. The prerequisites for replacement bone formation are *condroclasts,* differentiated connective tissue cells, which remove cartilage and enable the osteoblasts to form bone. Two types of replacement bone formation are recognized - *endochondral* and *perichondral.*

Endochrondral ossification begins within cartilage, and occurs near the epiphyses. *Epiphyses are* found at the ends of long bones, whilst the shafts are called *diaphyses. Perichondral ossification,* which originates in the perichondrium, is confined to the diaphysis. The *epiphysial disk* (growth plate), which is necessary for growth in length, forms a layer between the epiphysis and the diaphysis. That part of the shaft adjacent to the epiphysial disk is called the *metaphysis* and develops first on an endochondral basis. Within the epiphysial cartilage, the processes of ossification occur in separate zones. First, in the epiphysis is the *zone of the capping,* hyaline cartilaginous material which has not been influenced by bone formation. Next to this area of 'resting cartilage' is the *zone of cartilage cell columns,* the growth zone. Here cartilage cells divide and so increase in number. The next layer, which lies nearer to the shaft, is the *zone of large vesicular cartilage cells,* in which calcification is occuring. This is contiguous with the *zone of cartilage destruction,* where cartilage is broken down by chondroclasts and replaced by bone-forming osteoblasts. A cartilage remnant persists, which enables endochondral bone and perichondral bone to be distinguished in the diaphysis. It is secondarily replaced by perichondral bone. Endochondral bone is destroyed by the immigrant osteoclasts. Increase in thickness in the region of the diaphysis is brought about by deposition of new bony materal on the outer surface beneath the cellular layer of the periosteum. The bone *marrow cavity* becomes larger as a result of bone destruction. All growth processes are regulated by hormones.

The bony anlagen in the epiphyses first appear after birth, except for those in the distal femoral epiphysis and the proximal tibial epiphysis. In both of these epiphyses, and in the cuboid bone, osteogenesis begins just before birth in the tenth intrauterine month (a sign of maturity).

Clinical Tips: *After closure of the epiphysial disk in x-rays, there remains a fine visible line known as the epiphysial disk scar.*

According to Shape

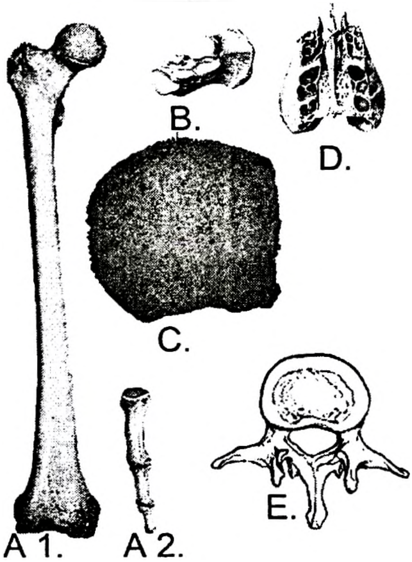

Fig. 3. Bone classification.
A.Tubular: 1. Long, 2. Short. B. Spongy. C.Flat.
D. Pneumatic. E. Irregular.

1. **Tubular bones long & short**, confined to the limbs, and serve as levers for muscles. A long bone has a body or shaft and two ends. The ends, usually being specialized for joints, are smooth, covered with articular (joint) cartilage, either convex or concave, and enlarged. The body (shaft) is hollow (medullary cavity, which contains red or yellow bone marrow), thus providing maximum strength with minimum material and weight. Typically, a long bone has 3 borders that separate 3 surfaces, so on cross-section it is triangular rather than circular. *Medullary cavity is the reason for the name 'tubular bones'.*

Long bones develop (are preformed) in cartilage. The body of every long bone begins to ossify near its middle (primary center) about the 2nd to 3rd month of inlrauterine life. One or both ends begin to ossify (secondary centers) soon after birth.

Tubular bones grow mainly in one direction.

2. **Spongy Bones.** The short bones, which include, for instance, the small bones of the wrist (e.g. the capitate bone), have a spongy core surrounded by compact bone. Short bones are cubical or modified cubes and

are confined to the carpus and tarsus. They develop in cartilage, and they begin to ossify soon after birth.

2a. Sesamoid bones are nodules of bone that develop in certain tendons where they rub on convex bony surfaces. ("Sesamoid" is of Arabic origin, meaning like a seed.) The rubbing surface of the nodule is covered with articular cartilage to form true joints; the rest is buried in the tendon. They mostly occur in the skeleton of the hands and feet. They may also be found in tendons, e. g., the *patella* or kneecap, the largest sesamoid bone in the body, occurs in the quadriceps femoris tendon.

Of the short bones, 3 (calcaneus, talus, and cuboid) start ossifying before birth; so do the epiphyses of 3 long bones (knee end of femur and of tibia and commonly the shoulder end of humerus).

3. Flat Bones resemble sandwiches. They consist of 2 layers or plates of compact bone with spongy bone and marrow between them. Many of the skull bones, the sternum, scapulae, and parts of other bones, are of the flat type. Most flat bones help to form the walls of rounded cavities and therefore are curved. At birth a flat bone consists of a single plate. In the flat bones of the skull, the spongy bone, here called diploe (pronounced "dip-lo-ee"), and its contained marrow appear some years later and split the plate into inner and outer tables of compact bone.

Basically, growth in flat bones proceeds in two *main* directions.

4. Irregular bones have any irregular or mixed shape. These include all those bones, such as vertebrae, which do not belong to any of the preceding groups. All skull bones not of the flat type are irregular (e.g., sphenoid, maxilla); so too are the vertebrae and the hip bones. They are composed of spongy bone and marrow within a compact covering.

5. Pneumatic bones are formed by the outward expansions of the mucous lining of the nasal cavities and of the middle ear and mastoid antrum that invade the diploe of certain flat and irregular bones of the skull, thereby producing paranasal air cells or air sinuses. They are found in the skull (ethmoid, maxilla, sphenoid, frontal etc.). This pneumatic method of construction may be economical in bony material, but it invites infections of the nose that often extend to these sinuses.

Accessory bones may sometimes result from the ossification of connective tissue. Most bones normally ossify from several centers, and it sometimes happens that one or more of these centers fails to unite with the main mass of the bone; again, an abnormal or extra center of ossification may make its appearance and the resulting bone may remain discrete. In either case, the result is an accessory bone, which in an X-ray photograph could be misdiagnosed *as a* fracture.

THE SKELETON

The bones of the skeleton is subdivided into the axial skeleton (including skull, vertebral column and thoracic cage) and appendicular skeleton (which is compound by bones of limbs) (Fig. 4).

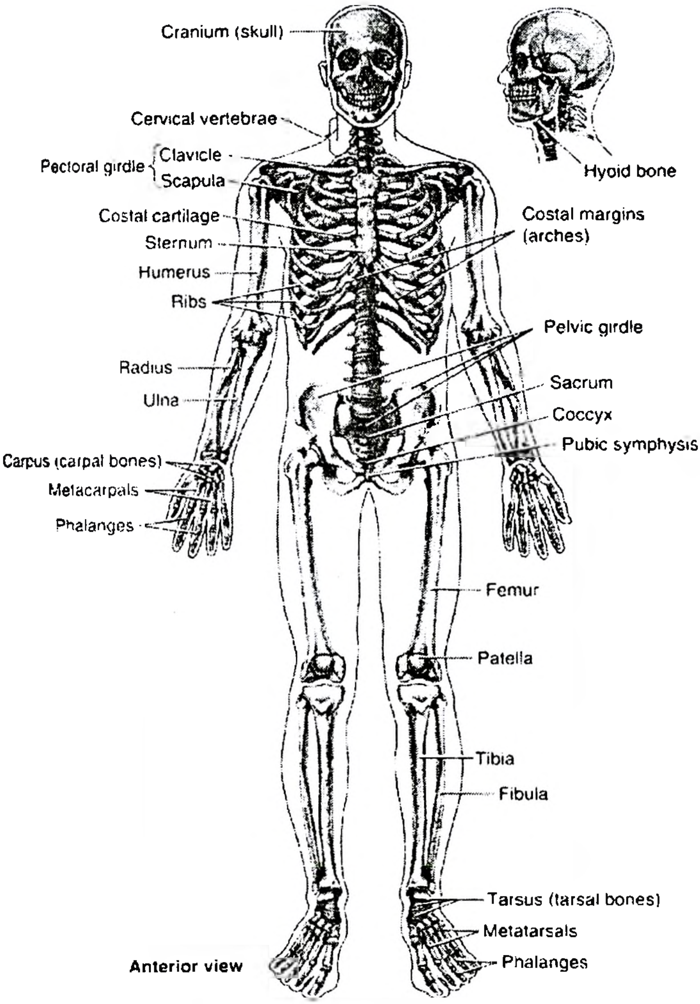

Fig. 4. Skeleton

THE SKELETON OF THE TRUNK

THE VERTEBRAL COLUMN

The vertebral column *(columna vertebralis)* or the spine forms the basic structure of the trunk. The vertebral column has a metameric structure (a feature connecting the vertebrates with the earliest invertebrates) and consists of separate bone segments, *vertebrae*, placed one over another in a series; they are short spongy bones. It consists of 33-34 *vertebrae* and *intervertebral disks (disci intervertebrales)*. The vertebrae are divided into 7 *cervical (vertebrae cervicales),* 12 *thoracic (vertebrae thoracicae),* 5 *lumbar (vertebrae lumbales),* 5 *sacral (vertebrae sacrales) and* 4-5 *coccygeal vertebrae (vertebrae coccygeae).* The sacral vertebrae fuse to form the *sacrum* and the coccygeal vertebrae fuse to form the *coccyx.* Thus the sacral and coccygeal vertebrae are *false vertebrae* whilst the others are *true vertebrae* (Fig. 5).

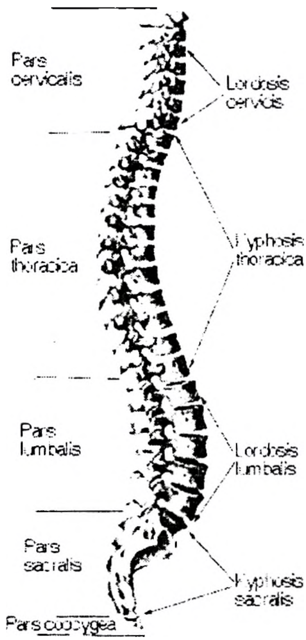

Fig. 5. Columna vertebralis

Function of the spine. The spine acts as the axial skeleton supporting the body. It protects the spinal cord enclosed in its canal and takes part in. the movements of the trunk and head. The position and shape of the vertebral column are determined by the upright position of man.

General (common) features of the vertebrae (Fig. 6).

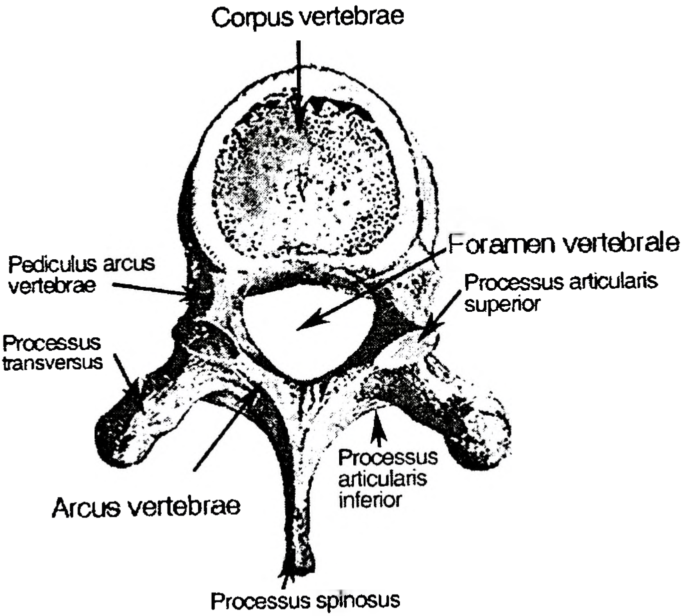

Fig. 6. Vertebra

In accordance with the three functions of the spine, each vertebra (Gk *spondylos)* has the following features: (1) an anterior part, which is responsible for support and which thickens in the shape of a short column, this is the body *(corpus vertebrae);* (2) an arch *(arcus vertebrae),* which is attached to the posterior surface of the body by two *pedicles (pediculi arcus vertebrae)* and contributes to the formation of the vertebral foramen *(foramen vertebrale);* a series of these foramina forms the vertebral, or spinal, canal *(canalis vertebralis),* which protects the spinal cord lodged in it from external injury. The vertebral arch, therefore, primarily fulfils a protective function; (3) the arch also carries structures permitting movement of the vertebra called processes. A spinous process *(processus spinosus)* arises from the arch on the midline; a transverse process *(processus transversus)* projects laterally on each side; paired superior and inferior articular processes *(processus articu-*

lares superiores and *inferiores)* project upward and downward. The articular processes bind notches on the posterior aspect; these are the paired *incisurae vertebrates superiores* and *inferiores* from which the intervertebral foramina *(foramina intervertebralia)* form when one vertebra is placed on another. The foramina transmit the nerves and vessels of the spinal cord. The articular processes serve for the formation of intervertebral joints at which movement of the vertebrae is accomplished; the transverse and the spinous processes serve for the attachment of ligaments and muscles which make the vertebrae move.

Some parts of the vertebrae in the different parts of the spine have a distinctive size and shape and the following vertebrae are consequently distinguished: cervical (seven), thoracic (twelve), lumbar (five), sacral (five), and coccygeal (one to five). The weight-bearing part of the cervical vertebrae (the body) is naturally relatively small (the first cervical vertebra has almost no body), but from the head down, the vertebral bodies gradually increase in size and are largest in the lumbar segment. The sacral vertebrae carry the whole weight of the head, trunk, and upper limbs, connect the skeleton of these parts of the body with the bones of the pelvic girdle, and, through them, fuse with the lower limbs to form a single sacral bone. In contrast, the coccygeal vertebrae, which in man are remnants of a tail, are small bony structures with a body that can hardly be detected and no arch. The vertebral arch, as a protective part, forms a wider vertebral foramen where the spinal cord is thickened (lower cervical, upper thoracic and upper lumbar vertebrae). Since the spinal cord terminates at the level of the second lumbar vertebra, the vertebral foramen of the lower lumbar and the sacral vertebrae gradually narrows and disappears completely in the coccyx. The transverse and spinous processes, the sites of muscle and ligament attachment, are more pronounced in those parts to which the most powerful musculature is attached (lumbar and thoracic segments); on the sacrum these processes are diminished because the tail musculature has disappeared, and they form small crests on the fused sacrum. As a consequence of fusion of the sacral vertebrae, the articular processes disappear; these processes are developed particularly well in the mobile parts of the spine, especially in the lumbar segment. Thus, to understand the structure of the vertebral column, one must bear in mind that the vertebrae and certain vertebral parts develop more in those segments which experience the greatest functional load. Reduction of the corresponding parts of the spine is encountered, in contrast, in segments of which fewer functional demands are made, for instance, in the coccyx which is a rudimentary structure in man.

INDIVIDUAL TYPES OF VERTEBRAE

1. Cervical vertebrae *(vertebrae cervicales)*

The first vertebra, the **atlas**, the second, the **axis** and the seventh, the **vertebra prominens**, are distinguished from the rest of the cervical vertebrae. There are only small differences between the 3rd-6th cervical vertebrae. Since the load suffered by the cervical vertebrae is lighter than that suffered by the more distally located spinal segments, their bodies are correspondingly smaller (Fig. 7). The *vertebral body (corpus vertebrae)* lies immediately behind the *vertebral arch (arcus vertebralis)*. The bodies are transverse-oval in shape, and the upper and lower surfaces are concave. Each vertebral arch has an anterior part, the *pedicle*, and a posterior part, the *lamina*. At the point of transition between the two parts, the *superior articular process (processus articularis superior)* and the *inferior articular process (processus articularis inferior)* project cranially or caudally. There is a narrow indentation between the body and the superior articular process, the *incisura vertebralis superior*. A broader *incisura vertebralis inferior* is present between the body and the inferior articular process. The articular processes have *articular surfaces (facies articularis)*, the superior facing dorsally and the inferior facing ventrally. From the median convergence (juncture) of the laminae, a *spinous process (processus spinosus)* projects dorsally and is bifurcated at the tip in the 3rd-6th cervical vertebrae. Between the body and the arch of the cervical vertebrae lies a relatively large *vertebral foramen (foramen vertebrale)*. The *transverse processes (processus transversus)* extend laterally. Each transverse process is characterized by the presence of a hole *(foramen transversarium)*, which forms as a result of fusion of the transverse process with the rib rudiment *(processus costarius)*. Each transverse process develops from the anlage of a vertebra and a rib. The rib anlage is incompletely fused with the vertebral anlage so that the *foramen transversarium* develops. The canal which forms from a series of these foramina protects the vertebral artery and the vein that it transmits. The transverse process *(processus transversus)* also has an *anterior tubercle (tuberculum anterius)* and a *posterior tubercle (tuberculum posterius)*; between them we find a groove, the *sulcus for the spinal nerve (sulcus nervi spinalis)*. The anterior tubercle *(tuberculum anterius)* of the sixth vertebra is enlarged and is called the *carotid tubercle (tuberculum caroticum)* (the carotid artery can be compressed against it to arrest bleeding). On the upper articular surface of the body of the 3rd-7th cervical vertebrae there are laterally two protuberances, the *uncal processes*.

The first and second cervical vertebrae have a specific shape because they form the mobile articulation with the skull. Most of the body of the **first vertebra**, the **atlas**, remains separate and joins the second vertebra as a tooth-like process, the *dens*.

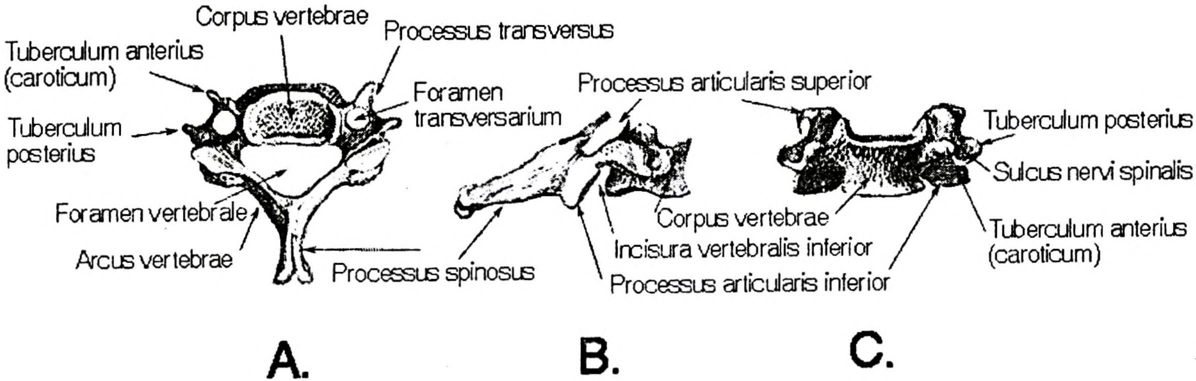

Fig. 7. Vertebra cervicalis 6
A- view from above; B- lateral viev; C- anterior view.

1st Cervical Vertebra

The atlas differs basically from the other vertebrae in that it lacks a vertebral body (the vertebral foramen that receives the dens is larger) (Fig. 8).

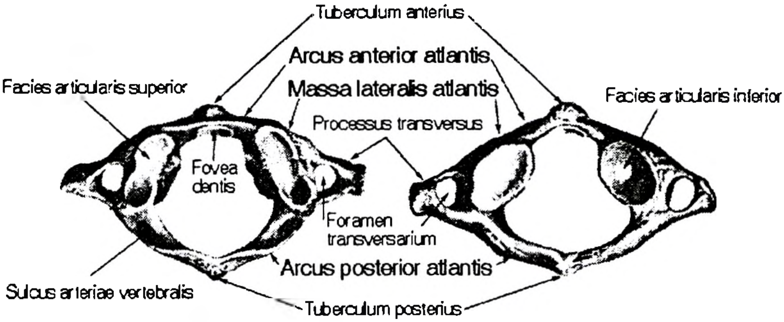

Fig. 8. Atlas (Vertebra cervicalis 1)
A- view from above; B- inferior viev.

In the atlas we therefore describe a smaller *anterior (arcus anterior)* and a larger *posterior arch (arcus posterior)*. Both arches have small protuberances in the median plane (the outer surfaces of the anterior and posterior arches), the *anterior* and *posterior tubercles (tuberculum anterius* and *posterius)*. The posterior tubercle may sometimes be very poorly developed. The anterior *(arcus anterior)* and posterior *(arcus posterior)* arches of the atlas are connected to each other by lateral masses *(massae laterales)*. So, lateral to the large *vertebral foramen (foramen vertebrale)* of the atlas lie the *lateral masses (massae laterales)*, each of which has a *superior (fovea articularis superior)* and an *inferior articular facet (fovea articularis inferior)*. The upper articular facet is concave and its medial margin is often indrawn. Sometimes a superior articular facet may be subdivided. The convex superior articular facet *(fovea articularis superior)* receives the corresponding condyle of the occipital bone. The lower articular facet is flat or may be very slightly deepened and almost circular. The flattened inferior articular facet *(fovea articularis inferior)* receives the articular surface of the second cervical vertebra. On the inner side of the anterior arch is the articular facet for the dens *(fovea dentis)*. From the *foramen of the transverse process (foramen transversarium)*, which is located in the *processus transversus*, a groove, the *sulcus arteriae vertebralis*, extends across the posterior arch for the reception of the vertebral artery.

Variants: The sulcus for the vertebral artery *(sulcus arteriae vertebralis)* may be replaced *by a canal.* Rarely the atlas is divided into two halves joined by cartilage. Equally rarely unior bilateral assimilation of the atlas, i.e., bony fusion with the skull may be observed.

2nd Cervical Vertebra

The second cervical vertebra, the **axis** (consequently the axial vertebra) s. *epistropheus* (BNA) (Gk *epistrephomai* pivot, consequently the pivotal vertebra) differs sharply from the 3rd-6th cervical vertebrae by the presence of the tooth-like process, the *dens* or *odontoid process* (Fig. 9). On the cranial surface of the body the axis carries a tooth-like process, the *dens axis,* which ends in a rounded point, the *apex dentis*. The anterior surface of the dens has a definite articular surface - the *anterior articular facet (facies articularis anterior)* which serve to articulate with the anterior arch of the atlas. The posterior surface may have a smaller articular facet, the *posterior articular facet (facies articularis posterior)* which serve to attach the transverse ligament. Another distinction of the axis is that its superior articular surfaces articulating with the atlas are not on the arch hut on the superior surface of the body to the sides of the dens.

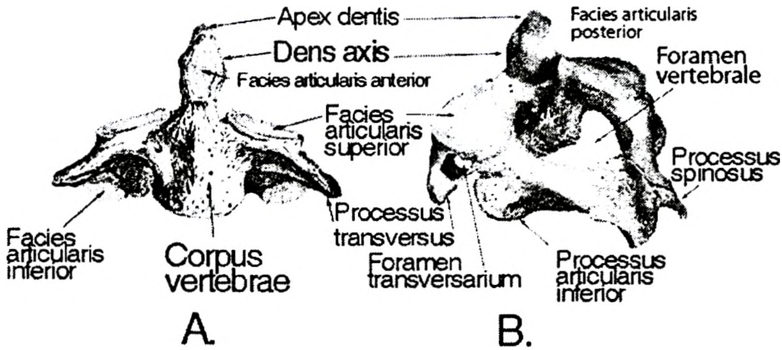

Fig.9. Axis (Vertebra cervicalis II)
A- anterior view; B- view from above & lateral.

The lateral articular facets slope laterally. The poorly developed *transverse process (processus transversus)* bears the *foramen of the transverse process (foramen transversarius).* The shape of the lateral articular facets is somewhat complex. Although they may appear almost flat in a bony (macerated) preparation, they are more ridged when their cartilaginous covering is present. The cartilaginous covering is important in the joint between the atlas and the axis. The *spinous process (processus spinosus)* is large and often, though not always, it has a bifurcated tip.

Clinical Tips: Isolated fractures of the arch of the atlas may occur, especially after car accidents, and should be differentiated from congenital variants of the atlas. A fracture of the dens is the typical axis fracture. Care is required because free pro-atlas segments may rarely be found within the atlanto-occipital membrane.

The position of the axis of the dens relative to the body of the 2nd cervical vertebra depends on the curvature of the cervical spine. In the absence of a *lordosis* it faces slightly backwards. Its longitudinal axis then makes an angle with the vertical through the body of the 2nd cervical vertebra.

7th Cervical Vertebra

The seventh cervical vertebra is distinguished by a large spinous process, and for that reason it is called the **vertebra prominens** (Fig. 10). The 7th cervical vertebra has a particularly large spinous process, which is usually the highest palpable spinous process of the vertebral column; it is therefore called the *vertebra prominens*. This vertebra is easily located in a living person and is often helpful in making diagnosis.

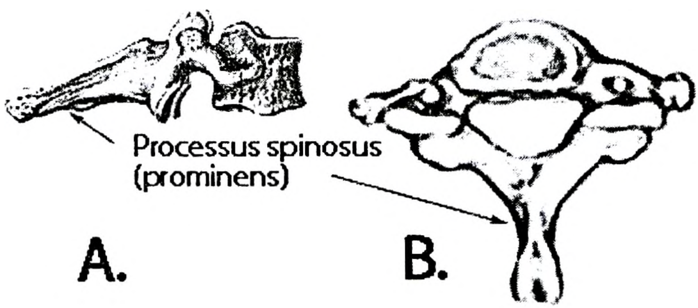

Fig. 10. Vertebra cervicalis 7
A- lateral viev; B- view from above.

Variants: If the transverse process of the 7th cervical vertebra is incomplete and the rib anlage is incompletely fused, the part which develops from this anlage is clearly demarcated from the vertebra. If the rib anlage remains independent, a cervical rib results. Cervical ribs are usually bilateral, but if one is unilateral, it is more common on the left than on the right. The foramen of the transverse process in various vertebrae is often bisected. The 7th vertebra usually lacks an anterior tubercle.

Clinical Tips: The presence of a cervical rib may cause a triad of disorders.

1. Pain due to distortion of vessels.
2. Pains related to the brachial plexus (sensory disturbances, especially of the ulnar nerve).

3. Palpable abnormalities in the greater supraclavicular fossa.

2. Thoracic Vertebrae *(vertebrae thoracicae)*

The **12 thoracic vertebrae** *(vertebrae thoracicae)* articulate with the ribs. Each of them have a *vertebral body (corpus vertebrae)*, which has incompletely ossified cranial and caudal plates of compact bone and on the dorsal surface openings for the exit of the basivertebral veins (Fig. 11). Their distinctive feature, consequently, is the presence of articular facets for the ribs, *costal facets (fovea costales)*. Since the ribs usually articulate with two adjoining vertebrae, laterally, the vertebral body usually has two *costal facets*, each of which is half of an articular facet for articulation with the head of a rib: one on the superior edge of the vertebra *(fovea costalis superior)* and the other on the inferior surface *(fovea costalis inferior)*. When one vertebra is placed on the other, the two half-facets form a single whole articular facet, which receives the head of the rib.

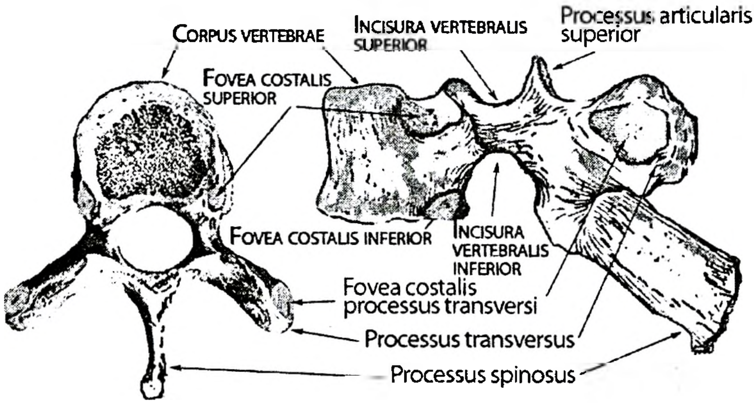

Fig. 11. Vertebra thoracicae
A- view from above; B- lateral viev.

The 1st, 10th, 11th and 12th thoracic vertebrae are exceptions. The 1st thoracic vertebra has a complete articular facet at the cranial border of its body for the first ribs and a half facet at the caudal border for the second ribs. The 10th vertebra has only a half articular facet for the tenth ribs, while the 11th has a complete articular facet at its cranial border. The 12th thoracic vertebra has the articular facet for articulating with the corresponding ribs in the middle of the lateral surface of the body. These vertebrae (first, tenth, eleventh, and twelfth) can, therefore, easily be distinguished from the others. From the posterior surface of the body arises the *vertebral arch (arcus verte-*

brae) with its *pedicles* that continue on each side into the laminae *of the vertebral arch*. The two laminae unite to form the *spinous process (processus spinosus)*. The spinous processes *(processus spinosus)* of the thoracic vertebrae are long and are inclined sharply downward. The spinous processes *(processus spinosus)* of the 1st through the 9th thoracic vertebrae overlap each other like roof-tiles, mainly in the middle of the thoracic part of the spine, so that their tips lie one to one and a half vertebrae lower than the corresponding vertebral bodies Such direction of the processes limits extension of the spine here, which is a protective accommodation for the heart. They are triangular in cross section in contrast to the spinous processes of the last three thoracic vertebrae which are vertically oriented plates. They do not descend but extend directly dorsally. On the upper margin of the pedicle of the arch is the poorly developed superior *vertebral notch (incisura vertebralis superior)*, and on the lower margin the deeper *inferior vertebral notch (incisura vertebralis inferior)*. The *vertebral foramen (foramen vertebrale)* lies between the vertebral arch and the posterior surface of the body.

Cranially, where the pedicle of the vertebral arch becomes the lamina, there are the *superior articular process (processus articularis superior)* and caudally the *inferior articular process (processus articularis inferior)*. The articular processes are positioned frontally. Laterally and a little posteriorly lie the *transverse processes (processus transversus)*, which in the 1st to the 10th thoracic vertebrae carry a *costal facet* for articulation with the costal tubercle *(fovea costalis processus transversus)*. The transverse processes are directed laterally and to the back. The facets are concave only in 2nd through 5th vertebrae (II-V). On the 1st, the 6th through 9th and the 10th vertebrae the facet is flattened. The shape of the facet imparts a differing mobility to the ribs. The transverse processes of the last two vertebrae (eleventh and twelfth) lack these facets.

In accordance with the greater weight they bear, the bodies of the thoracic vertebrae are larger than the bodies of the cervical vertebrae.

Special Features:

Like the cervical vertebrae, the first thoracic vertebra often has an *uncus corporis* on each side of its body. In the 11th and 12th thoracic vertebrae the transverse processes may already be rudimentary. In this case, as occurs in the lumbar vertebrae, there may be an *accessory process* and a *mamillary process* on each side.

Clinical Tips:

A transverse process is typical of all thoracic vertebrae. The vertebral notches, one caudal and one cranial, together form the *intervertebral foramen (foramen intervertebrale)* which serves for the passage of the spinal nerves. Processes affecting the bones in this area may produce a narrowing which in turn may cause nerve lesions.

3. Lumbar Vertebrae *(vertebrae lumbales)*

Lumbar vertebrae *(vertebrae lumbales)* are distinguished by a massive body since they carry weight that is still greater than that borne by the part of the spine proximal to them (Fig. 12).

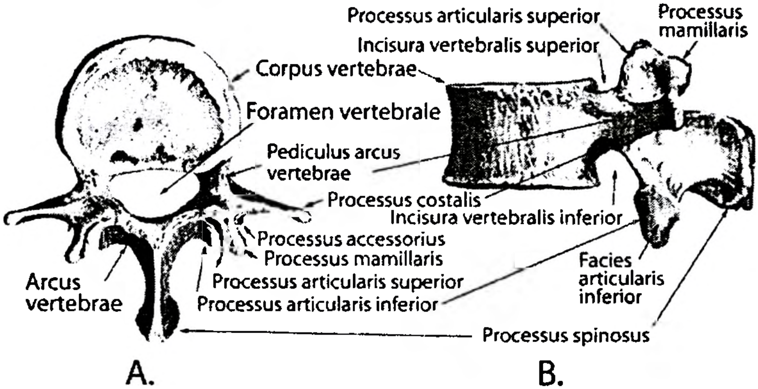

Fig. 12. Vertebra lumbalis I
A- view from above; B- lateral viev.

The *bodies* of the 5th **lumbar vertebrae** are much larger than those of the other vertebrae. The *spinous process* is flat and is directed sagitally (directed horizontally, to the back). The *lamina of the arch* is short and sturdy, and the *pedicles of the vertebral arch* are very thick, corresponding in size to that of the lumbar vertebra. The flattened lateral processes of the lumbar vertebrae may be called *costal processes*, and since they originate from rib anlagen, they are fused with the vertebrae. Behind the costal process is an *accessory process* of variable size, which, together with the *superior articular process (processus articularis superior)* and its *mamillary process*, represents the remnant of the *transverse process (processus transversus)*. The *inferior articular process (processus articularis inferior)* extends caudally. The articular processes are in the sagittal plane. In essence the articular facets face medially on the superior articular processes and laterally on the inferior articular processes. There is always a more or less marked angulation of these articular surfaces. Between the superior and inferior articular processes there is a region which is almost bereft of spongiosa. Clinically, it is known as the interarticular part.

As in all other vertebrae, there is a small *superior vertebral notch (incisura vertebralis superior)* between the body of the vertebra and the superior articular process. The much larger *inferior vertebral notch (incisura vertebralis inferior)* extends from the posterior surface of the body as far as the root of the inferior articular process. The *intervertebral foramina (foramen intervertebrale),* formed by the corresponding notches, are relatively large in the lumbar vertebrae. The *vertebral foramen (foramen vertebrale)* is relatively small. On the posterior surface of the body, within that foramen, there is a large opening for the exit of a vein. On the superior and inferior surfaces of the lumbar vertebrae, as on other vertebrae, a compact annular bony lamellar margin is visible, and in the center of the body the spongiosa is clearly apparent. The ring of compact bone corresponds to the bony portion of the epiphysis of the vertebral body. Of the five lumbar vertebrae only the 5th differs in that its body is higher anteriorly than posteriorly.

Clinical Tips: Lumbar ribs may cause pain because of their proximity to the kidney. Spondylolysis may occur in the region of the interarticular part.

Malformations and Variants

Malformations of the vertebrae may be associated with more or less severe changes in the spinal cord. Various fissures or other abnormalities which may not have caused any symptoms can sometimes be detected by chance on radiographs. Since these are developmental defects, some grouping will be done here. Moreover, only the free vertebrae will be considered-variations of the os sacrum. Likewise, cervical ribs and lumbar ribs will not be mentioned here.

A part from such variations as the presence of a *vertebral artery canal,* or such malformations as *assimilation of the atlas* (unior bilateral fusion with the base of the skull), the commonest malformations are fissures in the region of the vertebral arches. *Posterior fissures* must be distinguished from *lateral* ones and from *fissures at the root of the vertebral arches,* as well as from those *between the body and the arch.* In addition, there is the rare anterior *fissure of the anterior vertebral arch of the atlas.* Anterior and posterior vertebral fissures may be described as median fissures. Median posterior vertebral arch fissures can be associated with malformations of the spinal cord. They arise during the mesenchymal phase of vertebral development.

Posterior fissures are quite common in the atlas but they occur less often in the lower cervical vertebrae and are very rare in the upper thoracic vertebrae. They are not uncommon in the lower thoracic and upper lumbar vertebrae and are most frequent in the sacrum.

Very infrequently the atlas has an anterior median fissure and in the example illustrated here there is also a posterior median fissure.

Lateral vertebral arch fissures occur immediately posterior to the superior articular process, with the result that the inferior articular processes, together with the arch and the spinous process, are separated from the other parts of the vertebra. This bony division is called *spondylolysis* and may lead to true slipping of the vertebra *(spondylolisthesis).*

Another malformation is the occurrence of fused vertebrae, i.e., the fusion of two or more vertebral bodies, as happens normally in the sacrum. Fused vertebrae occur most commonly in the neck, upper thoracic and lumbar regions. The example illustrated shows fusion of the 2nd and 3rd cervical vertebrae. Fused vertebrae may be caused by a number of things but the disturbance is always in the mesenchymal phase of development of the vertebral column.

4. Sacral vertebrae *(vertebrae sacrales)*

Sacral vertebrae *(vertebrae sacrales)* fuse in youth to form a single bone, the **sacrum** (Fig. 13). This fusion is an adaptation to the considerable load carried by the sacrum because of the upright posture of the human. The sacrum is triangular in shape, and its base *(basis ossis sacri)* faces upward, while the apex *(apex ossis sacri)* faces downward and lies opposite to the adjoining coccyx. The anterior border of the base together with the body of the last lumbar vertebra forms an angle projecting forward, a *prominence (promontorium)*. The ventral or *pelvic surface* of the sacrum *(facies pelvina)* is concave. The dorsal surface is regularly convex. The sites of the fusion of the vertebral bodies are seen on it as *transverse lines (lineae transversae)* with the *anterior sacral foramina (foramina sacralia pelvina)* at their ends. The pelvic surface has four paired pelvic *anterior sacral foramina* as exits for the ventral branches of the spinal nerves. These foramina are not equivalent to the intervertebral foramina found in other vertebrae, which here lie directly within the sacral canal, but are surrounded both by vertebral and rib anlagen. They correspond to those foramina that are formed by vertebrae, ribs (or rib anlagen) and superior costotransverse ligaments. Between the right and left anterior sacral foramina lie the *transverse lines*, which are due to fusion of the adjacent surfaces of the vertebrae and intervertebral disks. That part of the sacral bone which lies laterally to the pelvic foramina is called the *pars lateralis*. On the dorsal surface there are, correspondingly, the *posterior sacral foramina (foramina sacralia dorsalia)*. Five longitudinal ridges or five crests, not always clearly developed, have their origin in fusion of the corresponding processes of the vertebrae. An unpaired *spinous tubercles of the sacrum* on the median line *(crista sacralis mediana)* formed as the result of fusion of the spinous processes; lateral to it, but medial to the *posterior sacral foramina* is the *intermediate sacral crest (cristae sacrales intermediae)* which is usually the most poorly developed. It represents the fused remnants of the articular processes of the vertebrae. And, lateral to these, lateral to the dorsal foramina, the *transverse tubercles of the sacrum (cristae sacrales laterales)* can be seen, which represents remnants of the transverse processes. Lateral to the sacral foramina are the *lateral parts* of the sacrum *(partes laterales sacri)* formed by fusion of the transverse processes and the sacral ribs. They have on their lateral aspect an articular surface curved like the auricle, which is called the *auricular surface (facies auriculares)*. It serves for joining with the iliac bone. At the back of each auricular surface is the *sacral tuberosity (tuberositas sacralis)* (the site of attachment of muscles and ligaments).

The *sacral canal (canalis sacralis)* passes in the sacrum. It is a continuation of the vertebral canal. As a consequence of the disappearance of the tail and reduction of the tail musculature in man, the corresponding parts of

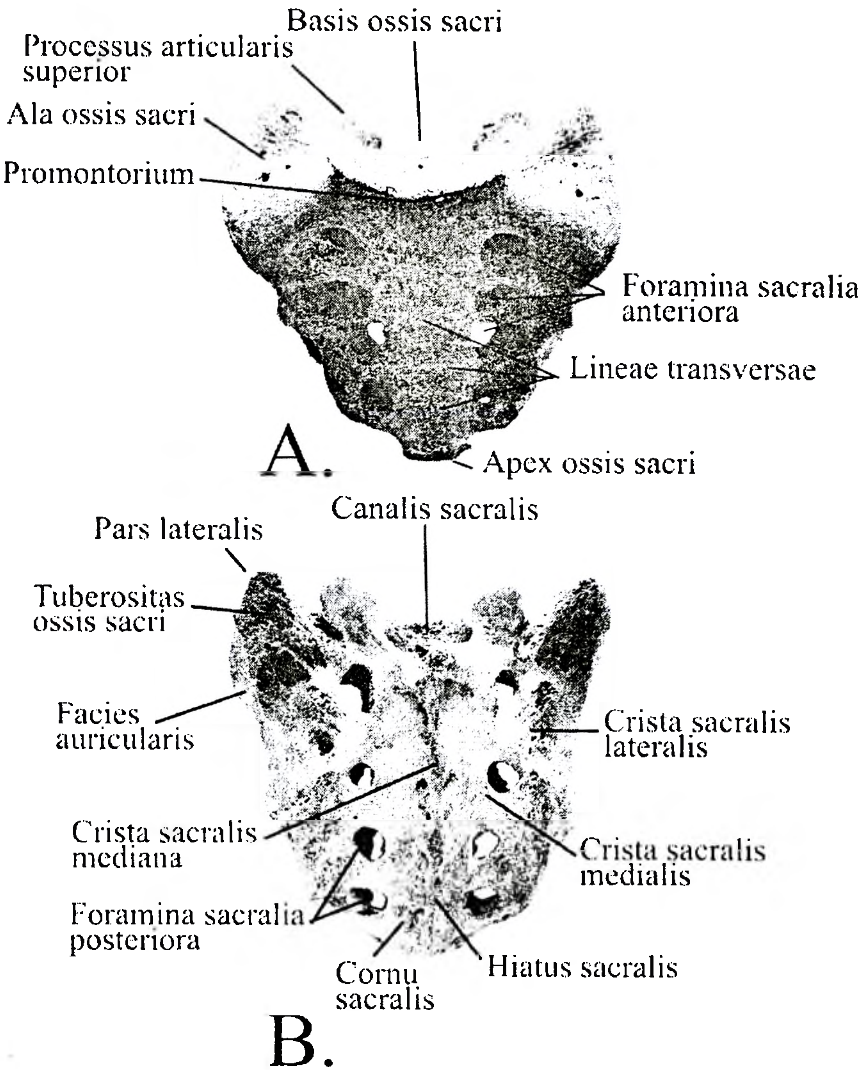

Fig. 13. Os sacrum (vertebrae sacrales)
A- anterior view; B- posterior viev.

the sacral vertebrae are reduced. Therefore, the sacral canal is not closed in its distal part but opens as the *sacral hiatus (hiatus sacralis).* Lateral to this hiatus are the *sacral cornua (cornua sacralia),* remnants of the last sacral vertebra, which articulate with similar cornua of the coccyx.

The *sacral canal* lies within the sacrum and, corresponding in shape to the sacrum, is irregularly curved and of uneven width. About the level of the 3rd sacral vertebra the canal is narrowed. Channels, which correspond to the intervertebral foramina and are formed from the fused superior and inferior vertebral notches, open laterally from the sacral canal. The corresponding sacral foramina open ventrally and dorsally from these short channels.

Sex Differences:

Males have a longer sacrum with more marked curvature. Females have a shorter but broader sacrum, which is less curved.

5. Coccygeal vertebrae *(vertebrae coccygeae)*

Coccygeal vertebrae *(vertebrae coccygeae s. caudales)* are remnants of the tail and rudimentary structures fusing at middle age to form a single bone, the *coccyx (os coccygis).* The **coccyx,** which is usually formed from three to four vertebrae, is normally only rudimentary (Fig. 14). The first coccygeal vertebra is larger than the rest and has on the dorsal surface two processes - *cornua* or *horns (cornua coccygea),* which are directed upward to meet the sacral cornua. The remainder of the coccygeal vertebrae consist only of small, round bones.

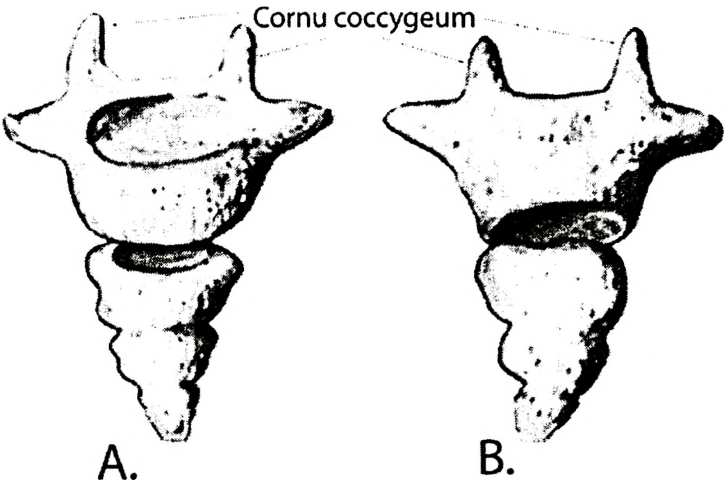

Fig. 14. Os coccyges (vertebrae coccygeae)
A- anterior view; B- posterior viev.

The cranial to caudal vertebrae decrease in size. Only the first coccygeal vertebra shows any similarity to the structure of a typical vertebra. It shows two lateral processes which represent the remnants of the transverse processes.

Variations in the Sacral Region

The vertebral column usually consists of 24 presacral vertebrae, the remainder being arranged into five fused sacral vertebrae and three to four coccygeal vertebrae. About one third of individuals have an additional sacral vertebra, so that the sacrum consists of six vertebrae. Either one lumbar vertebra may be included in the sacrum, or the 1st coccygeal vertebra may be fused with it. Situation is called sacralization of a lumbar vertebra, and is called sacralization of the coccyx or a coccygeal vertebra. If either a lumbar or a coccygeal vertebra is fused with the sacrum, there are five sacral foramina in each side and the sacrum appears larger than in its typical form.

Fusion of the last lumbar vertebra may be unilateral, producing a lumbosacral transitional vertebra, which may lead to scoliosis of the spine. A lumbosacral transitional vertebra occurs also when there is lumbalization of the 1st sacral vertebra. In this case torsally there is incomplete fusion of the 1st sacral with the rest of the vertebrae and there is no bony union in the region of the lateral parts, i.e., in those areas that originated from remnants of ribs.

It should be noted that when lumbalization of a sacral vertebra occurs, here may nevertheless be five vertebrae if the 1st coccygeal vertebra is used with the sacrum. An increased lumber of sacral vertebrae, i.e., sacralization of a lumbar or coccygeal vertebra, is more common in males than in females.

Quite often an incomplete medial sacral crest is found. In these cases the posterior wall of the sacral canal appears to be defective. A part from this, incomplete fusion of the spinous processes of the 1st sacral vertebra with the spinous processes of the other sacral vertebrae produces a vertebral arch in the 1st sacral segment and so the medial sacral crest starts from the 2nd vertebra.

Lastly, sometimes none of the vertebral arches are fused, so that there is no posterior bony wall in the sacral canal. This malformation is called spina bifida.

When the spinal cord is intact and the skin of the area is undamaged the condition is called spina bifida "occulta".

X-RAY EXAMINATION OF BONE STRUCTURE

Simple inspection of macerated bone gives an idea of the external appearance of the bone, but its internal structure can be studied only by dissection. X-rays of the live human subject, however, demonstrate simultaneously the external and internal bone structure without harm to normal anatomical functions.

The compact and spongy substances are easily seen on radiographs. The *compact substance* produces a shadow of increased density corresponding to the plane of the cortical layer, whereas the shadow in the region of the *spongy substance* has the character of meshwork.

The *compact substance* of the *epiphyses* of tubular bones and that of bones composed mostly of spongy substance (the carpal and tarsal bones, the vertebrae) is seen as a thin layer edging the spongy substance. This thin cortical layer is thicker on the articulating cavity than on the head of the bone.

The *compact substance* in the *diaphyses* of tubular bones varies in thickness: it is thicker in the middle part but becomes thinner in the direction of the ends. The marrow cavity is discernible between the two shadows of the cortical layer as an area of diminished density against the background of the whole shadow of the bone. A cavity that cannot be traced for its entire length indicates the presence of a pathological process.

The X-ray outlines of the *diaphyseal compact substance* are clearly defined and regular. At sites of attachment of ligaments and muscles the outlines of the bone are irregular. Thin bands of diminished density, corresponding to the vascular canals, are demonstrated against the shadow of the diaphyseal cortical layer. They usually stretch obliquely, closer to and in the direction of the elbow joint in the long tubular bones of the upper limbs and further from and in the direction of the knee joint in the long tubular bones of the lower limbs. In the short tubular bones of the hand and foot, they stretch closer to and in the direction of the end which has no true epiphysis.

The *spongy substance* is demonstrated on the radiograph as a looped meshwork of bone trabeculae with spaces of diminished density between them. The character of the meshwork is determined by the arrangement of the bony lamellae in the given area according to the lines of compression and tension.

The X-ray image of an adult vertebral column

The vertebral body *(corpus vertebrae)* of an adult is quadrangular on a radiograph. The angles of the body represent a conventional, purely radiological concept associated with the projection of a cylindric body on the surface of the radiograph; the apices of the angles are rounded. The outlines of the body are clear and even. Lack of an increase in the height of the body from vertebra to vertebra in the caudal direction is a pathological phenomenon. The bodies of the lumbar vertebrae resemble a "reel" with a narrow "waist". The *pedicle of the arch (pediculus arcus vertebrae)* is demonstrated on an anteroposterior radiograph as a circular or oval contrast shadow superimposed on the shadow of the body. The arch in this case is projected as if in a transverse section.

On lateral radiographs of the vertebral column, the arch is clearly seen in all detail. Both arches of the atlas with the posterior and anterior tubercles are demonstrated; the anterior tubercle is the guiding point in counting the vertebrae on the radiograph.

The articular processes *(processus articulares superiores and inferiores)* are not adequately demonstrated in different spinal segments. Clarity depends on the position of the articular surfaces. An "X-ray joint cavity" can be seen between them, which diners from the anatomical joint cavity. The latter is the space between the surfaces of the articular cartilage which covers the bone, while the "X-ray joint cavity" is the space between the articular surfaces of the bone, including the cartilaginous tissue which is permeable to X-rays and which produces no image on the radiograph.

The transverse processes *(processus transversus)* are located in the front plane and are demonstrated clearly on anteroposterior radiographs. A rudiment of the true transverse processes (processus accessorius) is seen at the root of the transverse processes of the lumbar vertebrae. When long (4 mm), it resembles a style (processus styloideus). It should not be mistaken for a pathological structure.

The spinous processes *(processus spinosus),* lying in the sagittal plane, are demonstrated best on lateral radiographs.

The sacrum and coccyx. The characteristic feature of the sacrum is fusion of the vertebrae to form a single bone. An anteroposterior radiograph shows a clear image of the whole sacrum and coccyx with all the details described in osteology.

The X-ray picture of the vertebral column at old age is characterized by the following features.

1. Generalized rarefaction of the spinal bony substance, osteoporosis. Relative translucency of the bone tissue is noted on the radiograph.

2. Calcification of the intervertebral disc.

3. Calcification of the anterior longitudinal ligament at the attachment of the limbus vertebrae as a result of which bony projections, osteophytes, are seen on the superior and inferior edges of the body; due to these osteophytes the rounded apices of the X-ray "angles" of the vertebral bodies change to acute.

Thus, the vertebral body undergoes considerable changes in the process of ontogenesis: in the intrauterine period it contains an ossification point; in the newborn it is shaped like an egg and has no "angles"; in childhood apophyses in the form of three-edged structures appear at the sites of the future "angles"; in an adult the body becomes quadrangular with rounded "angles" as the result of synostosis between the apophysis and diaphysis; at old age these "angles" are tapered. Consequently the age changes in the vertebral column can be judged from the shape of the body and its "angles" on the X-ray picture.

Variants in the number of vertebrae. Variations of the number of vertebrae are often found on the radiographs of healthy individuals: lumbarization occurs in 4 per cent and various forms of sacralization (partial, complete, unilateral, bilateral) in 7 per cent of females and 15 per cent of males. The tendency to sacralization is encountered in up to 50 per cent of the population.

THE STERNUM

The **breast-bone** *(sternum)* resembling a dagger in shape, consists of three parts: the upper part, the manubrium sterni, the middle part, the body *(corpus sterni)*, and the lower part, the xiphoid process *(processus xiphoideus)* (Fig. 15).

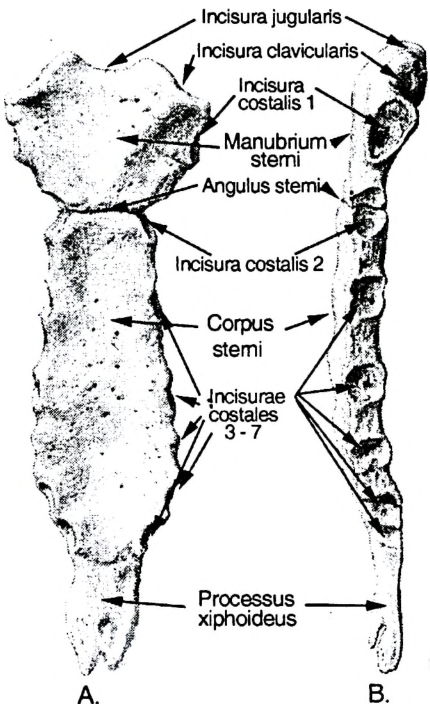

Fig. 15. Sternum
A- anterior view; B- lateral viev.

The manubrium has a jugular notch *(incisura jugularis)* on its superior border and lateral to this, a clavicular notch *(incisura clavicularis)* on each side, by means of which the sternum articulates with the sternal end of the clavicle. The inferior border of the manubrium and the superior border of the body join at an anteriorly protruding angle, the angle of the sternum *(angulus sterni)*, which is open toward the back. The lateral border of the sternal body has costal facets *(incisurae costales)* for articulation with the cartilages of the ribs, beginning with the second rib. The costal notch for the 7th rib lies just at the point of transition between the body and the xiphoid process. The manubrium and body of the sternum are usually joined by the *manubriostenal synchondrosis*. The body of the sternum widens somewhat toward the lower end and carries on its anterior surface three transverse lines, remnants of the union of the four primary sternal segments. A *xiphosternal synchondrosis* between the body and the xiphoid process is much less common.

The xiphoid process *(processus xiphoideus)* is cartilaginous until maturity; with advancing age it may become ossified completely or remain partially cartilaginous. The xiphoid process varies in shape. It may consist of one piece or it may be forked. Sometimes it contains a foramen and it may be bent forward or backward. The xiphoid process varies greatly in appearance and may be perforated, bifid, turned laterally, and so forth. The sternal structure is distinguished by a copious fine, spongy substance with a very rich network of blood vessels, which allows intrasternal transfusion of blood. The abundant development of bone marrow in the sternum makes it an excellent collection point for marrow transplantation in the treatment of radiation sickness.

Variants: Very rarely there are suprasternal bones, also called the episternum, at the cranial end of the manubrium near the jugular notch. Sometimes there is an opening (foramina) within the sternum, a congenital sternal fissure which arises during development.

THE RIBS

The ribs *(costae)* are narrow curved plates which in their longest, posterior part are formed of bone, *os costale*, belonging to the group of long spongy bones, and in the narrower anterior part, of cartilage, *cartilago costalis* (Fig. 16). There are twelve ribs on each side. All ribs articulate by their posterior ends with the bodies of the thoracic vertebrae. The anterior ends of the **upper seven ribs** are joined directly to the sternum by cartilages. These are the true ribs *(costae verae)*. The next three ribs, **eighth, ninth**, and **tenth,** are joined by their cartilages not to the sternum but to the cartilage of the rib next above, and are referred to as false ribs *(costae spuriae)*. The anterior ends of the eleventh and twelfth ribs lie free, and these ribs are called floating ribs *(costae fluctuantes)*.

On the anterior end the bony part of the rib fuses closely with the cartilaginous part. Posterior and anterior ends and a shaft of the rib *(corpus costae)* between them are distinguished in each bony rib. The posterior end is slightly enlarged to form the head of the rib *(caput costae)*, which has an articular facet separated by a ridge; the rib articulates by means of this facet with the vertebral bodies. The facet of the first, eleventh, and twelfth ribs does not have a separating ridge. A narrowed part, the neck of the rib *(collum costae)*, immediately succeeds the head; it has a longitudinal crest of the neck of the rib *(crista colli costae)* on its superior border. The first and last ribs lack this crest. At the junction of the neck and shaft, there is a tubercle of the rib *(tuberculum costae)*, which carries a facet for joining with the articular surface of the transverse process of the corresponding vertebra.

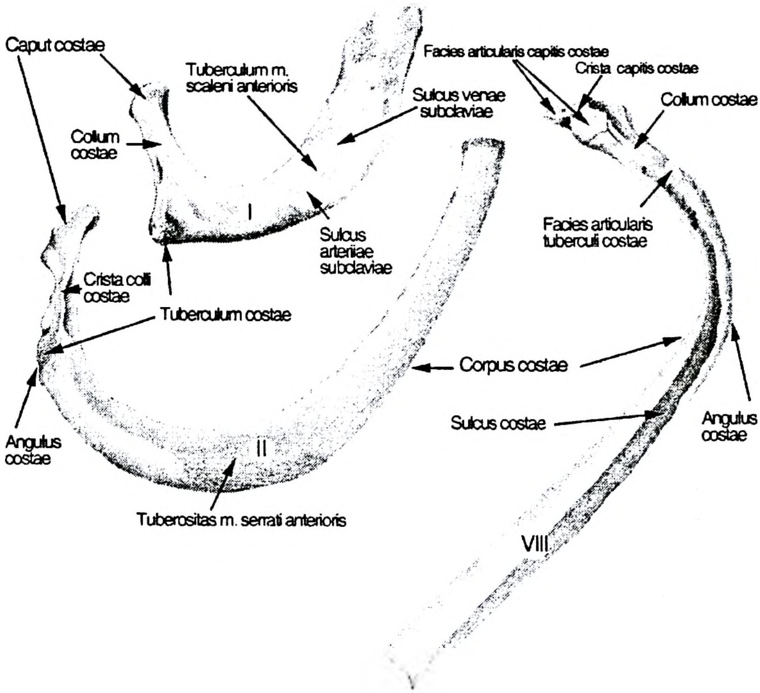

Fig. 16. Costae (I, II, VIII)
I, II- view from above; VIII- inferior viev.

The eleventh and twelfth ribs do not have this tubercle because they do not articulate with the last thoracic vertebrae. Lateral to the tubercle, the rib curvature is greatly accentuated and the angle of the rib *(angulus costae)* is located here posteriorly on the shaft. The angle and the tubercle coincide on the first rib. On the other ribs the distance between them increases down to the eleventh rib, while on the twelfth rib there is no angle. A groove *(sulcus costae)* is detectable on the inferior border of the inner surface of the middle ribs (with the exception of the 1st, 11th and 12th); it conducts the intercostal vessels.

The superior surface of the first rib carries the scalene tubercle *(tuberculum m. scaleni anterioris),* which is of practical importance because it gives attachment to the scalenus anterior muscle *(m. scalenus anterior).* Immediately posterior to this tubercle, a small groove, the groove for the subclavian artery *(sulcus a. subclaviae),* can be seen, into which the subclavian artery fits when it curves over the first rib. Another, flatter groove for the subclavian vein *(sulcus v. subclaviae)* is found to the front of the tubercle.

The ***size*** and ***shape*** of the different ribs are closely associated with the shape of the thoracic cage and their location in relation to it. It should firstly be pointed out that the ribs slope, their anterior ends slanting downward considerably. They increase in length from the first to the seventh rib; the seventh and eighth ribs are the longest. The lower four ribs again diminish in length. Since the thoracic cage is ovoid, the ribs are curved in relation to the plane and their border. Longitudinal convexities form posteriorly in the thoracic cage on both sides of the spine and concavities (pulmonary sulcus) on the inner surface because the curvature of the posterior part of the ribs is very steep.

Curvatures: There are three curvatures of the edge, of the flat surface and a torsion curvature. Although the *edge curvature,* which is the principal one in the 1st rib, is readily apparent, the *flat surface curvature* can only be seen on close inspection. It is present from the 3rd rib on. If the upper surface of a rib is viewed near its anterior end, and is followed toward the back it will be seen that the surface slowly turns dorsally. In addition to this curvature, there is a longitudinal twist in the rib, which is most marked in the middle ribs and is called torsion. It is not present in the 1st, 2nd or 12th ribs.

The **hyaline costal cartilage** begins to calcify with increasing age, more in males than in females. This reduces mobility of the thorax.

Individual Features of Particular Ribs:

The **1st rib** is small and flattened. On the inner circumference of its cranial surface is an area of roughness, the *scalene tubercle,* to which the anterior scalenus is attached. Posterior to it lies the *sulcus of the subclavian artery (sulcus arteriae subclaviae)*, and in front of it is the *sulcus of the subclavian vein (sulcus venae subclaviae)* which is not always clearly visible.

Identification:

1. *It is the shortest, broadest and most curved rib.*
2. *The shaft is not twisted.*
3. *It is flattened from above downwards so that it has superior and inferior surfaces, and outer and inner borders.*

The **2nd rib** has a rough area on its upper surface, the *tuberosity for the serratus anterior muscle*, from which one part of the serratus anterior originates.

Identification:

1. *The length is twice that of the first rib.*
2. *The shaft is sharply curved, like that of the first rib.*
3. *The non-articular part of the tubercle is small.*
4. *The angle is slight and is situated close to the tubercle.*
5. *The shaft is no twist. The outer surface is convex and faces more upwards than outwards. Near its middle it is marked by a large rough tubercle. The inner surface of the shaft is smooth and concave. It faces more downwards than inwards. There is a short costal groove on the posterior part of this surface.*
6. *The posterior part of the upper border has distinct outer and inner lips. The part of the outer lip just in front of the angle is rough.*

The 10^{th} closely resembles a typical rib, but is shorter, and has only a single facet on the head, for the body of the 10^{th} thoracic vertebra.

The *costal tubercle* and *costal sulcus* are absent from **ribs 11** and **12**, and the *costal angle* is only indicated. These ribs are short. They have pointed ends.

Variants:

In two thirds of cases the 10th rib ends freely, i.e., it is not connected with the 9th rib and with the sternum. The first seven ribs are usually directly connected to the sternum, although sometimes the first eight may be so associated, and less commonly only the first six.

The number of pairs of ribs is variable. There are usually 12 pairs, but sometimes 11 or 13 are found. When there are 13 pairs, cervical or lumbar ribs may be present.

Malformations may lead to fenestrated or forked ribs. Most commonly they affect the 4th rib.

The X-ray image

In adults, the 12 pairs of ribs are clearly seen on a postero-anterior radiograph; the anterior parts of the ribs are superimposed on the posterior parts and intersect mutually. To interpret the picture properly, it should be borne in mind that the posterior parts of the ribs are connected to the vertebral column and run obliquely, downward and laterally. The anterior parts slope downward, but in an opposite direction, medially. The shadow of the anterior ends is abruptly interrupted where the bone tissue is continuous with the cartilaginous tissue. The radiograph demonstrates the heads and necks superimposed on the shaft, as well as the transverse processes of the corresponding vertebrae. The tubercles of the ribs and their articulations are also seen close to the transverse processes.

THE SKELETON OF THE UPPER LIMB

In the upper limb we distinguish the **shoulder girdle** *(cingulum membri superioris)* and the **free extremity** *(pars libera membri superioris)*.

THE SHOULDER GIRDLE

The shoulder girdle *(cingulum membri superioris)* consists of two paired bones, the clavicle (collar bone) and the scapula (shoulder blade).

THE CLAVICLE

The **collar bone** or **clavicle** *(clavicula)* is an S-shaped bone, anteriorly convex in the medial two thirds of its length, while the lateral third is concave anteriorly (Fig. 17). The clavicle *(clavicula) is* the only bone fastening the upper limb to the skeleton of the trunk. It is of high functional importance because it holds the shoulder joint at the needed distance from the thoracic cage and thus permits greater freedom of movement of the limb. As pointed out above, the clavicle is well developed in mammals capable of various movements of the front (upper) limbs. In contrast, it is insufficiently developed in animals with limbs specialized in movement in one (sagittal) plane.

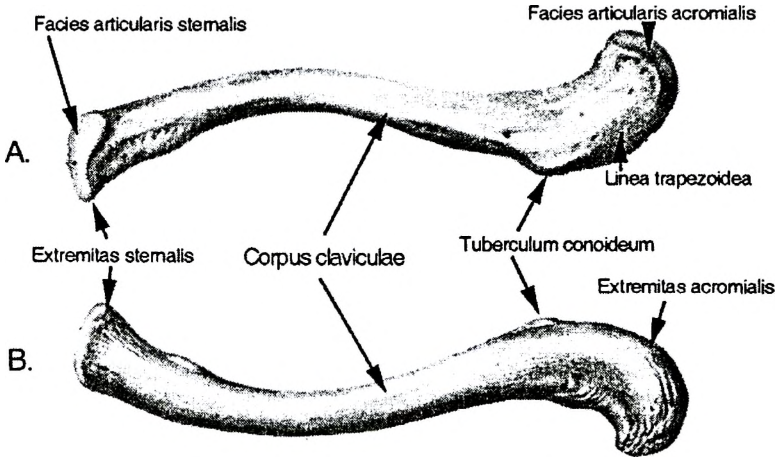

Fig. 17. Clavicula
A- inferior viev; B- view from above.

The shoulder joint of a person with a fractured clavicle is pressed to the thoracic cage *(thorax)* by the action of the muscles, and movements of the upper limb become very limited. Comparison of the clavicle in the different hominid forms shows that it increases gradually in size and is developed best in modern man, which is linked with his work activity. The clavicle develops before all the other bones. It is a membrane bone transposed from the trunk and ossifies, therefore, partly in connective tissue (middle segment) and partly in cartilage (the ends); an independent ossification nucleus is laid down only in one (sternal) epiphysis (monoepiphyseal bone). According to some data, the clavicle undergoes both perichondral and enchondral ossification.

The clavicle is a tubular bone, and a body or shaft *(corpus)* and two ends, medial and lateral, are distinguished in it. The thickened medial or sternal end *(extremitas sternalis)* carries a saddle-shaped articular surface for uniting with the sternum. The lateral, or acromial end *(extremitas acromialis)* has a flat articular surface for articulating with the acromial process of the scapula. On the inferior surface of the acromial end is the conoid tubercle *(tuberculum conoideum)* (the site of attachment of the same name ligaments). The shaft of the clavicle is curved so that its medial part which is nearer to the sternum is convex anteriorly, while the lateral part is convex posteriorly. On the inferior surface of the sternal end is the costal tuberositas *(tuberositas costarum)* (the site of attachment of ligament).

Clinical tips: The clavicles may be congenitally absent, or imperfectly developed (in a disease called *cleido-cranial dysoslosis).* Cleido-cranial dysostosis is a malformation due to maldevelopment or nondevelopment of the connective tissue part of the clavicle. In this condition the shoulders droop, and can be approximated anteriorly in front of the chest. It is associated with defects of those bones of the skull that are preformed in connective tissue.

The clavicle is commonly fractured by falling on the outstretched hand (indirect violence). The commonest site of fracture is the junction between two curvatures of the bone, which is the weakest point. The lateral fragment is displaced downwards by the weight of the limb.

THE SCAPULA

The **shoulder blade** or **scapula** *(scapula)* is a flat triangular bone lying on the posterior surface of the thoracic cage in the space between the second and seventh ribs (Fig. 18). Three borders are distinguished in it: the medial border *(margo medialis),* facing the spine, the lateral border *(margo lateralis),* facing to site, and the superior border *(margo superior),* on which is the scapular notch *(incisura scapulae).*

The three borders meet at three angles, one of which, the inferior angle *(angulus inferior)* is directed downward, while the other two, the superior angle *(angulus superior)* and lateral angle *(angulus lateralis)* are at the ends of the superior border of the scapula. The lateral angle is greatly thickened and supplied with a shallow depression, a laterally positioned articular glenoid cavity *(cavitas glenoidalis).* The edge of the cavity is separated from the rest of the scapula by a constriction, the neck of the scapula *(collum scapulae).* Above the superior edge of the cavity is the supraglenoid tubercle *(tuberculum supraglenoidale),* which provides attachment for the tendon of the long head of the biceps. A similar infraglenoid tubercle *(tuberculum infraglenoidale)* for attachment of the long head of the triceps is found at the inferior edge of the fossa. The coracoid process *(processus coracoideus)* (the former coracoid) arises from the superior border of the scapula in the vicinity of the glenoid cavity. The anterior, costal surface of the scapula *(facies costalis),* forms a hollow depression called the subscapular fossa *(fossa subscapularis)* which gives attachment to the subscapular muscle. The spine of the scapula *(spina scapulae)* projects from the dorsal surface of the scapula *(facies dorsalis)* and divides it into two recesses of unequal size, the supraspinous fossae *(fossa supraspinata)* and infraspinous fossae *(fossa infraspinata).* The spine of the scapula stretches laterally and is continuous with the *acromion* overhanging the glenoid cavity at the back and above. The acromion carries the articular facet *(facies articularis acromii)* for articulation with the clavicle.

The scapula lies on the thorax with the base of its spine at the level of the 3rd thoracic vertebra. The inferior angle of the scapula should lie between ribs 7-8 and, when the arm hangs down, its medial margin should be parallel to the row of spinous processes. The scapular plane is the plane in which the

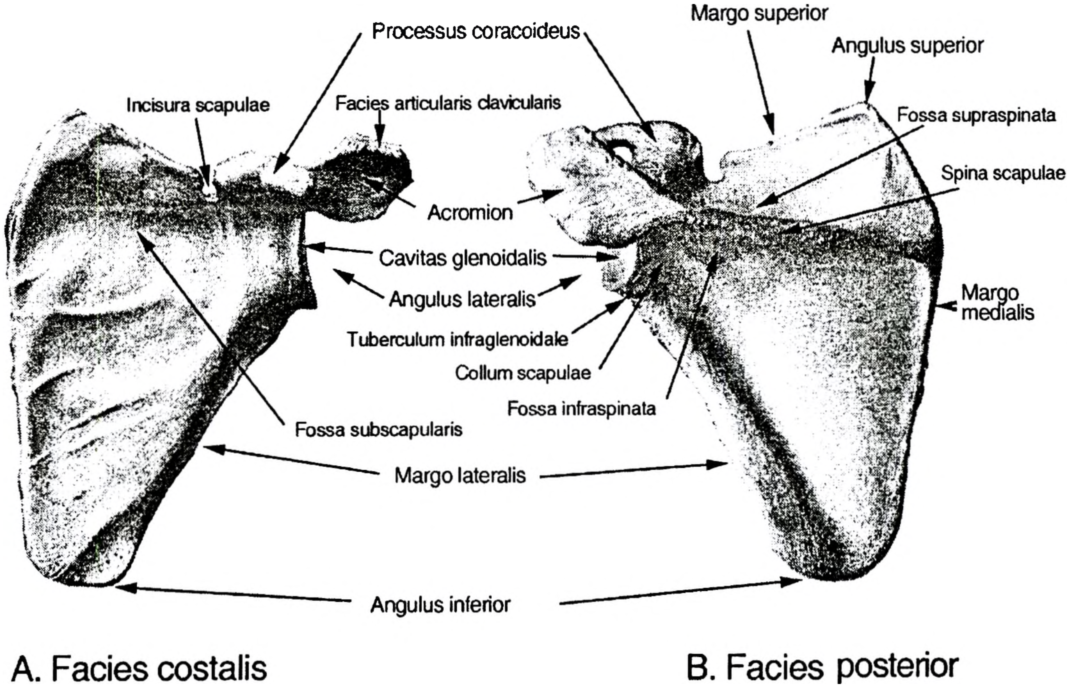

Fig. 18. Scapula
A- anterior view; B- posterior viev.

scapular plate lies. It forms an angle of 60° with the plane of symmetry (median sagittal). The glenoid cavity faces laterally and anteriorly.

X-ray image

A postero-anterior radiograph of the scapula demonstrates a characteristic triangular structure with three borders, angles, and processes. A notch, incisura scapulae, can sometimes be detected on the superior border at the base of the coracoid process; it can be mistaken for a focus of bone destruction, particularly when it is converted into a foramen as a consequence of the age calcification of the superior transverse ligament of the scapula.

Variants:

The scapular notch may be transformed into a *scapular foramen*. The medial margin of the scapula is sometimes concave and the scapula is then called a *scaphoid scapula*.

THE SKELETON OF THE FREE UPPER LIMB

The skeleton of the free upper limb *pars libera membri superioris)* consists of the humerus, two forearm bones (the radius and ulna), and the bones of the hand (metacarpal bones and the phalanges).

THE HUMERUS

The **humerus** *(os humerus)* articulates with the scapula and the radius and ulna. The humerus is a long lever of movement, which develops like a typical long tubular bone (Fig. 19). In conformity with this function and development, it is made up of a diaphysis, metaphyses, epiphyses, and apophyses. It consists of the body *(corpus osis humeri)* and upper (proximal) *(epiphysis proximalis)* and lower (distal) ends *(epiphysis distalis)*. Its upper end is supplied with a spherical head *(caput humeri)* (the proximal epiphysis), which articulates with the glenoid cavity of the scapula. The head is separated from the rest of the bone by a narrow groove called the anatomical neck *(collum anatomicum)*. Directly below it are two tubercles for attachment of the muscles. The greater tubercle *(tuberculum majus)* is on the lateral side; the lesser tubercle *(tuberculum minus)* is a little to the front of it (apophyses). Bony crests (for attachment of the muscles) run downward from the tubercles, the lateral lip of the bicipital groove *(crista tuberculi majoris)* and the medial lip of the bicipital groove *(crista tuberculi minoris)*. The intertubercular groove *(sulcus intertubercularis)* passes between both tubercles and crests and lodges the tendon of the long head of the biceps brachii muscle. The part of the humerus directly below the tubercles at the junction with the diaphysis is called the surgical neck *(collum chirurgicum)* (where fractures often occur). The upper part of the body (shaft) of the humerus has cylindrical outlines, but its lower part has a distinctly trihedral shape, in which a posterior surface *(facies posterior)*, an anterolateral surface

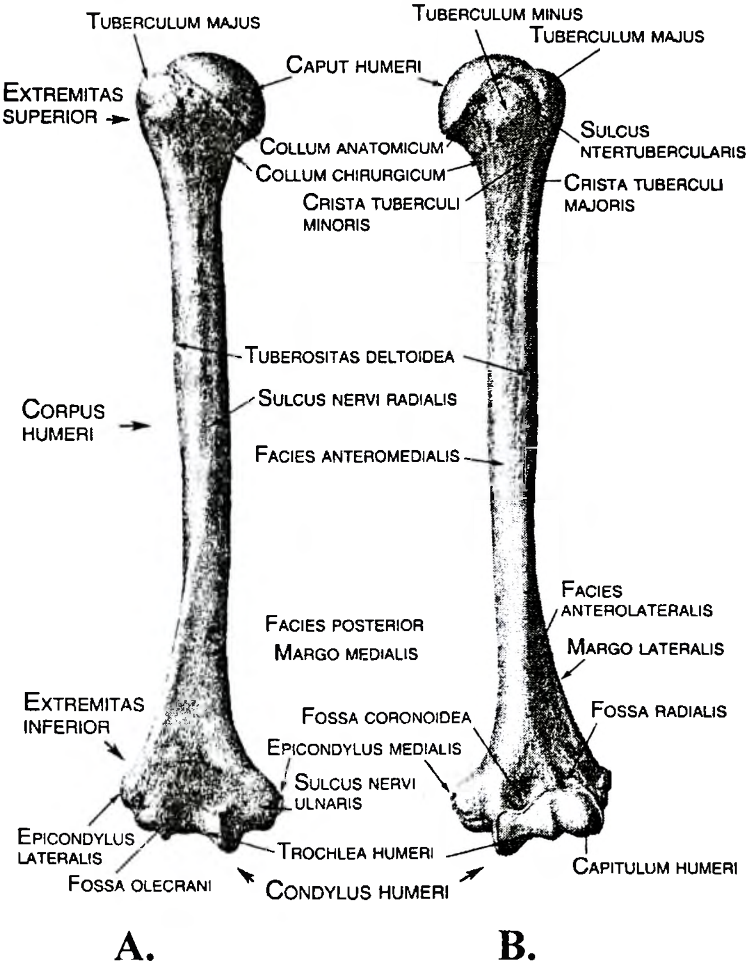

Fig. 19. Humerus
A- posterior view; B- anterior viev.

(facies anterior lateralis), and an anteromedial surface *(facies anterior medialis)* are distinguished. The two anterior surfaces are separated from the posterior surface by lateral *(margo lateralis)* and medial *(margo medialis)* borders. About the middle of the shaft, on its anterolateral surface, is the deltoid tuberosity *(tuberositas deltoidea)*, to which the deltoid muscle is

attached. A sloping spiral, shallow groove of the radial nerve *(sulcus nervi radialis, s. sulcus spiralis)* passes behind the tuberosity on the posterior surface of the body from the medial to the lateral border.

The widened distal part of the humerus, the condyle *(condylus humeri)* is bent slightly forward and has two rough projections on its sides, the medial *(epicondylus medialis)* and lateral epicondyles *(epicondylus lateralis)*, which are continuous with the medial and lateral borders of the bone and provide attachment for the muscles and ligaments (apophyses). The medial epicondyle is more prominent than the lateral one and has on its posterior surface a groove for the ulnar nerve *(sulcus nervi ulnaris)*. An articular surface for uniting with the forearm bones (distal epiphysis) is situated between the epicondyles. Two parts are distinguished in it. Medially is the pulley-shaped trochlea grooved in the middle; it articulates with the ulna and is embraced by its notch *(incisura trochlearis ulnae)*. Above the trochlea are two fossae, one, the coronary fossa *(fossa coronoidea)* in front, and the other, the olecranon fossa *(fossa olecrani)* behind. These fossae are so deep that the bony septum separating them is thin enough to be transparent and may even be perforated. Laterally of the trochlea is an articular surface the shape of a segment of a sphere, the capitulum of the humerus *(capitulum humeri)* for articulation with the radius. A small radial fossa *(fossa radialis)* lies above it in front.

The humerus is twisted at its proximal end, i.e., the head is posteriorly rotated at about 20° in relation to the shaft (torsion angle). The angle between the long axis of the humerus and that of the head averages 130°, and at the distal end, between the transverse axis of the joint and the long axis of the body of the humerus, there is an angle of 76° to 89°.

Variants:

Just above the medial epicondyle a *supracondylar process* is occasionally found, and above the trochlea there may be a *supratrochlear foramen*.

Clinical Tips:

The common sites of fracture are the surgical neck, the shaft and the supracondylar region. 50% of fractures of the humerus occur in the shaft. There is a risk of damage to the radius (radial nerve). Supracondylar fracture is common in young age. It is produced by a fall on the outstretched hand. The lower fragment is mostly displaced backwards, so that the elbow is unduly prominent, as in dislocation of the elbow joint. However, in fracture, the three bony points of the elbow form the usual equilateral triangle. This fracture may cause injury to the median nerve.

BONES OF THE FOREARM

The forearm bones belong to the group of long tubular bones. There are two of them, the *ulna*, which is the medial bone, and the *radius*, the lateral bone. The shafts of both bones are trihedral with three surfaces and three borders. The surfaces are as follows: posterior, anterior, and lateral in the radius and medial in the ulna. One of the three borders is sharp. It separates the anterior from the posterior surface and faces the neighbouring bone, thus delimiting the interosseous space; hence its name, the interosseous border *(margo interossea)*. The anterior surface of the shaft has a vascular foramen *(foramen vasculosum)* leading into the vascular canal for the vessels. Besides these signs common to both bones, there are some features characteristics of each bone separately.

THE ULNA

The **ulna** (s. *cubitus)* has a shaft and proximal and distal ends (Fig. 20).

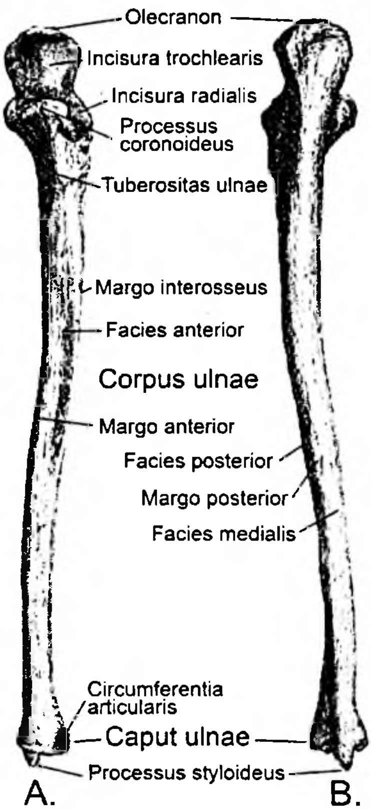

Fig. 20. Ulna
A- anterior viev; B- posterior view.

The upper (proximal) thickened end of the ulna (epiphysis) is separated into two processes: the thicker, posterior process, olecranon and the smaller anterior, coronoid process *(processus coronoideus)*. Between these two processes is the trochlear notch *(incisura trochlearis)* for articulation with the trochlea of the humerus. The radial side of the coronoid process has a small radial notch *(incisura radialis)*, the site of articulation with the head of the radius; in front, under the coronoid process, there is the tuberosity of the ulna *(tuberositas ulnae)*, to which attaches the tendon of the brachial muscle. The lower (distal) end of the ulna carries a spherical head with a flat inferior surface *(caput ulnae)* (epiphysis) from the medial surface of which the styloid process *(processus styloideus)* (apophysis) projects. The head carries on its circumference an articular surface *(circumferentia articularis)*, by means of which it articulates with the adjacent radius.

Applied Anatomy: The ulna is the stabilizing bone of the forearm, with its trochlear noch gripping the lower end of the humerus. On this foundation the radius can pronate and supinate for efficient working of the upper limb.

The shaft of the ulna may fracture either alone or along with that of the radius. Cross union between the radius and ulna must be prevented to preserve pronation and supination of the hand.

THE RADIUS

The **radius** consists of a shaft and proximal and **distal** ends (Fig. 21). The radius, in contrast to the ulna, has a distal end that is thicker than the proximal end. The proximal end forms a rounded head *(caput radii)* (epiphysis), which has a concave surface for articulation with the head of the humerus. One third or one half of the head circumference is also occupied by an articular surface *(circumferentia articularis)* articulating with the radial notch of the ulna. The head of the radius is separated from the rest of the bone by a neck *(collum radii)* directly below which on the antero-ulnar side is the radial tuberosity *(tuberositas radii)* (apophysis), providing attachment for the biceps muscle of the arm. The lateral border of the distal end of the radius (epiphysis) is continuous with the styloid process *(processus styloideus)* (apophysis). The carpal articular surface *(facies articularis carpea)* on the distal epiphysis is concave and serves for articulation with the scaphoid and lunate carpal bones. The medial border of the distal radial end has a small *ulnar notch (incisura ulnaris)* for articulation with the circumferentia articularis of the ulnar head. Dorsally we find a number of **grooves** of variable depth in which run the tendons of the long extensor muscles. From lateral (radial) to medial (ulnar) we have *1st* the *sulcus* for the tendons of the abductor pollicis longus and extensor pollicis brevis lying on the styloid process, and *2nd* the *sulcus* for the tendons of the extensor carpi radialis longus and brevis. The *3rd sulcus* is oblique and accomodates the tendon of tendon of the extensor pollicis longus. The *4th sulcus* carries the tendons of the extensor digitorum and the extensor indicis. The bony elevation (ridge), which lies lateral to the 3rd sulcus, is usually palpable and is known as the *dorsal tubercle.*

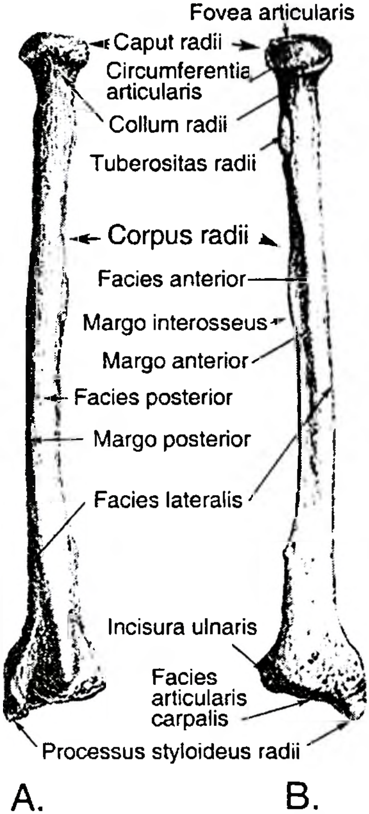

Fig. 21. Radius
A- posterior view; B- anterior viev.

Clinical Tips: The styloid process of the radius extends 1 cm further distally than that of the ulna. This must be taken into consideration when fractures are set. The radius commonly fractures about 2 cm above its lower end (*Colles's fracture).* This fracture is caused by a fall on the outstretched hand. The distal fragment is dispplaced upwards and backwards, and the radial styloid process comes to lie proximal to the ulnar styloid process (it normally lies distal to the ulnar styloid process).

Smith's fracture is the reverse of *Colles's fracture,* the distal segment being palmar flexed rather than dorsiflexed. It is uncommon, and is produced by a fall on the dorsum of a palmar flexed hand.

THE BONES OF THE HAND

The bones of the hand are subdivided into the carpal and metacarpal bones and the bones which are the components of the fingers and the phalanges (Fig. 22).

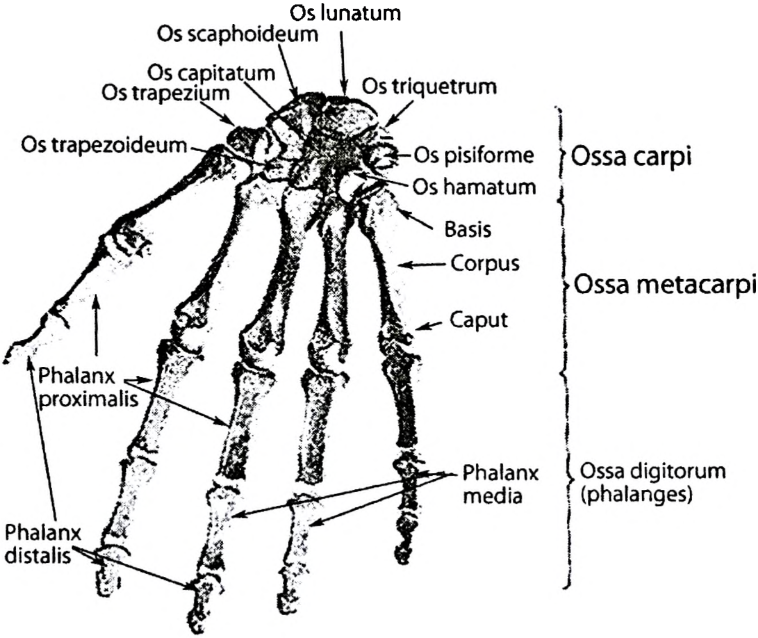

Fig. 22. Ossa manus sinister – anterior viev.

THE CARPUS

The carpus consists of eight **carpal bones** arranged in two rows of four. In the *proximal* row from lateral to medial are the scaphoid *(os scaphoideum)*, lunate *(os lunatum)*, triquetrum *(os triquetrum)* and superimposed on it the pisiform *(os pisiforme)*. In the *distal* row from the lateral to the medial side are the trapezium *(os trapezium, s. os multangulum majus)*, trapezoid *(os trapezoideum s. os multangulum minus)*, capitate *(os capitatum)* and hamate *(os hamatum)*. Each carpal bone has several facets for articulation with the neighboring bones.

The first three bones of the *proximal*, or *first* row, unite to form an ellipsoid convex surface facing the forearm for articulation with the distal end of the radius. The pisiform bone does not take part in this articulation and is attached to the triquetral bone separately. It is a sesamoid bone developing in the tendon of the ulnar flexor muscle of the wrist.

Individual Bones of the Carpus

The scaphoid, is boat-shaped, is the largest bone in the proximal row. On its palmar surface is a *tubercle*, which is easily palpable through the skin. The tubercle is directed laterally, forwards and downwards. The scaphoid articulates proximally with the radius, distally with the trapezium and trapezoid, and medially with the lunate and capitate. Blood vessels enter along the entire roughened surface of the bone. In one third of cases, blood vessels reach the scaphoid bone only on its distal face and in them a fracture of the scaphoid bone, may be followed by necrosis of the proximal fragment.

The **lunate** *(os lunatum)* is crescent-shaped or half-moon-shaped, articulates proximally with the radius and the articular disk, medially with the triquetrum, laterally with the scaphoid and distally with the capitate and sometimes also with the hamate. A small semilunar surface for the scaphoid is on the lateral side, and a quadrilateral articular surface for the triquertal bone is on the medial side.

The triquetrum *(os triquetrum)* is almost pyramidal in shape with its apex pointing medially. The base faces laterally and articulates with the lunate. Proximally it articulates with the articular disk and distally with the hamate. The palmar surface has a small oval-shaped articular facet for the pisiform. The medial and dorsal surfaces are continuous and nonarticular.

The pisiform *(os pisiformis)* is pea-shaped, is the smallest of the carpal bones. It is easily palpated through the skin. It has only one oval facet on the proximal part of its dorsal surface. The lateral surface is grooved by the ulnar nerve.

The trapezium *(os trapezium)* is quadrangular in shape. The trapezium possesses a *tubercle* which is palpable on dorsiflexion of the hand, and medial to it there is a groove for the tendon of the flexor carpi radialis. Distally it has a saddle-shaped articular facet for the 1st metacarpal bone. A facet for articulation with the trapezoid lies medially, and between the distal and medial articular facets there is a further small facet for the joint with the 2nd metacarpal bone. Proximally the trapezium articulates with the scaphoid.

The trapezoid *(os trapezoideum)* resembles the shoe of a baby. **The trapezoid** is wider dorsally than on its palmar surface. It articulates proximally with the scaphoid, distally with the 2nd metacarpal, laterally with the trapezium and medially with the capitate.

The capitate *(os capitatum)* is the largest carpal bone with a rounded head. It has facets proximally for articulation with the scaphoid and the lunate, laterally for the trapezoid, medially for the hamate and distally mainly for the 3rd metacarpal bone, as well as partly for the 2nd and 4th metacarpals.

The hamate *(os hamatum)* is wege-shaped, with a hook near its base. The hamate is readily palpable. On its palmar aspect is the *hamulus*, which is curved laterally. The latter is related to the flexor digiti minimi brevis and the pisohamate ligament. It articulates distally with the 4th and 5th metacarpal bones, laterally with the capitate, proximally and medially with the triquetrum, and proximally and laterally with the lunate.

Clinical Tips:

The scaphoid is of particular clinical importance as it is the most often fractured of all carpal bones. Inadequate treatment of a scaphoid fracture may result in a pseudarthrosis. One of the fractured parts may even become necrotic. Of all scaphoid fractures 70% occur through the middle third of the bone. The fracture is caused by a fall on the outstretched hand, or on the tips of the fingers

Dislocation of the lunate may be produced by a fall on the acutely dorsiflexed hand with the forearm flexed. This displaces the lunate anteriorly, causing carpal tunnel syndrome.

Variants:

There are sometimes small accessory bones between the carpal bones and as many as 20 of them have been described. The possibility of their presence must always be borne in mind when examining radiographs of the wrist. The commonest additional bone is the os centrale. Its cartilaginous anlage is an almost constant finding in man, but it almost always becomes synostosed with the scaphoid. Fusion of carpal bones has also been described, the most frequent fusion being between the lunate and triquetrum.

The scaphoid, triquetrum and pisiform bones may also be divided into two. This may be confused with fractures of these bones.

THE METACARPUS

The metacarpus consists of five **metacarpal** bones *(ossa metacarpalia)*, which are related in type to short tubular bones with one true epiphysis (monoepiphyseal bones) and are numbered in sequence, beginning with the thumb: first, second, third, fourth, and fifth. Each carpal bone has a base *(basis)*, a diaphysis (body, shaft) *(corpus)* and a rounded head *(caput)*.

On all of the there are articular facets at one end (base) for articulation with the carpals (for articulation with the second row of carpal bones for articulation with the second row of carpal bones) and facets on their sides for articulation with each other and at the other (head) for the phalanges. The palmar surface is slightly concave and the dorsal surface slightly convex. The dorsal surface exhibits a characteristic triangular configuration toward the head. The proximal articular facet of the 1st metacarpal (receiving the trapezium bone) is saddle-shaped and there are no facets on the sides; the 2nd metacarpal has a notched base (an angle-like notch) proximally for articulation with the carpus (the trapezoid bone), and on the medial side with the 3rd metacarpal. On the dorsoradial side of the base of the 3rd metacarpal is a *styloid process* and radially an articular facet for the 2nd metacarpal. Proximally, for junction with the carpus, there is one articular facet, and on the ulnar side there are two articular facets for articulation with the 4th metacarpal. The 4th metacarpal has two articular facets radially but only one on its ulnar side for articulation with the 5th metacarpal. The base of the fifth metacarpal has an elevation on its ulnar side, *tuberositas ossis metacarpi* V. The heads of the metacarpals carry convex articulation surfaces for uniting with the proximal phalanges of the fingers. On the sides of the heads are roughened depressions for attachment of the ligaments. The metacarpal of the thumb is the shortest but, at the same time, the strongest bone. Together with the thumb it diverges from the row of the other metacarpals. The second metacarpal is the longest, the next in length are the third, fourth and fifth bones.

BONES OF THE FINGERS

The bones of the fingers or the bones of the digits *(ossa digitorum manus)*, called phalanges, are small, short, consecutive, tubular bones with one true epiphysis (monoepiphyseal bones). Each finger, with the exception of the thumb, is made up of three phalanges: proximal *(phalanx proximalis)*, middle *(phalanx media)*, and distal *(phalanx distalis)* or ungual phalanx *(phalanx unquinalis)*. The thumb *(Hallux)* has only two phalanges, the proximal and the distal phalanx. In all animals the thumb is less developed than the other fingers; it is highly developed only in man. Each proximal phalanx has a flattened palmar surface dorsally and transversally it is convex and has roughened sharpened borders for the attachment of the fibrous tendon sheaths of the flexor muscles. It has a *shaft (body)*, a distal *phalangeal head*, also called a "trochlea" *(caput)*, and a *proximal base (basis)*. The base has a transverse oval socket (solitary facet) *(facies articularis)* for articulation with the spherical head of the corresponding metacarpal bone.

The base of the middle phalanx has two convex facets separated by a smooth ridge to conform to the shape of the head of the proximal phalanx. The heads are pulley-shaped with a groove in the middle.

The base of the distal phalanx also bears a ridge. At the distal end there is a rough palmar surface for insertion of the tendon of the flexor digitorum profundus as well as a palmar-facing roughened, spade-shaped *plate* at its terminus, *the tuberosity of the distal phalanx (tuberositas phalangis distalis)*.

Sesamoid bones are regularly found in the joints between the metacarpals and the proximal phalanx of the thumb, one lying medially and other laterally. Two sesamoid bones are always found on the palmar surface of the head of the first metacarpal bone.

One sesamoid is found in the capsule of the interfalangeal joint of the little finger, in about 75% of subjects. Less frequently there is a sesamoid on the lateral side of the metacarpophalangeal joint of the index finger.

Sometimes sesamoid bones are also found in variable numbers in the other fingers and other metacarpophalangeal joints.

Clinical Tips:

Pseudoepiphyses may develop in the metacarpal bones. In x-rays they may be distinguished from true epiphyses as they are attached to the diaphysis by a piece of bone. The 1st metacarpal bone may have a pseudoepiphysis at its distal end, but all other metacarpal bones have them at the proximal end: they must be distinguished from fractures. Pseudoepiphyses are found more commonly in certain diseases.

THE SKELETON OF THE LOWER LIMB

The skeleton of the lower limb consists of the pelvic girdle and the free lower limb.

THE PELVIC GIRDLE

The pelvic girdle is made up of the paired hip or innominate bone. The hip bone *(os coxae) is* a flat bone concerned with the function of movement (takes part in articulations with the sacrum and femur), protection (shields the pelvic organs), and support (transfers the weight of the whole proximal part of the body to the lower limbs). The latter function prevails, and this determines the complex structure of the hip bone and its formation from fusion of three separate bones, the ilium *(os ilium),* the pubis *(os pubis)* and the ischium *(os ischii).* These bones fuse in the region bearing the greatest weight, namely, in the region of the acetabulum, the articular cavity of the hip joint, by means of which the pelvic girdle is connected to the free lower limb. The ilium is above the acetabulum, the pubis below and to the front of it, and the ischium is below and to the back of the acetabulum. In individuals under 16 years of age these bones are separated one from another by layers of cartilage which in an adult undergo ossification, i.e. synchondrosis changes to synostosis. As a result the three bones fuse to form a single bone possessing great strength necessary for bearing the weight of the whole trunk and head. The acetabulum ("vinegar curet" from L *acetum* vinegar) is on the lateral surface of the hip bone and serves for articulation with the head of the femur. It is a rather deep, cup-shaped cavity with a high rim, in the medial side of which is a *notch (incisura acetabuli).* The smooth *articular surface* of the acetabulum *(facies lunata)* is crescent-shaped; the centre, the *acetabular fossa (fossa acetabuli)* and the part nearest to the notch are rough.

HIP BONE *(OS COXAE)*

The hip **bone** *(os coxae)* consists of three parts, the pubis *(os pubis)*, the ilium (*os ilii)* and the ischium (*os ischii)* which synostose in the *acetabular fossa (acetabulum)*, which is bordered by the *limbus of the acetabulum (labrum acetabulare)* and is surrounded by the *lunate articular surface (facies lunata)*. The *acetabular notch (incisura acetabuli)* opens the acetabulum inferiorly and thus limits the *obturator foramen (foramen obturatorium)* (Fig. 23).

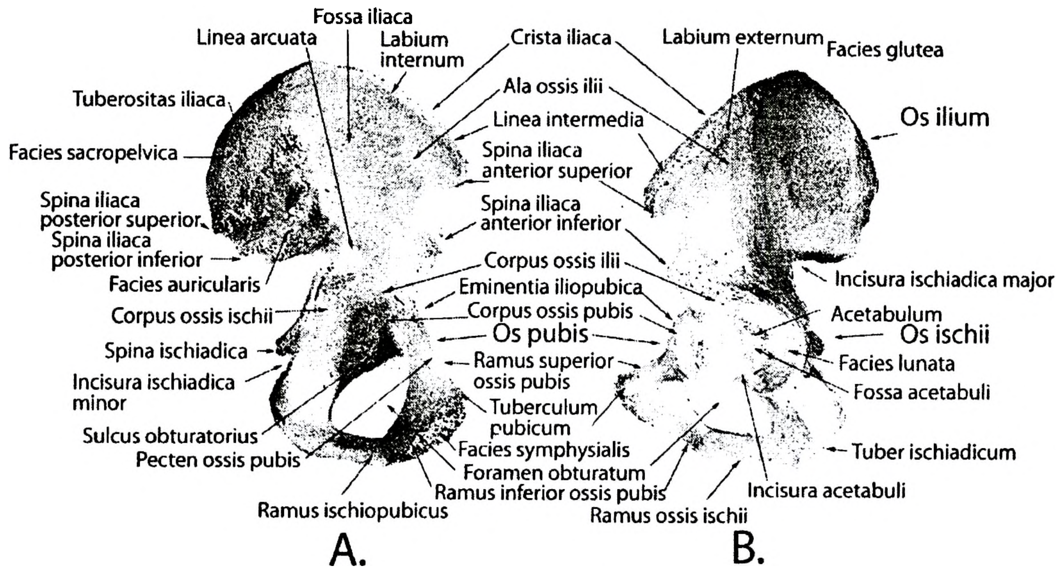

Fig. 23. Os coxae
A- facies interna; B- facies externa.

THE ILIUM *(OS ILIUM)*

The ilium *(os ilium)* is divided into the *body* and the *ala*. The ilium fuses by means of its short, thick, inferior part, called the body *(corpus ossis ilii)*, with the other parts of the hip bone in the region of the acetabulum. The body forms part of the acetabulum and is delimited externally by the *supra-acetabular sulcus (sulcus supra-acetabularis)* and internally by the arcuate line (*linea arcuata)*. The superior part is fan-shaped and fairly thin part of the ilium forms the wing or ala *(ala ossis ilii)*. External to the ala lies the *gluteal surface (facies glutea)* and internal to it the *iliac fossa (fossa iliaca)* is visible. The inner (medial) surface of the iliac wing is smooth, slightly concave, and forms the iliac fossa *(fossa iliaca)* produced from supporting the viscera in vertical posture of the body. Behind the iliac fossa there is the sacropelvic surface *(facies sacropelvina)* with the *iliac tuberosity (tuberositas iliaca)* and the *auricular surface (facies auricularis)*. The iliac fossa is separated from the medial surface of the distally located iliac body by an arched edge, the arcuate line *(linea arcuata)*. The relief of the bone is mainly determined by the muscles under the effect of which crests, lines, and spines formed at the sites of tendon attachment, and fossa formed where the muscles originated. The superior free border of the wing is a sinuous crest *(crista iliaca)* to which three broad abdominal muscles are attached (m.m. obliqui abdominis externus et internus, m. transversus abdominis). The *iliac crest (crista iliaca)* starts anteriorly at the *superior anterior iliac spine (spina iliaca anterior superior)* and divides into the *outer* and *inner lips (labium externum et labium internum)*, and an *intermediate line (linea intermedia)*, which extends upward and backward. There, the outer lip bulges laterally as the *iliac tubercle (tuberculum iliacum)*. The iliac crest ends in the *posterior superior iliac spine (spina iliaca posterior superior)*. Beneath the latter lies the *posterior inferior iliac spine (spina iliaca posterior inferior)* whilst anteriorly beneath the anterior superior iliac spine lies the *anterior inferior iliac spine (spina iliaca anterior inferior)*. The *inferior gluteal*, *anterior gluteal* and *posterior gluteal lines (linea glutea inferior, anterior and posterior)* lie on the gluteal surface *(facies glutea)*. In addition, there are various vascular canals amongst which at least one corresponds functionally to an emissary vessel.

The inferior spinae are separated from the superior spinae by notches. Below and to the front of the anterior inferior spine at the junction of the ilium with the pubis is the iliopubic eminence *(eminentia iliopectinea)* and below the posterior inferior spine is the deep greater schiatic notch *(incisura ischiadica major)*, continuous downward with the ischial spine *(spina ischiadica)*, which is on the ischium.

THE PUBIS *(OS PUBIS)*

The pubic bone *(os pubis)* has a short thickened body *(corpus ossis pubis)* adjoining the acetabulum, and the superior and inferior rami *(ramus su-*

perior and *ramus inferior ossis pubis)* forming an angle. The two rami border the obturator foramen anteriorly and inferiorly. At the apex of the angle facing the midline is an oval symphyseal surface *(facies symphysialis)* for articulation with the contralateral pubic bone. A small pubic tubercle *(tuberculum pubicum)* lies 2 cm lateral of this surface; the pectineal line *(pecten ossis pubis)* runs from the tubercle along the posterior border of the superior surface of the superior ramus and is continuous posteriorly with the arcuate line on the ilium described above. The inferior surface of the superior pubic ramus carries a small groove, the obturator groove *(sulcus obturatorius)* transmitting the obturator vessels and nerve. The *obturator groove* is bordered internally by the *anterior obturator tubercle* and the *posterior obturator tubercle*, which is not always present.

THE ISCHIUM *(OS ISCHII)*

The ischium *(os ischii)* has, like the pubis, a body *(corpus ossis ischii)*, which forms part of the acetabulum, and a ramus *(ramus ossis ischii). Ramus of the ischium* together with the inferior ramus of the pubis forms the inferior border of the obturator foramen. The body and the ramus meet at an angle, the apex of which is greatly thickened and is the ischial tuberosity *(tuber ischiadicum)*. On the posterior border of the body, upward from the ischial tuberosity, is the lesser sciatic notch *(incisura isciadica minor)* separated from the greater sciatic notch *(incisura ischiadica major)* by the ischial spine *(spina ischiadica)*. The ischial ramus branching from the ischial tuberosity fuses with the inferior pubic ramus. As a result, the rami of the pubis and ischium surround the obturator foramen *(foramen obturatum)* which is located inferior and medial to the acetabulum and is triangular with rounded angles.

ACETABULUM

It is a deep cup-shaped hemispherical cavity on the lateral aspect of the hip bone, about its centre. It is directed laterally, downwards and forwards. The margin of the acetabulum is deficient inferiorly: this deficienty is called the acetabular noch *(incisura acetabuli, s. acetabularis)*. It is bridged by transverse ligament *(lig. transversum acetabuli)*. The nonarticular roughened floor is called the acetabular fossa *(fossa acetabularis)*. It contains a mass of fat which is lined by synovial membrane. A horseshoe shaped articular surface (lunate surface) *(facies lunata)* is seen on the anterior, superior and posterior parts of the acetabulum. It is lined with hyaline cartilage, and articulates with the head of the femur to form the hip joit *(art. coxae)*. The fibrocartilaginous acetabular labrum *(labrum acetabularis)* is attached to the margins of the acetabulum; it deepens the acetabular cavity. The acetabulum is formed by all three elements of the hip bone. The ilium forms the upper 2/5; the pubis forms the anterior 1/5; and the ischium forms the posterior 2/5 of the lunate surface and the whole of the acetabular fossa.

THE OBTURATOR OPENING *(FORAMEN OBTURATORIUM)*

The *obturator foramen* is a large gap in the hip bone, situated anteroinferiorly to the acetabulum, between the *rami superior et inferior osis pubis* and the *ramus osis ischii*. It is large and oval in males; and small and triangular in females. It is closed by obturator membrane *(membrana obturatoria)*, which is attached to its margins, except at the obturator groove *(sulcus obturatorius)*, where the obturator vessels and nerve pass out of the pelvis.

THE SKELETON OF THE FREE LOWER LIMB

The skeleton of the free lower limb consists of the femur, or thigh bone, two leg bones, and the bones of the foot. Besides, a small (sesamoid) bone, the patella, adjoins the thigh bone.

THE FEMUR

The femur or thigh bone *(os femoris)* is the largest and thickest long tubular bone. Like all such bones it is a long lever of movement and has a diaphysis, metaphyses, epiphyses, and apophyses in accordance with its development (Fig. 24). The upper (proximal) end *(extremitas proximalis)* of the femur carries a spherical articular head *(caput femoris)* (epiphysis); a little downward from the centre of the head is a small rough depression *(fovea capitis femoris)*, where the ligament of the head is attached. The head is connected with the rest of the bone by a neck *(collum femoris)* (metaphysis), which meets the axis of the femoral shaft at an obtuse angle (about 130 degrees); in the wider female pelvis this angle is closer to 90 degrees. Two bony prominences called trochanters (apophyses) are found at the junction of the neck with the shaft of the femur. The greater trochanter *(trochanter major)* is the upper end of the femoral shaft. On its medial surface facing the neck is the trochanteric fossa *(fossa trochanterica)*. The lesser trochanter *(trochanter minor) is* at the inferior margin of the neck on the medial surface and a little to the back. Both trochanters are joined on the posterior surface of the femur by an oblique intertrochanteric crest *(crista intertrochanterica)* and on the anterior surface by the intertrochanteric line *(linea intertrochanterica)*. All these structures, the trochanters, crest, line, and fossa, developed as a result of the attachment of muscles. The *head of the femur* with its navel-like recess, the *fovea of the head,* has an irregular border with the neck.

The *body* (shaft) *(corpus osis femoris)* of the femur is slightly convex forward and has a rounded trihedral shape. In the shaft we distinguish three surfaces: an *anterior, a lateral* and a *medial surface (facies anterior, lateralis et medialis)* The anterior and lateral surfaces of the body are smooth, while the posterior surface bears a mark of attachment of the thigh muscles, *linea aspera* (a rough line) which has two lips: *lateral (labium laterale)* and *medial* *(labium mediate).* Both lips bear marks of muscle attachment in their proximal part: *tuberositas glutea* on the lateral lip for attachment of the gluteus maximus muscle and *linea pectinea* on the medial lip for attachment of the pectineus muscle. It is sometimes particularly prominent and is known then as the *3rd trochanter*. The medial lip extends to the lower surface of the neck. A little more lateral to the medial lip we find a ledge which descends from the lesser trochanter, the pectineal line. Below the lips diverge and enclose a smooth triangular *popliteal surface (facies poplitea)* on the posterior surface of the femur.

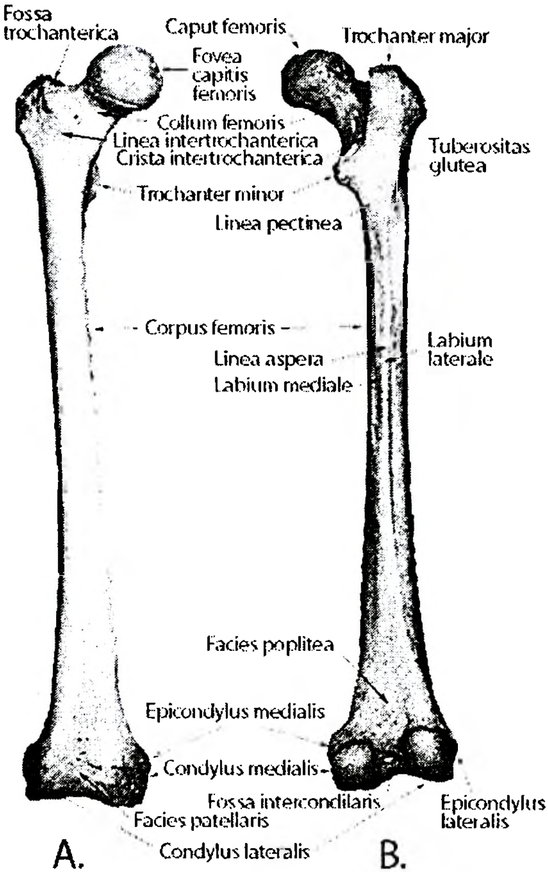

Fig. 24. Femur
A- anterior viev; B- posterior view.

Both proximally and distally the femoral shaft loses its triangular form and becomes more four-sided.

The lower (distal) thickened end of the femur *(extremitas distalis)* forms two rounded, posteriorly turned medial and lateral condyles *(condylus medialis* and *condylus lateralis)* (epiphysis); the medial condyle protrudes downward more than the lateral. Despite the difference in the size of these two condyles, however, they are located on the same level because the femur in its natural position stands obliquely with its lower end closer to the midline than the upper end. Anteriorly the articular surfaces of the condyles blend with each other to form a small concavity in the sagittal direction. This common part of the articular surfaces is called *facies patellaris* because the posterior surface of the patella abuts against it in extension at the knee joint. On the posterior and inferior surfaces, the condyles are separated by a deep intercondylar fossa, or notch *(fossa intercondylaris).* Rough prominences are found on the sides of each condyle above the articular surface. These are the *medial* and *lateral epicondyles (epicondylus medialis* and *epicondylus lateralis)* (apophyses). The *medial epicondyle* has an eminence, the *adductor tubercle (tuberculum adductorium).* The *lateral epicondyle* is separated from the lateral condyle by the *popliteal groove.*

The *medial* and *lateral* condyles differ both in size and shape. They diverge distally and posteriorly. The lateral condyle is wider in front than at the back, whilst the medial condyle is of uniform width. The oblique position of the shaft of the femur means that in the upright position both condyles are in the horizontal plane despite their different sizes.

In the transverse plane both condyles are only slightly and almost equally curved about the *sagittal axis* and in the sagittal plane there is a curvature which increases posteriorly. This means that the radius of curvature decreases posteriorly. The mid-points of the curve thus lies on a spiral line an "involute", i.e., on a curve the mid-points of which follow another curve. This produces not one but innumerable *transverse axes,* which permits the typical flexion of the knee joint that consists of sliding and rolling motion. At the same time, it ensures that the collateral ligaments become sufficiently lax to permit rotation of the knee joint. The medial condyle has an additional curvature about a *vertical axis,* the "rotation curve".

The angle formed between the neck and the shaft of the femur is called the collo-diaphysial angle or, more correctly, the neck-shaft angle, i. e., the angle of inclination. In the newborn it is about 150°, reducing at the age of 3 years to 145°. In adults the angle varies between 126° and 128°, and in old age it reaches 120°.

Clinical Tips:

In disease of bone (e. g., rickets), the angle of inclination may be reduced to 90°. The angle of inclination is decisive for the strength and stability of the femur, the smaller the angle, the greater the risk of fracture of the neck of the femur. The incidence of fractures of the neck of the femur in the elderly is related in addition to the loss of elasticity of the bony tissues, to the reduction in the angle of inclination.

The angle of inclination influences the relation of the femoral shaft with respect to the weight-bearing line of the leg. The weight-bearing line of the (healthy) leg lies along a straight line from the middle of the femoral head through the middle of the knee joint to the middle of the calcaneus. The plane which passes through the lower surface of the femoral condyles is at right angles to this vertical line. This produces an angle between the axis of the shaft of the femur and the weight-bearing line. This angle is related inter alia to the angle of inclination and is important in relation to the correct position of the lower limb.

Pathologic changes in the angle of inclination result in abnormal posture of the legs. An abnormally small angle of inclination produces coxa vara (varus), and an abnormally large angle coxa valga (valgus). The latter is usually combined with varum, as any change in the shape of the femur naturally must affect the knee joint. A coxa vara leads to genu valgum.

The femur also has a torsion angle. If a line drawn through the neck of the femur is superimposed on a line drawn transversely through the condyles, an angle will be produced. In a European the mean angle is 12°, with a range from 4° to 20°. The torsion angle, which is associated with the inclination of the pelvis, makes it possible for flexion movements of the hip joint to be transposed into rotatory movements of the head of the femur.

Abnormal values for the torsion angle result in atypical postures of the lower limbs. If the torsion angle is increased, the limb is turned inward, and if it is decreased or absent, the limb is turned out; both postures result in a reduced range of mobility to one side.

THE PATELLA

The *patella*, or knee-cap, is the largest sesamoid bone of the human body (Fig. 25).

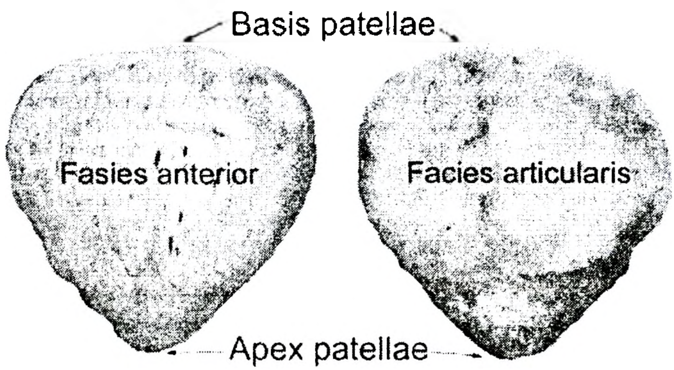

Fig. 25. Patella

It is triangular in shape with its base *(basis patellae)* facing proximally and its tip *(apex patellae)* facing distally. It has two surfaces, one towards the joint with the femur and the other directed anteriorly. The anterior surface of the patella is rough, while the posterior surface has smooth *articular surface (facies articularis)* by which the patella comes into contact with the patellar surface of the femur described above. These two surfaces join at a lateral (thinner) and a medial (thicker) margin. The anterior surface may be divided into three parts and incorporates the tendon of the quadriceps femoris muscle.

In the upper third there is a coarse, flattened, rough surface which often has exostoses and serves largely for the attachment of the tendon of the quadriceps muscle. The middle third is characterised by numerous vascular canaliculi whilst the lower third includes the apex which serves as the origin of the patellar ligament. The inner surface may be divided into an articular surface covering about three-quarters and a distal surface with vascular canaliculi. This is filled by fatty tissue, the infrapatellar adipose body. The joint surface is divided into a lateral and a medial facet by a variably developed vertical ledge. Four types may be distinguished: Type 1, the commonest, has a larger lateral and a smaller medial articular surface, Type 2, has two almost equally large articular facets, Type 3, has a particularly small, hypoplastic medial articular facet and in Type 4, the ledge which divides the facets is only indicated.

Near the margin on the medial facet, a groove is indicated which shows the area where there is direct contact with the femur during flexion. The whole articular surface area of the patellar in the adult is about 12cm^2 and, especially in the center, is covered by cartilage of 1-6 mm thickness. Maximal cartilage thickness is found at about 30 years of age and then continually decreases with increasing age.

Variants:

There is often emargination of the lateral proximal edge of the patella. This is called a patella emarginata. A patella bipartite is the result of ossification of an additional cartilaginous layer in the same area in which there has been an emargination. The old idea that several ossification centers occur in the patella but which then fail to fuse is not accepted today. In addition to a bipartite patella there are tripartite and multipartite patellas. Partite patellas occur almost exclusively in males. They may be distinguished from fractures by their position and their shape.

THE SKELETON OF THE LEG

The skeleton of the leg consists of two bones of unequal thickness, the tibia, or shin-bone, and the fibula. The first is on the medial and the second on the lateral side (Fig. 26). Only the tibia articulates with the femur by means of the knee joint. The vertical, also called the *mechanical,* axis of the whole lower limb, along which the weight of the trunk is transmitted to the supporting area passes from the centre of the femoral head, through the middle of the knee joint, and to the middle of the ankle joint. It coincides distally with the longitudinal axis of the tibia which thus bears the whole weight of the body and is therefore thicker than the fibula. In some cases, the tibia deviates medially or laterally from the mechanical axis, as a result of which the lateral angle formed by the thigh and leg is more acute or more obtuse. When these deviations are very conspicuous, the lower limbs are X-shaped with the knees abnormally close together, a condition called genu valgum, or 0-shaped with the knees abnormally separated, a condition called genu varum.

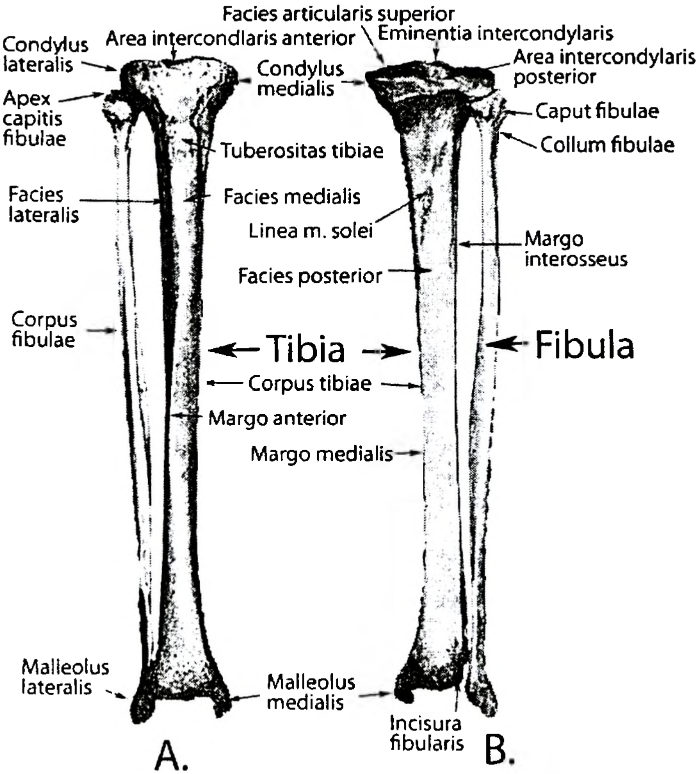

Fig. 26. Ossa cruris (leg)
A- anterior viev; B- posterior view.

THE TIBIA

The *tibia*, or shin-bone, is the stronger bone which alone provides the connection between the femur and the bones of the ankle and foot The tibia has a somewhat triangular shaft (body) and proximal and distal ends.

At the proximal end lie the *medial* and *lateral condyles (condylus medialis et condylus lateralis).* The proximal surface, the *superior articular facet (facies articularis superior)* is interrupted by the *intercondylar eminence (eminencia intercondylaris)*. This elevation is subdivided into a *medial* and a *lateral intercondylar tubercle (tuberculum intercondylare mediale et* *tuberculum intercondylare laterale).* In front of and behind the eminence lie the *anterior* and *posterior intercondylar* area (*area intercondylaris anterior et area intercondylaris posterior)*.

On the outward-facing overhang of the lateral condyle (posterolateral part) there is a small *flat articular surface (facies articularis fibularis),* directed laterally and distally, for articulation with the head of the fibula.

The three-sided shaft of the tibia has a sharp *anterior margin (margo anterior)*, which proximally becomes the *tibial tuberosity (tuberositas tibiae)* and is flattened distally. It separates the *medial surface* from the *lateral surface*. The medial surface and the anterior (the sharpest) border are easily palpated under the skin. The lateral surface joins the posterior surface at the *interosseous margin (margo interossea),* facing the fibula and providing attachment for the interosseous membrane; it is called *lateral border*. The posterior surface is separated from the medial surface by the *medial margin (margo medialis)*. Proximally on the posterior surface of the shaft of the tibia is a slightly roughened area, the *soleal line (linea m. solei)*, extending obliquely from the distomedial side to the proximolateral side. Lateral to this there is a *nutrient foramen (foramen nutricium)* of varying size.

The distal end is prolonged medially to form the *medial malleolus (malleolus medialis)* with its *malleolar articular surface (facies articularis maleolaris)*. The *malleolar groove (sulcus malleolaris)* made by tendons, runs along its posterior surface. The *inferior articular surface of the tibia,* which lies on the lower surface of the distal end of the tibia, articulates with the talus. On the lateral side, in the *fibular notch (incisura fibularis)*, there is a syndesmotic connection, i. e., a fibrous joint, with the fibula. In the adult the proximal end of the tibia is bent slightly backward. We speak of retroversion or an actual backward tilting of the tibia. The angle between the superior articular facet of the tibial condyle and the horizontal averages 4° to 6°. In the last intrauterine months this initially very small angle increases to about 30°. In the first months after birth, and more especially when learning to stand upright, the angle becomes smaller. The tibia also shows torsion, i. e., rotation between its proximal and distal ends. This is often present in adults and is attributed to increased growth of the medial tibial condyle.

THE FIBULA

The *fibula* (Gk *perone)* is a long thin bone with thickened ends. The *fibula* corresponds approximately in length to the tibia, but is a slimmer and therefore more flexible bone. It, too, consists of two extremities and a shaft. The upper (proximal) epiphysis forms the *head of the fibula (caput fibulae)* which articulates with the lateral condyle of the tibia by means of a hollow rounded *articular facet (facies articularis capitis fibulae)*. A little to the back and lateral of this surface the small protuberance *apex of the head (apex capitis fibulae)* projects upward. The body (shaft) of the fibula (*corpus fibulae)* is trihedral (triangular in its middle part) and twisted somewhat on its longitudinal axis, and has three margins and three surfaces. The *anterior (margo anterior), interosseous* (medial) *(margo interossea)*, and *posterior (margo posterior) borders* are distinguished. The three surfaces between the borders are slightly concave. The *medial crest* separates the *medial surface* from the *posterior surface.* It is separated from the *lateral surface* by the *posterior margin.* On the medial surface there is a low but very sharp bony ridge, the *interosseous margin,* to which the *interosseous membrane (membrana interossea cruris)* is attached. Approximately, in the center of the posterior surface or on the posterior margin, there is a nutrient foramen. The lower (distal) fibular epiphysis thickens to form the *lateral malleolus (malleolus lateralis),* which carries a smooth *articular facet (facies articularis malleoli)* on its inner surface for articulation with the talus. On the posterior surface of the lateral malleolus is a distinct hollow *malleolar fossa (fossa malleoli lateralis)* lodging the tendons of the peroneal muscles and to which the posterior talofibular ligament is attached.

THE BONES OF THE FOOT

The tarsus, metatarsus, and the bones of the toes (digits) are distinguished in the foot (Fig. 27).

THE TARSUS

The tarsus is made up of seven short spongy bones *(ossa tarsi),* which are arranged in two rows similar to the carpal bones. The posterior, or proximal, row is formed of two comparatively large bones, the talus and the calcaneus lying below it. The anterior, or distal, row consists of a medial and lateral part. The medial part is formed by the navicular and three cuneiform bones, the lateral part by a single cuboid bone. Because of the erect position of the human body, the foot bears the weight of the whole body. As a consequence the tarsal bones of the human foot have a peculiar structure, different from that of these bones in animals.

The calcaneus, for instance, located at one of the principal points of support of the foot, has aquired in man its large size and strength, as well as an elongated shape in the anteroposterior direction. Its posterior end is thickened to form the tuberosity of the calcaneus, tuber calcanei.

The talus has acquired accommodations for articulation with the leg bones (proximally) and the navicular bone (distally) and is therefore large, has a peculiar shape and carries articular surfaces. The remaining tarsal bones, which also carry a heavy load, have become comparatively massive and adapted to the arched shape of the foot.

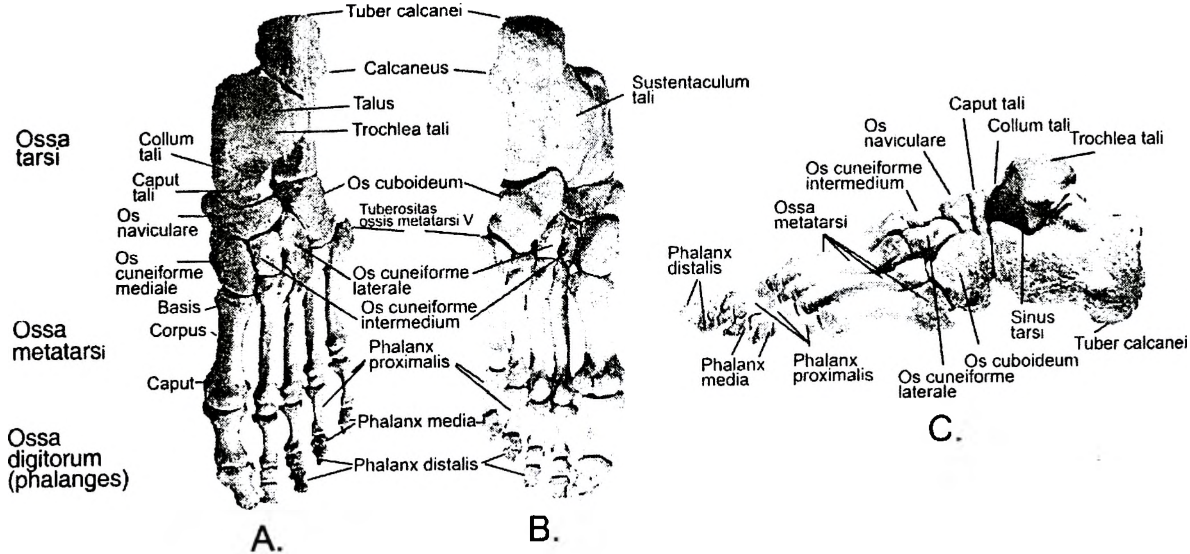

Fig. 27. Ossa pedis
A- view from above; B-. inferior viev; C- lateral view.

1. **The talus** (ankle bone) *(os talus)* transmits the weight of the entire body to the foot. The talus consists of a body *(corpus tali)*, which extends anteriorly as a constricted neck *(collum tali)*. The neck is continuous with an oval convex head *(caput tali)*, carrying a surface for articulation with the navicular bone *(facies articularis navicularis)*. On the superior surface of the body of the talus we distinguish the *trochlea (trochlea tali)* and behind this a *posterior talar process* with *lateral* and *medial* tubercles. Immediately adjacent to the medial tubercle is the *groove for the tendon of the flexor hallucis longus*. The trochlea of the talus and its superior surface are wider in front than at the back. This is more pronounced in right tali than in left tali. The body of the talus has a trochlea tali on its superior surface for articulation with the leg bones. The *superior articular surface* of the trochlea *(facies superior)*, the site of articulation with the distal articular surface of the tibia, is convex from front to back and slightly concave in the frontal direction. The trochlea has two articular surfaces on its sides, the *medial* and *lateral malleolar facets (facies malleolares medialis* and *lateralis)* for articulation with the malleoli. The *facet of the lateral malleolus (facies malleolaris lateralis)* curves downward onto a projecting *lateral tubercle of the talus (processus lateralis tali)*. Behind the trochlea, the body of the talus gives rise to a *posterior tubercle of the tali (processus lateralis tali)*, which is separated by a groove lodging the tendon of the m. flexor hallucis longus. On the inferior surface of the talus are two (anterior and posterior) articular facets for union with the calcaneus. A deep rough *groove (sulcus tali)* passes between them.

Variants:

In exceptional cases, the lateral tubercle of the posterior talar process forms an independent bone, the "os trigonum" or accessory talus.

2. **The calcaneus** (heel bone) *(os calcaneus)* is the largest tarsal bone and it has two articular surfaces (anterior and posterior) on its superior surface, which correspond to the inferior articular facets on the talus. The calcaneus gives off a medial process called the *sustenaculum* (L. support) *tali*, so called because it supports the head of the talus. The articular facets on the anterior part of the calcaneus are separated from the posterior articular surface of this bone by a groove *(sulcus calcanei)*, which adjoins a similar sulcus on the talus and forms together with it the bone canal *(sinus tarsi)* opening on the lateral surface of the dorsal surface of the foot. A groove for the tendon of the long peroneal muscle passes on the lateral surface of the calcaneus. On the distal (anterior) surface of the calcaneus, facing the second row of the tarsal bones, is a saddle-shaped *cuboid articular surface (facies articularis cuboidea)* for articulation with the cuboid bone. Posteriorly the body terminates as a rough *posterior surface of the calcaneum (tuber calcanei)*, from which two processes, *lateral* and *medial (processus lateralis* and *processus medialis tuberis calcanei)* project toward the sole. The Achilles tendon is inserted into the roughened area on the tuber calcanei.

Interiorly lies the *groove for the tendon of the flexor hallucis longus*. In most cases there is a slightly elevated bony tubercle on the lateral surface of the talus, the *peroneal trochlea*, under which runs the groove *for the tendon of the peroneus longus*.

Clinical Tips:

In some cases there is a forward directed bony process, the calcaneal spur, arising from the medial tuberal process, from which various muscles of the sole of the foot arise. A calcaneal spur may be very painful.

The navicular articulates with the talus and with the three cuneiform bones. A concave articular surface faces the head of talus. The *tuberosity of the navicular* is directed plantarly and medially. Distally there are three joint surfaces separated only by small crests for the three cuneiform bones.

3. The **navicular bone** *(os naviculare)* is situated between the head of the talus and the three cuneiform bones. On its proximal surface it has an oval concave articular surface, which receives the head of the talus. Its distal surface is slightly convex and is separated by two crests into two smooth facets for articulation with the three cuneiform bones. A rough *tuberosity of the navicular bone (tuberositas ossis navicularis)* projects from the medial surface downwards and can be easily felt through the skin. A small articular area for the cuboid bone is often found on the lateral surface.

4, 5, and 6. The three **cuneiform bones** *(ossa cuneiformia)* are so called because they are wedge-shaped. They are designated os cuneiforme mediale, intermedium and laterale, or the first, second, and third cuneiform bones (BNA), numbered from the medial border of the foot. The medial bone is the largest. The intermediate bone is the smallest, while the lateral cuneiform bone is of average size. They carry articular facets on the corresponding surfaces for articulation with the neighbouring bones.

7. The **cuboid bone** *(os cuboideum)* is placed on the lateral border of the foot between the calcaneus and the bases of the fourth and fifth metatarsal bones. In accordance with this, articular surfaces are found on the corresponding sites. On the plantar surface of the bone is a projecting transverse ridge *(tuberositas ossis cuboidei)* in front of which is a *sulcus of the tendon of the peroneus longus muscle (sulcus tendinis m. peronei longi).*

THE METATARSUS

The **metatarsus** consists of five metatarsal bones *(ossa metatarsalia)* related to the short (monoepiphyseal) tubular bones and resembling the carpals of the hand. The five metatarsals are convex dorsally. Just as in the hand, a proximal end, or *base (basis),* a middle part, a *shaft* or *body (corpus),* and a distal end, or *head (caput),* are distinguished in each metatarsal. They are arranged one next to the other and are separated by interosseous spaces *(spatia interossea metatarsi).* They are numbered from the medial border of the foot. The metatarsals articulate by their bases with the distal row of the tarsal bones so that the first, second, and third metatarsals each unite with the corresponding cuneiform bone, while the fourth and fifth metatarsals articulate with the cuboid bone. The base of the second metatarsal protrudes considerably to the back because the intermediate cuneiform articulating with it is short. In addition to the articular surfaces on the proximal ends (for articulation with the tarsals), the bases of the metatarsals have narrow facets on their sides for articulating with one another: the second metatarsal bone carries on its sides articular surfaces for receiving the neighbouring medial and lateral cuneiform bones; the third and fourth metatarsals have articular facets on both sides, while the fifth metatarsal has one only on the medial side of the base (for the fourth tarsal bone). The base of the fifth metatarsal has a projection *(tuberositas ossis metatarsalis V)* on its lateral side. The 1st metatarsal is the shortest and thickest. There is a *tuberosity (tuberositas ossis metatarsalis I)* at the base of the 1 st metatarsal on its plantar surface projecting toward the sole. In the region of this tuberosity and lateral to it, the bone articulates laterally with the base of the 2nd metatarsal and posteriorly via a curved surface with the medial cuneiform. The heads are flattened on the sides and, like the heads of the metacarpals, have facets on their sides for attachment of the ligaments. On its anterior end the head carries, on its plantar surface a small ridge, and on either side of it there are two small grooves. In these are regularly found two small sesamoid bones. The first metatarsal is the shortest and thickest, the second metatarsal the longest. The 2nd, 3rd and 4th metatarsals are slimmer and their bases are wider dorsally than on their plantar sides. On the facing sides there are joint surfaces for articulation with each other, and posteriorly proximally for the cuneiform and the cuboid bones. The heads of these three metatarsal bones are compressed laterally so that they resemble rollers.

THE BONES OF THE TOES
BONES OF THE DIGITS. PHALANGES

The bones of the toes, the phalanges *(phalanges digitorum pedis)* are short tubular monoepiphyseal bones distinguished from the finger phalanges by their small size. The 2nd-5th digits (toes), like the fingers, each have a proximal, middle and distal phalanx, while the 1 st digit has only two phalanges. Each phalanx has a base a *shaft* and a *head*. The distal ungual phalanges have a raised bony mass on their distal end *(tuberositas phalangis distalis),* which is their main distinguishing feature. There are small grooves on the proximal and middle phalanges.

Variants:

Occasionally, in the 5th digit the middle and distal phalanges may be joined. This may already be the case in the cartilaginous stage before birth.

Sesamoid bones. Sesamoid bones are found in the metatarsophalangeal joints (always in that of the big toe) and in the interphalangeal joint of the big toe (the 1st metatarsal).

THE SKELETON OF THE HEAD - SKULL

The head is related to the locomotor system only in part. The **bony frame-work** of the head, the **skull** or **cranium,** forms the upper end of the trunk. It acts as the container for the most highly developed part of the nervous system, the brain and the sensory organs connected with it; moreover, forms the substructure of the face, and also contains the initial portions (part) of the gastrointestinal (digestive) and respiratory tracts (Fig. 28).

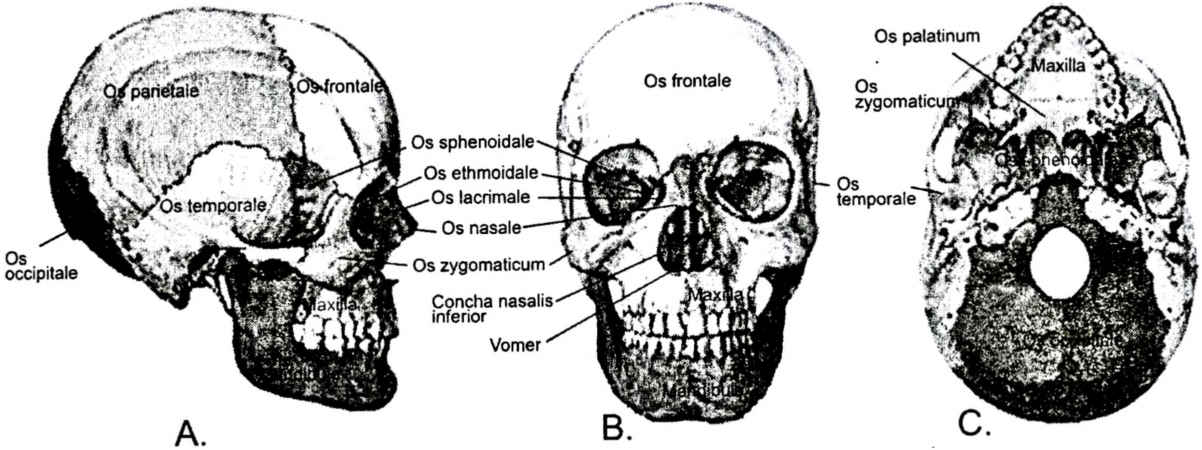

Fig. 28. Cranium
A- lateral view; B- anterior view; C- inferior view.

In accordance with this, the skull consists of two parts, the **neurocranium** *(neurocranium, cranium cerebrale)* for the brain, and the **splanchocranium** or **viscerocranium** *(cranium viscerale)*, the facial skeleton. The boundary between the two lies in the region of the root of the nose and extends along the upper margin of the orbits to the external auditory meatus. The skull-cap, or vault *(calvaria)* and the base *(basis)* are distinguished in the cerebral cranium. The margine between *calvaria* and *basis cranii* is separating line, which connects external occipital protuberance, superior nuchal line, superior border of the external acoustic meatus, infratemporal crest, frontal process of zygomatic bone (or spheno-zygomatic suture), supraorbital margin and glabella (or fronto-nasal suture).

The shape of the skull is partly determined by the muscles, which may produce certain changes due to their functions, and in part by the contents of the skull. Thus, there is a correlation between the neurocranium and the brain contained within it. The influence here is reciprocal, as excessive expansion of the brain may produce enlargement of the neurocranium, e.g., as in hydrocephalus. On the other hand, premature cessation of neurocranial growth may result in malformation of the brain. There is not only a reciprocal effect within the neurocranium but also a close relationship to the facial skeleton. Thus the development of the muscles and of the supporting system of the dura mater within the skull capsule are also interrelated.

The ***neurocranium*** consists of the occipital bone (*os occipitale*), sphenoid bone *(os sphenoidale)*, squamous *(pars squamosa)* and mastoid portion (*processus mastoideus)* of the petrous (*pars petrosa*) parts of the temporal bone (*os temporale)*, the parietal bones (*os parietale*) and the frontal bone (*os frontale*).

The ***viscerocranium*** is composed of the ethmoid bone (*os ethmoidale*), the inferior nasal conchae (*concha nasalis inferior)*, the lacrimal bones (*os lacrimale*), the nasal bones (*os nasale*), the *vomer*, the maxillae *(os maxilaris)* with the incisive bone, the palatine bones (*os palatinus)*, the zygomatic bones (*os zygomatica*), the tympanic parts (*pars tympanica*) and the styloid processes (*processus styloideus*) of the temporal bones (*os temporale)*, the mandible (*mandibula)* and the hyoid bone (*os hyoideum)*.

Bones preformed in cartilage include the occipital bone with the exception of the upper part of its squama, the sphenoid bone with the exception of the medial lamella of the pterygoid process, the temporal bone with its petrous part and the ear ossicles, the ethmoid bone, the inferior nasal concha and the hyoid bone.

The following bones are formed by **ossification in connective tissue**: the upper part of the squama of the occipital bone, the sphenoidal concha, the medial lamina of the pterygoid process, the tympanic part, the squamous part of the temporal bone, the parietal bone, the frontal bone, the lacrimal bone, the nasal bone, the vomer, the maxilla, the palatine bone, the zygomatic bone and the mandible.

THE BONES OF THE CEREBRAL CRANIUM

THE FRONTAL BONE *(OS FRONTALE)*

The **frontal bone** *(os frontale)* an unpaired, membrane bone, contributes to the formation of the vault of the skull and develops in connective tissue (Fig. 29). It is, moreover, associated with the organs of sense (smell and vision). In accordance with this double function, the frontal bone is made up of two parts: a vertical part, squama *(squama frontalis)* and a horizontal part. According to its relation to the organs of vision and smell, the paired orbital part *(pars orbitalis)* and an unpaired nasal part *(pars nasalis)* are distinguished in the horizontal part. As a result, the following four parts are distinguished in the frontal bone.

1. The **frontal squama** *(squama frontalis)* as any membrane bone, has the shape of a plate, externally convex and internally concave. It ossifies from two ossification points, which are apparent even in an adult as two frontal tubers *(tuberas frontalia)* on the external surface *(facies externa).* They are pronounced only in man due to the development of the brain. They are absent not only in anthropoid apes but also in extinct forms of man. The inferior border of the squama is called the supraorbital border *(margo supraorbitalis).* Approximately at the junction of the medial and middle third of this border is the supraorbital notch *(incisura supraorbitalis)* (which transforms sometimes into a foramen supraorbitale), transmitting the supraorbital arteries and nerve. Eminences, the superciliary arches *(arcus superciliares)* varying greatly in size and length, are seen immediately above the supraorbital border; they are continuous medially on the midline with a more or less prominent area, the glabella, the superior part of the bridge of the nose. The glabella is an important feature in distinguishing the skull of modern man from a fossil skull. The lateral end of the supraorbital border stretches out to form the zygomatic process *(processus zygomaticus),* which articulates with the zygomatic bone. A clearly detectable temporal line *(linea temporalis)* extends upward from the process; this line delimits the temporal surface *(facies temporalis)* of the squama. A small groove, sagittal groove *(sulcus sinus sagittalis superioris)* runs on the midline of the internal surface *(facies interna)* from the posterior border and is continuous at the lower end with the frontal crest *(crista frontalis).* These structures provide attachment for the dura mater. Depressions for the pacchionian granulations (arachnoid villi) are seen near the midline.

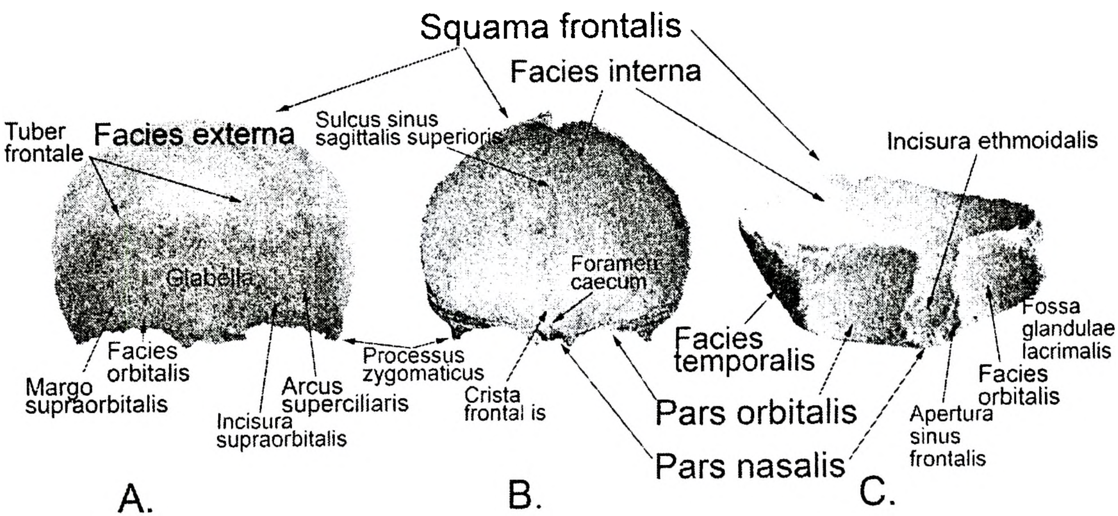

Fig. 29. Os frontale
A- anterior view; B- posterior view; C- inferior view.

2 and 3. The **orbital parts** *(paries orbitales)* are two horizontal plates whose inferior concave surface faces the orbit. The superior surface faces the cranial cavity, and the posterior border articulates with the sphenoid bone. The superior cerebral surface bears marks of the brain, namely cerebral ridges of cranium *(juga cerebralis)* (BNA) (L *juga* yoke), and digitate impressions *(impressiones digitatae)*. The inferior surface *(facies orbitalis)* forms the superior orbital wall and bears marks of adjacent accessories of the eye: the lacrimal fossa *(fossa glandulae lacrimalis)* near the zygomatic process; trochlear fossa *(fovea trochlearis)* near the supraorbital notch; and trochlear spine *(spina trochlearis)* where the trochlea for the tendon of one of the muscles of the eye is attached. The orbital parts are separated by the ethmoid notch *(incisura ethmoidalis)*, which in an intact skull is filled by the ethmoid bone.

4. The **nasal part** *(pars nasalis)* occupies the anterior part of the ethmoid notch on the midline. A projection ending as a sharp process, the nasal spine *(spina nasalis)*, is found here; it helps to make up the nasal septum. On either side of the spine are depressions, which serve as the superior wall for the sinuses of the ethmoid bone. To the front of them is an opening leading into the frontal sinus *(sinus frontalis)* located in the thickness of the bone to the back of the superciliary arches; the sinus varies greatly in size. The frontal sinus contains air and is separated by the septum of the frontal inus *(septum sinuum frontalium)*. Accessory frontal sinuses are sometimes encountered to the back of or between the main sinuses. Among all the skull bones, the frontal bone is most typical of man. It changed most in the process of evolution. In the earliest hominids (as in the anthropoid apes), it was sloped sharply backward, forming a forehead sloping to the back. Beyond the orbital narrowing it was sharply divided into the squama and the orbital parts. A continuous thick elevation stretched on the edge of the orbit from one zygomatic process to the contralateral one. The elevation diminished considerably in modern man, and only the superciliary arches remained. In accordance with the development of the brain, the squama straightened out to a vertical position. The frontal tubers developed at the same time; as the result the shape of the forehead changed from sloping to convex, lending the skull its characteristic appearance.

THE PARIETAL BONE *(OS PARIETALE)*

The **parietal bone** *(os parietale)* is a paired bone forming the middle part of the vault of the skull (Fig. 30). It is better developed in man than in animals because of the higher development of man's brain. This is a typical membrane bone, which primarily performs a protective function. Its structure, therefore, is relatively simple; it is a quadrangular plate with convex external and concave internal surfaces. Its four borders articulate with the ad-

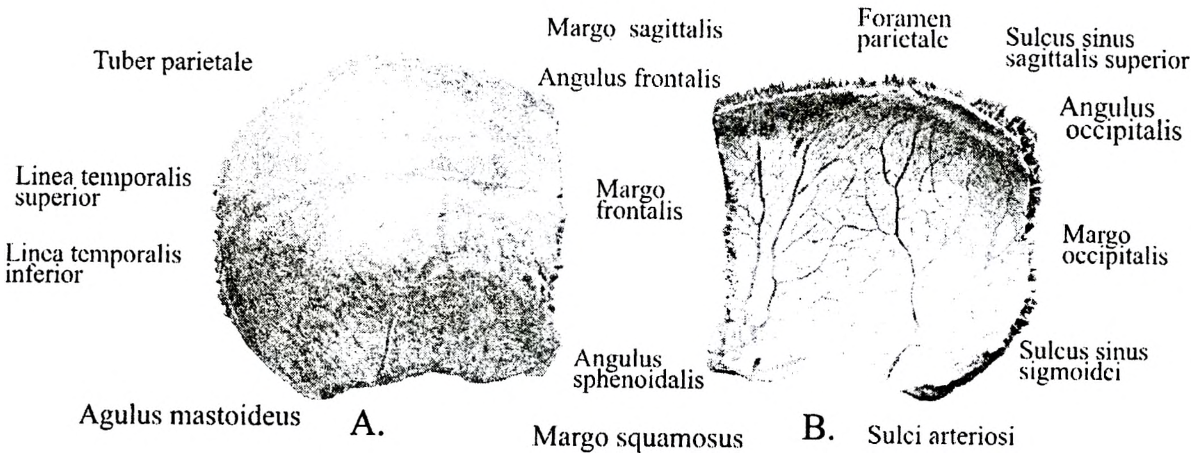

Fig. 30. Os parietale
A- facies externa; B- facies interna.

bone; the posterior, occipital border *(margo occipitalis)* with the occipital bone; the superior, sagittal border *(margo sagittalis)* with the contralateral bone, and the inferior, squamosal border *(margo squamosus)* with the squama of the temporal bone. The first three borders are serrated, while the last is adapted for the formation of a squamous suture. The four angles are as follows: the frontal angle *(angulus frontalis)* unites with the frontal bone; the sphenoidal angle *(angulus sphenoidalis)* joins with the sphenoid bone; the occipital angle *(angulus occipitalis)* articulates with the occipital bone; and the mastoid angle *(angulus mastoideus)* unites with the mastoid process of the temporal bone. The relief of the external convex surface is determined by the attachment of muscles and fasciae. In its centre is a prominence, the parietal eminence *(tuber parietalis)* (where ossification begins). Below it are two curved temporal lines *(linea temporalis superior* and *inferior)* for attachment of the temporal fascia and muscle. An opening, the parietal foramen *(foramen parietale)* for the artery and the venous emissary is seen near to the superior border. The relief of the internal concave surface *(facies interna)* is determined by the brain and especially the dura mater, which fit close to it. The sites of attachment of the dura mater to the bone are marked by a sagittal groove *(sulcus sinus sagittalis superioris)* (lodging the superior sagittal sinus) on the superior border, and a transverse groove *(sulcus sinus sigmoidei)* (lodging the sigmoid sinus), in the region of the angulus mastoideus. The vessels of the dura mater have left imprints forming a pattern of branching grooves on almost the entire internal surface. Pits for pacchionian granulations *(foveolae granulares)* are seen on either side of the *sulcus sinus sagittalis superioris.*

THE OCCIPITAL BONE *(OS OCCIPITALE)*

The occipital bone *(os occipitale)* forms the posterior and inferior walls of the brain case and is thus a part of the calvaria and a part of the base of the skull (Fig. 31). In accordance with this, it (as a mixed bone) ossifies both as membrane bone in connective tissue (the squama of the occipital bone) and in cartilage (the remaining part of the bone). In man it forms from fusion of several bones that exist independently in some animals. It is thus made up of four parts, which are laid down separately and fuse to form a single bone only between the ages of 3 and 6. These parts, which form the borders of the foramen magnum (where the spinal cord is continuous with the medulla oblongata and passes from the vertebral canal into the cavity of the skull), are as follows: anteriorly, the basilar part *(pars basilaris)* (os basilare in animals); laterally, the condylar parts *(paries laterales)* (ossa lateralia in animals); and posteriorly, the squamous part *(squama occipitalis)* (os superius in animals). The upper part of the squama, which is wedged between the parietal bones ossifies independently and is often separated by a transverse suture throughout life. In some animals, this also reflects the existence

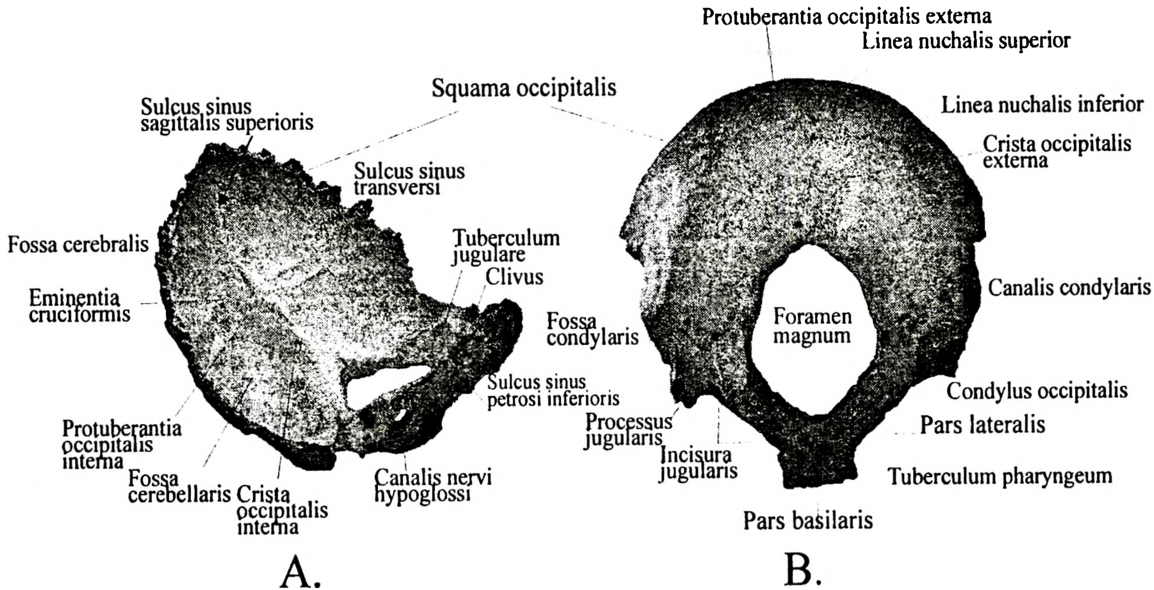

Fig. 31. Os occipitale
A- facies interna; B- facies externa.

of an independent, interparietal bone (os interparietale), as the bone is also called in man.

The squamous part of the occipital bone *(squama occipitalis)* as a membrane bone is shaped like a plate, improperly rounded, with a convex external surface and a concave internal surface. The attachment of muscles and ligaments lends it the external relief. The external occipital protuberance *(protuberantia occipitalis externa)* (the site of the appearance of the ossification nucleus) is in the centre of the external surface. A curved superior nuchal line *(linea nuchae superior)* passes laterally from the protuberance on each side. A less conspicuous highest nuchal line *(linea nuchae supremo)* is encountered a little higher. The external occipital crest *(crista occipitalis externa)* extends from the occipital protuberance downward on the midline to the posterior edge of the foramen magnum. The inferior nuchal lines *(lineae nuchae inferiores)* pass laterally from the middle of the crest. The relief of the internal surface is determined by the shape of the brain and the attachment of its meninges; as a result this surface is divided by two crests intersecting at aright angle into four fossae. These two crests form the cruciate eminence *(eminentia cruciformis)* and the internal occipital protuberance *(protuberantia occipitalis interna)* at the site of their intersection. The lower half of the longitudinal crest is sharper and is called the internal occipital crest *(crista occipitalis interna)* while the upper half of this crest and both halves (or usually the right half) of the transverse crest are supplied with clearly pronounced sulci: sagittal groove *(sulcus sinus sagittalis superioris)* and groove for the transverse sinus *(sulcus sinus trarisversi)* (prints of venous sinuses of the same name which are lodged here).

Each lateral part *(pars lateralis)* contributes to the union of the skull with the spine and therefore carries on its inferior surface the occipital condyle *(condylus occipitalis),* the place of articulation with the atlas. The anterior condylar canal *(canalis hypoglossi)* penetrates the bone approximately at the middle of the occipital condyle. Behind the condyle is the condylar fossa *(fossa condylaris)* on whose floor an opening of a posterior condylar canal *(canalis condylaris)* is sometimes present (for the transmission of a vein). The jugular process *(processus jugularis)* projects laterally to the condyle; it is homologous with the transverse processes of the vertebrae. The sigmoid groove *(sulcussinussigmoidei)* (a mark left by the sigmoid venous sinus), is on the superior surface of pars lateralis, next to the jugular process, while the jugular notch *(incisura jugularis)* is on its margin.

The basilar part *(pars basilaris)* fuses with the sphenoid bone by the age of 18 to form a single bone in the centre of the cranial base *(os basilare).* A sloping area, clivus, made up of two fused parts, is located on the superior surface of this bone; it lodges the medulla oblongata. The groove for the inferior petrosal sinus *(sulcus sinus petrosi inferioris)* is seen on the lateral edges of the basilar part of the occipital bone; it lodges the inferior petrosal sinus.

The inferior surface, which is a component of the superior pharyngeal wall, carries the pharyngeal tubercle *(tuberculum pharyngeum)* to which the fibrous capsule of the pharynx is attached.

THE SPHENOID BONE *(OS SPHENOIDALE)*

The sphenoid bone *(os sphenoidale)* is an unpaired bone whose structure is even more complex than that of the occipital bone (Fig. 32). The sphenoid bone resembles a bat or a flying insect, which explains the names of its parts (wings, pterygoid processes, Gk *pterygoin* wing). The name "sphenoid" probably appeared by mistake.

The sphenoid hone forms as the result of fusion of several bones that in animals exist independently. It therefore develops as a mixed bone from several paired and unpaired foci of ossification merging by the time of birth into three parts, which, in turn, fuse to form a single bone by the end of the first year of life. The following parts can be distinguished: (1) the body *(corpus)* (in animals, the unpaired basisphenoid and presphenoid); (2) the greater wings *(alae majores)* (in animals, the paired alisphenoid); (3) the lesser wings *(alae minores)* (in animals, the paired orbitosphenoid) and (4) the pterygoid processes *(processus pterygoidei)* (the medial plate of the bone, the former paired pterygoid, develops on the basis of connective tissue whereas the other parts of the bone develop from cartilage).

The body *(corpus)* has on the midline of its superior surface a depression, the shape of a Turkish saddle, the sella turcica, on the floor of which is a depression for the cerebral hypophysis *(fossa hypophysialis)*. To the front of the depression is an elevation, the tuberculum sellae, on which the sulcus chiasmatis lodging the crossing *(chiasma)* of the fibres of the optic nerve passes transversely. The optic foramina *(canales optici)* transmitting the optic nerves from the orbital cavity into the cranial cavity, are found at the ends of the sulcus chiasmatis. The sella turcica is bounded posteriorly by a bony plate, the dorsum sellae. The lateral parts of the dorsum project forward in the form of the posterior clinoid processes *(processus clinoidea posteriores)*. A curved carotid groove *(sulcus caroticus)* lodging the internal carotid artery passes on the lateral surface of the body. A ridge, the crest of the sphenoid *(crista spenoidalis)* is seen on the anterior surface of the body, which is a part of the superior wall of the nasal cavity. The crest continues down to become a pointed vertical prominence, the rostrum of the sphenoid *(rostrum sphenoidale)*, which fits between the wings of the vomer. The sphenoidal crest articulates in front with the perpendicular plate of the ethmoid bone. Irregularly shaped openings, apertures of the sphenoidal sinus *(aperturae sinus sphenoidalis)* are seen to the sides of the crest. They open into an air cavity, the sphenoidal sinus *(sinus sphenoidalis)* located in the body of the sphenoid bone and divided by a septum of the sphenoidal sinus *(septum sinuum sphenoidalium)* into two halves. The sinus communicates with the nasal cavity by

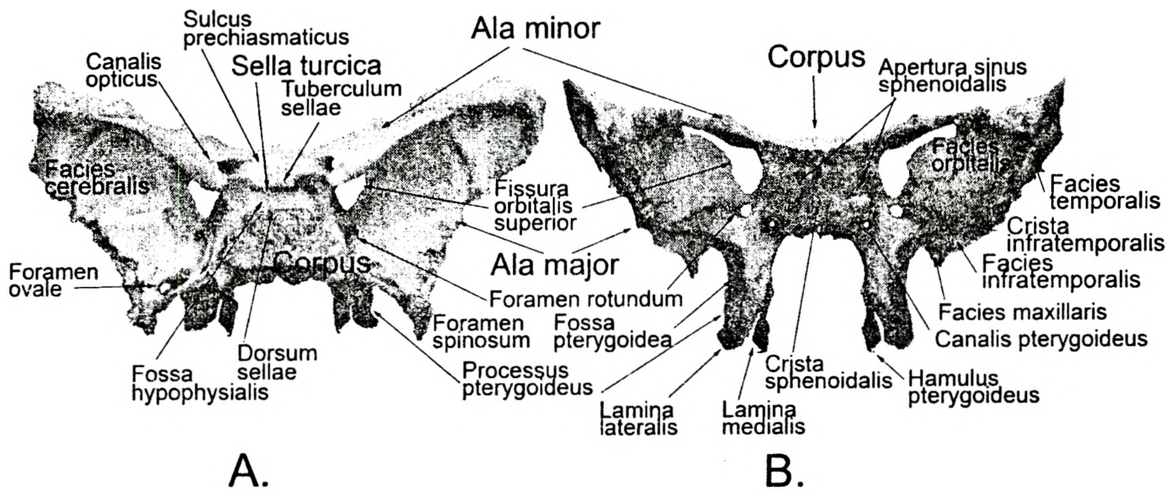

Fig. 32. Os sphenoidale

A- posterior view; B- anterior view

means of these openings. These sinuses are very small in the newborn and start growing rapidly only at about 7 years of age.

The lesser wings *(alae minores)* are two flat triangular plates arising by two roots from the anterosuperior edge of the body of the sphenoid bone and extending forward and laterally. The optic canals mentioned above are located between the roots of the wings. The posterior edges of the lesser wings are free and carry on their medial ends the anterior clinoid processes *(processus clinoidei anteriores)* formed, just as the posterior clinoid processes, from the attachment of the process of the dura mater. The superior orbital fissure *(flssura orbitalis superior)* leading from the cranial into the orbital cavity, is between the lesser and greater wings.

The greater wings *(alae majores)* spring from the sides of the body laterally and upwards. A round opening *(foramen rotundum)* leading in front into the pterygopalatine fossa, is located close to the body, to the back of the superior orbital fissure; it transmits the second branch of the trigeminal nerve *(n. trigeminus)*. Posteriorly the greater wing is wedged between the squama and pyramid of the temporal bone as a sharp angle; a sharp projection, the spine of the sphenoid *(spina ossis sphenoidalis)* is found on the inferior surface of this angle. Close to it is the spinous foramen *(foramen spinosum)* through which the middle meningeal artery passes. A much larger oval foramen *(foramen ovale)* is seen to the front of it; it transmits the third branch of the trigeminal nerve.

The greater wings have the following four surfaces: cerebral *(facies cerebralis)*; orbital *(facies orbitalis)*; temporal *(facies temporalis)*, and maxillary *(facies maxillaris)*. Their names indicate which cranial surface they face. The last two surfaces are separated by the infratemporal crest *(crista infratemporalis)*.

The pterygoid processes *(processus pterygoidei)*, drop vertically downward from the junction of the greater wings and the body of the sphenoid bone. Their base is pierced by a pterygoid canal *(canalis pterygoideus)* directed sagittaly, which transmits the pterygoid nerve and vessels. Its anterior opening communicates with the pterygopalatine fossa. Each process is made up of two plates, one medial and one lateral *(lamina medialis* and *lamina lateralis)*, between which the pterygoid fossa *(fossa pterygoidea)* forms posteriorly. The inferior portion of this fossa is continuous with the pterygoid fissure *(fissura pterygoidea)*. In the intact skull the pyramidal process of the palatine bone fits into this notch. The inferior part of the medial plate bends over to form a hook-like process called the hamulus pterygoideus. The tendon of m. tensor palatini (one of the muscles of the soft palate), which arises here, passes around the hamulus pterygoideus.

THE ETHMOID BONE *(OS ETHMOIDALE)*

The **ethmoid bone** *(os ethmoidale)* is an unpaired bone usually described in the group of bones of the cerebral cranium, although most of it helps to make up the visceral cranium. The ethmoid bone is located centrally between the bones of the face and comes in contact with most of them to form the nasal cavity and orbit. In an intact skull it is covered by them. It develops in connection with the nasal capsule in cartilage. Formed of thin bone plates surrounding the air sinuses, it is light and fragile (the ancient Egyptians made use of these properties when they removed the brain from the skull through the ethmoid bone for embalment).

The bony plates of the ethmoid bone are arranged in the form of the letter "T" in which the vertical line is the perpendicular plate *(lamina perpendicularis)* and the horizontal is the cribriform plate *(lamina cribrosa)*. From the lamina cribrosa, on either side of the perpendicular plate, hang the ethmoidal labyrinths *(labyrinthi ethmoidales)*. As a result four parts are distinguished in the ethmoid bone.

1. **Lamina cribrosa** is a rectangular plate fitting into the ethmoid notch of the frontal bone. It is perforated by small openings like a sieve, hence its name (Gk *ethmos* sieve, *eidos* form). These perforations transmit the branches of the olfactory nerve (about 30 of them). The crista galli projects upward from the midline of the cribriform plate (for attachment of the dura mater).

2. **Lamina perpendicularis** is a part of the nasal septum.

3 and 4. **Labyrinthi ethmoidales** make up a paired complex of bony air cells, pellulae ethmoidales, covered laterally by a thin orbital plate *(lamina orbitalis)*, which forms the medial wall of the orbit. The upper border of the orbital plate articulates with the orbital part of the frontal bone, the anterior border with the lacrimal bone, the posterior border with the orbital process of the palatine bone, and the inferior border with the upper jaw; all these bones cover the laterally located cellulae ethmoidales. On the medial surface of the labyrinth are two nasal conchae *(conchae nasales superior* and *media)*, although sometimes there is a third, highest nasal concha *(concha nasalis suprema)*.

The conchae (Gk *konche* shell) are thin, curved plates; as the result of such a shape, the surface of the nasal mucosa covering them increases.

THE TEMPORAL BONE *(OS TEMPORALE)*

The temporal bone *(os temporale)* is a paired bone whose structure is very complicated because it is concerned with all three functions of the skeleton and not only forms part of the lateral wall and base of the skull but houses the organs of hearing and equilibrium (Fig. 33).

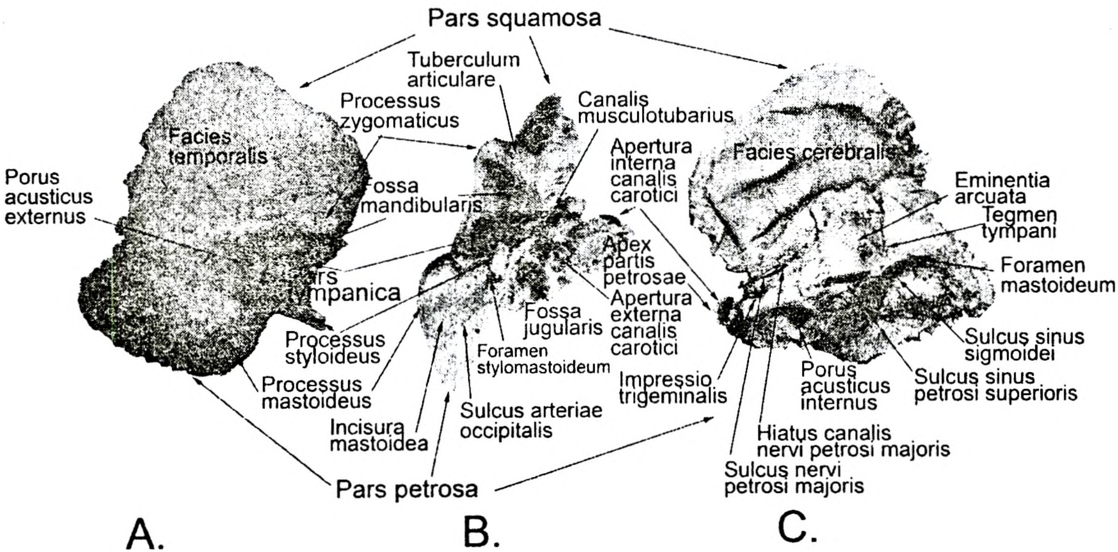

Fig. 33. Os temporale
A- facies externa; B- facies inferior; C- facies interna.

It is the product of fusion of several bones (mixed bone), which exist independently in some animals, and therefore consists of three parts: (1) squamous part *(pars squamosa)* (in animals, os squamosum); (2) tympanic part *(pars tympanica)* (in animals, tympanicum), and (3) petrous part *(pars petrosa)* (in animals, petrosum). A fourth part of the temporal bone, mastoid (pars mastoidea) was previously distinguished. The mastoid, however, does not have a nucleus for independent ossification and arises from the pars petrosa. In the formed bone these parts are, therefore, united under the common name pars petrosa (PNA), while in the newborn, in whom the three parts of the temporal bone are still not fused, this part is called pars petromastoidea.

Within the first year of life the parts fuse into a single bone and thus form the external acoustic meatus *(meatus acusticus externus)* with the squamous part to the top, the petrous part in a medial position, and the tympanic part to the back, bottom, and front. The traces of fusion of the separate parts of the temporal bone persist throughout life in the form of sutures and fissures, namely: petrosquamous fissure *(fissura petrosquamosa)* on the border between the squamous and petrous parts on the anterosuperior surface of the latter; the tympanosquamous fissure *(fissura tympanosquamosa)* in the depth of the mandibular fossa separated by the process of the petrous part into fissura petrosquamosa, and petrotympanic fissure *(fissura petrotympanica)* (through which the chorda tympani nerve passes).

The **squamous part** *(pars squamosa)* contributes to the formation of the lateral walls of the skull. This membrane bone, which ossifies in connective tissue, has a relatively simple structure of a vertical plate with a rounded edge articulating with the corresponding edge of the parietal bone, margo squamosa, like the scales of fish, hence its name (L *squama* scale).

The cerebral surface *(facies cerebralis)* of the squamous part bears marks of the brain, impressions for cerebral gyri *(impressiones digitatae)* and an ascending groove lodging the middle meningeal artery (a. meningea media). The smooth external surface of the squama contributes to the formation of the temporal fossa and is therefore called the *temporal surface (facies temporalis).* It gives rise to the zygomatic process *(processus zygomaticus),* which passes forward to join the zygomatic bone. The zygomatic process has two roots at its origin, an anterior and a posterior root, with a depression — articular fossa *(fossa mandibularis)* for articulating with the lower jaw between them. The inferior surface of the anterior root carries an articular tubercle *(tuberculum articulare),* which prevents anterior dislocation of the head of the mandible when the mouth is opened very wide.

The **tympanic part** *(pars tympanica)* of the temporal bone forms the anterior, inferior, and part of the posterior border of the external acoustic meatus. It fuses with the mastoid process laterally and with the petrous part medially. It undergoes endesmal ossification and, as all membrane bones, resembles a plate, although in this case the plate is sharply bent.

The external auditory meatus *(meatus acusticus externus)* is a short canal directed medially and somewhat anteriorly and leading into the tympanic cavity. The superior edge of its external opening, porus acusticus externus, and part of the posterior edge are formed by the squama of the temporal bone. The other edges are formed by the tympanic part of the bone.

The external acoustic meatus *is* incompletely formed in the newborn because the tympanic part is an incomplete ring *(anulus tympanicus)* closed by the tympanic membrane. Since the tympanic membrane is so near the external environment, newborns and infants often suffer from diseases of the membrane. The tympanic ring grows and is converted to a tube during the first year of life; this tube pushes the petrous part medially and forms most of the bony external acoustic meatus whose roof is the squamous part. The tympanic membrane now moves deeper into the external acoustic meatus and separates it (i.e. the external ear) from the tympanic cavity, cavum tympani (and becomes external in relation to the tympanic cavity). The floor of this cavity, just as the floor of the acoustic meatus, is formed by the tympanic part, while the superior and internal walls are formed by the petrous part.

The **petrous part** *(pars petrosa)* (Gk *petros* stone) is an important component of the temporal bone. It is so named because its bony substance is strong. It is a part of the base of the skull and at the same time is a bony encasement for the organs of hearing and equilibrium, which have a very fine structure and must be protected reliably from injuries. The petrous part develops in cartilage. This part is also called the pyramid because it is shaped like a trihedral pyramid with the base facing externally and the apex facing anteriorly and internally toward the sphenoid bone.

The pyramid has three surfaces: anterior, posterior, and inferior. The anterior surface is part of the floor of the middle cranial fossa, the posterior surface faces posteriorly and medially and forms part of the anterior wall of the posterior cranial fossa; the inferior surface faces downward and is visible only on the external surface of the base of the skull. The complex external relief of the pyramid is determined by its structure as a receptacle for the middle (the tympanic cavity) and the internal ear (the bony labyrinth made up of the cochlea and the semicircular canals), as well as by the passage of nerves and vessels. The anterior surface of the pyramid has a small depression near its apex. This is the trigeminal impression *(impressio trigemini),* which lodges the ganglion of the trigeminal nerve *(n. trigeminus).* Lateral to it pass two small grooves, a medial sulcus of the greater petrosal nerve *(sulcus n. petrosi majoris)* and a lateral sulcus of the lesser petrosal nerve *(sulcus n. petrosi minoris).* They lead to two openings of the same name, a medial opening *(hiatus canalis n. petrosi majoris)* and a lateral opening *(hiatus canalis n. petrosi minoris).* The arcuate eminence *(eminentia arcuata)* is lateral to these openings; it forms due to prominence of the vigorously developing labyrinth, particularly the superior semicircular canal. The bone surface between the petrosquamous fissure and the arcuate eminence forms the roof of the tympanic cavity *(legmen tympani)*.

In about the middle of the posterior surface of the pyramid is the porus acusticus internus leading into the internal auditory meatus *(meatus acusticus internus)*, which transmits the facial and auditory nerves and the internal auditory artery and veins.

The inferior surface of the pyramid that faces the base of the skull is found the musculotubal canal *(canalis musculotubarius)* leading to the tympanic cavity. The canal is divided by a septum into two parts: superior and inferior. The superior, smaller semicanal *(semicanalis m. tensoris tympani)* lodges the tensor tympani muscle, while the lower, larger semicanal *(semicanalis tubae auditivae)* is the bony part of the auditory tube for the conduction of air from the pharynx to the tympanic cavity.

The superior edge of the pyramid that separates the anterior and posterior surfaces bears a clearly detectable groove, groove for the superior petrosal sinus *(sulcus sinus petrosi superioris)* lodging the superior petrosal venous sinus.

The posterior edge of the pyramid joins the pars basilaris of the occipital bone to the front of the jugular fossa and together with this bone forms the groove for the inferior petrosal sinus *(sulcus sinus petrosi inferioris)* lodging the inferior petrosal sinus.

The external surface of the base of the pyramid provides attachment for the muscles; this determines its relief (process, notches, areas of roughness). Its lower end stretches out to form the mastoid process *(processus mastoideus)* to which the sternocleidomastoid muscle is attached. This muscle balances the head, which is necessary for maintenance of the vertical posture of the body. The mastoid process is absent, therefore, in quadrupeds and anthropoid apes and develops only in man due to his erect axis posture. The medial surface of the mastoid process bears a deep mastoid notch *(incisura mastoidea)*, the site of attachment of m. digastricus, and, still closer to the midline, a small occipital groove *(sulcus a. occipitalis)*. A smooth triangle on the external surface of the base of the mastoid process is the operative approach to the air cells of the process when they are filled with pus. The suprameatal spine *(spina suprameatum)* projects in front of the triangle.

The mastoid process contains compartments or cells *(cellulae mastoidea)*, which are air cavities separated by bone trabeculae. They receive air from the tympanic cavity with which they communicate by means of the mastoid, antrum *(antrum mastoideum)*. A deep sigmoid groove *(sulcus sinus sigmoidei)* is found on the cerebral surface of the base of the pyramid. The canal of the venous emissary opens into this sulcus; its external opening, mastoid foramen *(foramen mastoideum)*, varying greatly in accordance with the size of the canal, is near to or in the occipitomastoid suture.

CANALS OF THE TEMPORAL BONE

Name of canal	Point of starting	End of canal	Contents
Canalis caroticus	***foramen caroticum externum*** (upward, than it turns forward and medially)	***foramen caroticum internum***	a. carotis interna, plexus caroticus internus
Canaliculi caroticotympanici (2-3)	near the place of the beginning of ***carotic canel***	***tympanic cavity***	n.n. et a.a. caroticotympanici
Canalis nervi facialis	on the wall of the ***internal acoustic meatus*** (transversally to the center lines – longitudinal axis - of the pyramid of the temporal bone; 1 mm from hiatus canalis nervi petrosi major it turne 90 degree downward and laterally (*geniculum canalis nervi facialis)*; on the level of foramen stylomastoideus - downward	***forames stylomastoideus***	n. facialis (VII pair of the cerebral nerves)
Canaliculus chordae tympani	on the external wall of ***canalis n. facialis***, not far from exist through foramen stylomastoideus (upward and forward	***cavum tympani***	chorda tympani – tympanic nerve
		fissura petrotympanica	branch of n. facialis
Canaliculus tympanicus	***fossula petrosa*** (through cavum tympani)	*hiatus canalis n. petrosi minoris*	n. petrosi minoris, branch of the n. glossopharingeus
Canaliculus mastoideus	***fossa jugularis*** (crossing canalis n. facialis)	***fissura tympanomastoidea***	branch of the vagal nerve
Canalis musculotubarius	***apex of the pyramid*** of the temporal bone a) semicanalis m. tensor tympani (upper) b) semicanalis tubae auditivae (lower)	***cavum tympani***	*a) m. tensor tympani* *b) tuba auditiva*

The canals of the temporal bone. The largest is the carotid canal *(canalis caroticus),* which transmits the internal carotid artery. It begins as the external carotid foramen *(foramen caroticum externum)* on the interior surface of the pyramid, then ascends and bends at a right angle and opens by its internal foramen *(foramen caroticum internum)* at the apex of the pyramid medial to the canalis musculotubarius. The canal for the facial nerve *(canalis facialis)* begins in the depth of porus acusticus internus and then passes at first forward and laterally to the hiatus in the anterior surface of the pyramid. There the canalis facialis, still horizontal, bends at a right angle laterally and backward to form the geniculum of the facial canal *(geniculum canalis facialis);* it then descends and ends as the stylomastoid foramen *(foramen stylomastoideum)* on the inferior surface of the pyramid of the temporal bone.

THE BONES OF THE VISCERAL CRANIUM

The bones of the visceral cranium form bony receptacles for the organs of sense (vision, olfaction) and for the initial parts of the alimentary (oral cavity) and respiratory (nasal cavity) systems, which determines their structure. They reflect the changes which occurred in the soft tissues of the head in the process of humanization of the ape, i.e. the leading role of labour, the partial transference of the grasping function from the jaws to the hands, which became the tools of work, the development of articulate speech, the development of the brain and its tools, the organs of sense, and, finally, the preparation of food which made the work of the masticatory apparatus easier.

THE UPPER JAW BONE *(MAXILLA)*

The **upper jaw bone** *(maxilla)* is a paired bone of a complex structure determined by the diversity of its functions: it takes part in the formation of cavities for the organs of sense, the orbit and nose, in the formation of the septa between the cavities of the nose and mouth, and in the work of the masticatory apparatus. With the development of man's working activity, the function of grasping was transferred trom the jaws (where it is in animals) to the hands, which led to a diminution of the maxilla. The development of the faculty of speech made the structure of the human jaw finer as well. All this determines the structure of the upper jaw (in animals, *os maxillare*), which develops in connective tissue (Fig. 34).

The maxilla consists of a body and four processes.

A. *The body (corpus maxillae)* contains a large maxillary air sinus *(sinus maxillaris* s. *antrum Highmori,* BNA) (hence highmoritis, inflammation of the maxillary sinus), which communicates with the nasal cavity by a wide opening, the maxillary hiatus *(hiatus maxillaris).* The following four surfaces are distinguished on the body.

The **anterior surface** *(facies anterior),* which was flat in the Neanderthal man, is concave in modern man since his food is prepared and the function of mastication is consequently weaker. Inferiorly it is continuous with the alveolar process, in which a series of depressions *(juga alveolaria)* between the ridges of the tooth roots are seen. The ridge corresponding to the canine tooth is most pronounced. The canine fossa *(fossa canina)* is above and lateral to it. Superiorly the anterior surface of the maxilla is separated from the orbital surface by the infraorbital margin *(margo infraorbitalis).* Immediately below it is the infraorbital foramen *(foramen infraorbitale)* through which the infraorbital nerve and artery leave the orbit. The medial border of the anterior surface is formed by the nasal notch *(incisura nasalis)* whose edge extends forward to form the anterior nasal spine *(spina nasalis anterior).*

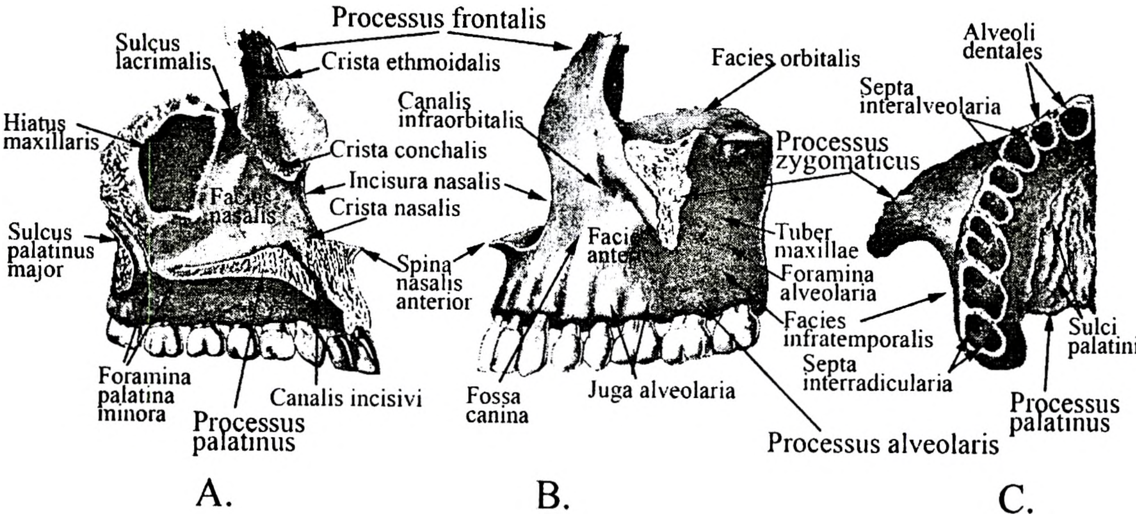

Fig. 34. Os maxilla
A- medial view; B- lateral view; C- inferior view.

The **infratemporal surface** *(facies infratemporalis)* is separated from the anterior surface by the zygomatic process and carries several small perforations (transmitting the nerves and vessels to the upper teeth), the maxillary tuber (tuberosity of maxilla) *(tuber maxillae)* and the greater palatine sulcus *(sulcus palatinus major)*.

The **nasal surface** *(facies nasalis)* is continuous interiorly with the superior surface of the palatine process. The conchal crest *(crista conchalis)* is seen on it. To the back of the frontal process is the nasolacrimal groove *(sulcus lacrimalis)* which, with the lacrimal bone and the inferior nasal concha, is converted into the nasolacrimal canal *(canalis nasolacrimalis)* by means of which the orbit communicates with the inferior nasal concha. Still farther back is a large opening that leads to the maxillary sinus. In an intact skull this opening is made somewhat smaller by parts of bones overlapping it, namely the lacrimal, ethmoid, and palatine bones and the inferior concha.

The smooth, flat **orbital surface** *(facies orbitalis)* is triangular. On its medial border, behind the frontal process, is the lacrimal notch *(incisura lacrimalis)* lodging the lacrimal bone. The infraorbital groove *(sulcus infraorbitalis)* originates near the posterior border of the orbital surface and is converted anteriorly into the infraorbital canal *(canalis infraorbitalis)*, which opens onto the anterior surface of the maxilla by means of the infraorbital foramen mentioned above. The alveolar canals *(canales alveolares)* arise from the infraorbital canal; they transmit nerves and vessels passing in the thickness of the anterior maxillary wall to the anterior teeth.

B. Processes.

1. The **frontal process** *(processus frontalis)* projects upward and joins the pars nasalis of the frontal bone. Its lateral surface is divided into two parts by a vertical lacrimal crest *(crista lacrimalis anterior)*, which is continuous downward with the infraorbital margin. The medial surface carries the ethmoidal crest *(crista ethmoidalis)* for attachment of the middle nasal concha.

2. The **alveolar process** *(processus alveolaris)* carries on its inferior border, alveolar arch *(arcus alveolaris)*, dental sockets *(alveoli dentales)* for the eight upper teeth; the sockets are separated by *septa inter alveolaria.*

3. The **palatine process** *(processus palatinus)* forms most of the hard bony palate *(palatum osseum)* by joining the contralateral process in the midline. Where they meet, the nasal crest *(crista nasalis)* rises on the superior surface facing the nasal cavity and articulates with the inferior edge of the vomer. Near the anterior end of the nasal crest on the superior surface is an opening that leads into the incisive canal *(canalis incisivus)*. The superior surface of the process is smooth, whereas the inferior surf ace, facing the oral cavity, is rough (impressions of the mucosal glands) and carries longitudinal palatine grooves *(sulci palatini)* lodging the nerves and vessels. The incisive suture *(sutura incisiva)* is often seen in the anterior part. It delimits the os incisivum which fuses with the maxilla. In many animals this bone exists as an

independent bone *(os intermaxillare)*, but in man it is rarely encountered.

4. The **zygomatic process** *(processus zygomaiicus)* articulates with the zygomatic bone to form a thick support through which pressure produced during mastication is transmitted to the zygomatic bone.

THE PALATINE BONE *(OS PALATINUM)*

The **palatine bone** *(os palatinum)* is a paired bone (Fig. 35). Though it is small, it nevertheless contributes to the formation of some of the cranial cavities, namely the cavities of the nose, mouth, orbits, the pterygopalatine fossa. This determines its peculiar structure: it is a thin bone consisting of two plates uniting at a right angle and supplementing the maxilla.

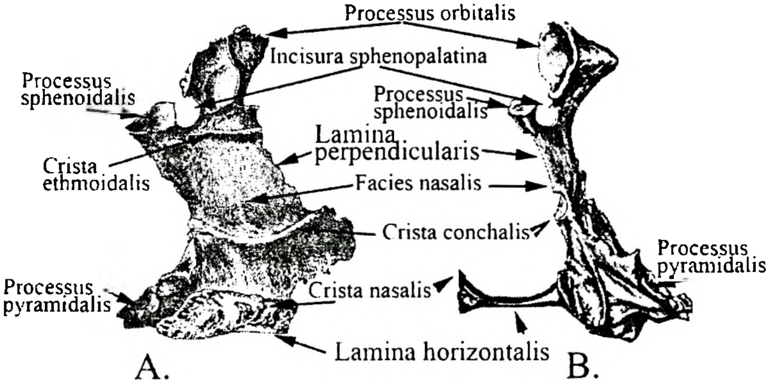

Fig. 35. Os palatinum
A- medial view; B- posterior view.

1. The **horizontal plate** *(lamina horizontalis)* complements the maxillary palatine process posteriorly to form the hard palate *(palatum osseum)*. Its medial border meets the medial border of the contralateral bone to form the nasal crest *(crista nasalis)*. On the inferior surface of the horizontal plate is the greater palatine foramen *(foramen palatinum majus)*, through which palatine vessels and nerves leave the canalis palatinus major (see below).

2. The **perpendicular plate** *(lamina perpendicularis)* adjoins the nasal surface of the maxilla. Along its lateral surface runs the greater palatine sulcus *(sulcus palatinus major)*, which together with the maxillary sulcus of the same name forms the canalis palatinus major. The medial surface has two crests for two nasal conchae, the middle (crista ethmoidalis) and the inferior (crista conchalis). The palatine bone has three processes. One of them, the pyramidal process *(processus pyramidalis)* projects backward and laterally from the junction of the horizontal and perpendicular plates. In an intact skull

the pyramidal process fits into the pterygoid fissure of the sphenoid bone. Nerves and vessels penetrate it vertically through the lesser palatine canals *(canales palatini minores).* The other two processes project from the superior edge of the perpendicular plate and form the sphenopalatine notch *(incisura sphenopalatina),* which meets the body of the sphenoid bone to form the sphenopalatine foramen *(foramen sphenopalatinum)* transmitting the sphenopalatine vessels and nerves. The anterior process forms the posterior corner of the orbit and is therefore known as the orbital process *(processus orbitalis);* the posterior process adjoins the inferior surface of the body of the sphenoid bone and is called the sphenoid process *(processus sphenoidalis).*

THE INFERIOR NASAL CONCHA *(CONCHA NASALIS INFERIOR)*

The inferior nasal concha or inferior turbinate bone *(concha nasalis inferior)* is a paired bone. As distinct from the superior and middle nasal conchae, which are components of the ethmoid bone, the inferior nasal concha is an independent bone. It is a thin, curled plate of bone whose upper edge is attached to the lateral wall of the nasal cavity; it isolates the middle nasal meatus from the inferior meatus. Its inferior edge is free, while the upper edge articulates with the conchal crests of the maxilla and the palatine bone.

THE NASAL BONE *(OS NASALE)*

The **nasal bone** *(os nasale)* joins the contralateral bone to form the ridge of the nose at its root. In man the nasal bone is underdeveloped in comparison to that in animals.

THE LACRIMAL BONE *(OS LACRIMALE)*

The **lacrimal bone** (*os lacrimale),* a paired bone, is a thin plate found in the medial wall of the orbit immediately behind the frontal process of the maxilla. Its lateral surf ace carries the crest of the lacrimal bone *(crista lacrimalis posterior).* To the front of the crest runs the lacrimal groove *(sulcus lacrimalis),* which meets the sulcus of the frontal process of themaxilla to form the fossa of the lacrimal sac *(fossa sacci lacrimalis).* The lacrimal bone of man is similar to that of anthropoid apes, which is evidence that these apes are closely related to hominids.

THE VOMER

The **vomer**, an unpaired bone, is an irregularly quadrangular plate, which resembles a plowshare (hence its name: L *vomer* plowshare) and forms part of the bony nasal septum. Its superior border is split into two wings *(alae vomeris),* which fit over the rostrum of the sphenoid bone. The upper half of the anterior edge articulates with the perpendicular plate of the ethmoid bone, and the lower part with the cartilaginous nasal septum. The inferior edge articulates with the nasal crests of the maxilla and palatine bone. The free, posterior edge is the posterior border of the bony nasal septum separating the posterior openings of the nasal cavity, choanae, by means of which the nasal cavity communicates with the nasopharynx.

THE ZYGOMATIC BONE *(OS ZYGOMATICUM)*

The **zygomatic bone** *(os zygomaticum)* is a paired bone, the strongest bone of the skull. The zygomatic bone is important to the architecture of the face because it connects the frontal and temporal bones and the maxilla by articulating with their zygomatic processes and thus strengthening the bones of the visceral skull in relation to the cerebral skull. It is also an extensive surface for the origin of the masseter muscle. According to the location of the bone, three surfaces and two processes are distinguished in it. The lateral surface *(facies lateralis)* is shaped like a four-point star and bulges slightly, it has opening *foramen zygomaticofacialis*. The smooth posterior surface faces the temporal fossa and is called the temporal surface *(facies temporalis)* whith opening on it - *foramen zygomaticotemporalis*. The third orbital surface *(facies orbitalis)* takes part in the formation of the orbital walls and take opening - *foramen zygomaticoorbitalis*. The superior frontal process of the zygomatic bone *(processus frontalis)* articulates with the zygomatic process of the frontal bone and the greater wing of the sphenoid bone. An eminence for attachment of the muscles and ligaments of the eyelids is often found on its orbital surface. The lateral temporal process *(processus temporalis)* articulates with the zygomatic process of the temporal bone to form the zygomatic arch, the site of origin of the masseter muscle.

THE LOWER JAW BONE *(MANDIBULA)*

The lower jaw (mandible) *(mandibula)* is only connected with the other bones of the skull by synovial joints (Fig. 36). It is preformed in connective tissue. The lower jaw bone or the mandible *(mandibula)* is a mobile skull bone. Its horseshoe shape is determined both by its function (the most important part of the masticatory apparatus) arid by its development from the first visceral (mandibular) arch whose shape it retains to a certain extent. In mammals, including the lowest primates, the mandible is a paired bone. In accordance with this, in man the mandible develops from two germs which, growing gradually, fuse in the second year after birth into an unpaired bone; the mark of the fusion of the two halves, however, remains (symphysis mandibulae). The bone develops in connective tissue. The masticatory apparatus consists of a passive part, i.e. the teeth, concerned with mastication, and an active part, i.e. the muscles. Accordingly, the mandible consists of a horizontal part or body *(corpus mandibulae)*, which carries the "teeth, and a vertical part in the form of two rami mandibulae *(rami mandibulae)*, which serve for

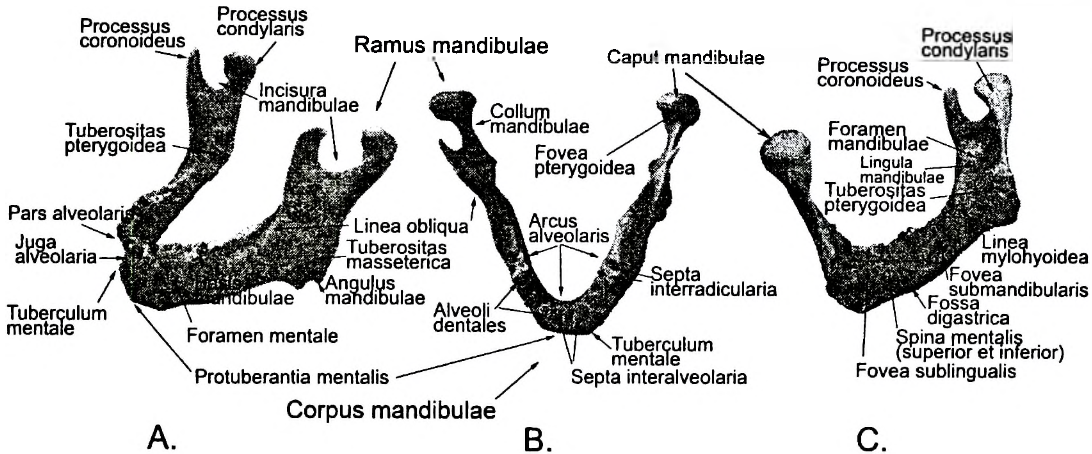

Fig. 36. Os mandibula

A- facies externa; B- view from above; C- facies interna.

the formation of the temporomandibular joint and for attachment of the muscles of mastication. The horizontal and the vertical parts meet at an angle called the angle of the mandible *(angulus mandibulae)*, on the external surface of which the masseter muscle is inserted into the masseteric tuberosity *(tuberositas masseterica)*. On the inner surface of the angle is the pterygoid tuberosity *(tuberositas pterygoidea)* for insertion of another muscle of mastication, m. pterygoideus medialis.

The activity of the masticatory apparatus, therefore, has an effect on the size of this angle. It is close to 150 degrees in the newborn, diminishes to 130-110 degrees in an adult, and again increases in old age with the loss of teeth and weakening of the masticating act. Comparison of apes with various hominid species'also reveals a gradual increase of the angulus mandibulae with weakening of the act of mastication: 90 degrees in the anthropoid ape, 95 degrees in the Heidelberg man, 100 degrees in the neandenthal man, and 130 degrees in modern man.

The structure and relief of the body of the mandible are determined by the teeth and by the fact that the mandible takes part in the formation of the mouth. For instance, the upper, alveolar part of the body *(pars alveolaris)* bears teeth as a consequence of which its border, the alveolar arch *(arcus alveolaris)* has sockets for the teeth *(alveoli dentalis)*, with interalveolar septa *(septa interalveolaria)* and corresponding depressions on the external surface *(juga alveolaria)*. The rounded massive and thick inferior border of the body forms the base of the mandible *(basis mandibulae)*. At old age when the teeth are lost, the alveolar part atrophies and the whole body of the mandible becomes thin and low. The ridge on the symphysis on the midline of the body is continuous with a triangular mental protuberance *(protuberantia mentalis)*, the presence of which is characteristic of modern man. Among all mammals only man, and modern man at that, has a pronounced chin. The anthropoid ape, the Pithecanthropus man, and the Heidelberg man have no mental protuberance; their jaw instead has a border that curves to the back. The Neanderthal man also lacks a protuberance, but the mandibular border here is rectangular. A true chin forms only in modern man.

In old age, i e., after loss of the teeth, the alveolar process undergoes regression.

On each side of this protuberance is a mental tubercle *(tuberculum mentale)*. On the lateral surface of the body, in the space between the first and second premolars, is the mental foramen *(foramen mentale)*, which is an opening of the mandibular canal *(canalis mandibulae)*, transmitting a nerve and vessels. An oblique line *(linea obliqua)* runs to the back and upward from the mental tubercle. Two mental spines *(spinae mentales)* project from the inner surface of the symphysis; these are the sites of attachment of the tendon of the genioglossus muscle. In anthropomorphic apes the spine here is replaced by a fossa because the genioglossus muscle is attached not by a tendon but by muscular tissue. All transient forms were found in a series of fossil skulls, from those with a fossa typical of the skull of apes (due to muscular attachment of *m. genioglossi*) and without a chin to those with a spine determined by attachment of the muscle by means of a tendon and with a protruding chin. A change in the means of attachment of the genioglossus muscle from muscular to tendinous thus caused the formation of a spine and the consequent development of a chin. Since the tendinous method of attachment of the tongue muscles was conducive to the development of articulate speech, tne transformation of the bone relief in the region of the chin, a purely human feature, should, therefore, also be associated with the faculty of speech. On both sides of the mental spine, nearer to the inferior border of the mandible is the site for attachment of the digastric muscle, the digastric fossa *(fossa digastrica).* Further to the back is the mylohyoid line *(linea mylohyoidea),* running backward and upward; it serves for attachment of the mylohyoid muscle.

The ramus of the mandible *(ramus mandibulae)* has two processes, the anterior *coronoid process* for insertion of a muscle, and the posterior *condylar process* for the joint surface. The ramus of the mandible *(ramus mandibulae)* rises on each side from the posterior part of the body of the mandible. On its inner surface is the mandibular foramen *(foramen mandibulae),* leading into the mandibular canal mentioned above. The medial edge of this foramen projects as the lingula of the mandible *(lingula mandibulae),* to which is attached the sphenomandibular ligament; the lingula is developed more in man than in apes. The mylohyoid groove *(sulcus mylohyoideus)* originates behind the lingula and runs downward and forward; it lodges the mylohyoid nerve and vessels. Superiorly the ramus of the mandible terminates as two processes, anterior coronoid process *(processus coronoideus)* (it forms under the effect of traction exerted by the strong temporal muscle) and a posterior condyfar process *(processus condylaris).* A crest for the attachment of the buccinator muscle *(crista buccinatoria)* runs on the inner surface of the ramus upward from the surface of the alveoli of the last molars towards the coronoid process.

The condylar process has a head *(caput mandibulae)* and a neck *(collum mandibulae).* On the anterior surface of the neck is the pterygoid pit *(fovea pterygoidea)* for attachment of the lateral pterygoid muscle. The head of the condylar process is stretched out in the transverse direction,.but the medial end of its axis slants to the back so that the longitudinal axes of both heads, when continued, intersect at the anterior border of the foramen magnum at an angle of 140-150 degrees.

In summary of the description of the mandible, it should be pointed out that its shape and structure characterize modern man. During the process of labour, which was responsible for the transformation of the ape into a human being, the function of grasping changed from the jaws to the hands which became organs of labour. Man's diet of prepared food made the work of his masticatory apparatus easier. All this led to diminished activity of the teeth and sharp reduction of the lower jaw, as compared with that of anthropoid apes and even with the lower jaw of fossil humans, for instance, with that of the Heidelberg man. At the same time, articulate speech developed in man; it was associated with increased and fine work of the tongue muscles attached to the mandible. The mental region of the mandible which is connected with these muscles, functioned intensely and withstood the factors of regression. Spines and a protuberance formed on it. Their formation was also promoted by distension of the mandibular arch as a consequence of the increased transverse dimension of the cerebral cranium under the effect of the growing brain. Thus, the shape and structure of man's lower jaw formed under the effect of the development of labour, articulate speech, and the brain, i.e. properties characteristic of man.

Shape of Mandible

The *angle of the mandible* differs at various stages of life. In the newborn it is still relatively large, about 150°, while during childhood it becomes smaller. In the adult it is reduced to about 120-130°. In old age it again increases to about 140°. The change in the angle of the mandible is dependent on the presence of the alveolar part with its alveolar arch and the teeth. With eruption of the teeth there is an alteration in the mandibular angle of the infant, and it changes again in old age when the teeth are lost. Apart from the change in the angle of the mandible at the various stages of life, the body of the mandible also shows variations. The body of the mandible bears the alveolar process, and in old age, after the teeth are lost, this regresses. During this regression the size of the body of the mandible becomes reduced and sometimes flattened, which may push the chin forward.

The alveolar part may vary in its orientation. In some instances, particularly among the primates, there may be an alveolar part protruding outward and the position of the teeth differs from that in modern man.

THE HYOID BONE *(OS HYOIDEUM)*

The **hyoid bone** *(os hyoideum)* is situated at the base of the tongue, between the mandible and the larynx (Fig. 37). The hyoid bone, which may be included with the bony skeleton of the skull, is not directly connected but is joined to it by muscles and ligaments. It belongs to the visceral skull and develops from the hyoid and first branchial arches. In accordance with this development, it acquires the shape of an arch. It consists of a body *(corpus)* and two pairs of horns *(cornua)*. The greater horns *(cornua majora)* are continued from both ends of the body and extend backwards and somewhat laterally; they are at first joined to the body by cartilage which later is replaced by bone. The lesser horns *(cornua minora)* arise from the junction of the body and the greater wings and project upward and backward. The lesser horns ossify only in the elderly and fuse with the body after the age of 50. The hyoid bone is suspended from the base of the skull by means of two long fibrous cords, stylohyoid ligaments *(lig. stylohyoideum)*, stretching from the lesser horns to the styloid processes of the temporal bones.

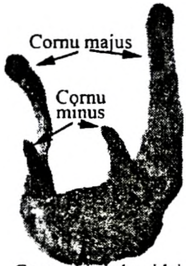

Fig. 37. Os hyoideum

THE SKULL AS A WHOLE

The external surface of the skull. Part of the external surface of the skull examined from the front (norma facialis s. frontalis) consists of the forehead superiorly and two orbits, with the piriform aperture of the nose between them; below the orbits and lateral to the opening of the nose is the anterior surface of the upper jaw with the upper teeth (Fig. 38). The orbit is bounded laterally by the zygomatic bone, which articulates both with the frontal bone and with the maxilla. Below is attached the mobile lower jaw carrying the lower teeth on its superior border.


Fig. 38. Cranium – norma facialis

Each of the flat bones of the skull consists of a compact outer table ("lamina externa"), and a compact inner table ("lamina interna"). Between the two lie the diploe (spongy layer), in which there are numerous veins within the diploic canals. Within other bones of the skull are certain air-filled spaces associated with the nasal sinuses. The temporal bones contain the sensory organs of hearing and balance.

On the outside the skull is covered by the pericranium, and the inner surface of the skull is covered by endocranium, the dura mater.

It is useful first of all to take a unified view of the skull from its various aspects, in order to recognise the functional associations of the latter and to comprehend the special features of the individual skull bones. The various cavities within the skull are also discussed below.

CALVARIA *(NORMA VERTICALIS)*

The vault of the cranium, the calvaria, consists of a frontal bone, parietal bones, parts of the temporal bones (brown) and the uppermost part of the occipital bone. Examination of the outside of the skull will show first of all the sutures, i. e. the *coronal suture (sutura coronalis)* which separates the *frontal squama* with the *frontal eminences* from the parietal bones. Each parietal bone, too, has a *parietal eminence*. Between the parietal bones lies the *sagittal suture (sutura sagittalis)*, which runs from the coronal suture to the *lambdoid suture (sutura lambdoidea)* (from its resemblance to the Greek letter lambda), i. e., the suture between the parietal bone and the *occipital squama*. Laterally, in the parietal region, are the *inferior* and *superior temporal lines*. In close relationship to the sagittal suture, immediately in front of the lambdoid suture, lie the *parietal foramina*.

The sutures are also visible *on the inner surface of the cranial vault*. On the cut surface the *outer table*, *diploe* and the *inner table* are exposed. In the most anterior part of the squama of the frontal bone lies the *frontal crest* which extends toward the parietal bones. In the region of the sagittal suture is the shallow *groove for the superior sagittal sinus*. The *arterial*sulci, which contain the branches of the middle meningeal artery and its accompanying vein, ascend from the lateral toward the midline and posterior areas. Lateral to the groove for the superior sagittal sinus and lateral to the frontal crest there are a variable number of indentations of different size *(granular foveolae)* into which the arachnoidal granulations extend.

On the inner and outer aspects of the parietal bone in the vault are the *frontal* and *occipital angles,* while the sphenoid and mastoid angles are found only at the base of the skull.

POSTERIOR VIEW OF THE SKULL (NORMA OCCIPITALIS)

In the dorsal view it is possible to see both parietal bones, which are joined by the *sagittal suture*. The *lambdoid suture* separates the two parietal bones from the occipital bone. The *external occipital protuberance* is prominent on the ccipital bone in the midline and is palpable through the skin. The *highests nuchal line* extends upward and laterally from the external occipital protuberance. The line below is the *superior nuchal line*, which represents a transverse ridge lateral to theprotuberance, and below it is the *inferior nuchal line*, which extends roughly in the center between the external occipital protuberance and the foramen magnum. The *inferior nuchal* line may begin at the more or less well-developed, *external occipital crest*. Lateral to the occipital bone lies the *mastoid process*, which is part of the temporal bone, but which is joined to the occipital bone by the *occipitomastoid suture*. A *petrosquamous suture* may be present completely or in part in the mastoid process. This suture shows that the mastoid process is formed from both the squamous and the petrous parts of the temporal bone. In the region of the, occipitomastoid suture is the *mastoid foramen*, through which the mastoid emissary vein passes. On the medial side of the mastoid process lies the *mastoid notch*, medial to which is the *groove for the occipitalartery*. Parietal foramina are situated in the region of the parietal bones.

Variants:

Sometimes the external occipital protuberance is particularly well developed. The upper squama may be present as a separate bone, the inca bone. The parietal foramina may be particularly large and may give rise to false.

INFERIOR VIEW OF THE SKULL

The external surface of the base of the skull *(basis cranii externa)* is made up of the inferior surfaces of the visceral (without the mandible) and the cerebral cranium (Fig. 39). The inferior surface of the base of the skull consists of an anterior visceral part and a posterior neural part. It extends from the incisors anteriorly to the superior nuchal line *(linea nuchae superior)* posteriorly; its lateral border stretches from the infratemporal crest to the base of the mastoid process. Three parts are distinguished in the external surface of the base of the skull: anterior, middle, and posterior.

The anterior part is formed of the hard palate (*palatum osseum)* and the alveolar arch of the maxilla. The anterior part on each side is formed by the *palatine process of the maxilla*, the *horizontal plate of the palatine bone*, the *alveolar process of the maxilla*, the *maxillary tuberosity* and the *zygomatic bone*. Medially the *vomer* separates the *posterior nasal apertures*, the *choanae*. The *palatine processes* meet at the *median palatine suture (sutura mediana)*, whose anterior end is marked by the *incisive foramen*. From there laterally to the 2nd incisor runs the *incisive suture*, which may sometimes be evident. The horizontal plate of the palatine bone contains the *greater palatine foramen (foramen palatinum majus),* the exit from the greater palatine canal, still further to the back, on the inferior surface of the pyramidal process, are the openings of the lesser palatine canals, the *lesser palatine foram-*

ina. From the greater palatine foramen the *palatine grooves* extend anteriorly. The *transverse palatine suture (sutura transversa)* lies between the maxilla and the palatine bone.

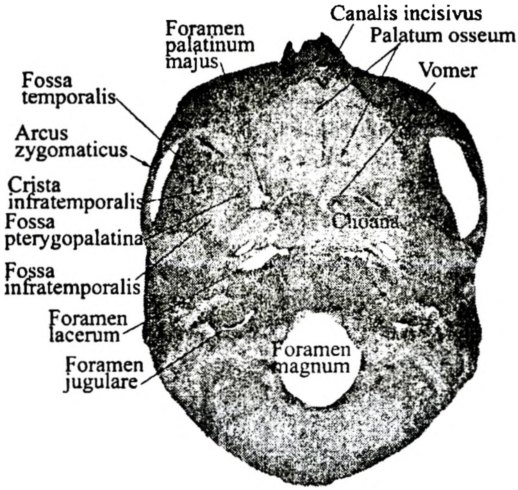

Fig. 39. Cranium – norma basalis (Basis cranii externa)

The middle part extends from the posterior edge of the hard palate to the anterior margin of foramen magnum. On the anterior border of this part are openings, *choanae*. They are isolated from each other by the vomer; they are bounded above by the body of the sphenoid bone, below by the horizontal plates of the palatine bones, and laterally by the medial plates of the pterygoid processes. In the posterior part of the base of the skull is the jugular foramen *(foramen jugulare)*, formed by the jugular fossa of the temporal bone and the jugular notch of the occipital bone. The jugular foramen transmits the ninth, tenth, and eleventh cranial nerves, and the jugular vein originates here.

In the center lies the *body of the sphenoid bone* and laterally its *greater wing* with the *infratemporal crest*. The greater wing bears the *sphenoid spine*, whose base is pierced by the *foramen spinosum*. Between the foramen spinosum and the foramen lacerum opens the *foramen* ovate, and between the sphenoid bone and the petrous part of the temporal bone we find the *sphenopetrpsal fissure*. From the latter the groove of the *auditory tube* extends posterolaterally. The *external aperture of the cochlear canaliculus* is found on the side of the *jugular fossa* and adjacent to the *external aperture of the carotid canal*. This is limited laterally by the *jugular and occipital processes*. Between the jugular fossa and the external aperture of the carotid canal is a small depression, the *fossula petrosa,* in which the canaliculus for the tympanic nerve opens. Next to this are the *tympanic part* of the temporal bone and the *styloid process* within its sheath. Immediately posterior to the process is the *stylomastoid foramen.* On the *mastoidprocess* is the *mastoid notch,* and medial to it is the *occipitomastoid suture* with a *groove for the occipital artery.* Anterior to the mastoid process lies the opening of the *external acoustic meatus,* which is bounded by the *tympanic part* and the *squamous part.*

The tympanic and squamous parts, as well as a small ridge of the petrous part, the *tegmental crest* bounded by the *petrotympanic* and *petrosquamous fissures,* form the *mandibular fossa.* This is limited anteriorly by the *articular tubercle.* The *zygomatic process* of the *temporal bone* extends anterolaterally. The *basilar part* of the occipital bone, which bears the *pharyngeal tubercle,* fuses with the *body of the sphenoid bone.* The *petrooccipital fissure* runs between the petrosal part of the temporal and the occipital bone. The jugular fossa is widened by the notch in the adjacent occipital bone to form the *jugular foramen.* The *foramen magnum* is bounded laterally by the *occipital condyles.* At the posterior border there is a *condylar fossa* which is perforated by an opening, the *condylar canal.* Beginning at the foramen magnum, the *external occipital crest* runs upwards toward the *external occipital protuberance.*

The posterior part of the base of the skull consists of the sphenoid bone the temporal bones and the occipital bone. The pterygoid processes form the lateral borders of the choanae. We distinguish a *medial plate,* with its *hamulus* and a *lateral plate.* Between them lies the *pterygoid fossa.* At the root of the medial plate is the *scaphoid fossa* and next to it the *foramen lacerum.*

INTERIOR VIEW OF THE BASE OF THE SKULL (BASIS CRANII INTERNA)

The **upper surface** of the base of the skull *(basis cranii interna)* can be examined only on a horizontal or sagittal section of the skull. The following bones form the inner surface of the base of the skull: the ethmoid bone, the frontal bone, the sphenoid bone, the temporal bones, the occipital bone and the parietal bones. The internal or superior surface of the base of the skull is separated into three fossae (Fig. 40). The anterior and middle fossae lodge the cerebrum, while the posterior fossa lodges the cerebellum. The posterior edges of the lesser wings of the sphenoid bone are the borderline between the anterior and middle fossae, and the superior edge of the pyramids of the temporal bones is the borderline between the middle and posterior fossae. The anterior cranial fossa is separated from the middle fossa by the *lesser wings of the sphenoid* and the *jugum sphenoidale.* The middle and posterior cranial fossae are separated from each other by the *superior borders* of the petrosal portions of the temporal bones and the *dorsum sellae.*

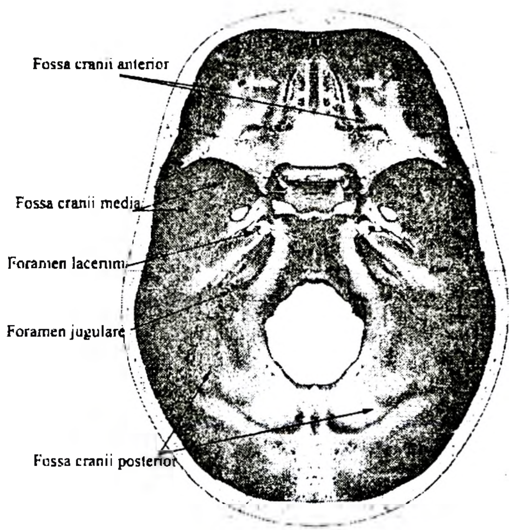

Fig. 40. Basis cranii interna

The **anterior cranial fossa** *(fossa cranii anterior)* is formed by the orbital part of the frontal bone, the cribriform plate of the ethmoid bone, and the lesser wings of the sphenoid bone. It is distinguished by pronounced digitate impressions and cerebral ridges (juga cerebralia). The *cribriform plate* formed by the ethmoid bone contains many small holes and bears in the midline the vertical *crista galli* with its *alar processes*. Anterior to the crista galli is the *foramen caecum* and laterally lie the *orbital plates* of the frontal bone with their *impressiones digitatae*. The cribriform plate is joined to the sphenoid bone by the *sphenoethmoidal suture*. In the middle, the *prechiasmatic groove* lies between the *optic canals*. The *anterior clinoid processes* border the optic canals.

The **middle cranial fossa** *(fossa cranii media)* is located deeper than the anterior fossa. Its median part is formed by the sella turcica. The lateral parts are made up of the greater wings of the sphenoid bone, the squamous part of the temporal bones, and the anterior surface of their pyramids. The openings of the middle fossa are as follows: the optic canal, the superior orbital fissure, foramen rotundum, the oval foramen, and the spinous foramen. In the center of the middle cranial fossa there is the *sella turcica* with the *hypophysial fossa* and lateral to the sella the *carotid groove*, which is the prolongation of the carotid canal. The carotid canal, which lies on the anterior wall of the petrous part of the temporal bone, is split open in its medial portion near the *foramen lacerum*. The medial end of the canal is bounded by the *lingula of the sphenoid bone*. Lateral to the carotid groove is the *foramen* ovale, in front the *foramen rotundum* and lateral the *foramen spinosum*. The *groove for the middle meningeal artery* runs laterally from the foramen spinosum. Near the apex of the petrous part, the *trigeminal impression* can be seen, and lateral and somewhat posterior to it is the *hiatus for the* tinues toward the sphenopetrosal fissure as the *groove for the greater petrosa nerve*. The *hiatus for the lessei petrosal nerve* lies immediately anterolateral to that of the greater petrosa nerve. The *superior* border of the petrous part carries the more or less well-developed *groove of the superior petrosal sinus*. A prominent swelling, the *arcuate eminence*, is produced by the anterior semicircular canal. The squamous part of the temporal bone is joined to the sphenoid bone by the *sphenosquamous suture*.

The **posterior cranial fossa** *(fossa cranii posterior)* is the deepest and largest of the three fossae. Its components are the occipital bone, the posterior parts of the body of the sphenoid bone, the petrous part of the temporal bone, and the inferoposterior angle of the parietal bone. The following openings are found in it: foramen magnum, hypoglossal canal, jugular foramen, condylar canal (sometimes absent), mastoid foramen (occurring most regularly), porus acusticus internus (on the posterior surface of the pyramid).

The *foramen magnum* lies in the middle of the posterior cranial fossa. The *clivus* ascends anteriorly and ends in the *dorsum sellae* and its *posterior clinoid processes*.

Between the occipital bone and the petrous part of the temporal lies the *groove of the inferior petrosal sinus* and also the petrooccipital synchondrosis, which may be seen in the macerated skull as the *petro-occipital fissure*. The groove of the inferior petrosal sinus ends in *the jugular foramen*. The *opening of the internal acoustic meatus* opens onto the posterior surface of the petrous part. Lateral to it, hidden under a small bony ridge, lies the *external opening of the vestibular aqueduct*. The jugular foramen is formed by the apposition of the jugular notches in the temporal and occipital bones. *The jugular notch in the occipital bone* is limited anteriorly by the projection of the *jugular tubercle*, and the jugular foramen is partly divided by the *intrajugular process of the temporal bone*. On its lateral side the jugular foramen is reached by the *groove of the sigmoid sinus* which continues posteriorly into the *groove of the transverse sinus*. This extends to the internal *occipital protuberance*, from which the *internal occipital crest* runs toward the foramen magnum. On either side of the anterior rim of the foramen magnum is the opening of the *hypoglossal canal*. The clivus is formed by the body of the sphenoid bone and the basilar part of the occipital bone. During puberty they fuse but previously they are connected by the sphenooccipital synchondrosis.

Common Variants of the Interior Surface of the Base of the Skull

In the middle cranial fossa, in the region of the sella turcica, a number of variants can be seen in radiographs. In some cases the *lingula* of the sphenoid bone, which is directed toward the temporal bone, may be fused with it.

Between the anterior and posterior clinoid processes there may be an additional process, the *middle clinoid process*. The latter may then fuse with the anterior clinoid process, when it forms a special opening, the *caroticoclinoid* foramen. Through this, the carotid notch, which lies medial to the anterior clinoid process, becomes an opening surrounded by bone on all sides. Another variant is the presence of an *interclinoidal bridge* between the anterior and posterior clinoid processes. This bony fusion of the two processes, when seen on radiographs, is termed the *sella bridge*. It may be present on one or both sides and can fuse with the middle clinoid process if it is present.

Between the foramen ovale and the body of the sphenoid bone, there is sometimes an aperture, which serves as the exit for a vein. This opening, the *foramen venosum* is also called the sphenoidal emissarium or the foramen of Vesalius. It is not very uncommon and it permits communication between the cavernous sinus and veins on the outside of the skull. The foramen of Vesalius may be present on one or both sides.

In some cases the dorsum sellae may be so eroded laterally by more extensive looping of the internal carotid artery that it no longer has any bony connection with the clivus. In that case, the dorsum sellae will be absent from the macerated skull.Sometimes the internal occipital crest is divided into two and between the parts is the well-developed *groove of the occipital sinus*. This may extend into a marginal groove, running lateral to the foramen magnum, to the jugular foramen.

The jugular foramina may be unequal in size, more often the left being smaller than the right. *The hypoglossal canal may be divided into two.*

The apex of the petrous part of the temporal bone may have a bony connection with the dorsum sellae. This bony bridge is also known as the *abducent bridge*, since the abducent nerve runs beneath it.

ORBITAL CAVITY (ORBITA)

The **orbits**, or **eyesockets** *(orbitae)* contain the organ of vision and are cavities in the shape of somewhat rounded, four-sided **pyramids** (Fig. 41). The apex of the pyramid lying deep inside and the base forming the orbital opening. It is demarcated by various bones. The base of the pyramid corresponds to the opening into the orbit *(aditus orbitae)*, while the apex is directed backward and medially. The medial orbital wall *(paries medialis)* is formed by the frontal process of the maxilla, the lacrimal bone, the orbital plate of the ethmoid bone, and the body of the sphenoid bone to the front of the optical canal. The orbital surfaces of the zygomatic bone and greater wings of the sphenoid bone form the lateral wall *(paries lateralis)*. The superior wall *(paries superior)* or the roof of the orbit is formed by the orbital part of the frontal bone and lesser wings of the sphenoid bone; the inferior wall *(paries inferior)* or floor of the orbit is made up of the zygomatic bone and maxilla, and in the posterior portion by the orbital surface of the orbital process of the palatine bone.

Orbital openings. Two openings are seen at the apex of the pyramid: a large lateral opening, the superior orbital fissure *(fissura orbitalis superior)*, and a smaller round medial opening, the optic canal *(canalis opticus)*; by means of both openings the orbit communicates with the cranial cavity.

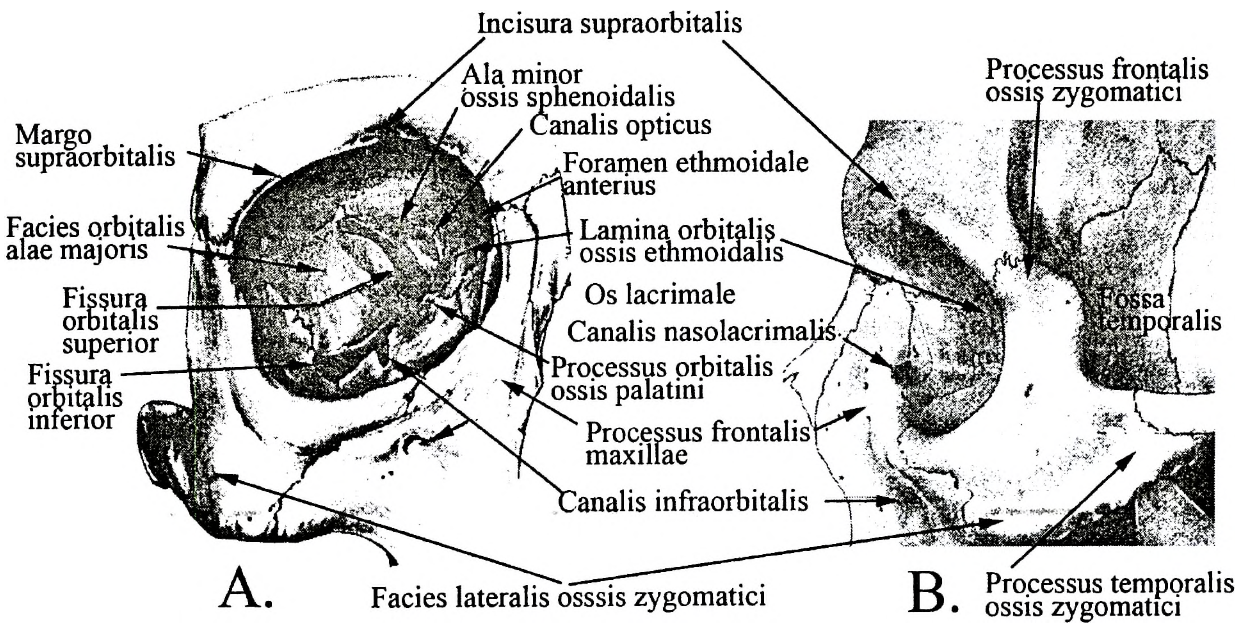

Fig. 41. Orbita
A- anterior view; B- lateral view.

In the corner formed by the lateral and inferior orbital walls is the inferior orbital fissure *(fissura orbitalis inferior)*, which is bounded laterally by the greater wing of the sphenoid bone and medially by the edge of the maxilla; its posterior end leads into the pterygopalatine fossa and the anterior end into the infratemporal fossa.

Near the entrance into the orbit lies the **groove for the lacrimal sac** which is bounded anteriorly and posteriorly by the *anterior (crista lacrimalis anterior)* and the *posterior lacrimal crests (crista lacrimalis posterior)*. It leads into the **fossa of the lacrimal sac** *(fossa sacci lacrimalis)* is in the anterior part of the medial wall; it is bounded by the frontal process of the maxilla in front and by the lacrimal bone in the back and leads into the **nasolacrimal canal** *(canalis nasolacrimalis)*. The other end of the lacrimal canal opens into the inferior nasal meatus. Further to the back, in the suture between the frontal and ethmoid bones, are two openings, the anterior and posterior **ethmoidal foramina** *(foramina ethmoidale anterius* and *posterius)*, transmitting the anterior and posterior ethmoidal vessels and nerves. The anterior foramen leads into the cranial cavity, the posterior foramen into the nasal cavity.

In the immediate neighborhood of the orbits are the paranasal sinuses. The variably sized orbital recess of the *frontal sinus* extends into the roof of the orbit. Medially lie the ethmoid cells and dorsally the sphenoidal sinus. Inferiorly, the orbit is separated from the *maxillary sinus* by a thin plate of bone.

NASAL CAVITY (CAVITAS NASALIS)

The cavity of the nose *(cavitas nasalis)* is the initial part of the respiratory tract and lodges the organ of olfaction. The piriform aperture leads into the cavity in front, and the paired openings, the choanae, connect it with the cavity of the pharynx. The bony septum of the nose (septum nasi osseum) divides the nasal cavity into two halves, which are not quite symmetrical, in most cases the septum deviates to one of the sides from the sagittal plane. Eachhalf of the nasal cavity has five walls: superior, inferior, lateral, medial, and posterior.

We distinguish a right and a left nasal cavity separated medially by the nasal septum. The septum often deviates from the midline. The nasal cavities open anteriorly into the piriform aperture and posteriorly each opens via the choana into the pharynx.

The anterior bony aperture of the nose *(apertura piriformis nasi)* is below and partly between the orbits. Laterally and interiorly it borders on the maxilla and superiorly and partly laterally on the free edges of the nasal bones. The anterior nasal spine *(spina nasalis anterior)* projects forward on the midline on the inferior margin of the piriform aperture. It is continuous posteriorly with the bony septum of the nose.

The nasal septum consists of cartilaginous and bony elements. The cartilaginous septum with its *posterior process* completes the bony partition between the two nasal cavities. The medial crus of the major alar cartilage is superimposed on each side on the septal cartilage as the medial border of the anterior opening of the nose. The bony partition, the septum nasi osseum, is formed by the *perpendicular plate of the ethmoid*, the *sphenoidal crest* and the *vomer*. The floor of the nasal cavity is formed by the *maxilla* and the *palatine bone*. The roof is formed anteriorly by the *nasal bone*, and then by the *cribriform plate of the ethmoid*.

The *lateral wall* is the most complex in structure; it is formed of the following (from front to back) bones: the nasal bone, the nasal surface of the body and frontal process of the maxilla, the lacrimal bone, the labyrinth of the ethmoid bone, the inferior concha, the perpendicular plate of the palatine bone, and the medial plate of the pterygoid process of the sphenoid bone (Fig. 42).

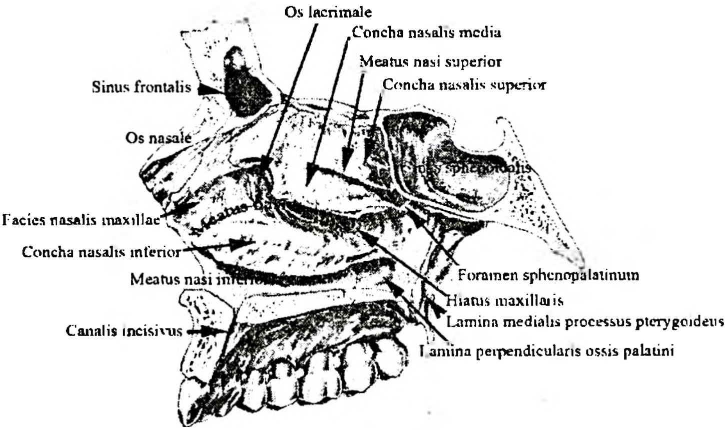

Fig. 42. Paries lateralis caviti nasalis ossea

The lateral wall of each nasal cavity is made irregular by the three turbinate bones, the conchae nasales and the underlying ehtmoidal cells. The *superior* and *middle concha* belong to the ethmoid bone, while the *inferior concha* is a separate bone of the skull.

Three nasal conchae project downward into the nasal cavity from the lateral wall; they separate the three nasal meatuses — superior, middle, and inferior—from each other. The superior nasal meatus *(meatus nasi superior)* is between the superior and middle conchae of the ethmoid bone; it is half the length of the middle meatus and is found only in the posterior part of the nasal cavity; it communicates with the sphenoid sinus and sphenopalatine foramen and the posterior air cells of the ethmoid bone open into it. The middle nasal meatus *(meatus nasi medius)* passes between the middle and inferior conchae. The anterior and middle cells of the ethmoid bone and the maxillary sinus open into it and a projection of the ethmoidal labyrinth *(bulla ethmoidalis)* (a rudiment of an accessory concha) is seen lateral to the middle concha. To the front of and a little below the bulla is a funnel-shaped passage *(infundibulum ethmoidale)* by means of which the middle nasal meatus communicates with the anterior ethmoidal cells and the frontal sinus. These anatomical communications explain the spread of the inflammatory process to the frontal sinus (frontitis) in rhinitis. The inferior nasal meatus *(meatus nasi inferior)* is between the inferior nasal concha and the floor of the nasal cavity. The nasolacrimal canal opens into its anterior part; through this canal the tears flow into the nasal cavity. That is the reason the amount of nasal discharge increases when a person cries and, conversely, the eyes "water" in rhinitis. The space between the conchae and the nasal septum is known as the common meatus of the nose *(meatus nasi communis).*

Behind the superior conchae lies the *sphenoethmoidal recess* into which the sphenoidal sinuses open. The *sphenopalatine foramen* lies in the lateral wall of the recess. It connects it to the pterygopalatine fossa. After removal of the three conchae, the *superior, medial* and *inferior nasal meati* are revealed, and the *perpendicular plate of the palatine bone* is fully exposed. The openings of the posterior ethmoidal cells can be seen in the superior nasal wall.

In the middle nasal meatus, the *uncinate process* partly covers the *maxillary hiatus* which connects the maxillary sinus with the nasal cavity. Superior to this process is the ethmoidal bulla, a particularly large anterior ethmoidal cell. Above and below the bulla the middle and the anterior ethmoidal cells open into the middle meatus of the nasal cavity.

Between the ethmoidal bulla and the uncinate process is the *ethmoidal infundibulum*, across which the *frontal sinus*, the *maxillary sinus* and the anterior ethmoidal cells are connected with the nasal cavity. The uncinate process also partly covers the *lacrimal bone*, which forms the lateral wall together with the *maxilla* and the ethmoid bone.

The *nasal opening of the nasolacrimal duct* lies in the inferior nasal meatus.

The *medial wall,* or the *osseous nasal septum (septum nasi osseum)* is formed by the perpendicular plate of the ethmoid bone and the vomer, above by the nasal spine of the frontal bone, posteriorly by the rostrum of the sphenoid bone, and inferiorly by the nasal crests of the maxilla and palatine bone.

The *superior wall* is made up of a small area of the frontal bone, the cribriform plate of the ethmoid bone, and partly the sphenoid bone.

The *inferior wall,* or floor, is formed by the palatine process of the maxilla and the horizontal plate of the palatine bone which make up the bony hard palate (palatum osseum); the opening of the incisive canal (canalis incisivus) is seen in its front part.

The *posterior wall* is very short and is found only in the superior part because the choanae are located below it. It is formed by the nasal surface of the body of the sphenoid bone with the paired aperture of the sphenoid sinus.

LATERAL VIEW OF THE SKULL (NORMA LATERALIS)

On examination of the skull from the side (*norma lateralis*), the temporal lines *(lineae temporales) (superior* and *inferior),* strike the eye first of all (Fig. 43). Each line rises at the zygomatic process of the frontal bone, curves upward and to the back to intersect the coronary suture, and then passes over to the parietal bone on which it runs in the direction of the mastoid angle and, curving anteriorly, extends to the temporal bone. It marks the attachment of temporal muscle and fascia.

Fig. 43. Cranium – norma lateralis

In the orbitomeatal plane, which runs through the inferior margin of the orbit and the superior margin of the external acoustic meatus, the **neurocranium** shows the *planum temporale*, which includes part of the temporal bone, the parietal bone, parts of the frontal bone and the sphenoidal bone. The temporal fossa is limited above by the somewhat more prominent *inferior temporal line* and the less obvious *superior temporal line*. From the *squamous part of the temporal bone* the *zygomatic process* extends anteriorly, and with the *temporal process* of the zygomatic bone it forms the *zygomatic arch*. Inferior to the root of the zygomatic process lies the *external acoustic meatus* which is bordered mainly by the tympanic part and to a lesser extent by the squamous part of the temporal bone. Immediately above this there is often a small *suprameatal spine* and a small cavity, *foveola suprameatica*. Posterior to the external meatus lies the *mastoid process*, which originated as a muscular apophysis. The *mastoid foramen* lies at the root of the mastoid process.

On examining the **viscerocranlum** we see above the orbit the *supraciliary arch* as a prominent ridge. Below it is the *supraorbital margin* with the *supraorbital notch*. The supraorbital margin is continued over the anterolateral margin of the orbital opening into the *infraorbital margin*. The latter is formed by the zygomatic bone and the *frontal process of the maxilla*. Medially is a depression, the fossa for the lacrimal sac.

There are one (or two) small foramina in the zygomatic bone, the *zygomatico-facial foramen*. Below the infraorbital margin lies the *infraorbital foramen*. At the lowest point of the nasal opening the *anterior nasal spine* is seen. The maxilla (dark yellow) has an *alveolar process* directed downward, which carries the maxillary teeth. The *maxillary tuberosity bulges out posterior to this.*

The following depressions merit special description because of their important topographical relations:

(1) the temporal fossa *(fossa temporalis),*

(2) the infratemporal fossa *(fossa infratemporalis);* and

(3) the pterygopalatine fossa *(fossa pterygopalatina).*

The **temporal fossa** *(fossa temporalis)* is bounded superiorly and posteriorly by the temporal line, inferiorly by the infratemporal crest and the inferior margin of the zygomatic arch, and anteriorly by the zygomatic bone. Thus the frontal and parietal bones, the greater wing of the sphenoid bone, the squama of the temporal bone, and the zygomatic bone take part in its formation. The temporal fossa lodges the temporal muscle.

The **infratemporal fossa** *(fossa infratemporalis)* is continuous downward with the temporal fossa, and their borderline is the infratemporal crest of the greater wing of the sphenoid bone. The *medial wall* of the infratemporal fossa is formed by the lateral plate of the pterygoid process. The *anterior wall* is formed by the infratemporal surface of the maxilla and the lower part of the zygomatic bone. The *superior wall* is formed by the inferior surface of the greater wing of the sphenoid bone and the oval and spinous foramina in it, as well as by a small area of the squamous part of the temporal bone. The infratemporal fossa is covered partly on the external surface by the mandibular ramus. It communicates with the orbit through the inferior orbital fissure and with the pterygopalatine fossa through the pterygomaxillary fissure.

The **pterygopalatine fossa** *(fossa pterigopalatina)* is located between the back of the maxilla (anterior wall) and the front of the pterygoid process (posterior wall). Its medial wall is the vertical plate of the palatine bone isolating the pterygopalatine fossa from the cavity of the nose. The pterygopalatine fossa may be approached from the lateral side through the *pterygomaxillary fissure*. Anteriorly to it lies the *maxilla*, posteriorly the *pterygoidprocess*, and medially the *perpendicular plate of the palatine bone*. It is an important junction area for vessels and nerves. It is connected with the cranial cavity by the *foramen rotundum* and with the lower surface of the base of the skull by the *pterygoid canal*. The *greater palatine canal* and the lesser palatine canal lead to the palate, the *sphenopalatine foramen* to the nasal cavity, and the *inferior orbital fissure* into the orbital cavity.

The following five openings are found in the pterygopalatine fossa: (1) a medial opening, the sphenopalatine foramen *(foramen sphenopalatinum)* leading into the nasal cavity and transmitting the sphenopalatine nerve and vessels; (2) a round posterosuperior opening *(foramen rotundum)* leading into the middle cranial fossa and transmitting the second branch of the trigeminal nerve which leaves the cranial cavity; (3) anterior opening, the inferior orbital fissure *(fissura orbitalis inferior)* leading into the orbit and transmitting the nerves and vessels; (4) an inferior opening, the greater palatine canal *(canalis palatinus major)* leading into the oral cavity; it is formed by the maxilla and the greater palatine sulcus of the palatine bone and is a funnel-shaped narrowing of the lower part of the pterygopalatine fossa and transmits the nerves and vessels leaving this fossa; (5) a posterior opening, the pterygoid canal *(canalispterygoideus)* transmitting the vegetative nerves (n. canalis pterygoidei) and leading to the base of the skull.

Sutures:

The *coronal suture* separates the frontal and parietal bones. It meets the *sphenofrontal suture*, which lies between the *greater wing of the sphenoid bone* and the frontal bone. The frontal and zygomatic bones are joined by the *frontozygomatic suture*. The *zygomaticomaxillary suture* lies between the zygomatic bone and the maxilla, and the *temporozygomatic suture* is found between the zygomatic and temporal bones. The *frontomaxillary suture* lies between the frontal bone and the maxilla, and the *nasomaxillary suture* is between the maxilla and the nasal bone. The *spheno-squamous suture* forms the boundary between the greater wing of the sphenoid bone and the temporal squama. The temporal bone joins the parietal bone at the *squamous suture*. It may extend into the mastoid process as the *petrosquamous suture* between its squamous and petrous parts.

The *lambdoid suture* separates the parietal from the occipital bone.

A small part of the greater wing of the sphenoid extends as far as the parietal bone, so that a *sphenoparietal suture* can be described. Between the mastoid process and the parietal bone on the one hand and the occipital bone on the other lie the *parietomastoid* and *occipitomastoid sutures*.

A SAGITTAL SECTION OF THE SKULL

Examination of a cranial section made in the midsagittal plane or, better, in the direct vicinity of this plane (so as to leave the bony septum of the nose intact in one of the cranial halves) allows study of certain structures that are less visible on other bone specimens. In the region of the frontal bone, it can be seen that the external and internal plates of the compact substance separate and form an air-filled space, the frontal sinus *(sinus frontalis),* which opens on each side into the middle nasal meatus (Fig. 44). The sphenoidal sinus *(sinus sphenoidalis)* is found in the body of the sphenoid bone. Vascular sulci, impressions of the vessels of the dura mater, are asily detectable on the inner surface of the parietal and frontal bones and the squama of the temporal bone.

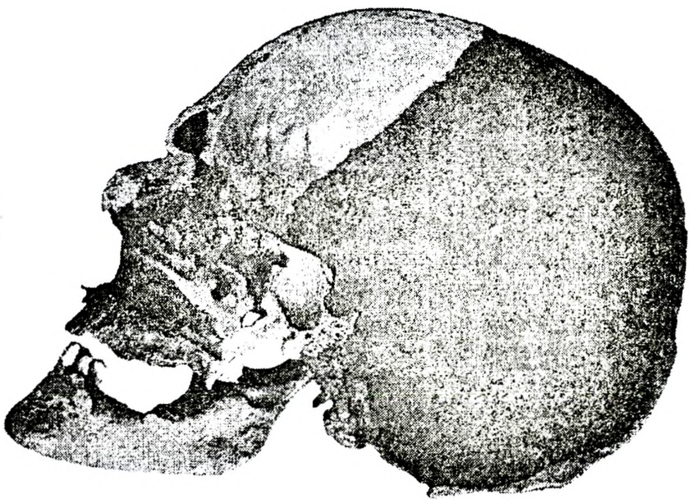

Fig. 44. Cranium – norma sagittalis

A sagittal section shows the striking predominance of the size of the cranium lodging the brain over the size of the visceral cranium, in contrast to the opposite situation in the scull of animals. The bony foundation of the nasal cavity can also be examined more closely on a sagittal section.

The topography of the Scull and its contents.
Basis cranii interna – interior view of the base of the skull.

I. Fossa cranii anterior.

1. *Foramen caecum* – transmits v. *emmissaria,* which connects *nasal cavity veins* and *sinus sagittalis superior.*

2. *Lamina et foramina cribrosae* os *ethmoidale* (openings of the cribriform plate of the ethmoid bone) – through which one from *regio olfactoria* cavum nasi extend 15-20 *filae olfactoriae* (I branch of the cranial nerves – n.n. olfactorii).

3. *Canalis opticus* in which transmits:

a) n. *opticus* – II branch of the cranial nerves

b) a. *ophalmica* – branch of the a. *carotis interna*.

II. Fossa cranii media.

1. *Fissura orbitalis superior* – in which:

a) n. *oculomotorius* – III branch of the cranial nerves

b) n. *trochlearis* – IV branch of the cranial nerves

c) n. *ophthalmicus* – first branch of the *nervus trigeminus* – V branch of the cranial nerves

d) n. *abducens* – VI branch of the cranial nerves

e) a. *ophthalmica superior* – run into the *sinus cavernosus*

2. *Fossa hypophysealis* – lies *hypophysis*

3. *Sulcus sinus cavernosus* - in which III, IV, VI branches of the cranial nerves located, n. *ophthalmicus, a. carotis interna* and *plexus caroticus internus.*

4. *Foramen rotundum* – transmits n. *maxillaris* - II branch of the n. *trigemini*.

5. *Foramen ovale* - через нее проходят:

a) n. *mandibularis* third branch of the n. *trigemini.*

b) *ramus meningeus accessorius* → a. meningea media → a. maxillaris → a. carotis externa.

6. *Foramen spinosum*

a) a. *meningea media* → a. maxillaris

b) *ramus meningeus* → ex n. mandibularis.

7. *Foramen lacerum* - through it pass or lie number (series):

a) n. *petrosus minor* → n. tympanicus → n. glossopharyngeus (IX pair of cerebral nerves)

b) n. *petrosus major* → n. facialis (VII pair of cerebral nerves)

c) n. *petrosus profundus* → ex *plexus caroticus internus*

d) a. *carotis interna* – lies above *foramen lacerum.*

8. *Hiatus canalis n. petrosi majoris* - through which n. *petrosus major* leaves and lies in the groove with same name

9. *Hiatus canalis n. petrosi minoris* - through which n. *petrosus minor* leaves and lies in the groove with same name

10. *Impressio trigemini* – in which *ganglion trigeminale (Gasseri)* lies.

III. Fossa cranii posterior.

1. *Clivus* – where a. *basilaris* (ex a. vertebralis → a. subclavia), *myelencephalon pons* lie.

2. *Porus* et *meatus acusticus internus* – in which passes:

a) n. *facialis* – VII pair of cerebral nerves

b) n. *vestibulocochlearis* – VIII pair of cerebral nerves

c) a. *labyrinthi* → a. cerebelli inferior anterior → a. basilaris

d) v. *labyrinthi* → in the sinus petrosus superior

e) *Ganglio vestibulare (Scarpae)* – which one lies on the floor.

3. *Foramen jugulare* transmits the ninth, tenth, and eleventh cranial nerves, and the jugular vein originates here:

a) *v. jugularis interna* originates here (v. jugularis continuation of the *sinus sigmoideus*)

b) *n. glossopharyngeus* – IX branch of the cranial nerves
c) *n. vagus* – X branch of the cranial nerves
d) n. *accessorius* – XI branch of the cranial nerves
e) a. *meningea posterior* → a. pharyngea ascendens → a. carotis externa
f) *Ganglia superior* et *inferior* n. *glossopharyngei*
j) *Ganglia superior* et *inferior* n. *vagi*.

4. Canalis hypoglossalis – in which n. *hypoglossus* passes– XII branch of the cranial nerves.

5. *Foramen magnum*
a) The place where *myelencephalon* passes into *medulla spinalis*
b) *Arteriae vertebrales* ex a. subclavia
c) *Plexus vertebralis* (ex ganglia cervicothoracica)
d) V.v. *vertebrales* runs in v.v. brachiocephalicae
e) A.a. *spinales anterior* et *posterior* pass in canalis vertebralis.

6. *Canalis condylaris* – v. emmissaria condylaris

7. *Foramen mastoideum* – through which pass:
a) *Vena emmissaria mastoideum*
b) *Ramus meningeus arteriae occipitalis*

Basis cranii externa.

1. *Canalis incisivus* - passes n. *nasopalatinus* – branch of the n.n. nasales posteriores superiores – gang. pterygopalatinum.

2. *Canales palatinus major* et *minor*:
a) A.a. *palatina descendens* → a. maxillaris → a. carotis externa (in the fossa pterygopalatina)
б) N.n. *palatini* – from ganglion pterygopalatinum

3. *Fissura orbitalis inferior* – in which pass:
a) A. *infraorbitalis* → a. maxillaris (from pterygopalatin part) → a. carotis externa
b) N. *infraorbitalis* → n. maxillaris (II branch of the n. *trigemini*)
c) *Foramen ovale, spinosum, lacerum* – see above.

4. *Foramen caroticum externum* (external carotid opening) in which a. *carotis interna* et *plexus caroticus internus* lies.

5. *Foramen stylomastoideum* – by it *canalis facialis* finishes, and *nervus facialis* (VII branch of the cerebral nerves) leaves

6. *Fissura petrotympanica (Glasseri)* – by it one *canaliculus chordae tympani* finishes, and chorda tympani ex n. facialis leaves.

7. *Fissura tympanomastoidea*, in which *canaliculus mastoideus* finishes, and *ramus auricularis ex n. vagi* leaves.

8. *Apertura inferior canaliculi tympanici* lies in the *fossula petrosa*, in which canaliculus for the tympanic nerve opens (n. *tympanicus*).

9. *Foramen jugulare, magnum, mastoideum, canalis hypoglossalis* et *condylaris* – see above.

Orbita – orbital cavity.

1. *Fossa glandulae lacrimalis* (the fossa of the lacrimal glandula) – the place of the glandula lacrimalis.

2. *Fossa sacci lacrimalis* (the fossa of the lacrimal sac) – the place of the saccus lacrimalis.

3. *Canalis nasolacrimalis* (nasolacrimal canal) – the nasal opening of the nasolacrimal duct lies in the *meatus nasi inferior* (opens into the inferior nasal meatus).

4. *Foramen ethmoidale anterior et posterior* (the anterior and posterior ethmoidal foramina)

a) A.a. ethmoidales anterior et posterior → a. ophalmica → a. carotis interna.

b) V.v. ethmoidales anterior et posterior впадают в v. ophalmica superior → sinus cavernosus.

c) N.n. ethmoidales anterior et posterior ex n. nasociliares → n. ophalmicus (I branch of n. *trigemini*).

5. *Foramen zygomaticoorbitale* (the zygomatico-orbital foramen) in which n. zygomaticus ex n. maxillaris (II branch of n. *trigeminus*).

6. *Sulcus, canalis* et *foramen infraorbitale* → arteria, vena et nervus infraorbitalis.

7. *Fissurae orbitales superior et inferior, canalis opthicus* (see above).

Cavum nasi – nasal cavity.

1. *Choanae* (the paired openings) – connects in to the cavity of the pharynx (with the *pars nasalis pharyngis)*.

2. *Foramen ethmoidale anterior et posterior, canalis nasolacrimalis, canalis incisivus (*is seen in the frontal part of the nasal cavity), – see above.

3. *Foramen sphenopalatinum* – connects in to the *fossa pterygopalatina*

a) A. sphenopalatina → a. maxillaris → a. carotis externa.

b) R.r. nasales posteriores superiores mediales et laterales → from *ganglion pterygopalatinum*

c) R.r. nasales posteriores inferiores – from *ganglion pterygopalatinum*

Sinuses paranasales:

1. *Sinus maxillaris* (*antrum Highmori*) opens through *hiatus sinus maxillaris* into *meatus nasi medius.*

2. *Sinus frontalis* opens through *infundibulum ethmoidale* into *meatus nasi medius.*

3. *Sinus sphenoidalis* - opens by means of the *aperturae sinus sphenoidalis* into *recessus sphenoethmoidalis.*

4. *Cellulae ethmoidales anteriores* et *media* - connects with the *meatus nasi medius.*

5. *Cellulae ethmoidales posteriores* - connects with the *meatus nasi posterior*

Fossa pterygopalatina – the pterygopalatin fossa.

The walls of the pterygopalatin fossa (paries):

a) Paries anterior – tuber maxillae

b) Paries posterior – processus pterygoideus

c) Paries medialis – lamina perpendicularis os palatini.

Openings:

1. By *fissura orbitalis inferior* with *orbitae*

2. *Foramen sphenopalatinum* – with *cavum nasi*

3. *Foramen rotundum* – with *fossa cranii media*

4. *Canalis palatinus major* – with *cavum oris*

5. *Canalis pterygoideus* - with area of the *foramen lacerum* (in wich lies *nervus canalis pterygoideus*: n. petrosus major + n. petrosus profundus).

Sites for Transmission for Vessels and Nerves

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

In the region of the anterior cranial fossa the *olfactory nerves* and the *anterior ethmoidal artery* pass through the cribriform plate to the nasal cavity.

The *optic nerve* and the *ophthalmic artery* run through the optic canal. Apart from the optic canal the superior orbital fissure also forms a communication between the skull and the orbit. The *superior ophthalmic vein*, the *lacrimal nerve*, the *frontal nerve* and the *trochlear nerve* run in its lateral part. The *abducent nerve*, the *oculomotor nerve* and the *nasociliary nerve* pass through it more medially.

The *maxillary nerve* passes through the foramen rotundum, while the *mandibular nerve*, together with a *venous plexus of the foramen* ovate which joins the cavernous sinus to the pterygoid plexus, runs through the foramen ovale. A recurrent branch of the mandibular nerve, the *meningeal branch*, together with the *middle meningeal artery*, reaches the cranial cavity through the foramen spinosum. The largest structure in the middle cranial fossa, the *internal carotid artery* passes through the carotid canal into the cranial cavity. The internal carotid artery is surrounded by the *sympathetic carotid plexus and a venous plexus of the internal carotid artery*. The *greater petrosal nerve* becomes visible at the hiatus for the greater petrosal nerve, and the *lesser petrosal nerve* runs through the hiatus for the lesser petrosal nerve together with the *superior tympanic artery*.

In the posterior cranial fossa, the ***medulla oblongata*** lies and on both side of it the *spinal part of the accessory nerve*, pass through the foramen magnum. Two large *vertebral arteries*, the small *anterior spinal artery*, the paired small *posterior spinal arteries* and the *spinal vein* also pass through the foramen magnum.

The *hypoglossal nerve* and the *venous network of the hypoglossal canal* pass through the hypoglossal canal. The *glossopharyngeal nerve*, the *vagus* and the *accessory nerve*, as well as the *inferior petrosal sinus*, the *internal jugular vein* and the *posterior meningeal artery* all pass through the jugular foramen.

The internal acoustic meatus transmits the *labyrinthine artery and vein*, the *vestibulocochlear nerve* and the *facial nerve*.

On the *outer surface of the base of the skull* the *facial nerve* becomes visible as it emerges from the stylomastoid foramen through which the *stylomastoid artery* enters the skull.

The *anterior tympanic artery* and the *chorda tympani* traverse the petrotympanic fissure.

The *greater palatine artery* and the *greater palatine nerve* pass through the greater palatine foramen in the hard palate, and the *lesser palatine arteries and nerves* run through the lesser palatine foramina. The *naso-palatine nerve* and an artery run through the incisive canal toward the palate.

The *emissary condylar vein* runs through the condylar canal.

THE X-RAY IMAGE OF AN ADULT SKULL

To understand the superimpositions of the skull bones on the radiograph, the following circumstances must be borne in mind: (1) the cranial bones and their parts formed of bone substance that is more compact than other bone substance (e.g. the petrous part of the temporal bone) produce shadows on the radiograph of greater density; (2) bones and their parts, which are made up of substance that is less compact (e.g. diploe), produce shadows of lesser density; (3) air cavities are seen as unshadowed areas; (4) shadows cast by parts of the skull bones that are nearer to the X-ray film are contrasted more sharply than the shadows of remote parts. The anterior parts of bones, therefore, are more sharply contrasted on an anteroposterior radiograph, and vice versa.

An *anteroposterior radiograph* demonstrates dense shadows of the skull bones and teeth and clear areas at the site of the air sinuses.

A *lateral radiograph* shows different parts of the cerebral and visceral skull. The bones of the vault are separated by sutures from which wave-like bands of low density corresponding to the canals of the diploic veins must be distinguished. These bands do not have the serrate character typical of the sutures and stretch in other directions. Knowledge of the X-ray picture of sutures and vascular canals helps to differentiate them from infractions of the skull. The "X-ray joint cavity" of the temporomandibular joint is demonstrated clearly as a curved band of low density corresponding to the intra-articular disc.

X-ray examination is the only method of examination of the sella turcica in a living person. It is clearly demonstrated on a lateral radiograph. Since the sella lodges the cerebral hypophysis, the dimensions of this endocrine gland may be judged from the shape and size of the sella. Three types of sella turcica are distinguished: (1) foetal, a small sella in the form of a "prone" oval; (2) infantile, a large sella the shape of a "standing" oval; (3) adult, a large sella in the form of a "prone" oval. The process of pneumatization of the sphenoid sinus is also important. It begins from the age of 3 or 4 years in the anterior part of the body of the sphenoid bone and spreads from front to back with age with involvement of the dorsum sellae at old age.

AGE FEATURES OF THE SKULL

Fetal Skull. Some of the impotent differences between the fetal skull and the skull of the adult are as follows:

- the fetal skull is large in proportion to the rest of the skeleton;
- the facial skeleton is small as compared to the calvaria;
- the frontal and parietal tubera are prominent;
- the two halves of the frontal bone are separate. They are united by the metopic suture. The mandible is present in two halves. The temporal and occipital bones consist of four parts each;
- the mastoid process is absent. The external acoustic meatus is shot. As a result, the stylomastoid foramen and the facial nerve are much nearer the surface than in the adult.

The **skull of the newborn** is characterized by a small visceral cranium as compared to the cerebral part (Fig. 45). The skull cap develops in connective tissue and has several ossification centers from which bone formation radiates in all directions. In this way paired protuberances develop - two *frontal eminences* and two *parietal eminences*. The bones develop from these eminences.

The fontanelles *(fonticuli)* are another characteristic feature of a newborn's skull. The skull of a newborn infant carries traces of the three stages of ossification, which are not yet completed. The fontanelles are remnants of the first, membranous stage; they occur at the intersection of sutures where remnants of non-ossified connective tissue are found.

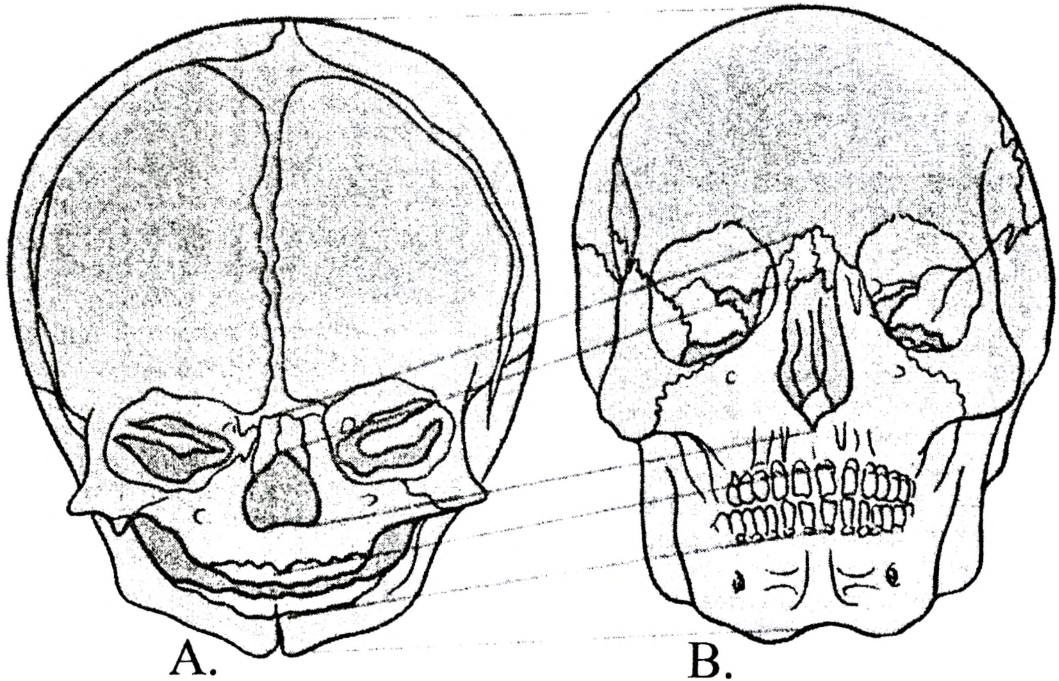

Fig. 45. A- skull of the newborn; B- skull of the adult.

At birth, large connective tissue areas, the *fontanelles* or *fonticuli*, are still left between the individual bones (Fig. 46). The *anterior fontanelle* is an unpaired opening closed by connective tissue, which is almost square and at birth has a diagonal length of 2.5-3 cm. The rhomboid anterior fontanelle *(fonticulus anterior)* located on the midline at the intersection of four sutures (sagittal, frontal, and two halves of the coronary sutures); it closes in the second year of life. The anterior fontanelle lies between the two frontal bone anlagen and both parietal an lagen.

The smaller, unpaired *posterior fontanelle* is also closed by connective tissue and is triangular in shape. The posterior fontanelle *(fonticulus posterior),* at the posterior end of the sagittal suture between the two parietal bones in front and the squama of the occipital bone at the back; it closes in the second month after birth. The posterior fontanelle lies between the two parietal bone anlagen and the anlage of the upper squama of the occipital bone.

The paired lateral fontanelles, two on each side; the anterior one is called sphenoidal *(fonticulus sphenoidalis)* and the posterior one is called mastoid *(fonticulus mastoideus).* The paired fontanelles lie laterally, of which the *sphenoidal fontanelle*, closed by connective tissue, is the larger and should be distinguished from the small *mastoid fontanelle*, which is occluded by cartilage (corresponding to a synchondrosis). The sphenoidal fontanelle lies between the frontal, parietal and sphenoid bones and the squama of the temporal bone; it closes in the second or third month of life. The mastoid fontanelle lies between the sphenoid, temporal and occipital bones (the mastoid angle of the parietal bone, the base of the pyramid of the temporal bone and the squama of the occipital bone). The sphenoidal and mastoid fontanelles are mostly found in premature infants; some full-term infants may also have no occipital (posterior) fontanelle.

Their presence is of high functional importance because they permit the bones of the vault of the skull to be displaced considerably as the skull adapts to the shape and size of the birth canal during delivery. The fontanelles only become closed after birth, the first being the posterior fontanelle in the 3rd month, the sphenoidal fontanelle follows in the 6th month, the mastoid fontanelle in the 18th month and the anterior fontanelle in the 36th month.

In the newborn and in infants the anterior fontanelle can be used for taking blood samples from the dural sinuses. Vene-puncture is also possible through the great fontanelle.

The remnants of connective tissue between the skull bones form the sutures, which permit continued growth of the bones. Only when the bones are completely fused as synostoses does growth cease.

Between some of the bones preformed in cartilage *(chondrocranium)*, there are cartilaginous areas (*synchondroses cranii*). The *sphenooccipital synchondrosis,* which ossifies at about the 18th year, is of practical interest.

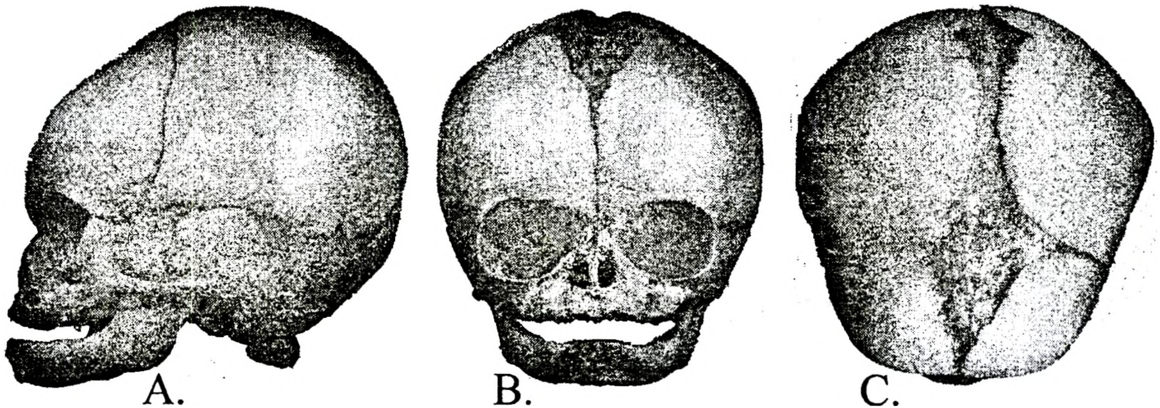

Fig. 46. Skull of the newborn
A- lateral view; B- anterior view; C- view from above.

In the region of the sphenoid body the *intersphenoidal synchondrosis* is found, which ossifies early, while between the sphenoid and ethmoid bones is the *sphenoethmoidal synchondrosis,* which does not ossify until maturity. In addition, cartilage remnants are retained throughout life between the petrosal part of the temporal bone and the adjacent bones, the *sphenopetrosal synchondrosis* and the *petrooccipital synchondrosis.*

Remnants of the second, cartilaginous stage of the development of the skull are the cartilaginous layers between some parts of the bones of the base, which have not yet fused. As a result, the number of these bones is greater in the newborn than in an adult. The air sinuses in the skull bones are still not developed. The different muscular tuberosities, crests, and lines are not pronounced because the muscles do not function yet and are therefore weakly developed. Weakness of the muscles due to absence of the masticating function causes weak development of the jaws: the alveolar processes are hardly formed and the mandible consists of two non-united halves. As a result, the visceral cranium is less prominent in relation to the cerebral skull and is only one-eighth the size of the latter, whereas in an adult their ratio is 1:4.

GROWTH OF THE SKULL; OSSIFICATION

Growth of the skull, as already stated, is dependent on the function and the contents of the skull. The neurocranium and viscerocranium do not grow at an equal rate.

Three periods are distinguished in the *growth of the skull:* the first period (the first 7 years) is characterized by intensive growth, mainly of the posterior part; the second (from the age of 7 to the beginning of puberty) is the period of relative rest; the third period, from the beginning of puberty (13-16 years of age) to the end of skeletal growth (20-23 years of age), is again one of intensive growth, but now mainly of the anterior part. The skull grows slowly later, too, which makes the sutures very important because they make it possible for the plane of the cranial bones to increase.

At mature age, the cranial sutures disappear (obliterate) because the syndesmoses between the bones of the vault are converted to synostosis. At old age, the bones of the skull are often thinner and lighter. As the result of the loss of teeth and the atrophy of the alveolar margins of the jaw bones, the face becomes shorter and the lower jaw protrudes forward, while the angle formed by the ramus and the body increases. The described age changes of the skull are demonstrated well by X-ray examination, which is important from the standpoint of diagnosis. The radiograph of the skull of the newborn shows, for instance, that: (1) some of the bones (the frontal, occipital, and the mandible) are not fused into a single whole; (2) pneumatization of the air bones is absent; (3) the spaces between the bones of the vault, in the region of the fontanelles in particular, are wide. An anteroposterior radiograph shows a clear space in place of the frontal suture, which separates the frontal bone into two parts, as well as evidence of incomplete union of both halves of the mandible. A posteroanterior radiograph demonstrates spaces between the interparietal bone and the inferior part of the squama of the occipital bone, and between the lateral parts and squama of this bone. A clear space corresponding to sphenooccipital .synchondrosis is seen on a lateral radiograph. The age changes found on radiographs later are as follows.

1. Fusion of separate parts of bones to form a single whole, namely: (a) union of both halves of the mandible (1-2 years of age); (b) fusion of both halves of the frontal bone at the site of the frontal suture (2 years); (c) fusion of all parts of the occipital bone; (d) synostosis between the body of the occipital bone and the sphenoid bone to form a single os basilare at the site of the spheno-occipital synchondrosis; with the development of this synostosis (between the ages of 18 and 20) growth of the base of the skull in length ceases.

2. Disappearance of the fontanelles and the formation of sutures with typical serrated contours (2-3 years of age).

3. Appearance and further development of pneumatization.

X-ray examination is the only method for studying the developing air sinuses of the skull in a living person: (a) the frontal sinus is detectable on a radiograph at the end of the first year of life, after which it grows gradually. In some cases it is small and does not extend beyond the medial segment of the superciliary arch; in others it extends along the entire supraorbital margin, while in still others it may be absent completely; (b) the bony cells of the ethmoid bone are already discernible in the first years of life; {c) the maxillary sinus is demonstrated on the radiograph of the skull at birth as an elongated clear space the size of a pea. It reaches full development in the period of replacement of deciduous teeth .by the permanent teeth and is distinguished by great variability; (d) the sphenoidal sinus is discxissed above.

4. Replacement and loss of teeth.

5. Disappearance of the sutures and fusion of bones beginning at mature age.

SEX DIFFERENCES OF THE SKULL

The skull of a man is larger than the skull of a woman on the average; its capacity is greater than that of the female skull by approximately 10 per cent, which is determined by the sex difference in the body dimensions. The surface of the female skull is smoother because the roughnesses at the sites of muscle attachment are less pronounced. The superciliary arches are less prominent, the forehead more vertical, and the vertex flatter. In some cases, however, the sex signs on the skull are so indistinct that the sex of the individual cannot be determined from them, especially since in approximately 20 per cent of cases the capacity of the female skull is no less than the average capacity of the male. The smaller size of the female skull does not signify poorer development of the brain but corresponds to the smaller dimensions and proportions of the female body.

CRANIOLOGY

The skull is one of the most important objects of anthropological research because of its proximity to such significant organs as the brain, the organs of sense, and the initial parts of the alimentary and respiratory systems.

Anthropomethrical points of the neurocranium

The *vertex* is the highest point on the sagittal suture.

The *vault of the skull* is the arched roof or dome of the skull.

The *bregma* is the meeting point between the coronal and sagittal sutures. In the fetal skull this is the site of a membranous gap, called the anterior fontanelle, which closes at $1^1/_2$ years of age.

The *lambda* is the meeting point between the sagittal and lambdoid sutures. In the fetal skull this is the site of the posterior fontanelle, which closes at 2 to 3 month of age.

The *parietal tuber (eminence)* is the area of maximum convexity of the parietal bone. This is a common site of fracture of the skull.

The most prominent point on the external occipital protuberance is called the *inion*.

The *superciliary arch* is a rounded curved elevation situated just abobe the medial part of the each orbit. It overlies the frontal sinus and is better marked in males than in females.

The *glabella* is a median point at the root of the nose where the internasal suture meets with the frontonasal suture.

The *frontal tuber (eminence)* is a law rounded elevation above the superciliary arch, one on each side.

The *asterion* is the point where the parietomastoid, occipitomastoid and lambdoid sutures meet. In infant the asterion is the site of the posterolateral (mastoid) fontanelle, which clouses at the end of the first year.

Fossil skulls, moreover, remain intact for long periods of time and serve as sources of information about races long extinct. The human skull generally takes one of three main shapes, although the shape of the individual skull may vary greatly. Skulls are classified according to the cephalic index (the ratio of the maximum diameter to the maximum length of the skull), obtained by the formula:

(1) short or brachycephalic (cephalic index above 80);

(2) average or mesocephalic (cephalic index of 79-76);

(3) long or dolichocephalic (cephalic index less than 75).

The presence of long and short skulls and Neanderthal features in all races testifies to their similarity and common origin rather than to their differences. The circumference of the head also varies in all races (from 53 to 61 cm). The circumference of some men of genius, Leibnitz and Kant, for example, was very small (55 cm); the circumference of Dante's head measured 54 cm. In the course of human evolution, the capacity of the average skull is steadily increasing from 900 cm^3 in the Pithecanthropus to 1500 cm^3 in modern man.

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