**Jessenius Faculty of Medicine in Martin**

**Comenius University in Bratislava**

**Department of Anatomy**

# AXIAL SKELETON

# STUDY GUIDE

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# AXIAL SKELETON STUDY GUIDE

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## PREFACE

This study guide has been prepared for medical students as a basic educational material for the anatomy practicals.

The first chapter provides explanation of basic anatomical terms used for the description of the structures of human body. Understanding of these terms is essential for the study of anatomy and for the future clinical practise.

The main part of the study guide presents concise knowledge about the axial skeleton – vertebral column, skeleton of the thorax and the skull. The text is fulfilled by the photographs of dry bones (bony preparations) used during the anatomy practicals in our department, however, it is necessary combine the study with using of anatomy atlases (Sobotta´s, Gray´s, Gilroy ´s or Netter´s atlas of human anatomy). Several figures are retrieved from the public domein of Gray´s Anatomy of human Body (1918).

The last part of the study guide contains a set of review questions which can help the students when they will prepare for the credit tests and final exam.

I hope you will find this study guide useful resource for your independend study and review.

CONTENT

## INTRODUCTION

**Anatomy** is a morphological discipline, usually defined as a science dealing with the structures of organisms including their systems, organs and parts. The term anatomy is derived from the Greek term “anatemnein” which means “to cut” because of its technique used for the observation - dissection.

**Human anatomy** studies the organs of human body in physiological conditions. It belongs to basic and one of the most relevant disciplines of medicine. Traditionally it is subdivided to macroscopic (gross) anatomy, usually termed only anatomy and microscopic anatomy or histology. Gross anatomy studies the structures which can be seen grossly without magnification, histology studies the cells and tissues with the aid of magnification using a microscopes.

The study od human anatomy at medical faculties is based on the observation, and visualization of previously dissected cadavers and naturally on the dissection of cadavers by students. In addition, plastic models and computer teaching softwares are used as well. Studying of anatomy is not only memorizing of the list of names (althought the anatomy terminology is important), but it also requires visualisation and imagination of studied structure – it means its position or coarse, its relations to the surrounding organs and neurovascular structures.

Anatomy can be studied by two approaches: topographically and systematically.

**Topographic anatomy** uses a regional approach when each body region (e.g. head, neck, thorax, abdomen, back, pelvis, upper and lower limb) is studied separatelly with all structures contained in it – the bones, muscles, internal organs, vessels and nerves.

**Systematic anatomy** describes individual systems of the body: skeletal and muscular system, joints, cardiovascular, lymphatic, gastrointestinal, respiratory, urogenital and nervous system.

On the basis of our long - time experiences we prefer to start the study of anatomy with systematic approch with subsequent topographic approch and reviewing.

## BASIC ANATOMICAL TERMS

### Standard anatomical position

In human anatomy, all parts of the the human body (bones, muscles, joints, internal organs etc.) are described when the body is in standard anatomical position. This prevents from confusions in anatomical description because the head, upper and lower limbs can change their position with respect to the trunk of the body.

The human body is in standard anatomical position when **standing upright with face looking forward, lower limbs together or only slightly separated, upper limbs by the side with palms facing forward - in supinatory position** (thumbs are pointed away from the body).

Three basic **anatomical planes** are commonly used for the description:

- **coronal (also known as frontal) planes** - are vertical longitudinal planes, perpendicular to the sagittal and transverse planes, they separate the front from the back, divide the body into anterior (ventral) and posterior (dorsal) parts

- **sagittal planes** – are parallel to the sagittal suture, perpendicular to the coronal and transverse planes, **median sagittal plane** divides the body into equal right and left parts

- **transverse (also known as horizontal or axial) planes –** are parallel to the ground,perpendicular to the coronal and sagital planes, they divide the the body into superior (cranial) and inferior (caudal) parts

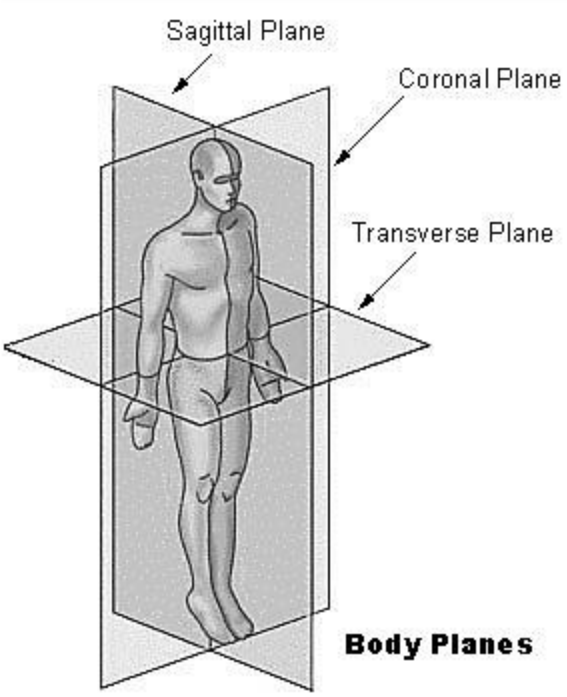



**Fig. 1** ***Basic anatomical planes***. *Retrieved from http://training.seer.cancer.gov*

**Anatomical terms to describe /for location and direction**:

- **anterior** or **ventral** (what is in front) / **posterior** or **dorsal** (what is to the back)
- **superior** or **cranial** (what is above) / **inferior** or **caudal** (what is below)
- **medial** (what is close to the median plane of the body) / **lateral** (what is more on the sides)
- **proximal** (what is close to the centre of the body) / **distal** (what is more distant from the centre of the body)
- **superficial** (what is near the surface of the body) / **deep** (what is further away from the surface of the body)

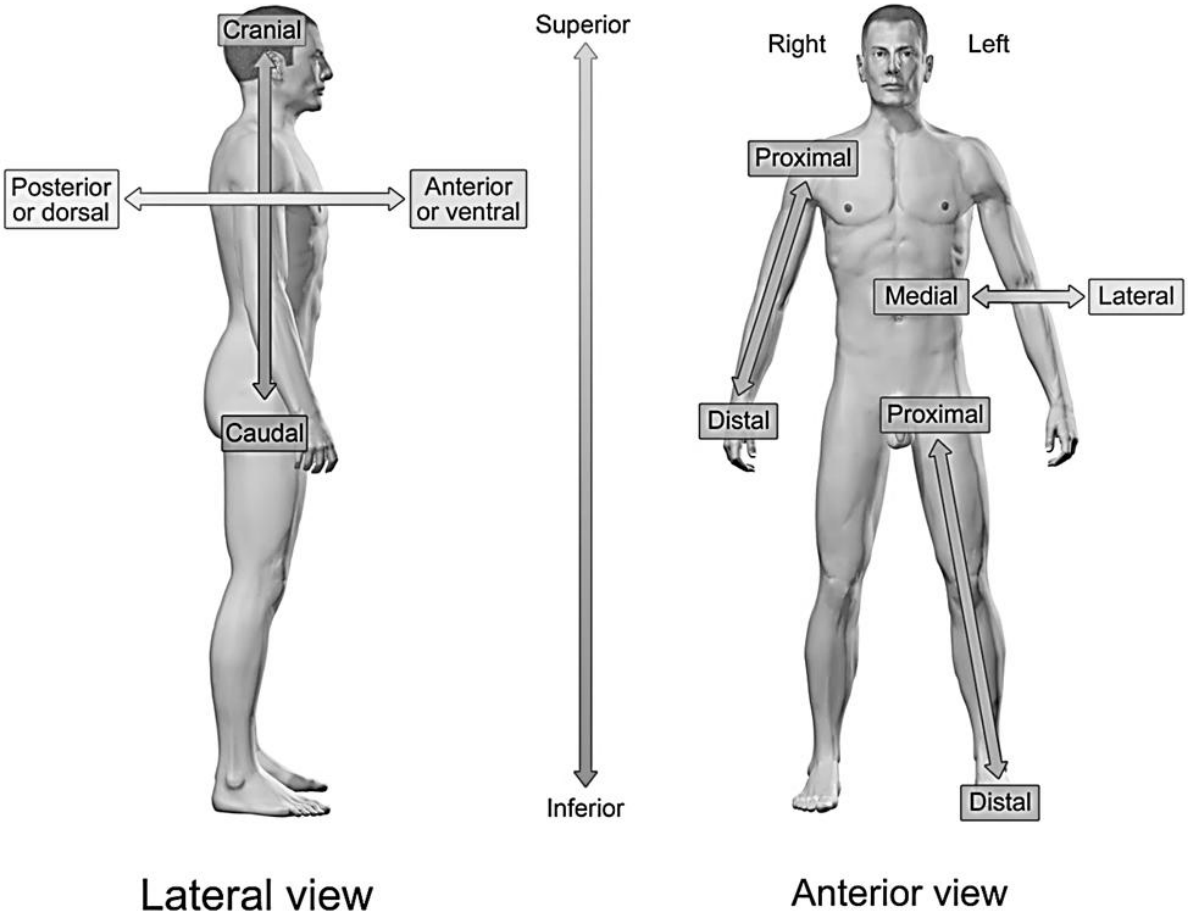



**Fig. 2** ***Anatomical locations and direction****s.*

*Retrieved from Blausen.com staff.*

## HUMAN SKELETON

**Human skeleton** consists of 270 bones at the birth and decreases to 206 bones by adulthood after some bones have fused together.

Skeleton performs several important functions:

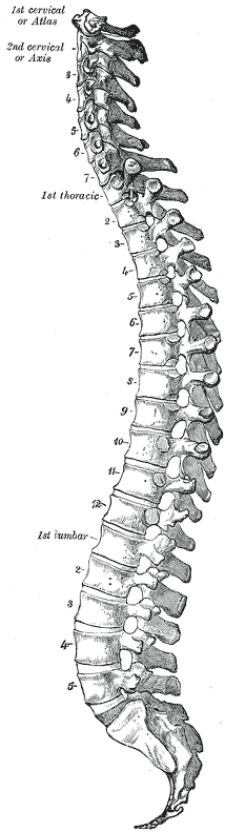
- **support** - it forms internal framework which supports the body,
- **movement** - it is allowed by the joints between the bones and powered by the muscles attached to the bones,
- **protection** - skull protects the brain, thoracic skeleton protects the lungs and the heart with large vessels, vertebral canal protects the spinal cord,
- **haematopoiesis** - blood cell production in the bone marrow,
- **metabolism of minerals** - e.g. bone matrix participates in calcium metabolism, bone marrow in iron metabolism,
- **endocrine function** - osteoblasts release the hormon osteocalcin.

**Human skeleton is subdivided into:**

- the **axial skeleton** - is formed by vertebral column, skull, sternum and ribs,
- the **appendicular skeleton –** contains the bones of the pectoral girdle and free upper limb, and the bones of pelvic girdle and free lower limb.

# AXIAL SKELETON

## VERTEBRAL COLUMN




Vertebral column serve three important functions: pretecting of the spinal cord and spinal nerves, transmitting the weight of the body and providing a flexible axis for movements of the head, neck and trunk.

**Vertebral column** is formed by 33 vertebrae, which are subdivided into 5 groups according their position:

- **7 cervical vertebrae** (CI – CVII)
- **12 thoracic vertebrae** (TI – TXII)
- **5 lumbar vertebrae** (LI – LV)
- **sacrum** (formed by 5 fused sacral vertebrae)
- **coccyx** (formed by 3-5 fused coccygeal vertebrae)

**Fig. 3** ***Vertebral column from the sagittal view.***
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

### General characteristics of vertebrae

A typical vertebra consists of **vertebral body** situated ventrally and **vertebral arch** projected dorsally. **Terminal surfaces of the vertebral body** are connected with the bodies of adjacent upper and lower vertebra by the intervertebral discs. The size of the vertebral bodies increases caudally.

**Vertebral arch** is formed by a pair of pedicles and a pair of laminae (pedicles connect the laminae to the vertebral body).

**Three types of processes** arise from the vertebral arch:

- **spinous process** (spine) –extends posteriorly in the midline where two laminae of vertebral arch connect together

- **transverse processes –** project laterally or posterolaterally from the site where pedicles join the laminae of the vertebral arch
- **articular processes –** extend upwards (**superior articular processes**) and downwards (**inferior articular processes**) and they articulate with the articular processes of adjacent vertebrae (immediately upper and lower one).

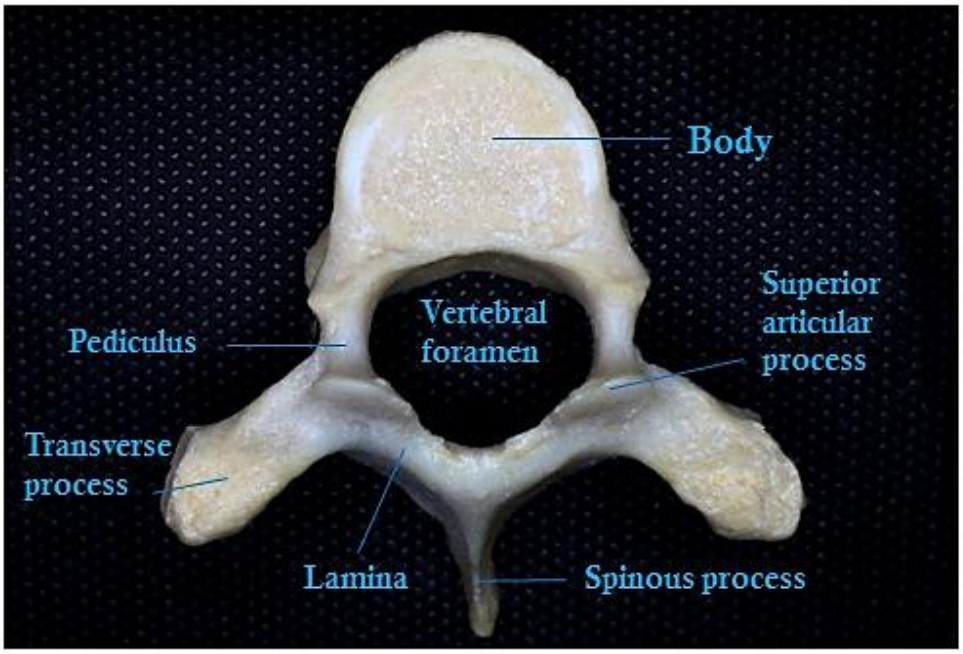



Fig. 4 A *Typical vertebra from the superior view.*

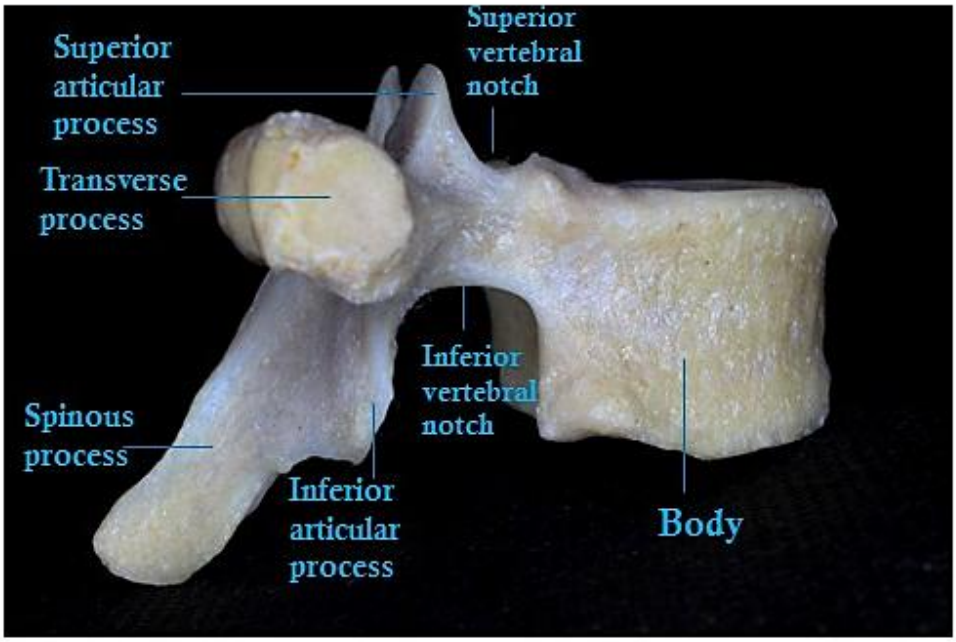
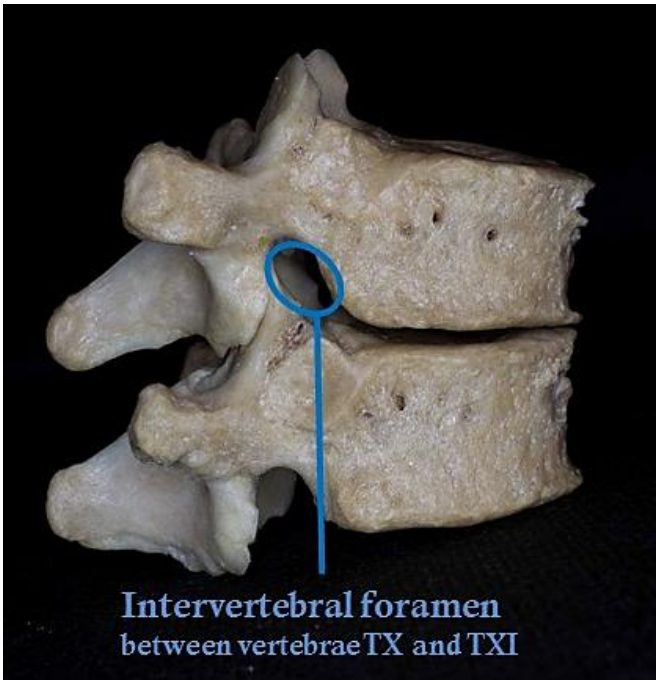



Fig. 4 B *Typical vertebra from the lateral view.*

Vertebral body and vertebral arch enclose the **vertebral foramen**. Vertebral foramina of all vertebrae form **the vertebral canal** which serves as bony protection for the spinal cord running through it.




Spinal nerves arising from the spinal cord emerge from the vertebral canal through the **intervertebral foramina**. Each intervertebral foramen is bordered by the **superior** and **inferior vertebral notch** at the pedicles.

Fig. 4 C
*Intervertebral foramen between thoracic vertebrae TX and TXI. Lateral view.*

**CERVICAL VERTEBRAE (CIII – CVI)**

All cervical vertebrae (CI - CVII) have a unique feature - **foramen transversarium** - the opening at the transverse processes by which they can be distinguished from the other types of vertebrae. Foramina transversaria of the cervical vertebrae contain vertebral vessels running at the neck and reaching the skull through foramen magnum. Vertebral artery ascends through foramina transversaria of CVI to CI, vertebral vein descends through foramina transversaria of CI to CVII.

A typical cervical vertebra (CIII – CVI) has small body which is broader transversely than anteroposteriorly. Superior surface of the body is usually transversely concave and shows uncinate processes on either side. Spinous process of cervical vertebrae CII – CVI is short and splits at the end (it is bifid). Superior articular processes show articular surfaces which are dorsocaudally oriented. Vertebral foramen is triangular in shape (it results from the shape of the cervical spinal cord).

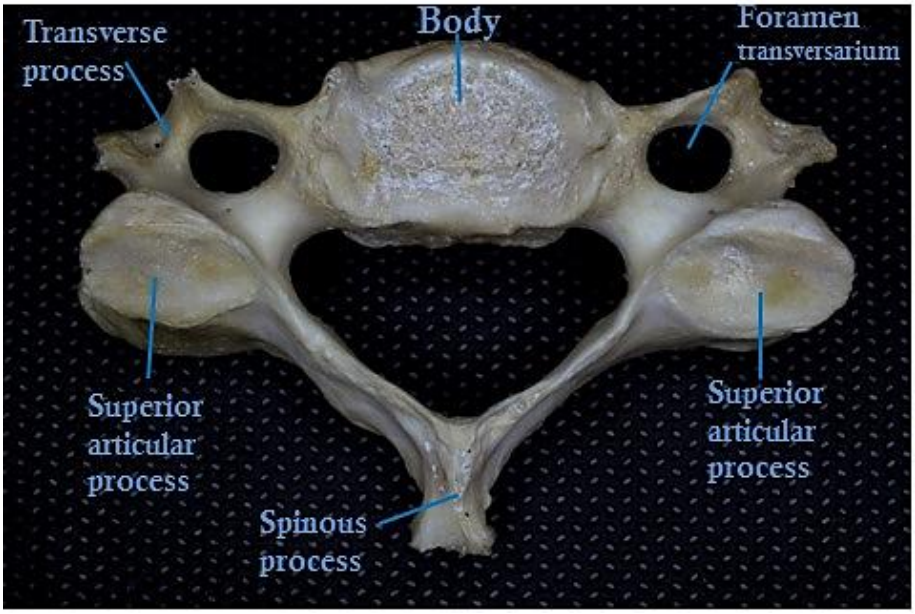



Fig. 4 A
*Cervical vertebra from the superior view.*

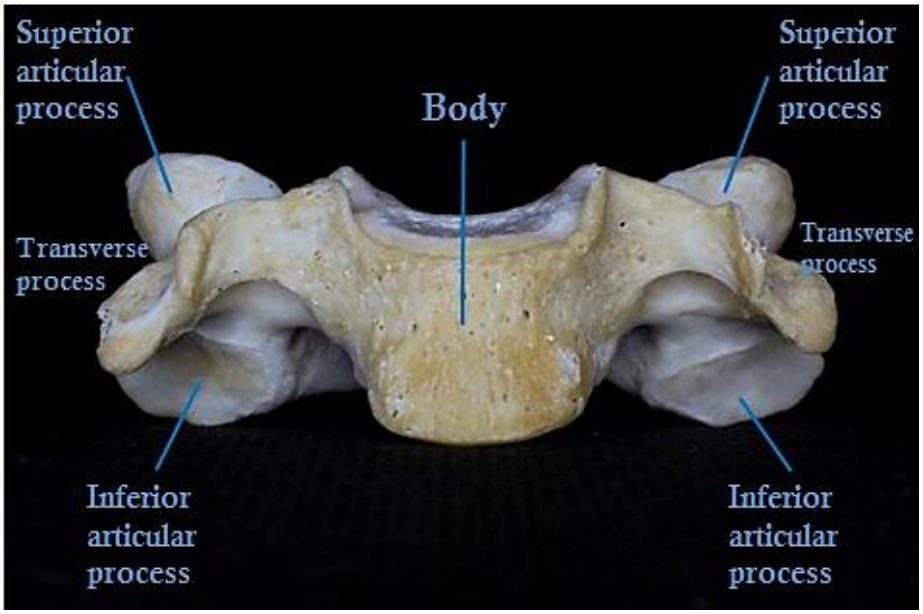



Fig. 4 B
*Cervical vertebra from the anterior view.*

**Atlas (CI)**

The first cervical vertebra atlas supports the head and its name is derived from the giant (titan) of Greek mythology named Atlas who supported the heavens.

Atlas is an atypical vertebra which shows **no vertebral body** and **no spinous process**. During the intrauterine development its body fuses with the body of CII and forms the dens of axis.

Atlas consists of **anterior** and **posterior arch** with **lateral masses** in between.

At the external aspect of the **anterior arch** there is **anterior tubercle** (the site of attachment of anterior longitudinal ligament). **Facet for the dens** (fovea dentis) sits at the internal surface of the anterior arch and it is the articular surface for the dens of axis (odontoid process).

**Posterior arch** is longer than anterior one (posterior forms 3/5 of the ring, anterior 1/5 of the ring). At the site where spinous process should be there is **posterior tubercle** which is like rudimentary spinous process. Ligamentum nuchae is attached to the posterior tubercle. Superior surface of posterior arch shows **grooves of the vertebral artery** immediately behind lateral masses. In this area vertebral artery exits the foramen transversarium of CI and continues in to the skull through foramen magnum. **Lateral masses** bear **superior and inferior articular surfaces (facets)**.

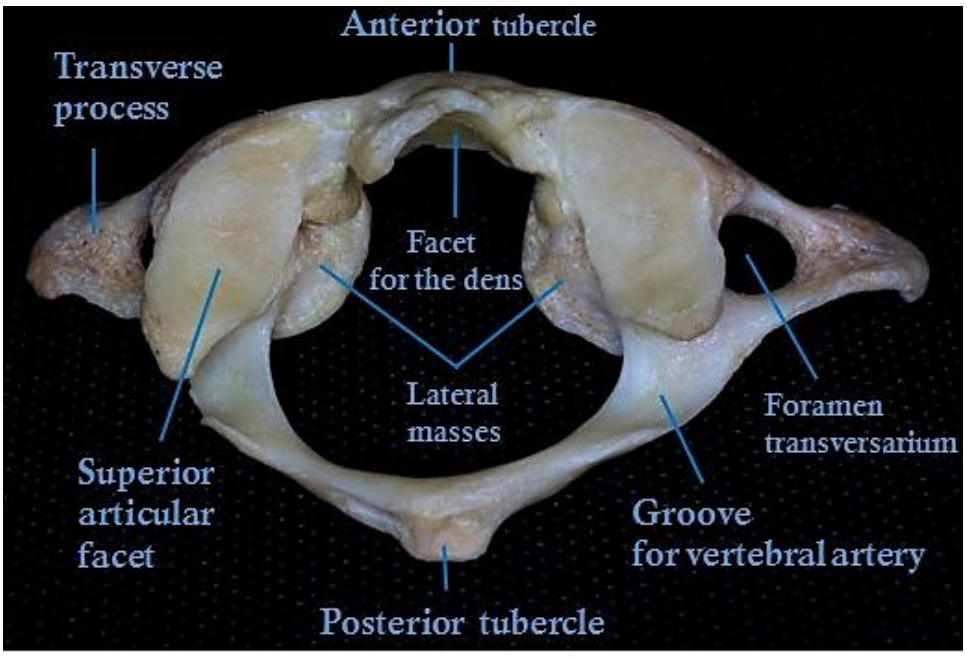



Fig. 5 A
*Atlas from the superior view.*

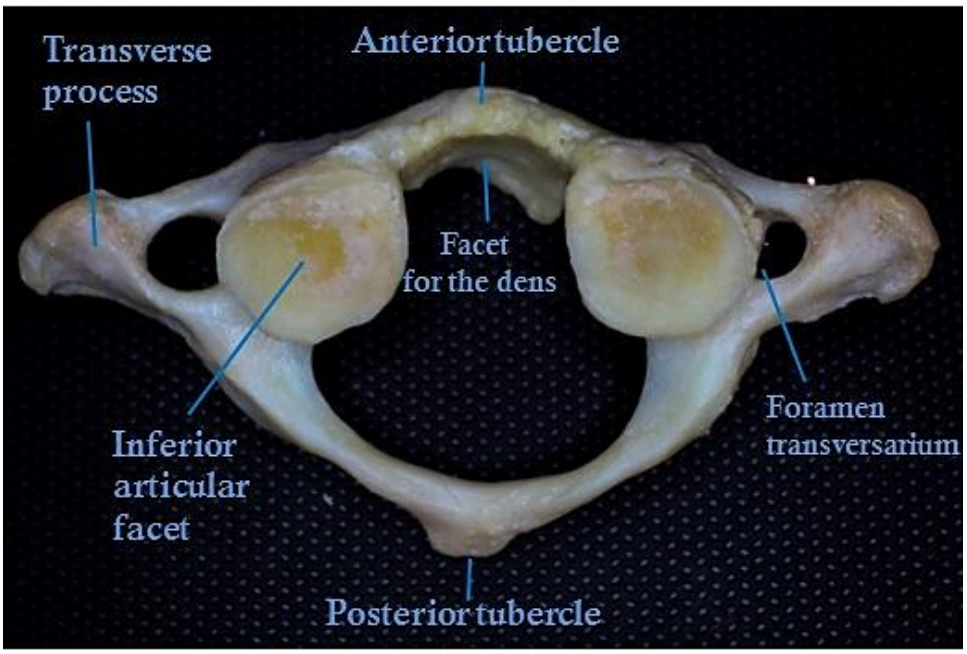



Fig. 5 B
*Atlas from the inferior view.*

**Superior articular surfaces** are elongated, bean-shaped, concave and articulate with the occipital condyles. **Inferior articular surfaces** are more oval and flat and articulate with superior articular processes of the axis.

**Transverse processes** of the atlas are longer than those of CII – CVI and marked by foramen transversarium like all cervical vertebrae.

**Axis or epistropheus (CII)**

The most characteristic feature of the axis is **the dens of axis** (odontoid process, tooth –like projection extending superiorly from the body). At the anterior surface of the dens there is an oval articular surface which articulates with the facet for the dens of atlas. At the posterior aspect of the dens there is a groove for transverse ligament of the atlas (this ligament is important for the stabilization of the median atlatooccipital joint).

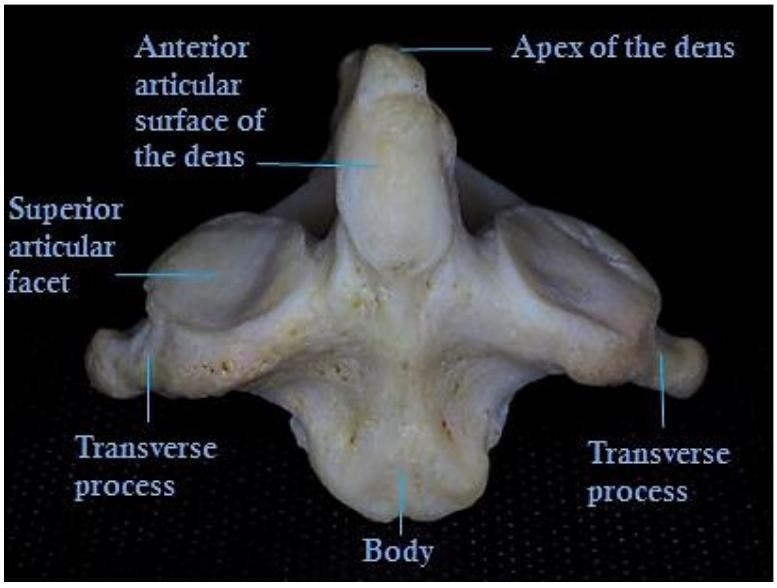



Fig. 6 A
*Axis from the anterior view.*

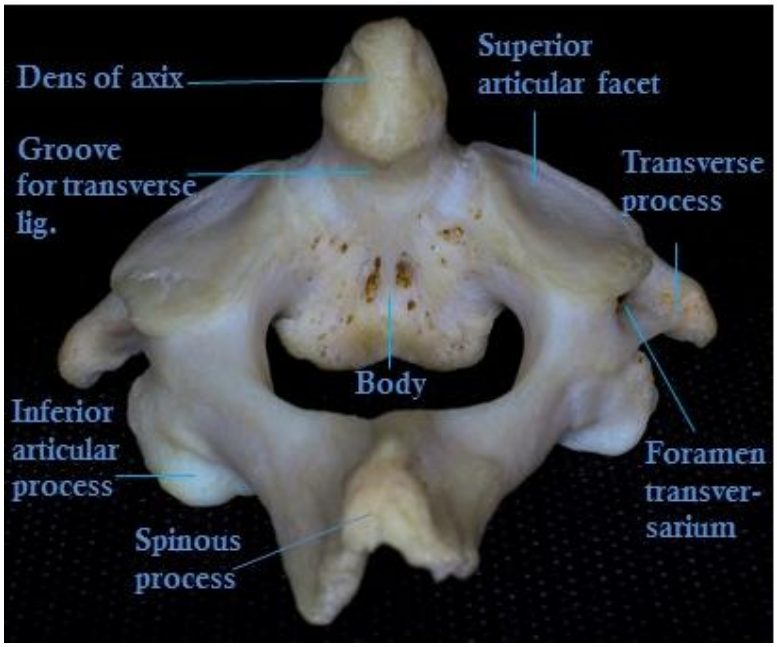



Fig. 6 B
*Axis from the posterior view.*

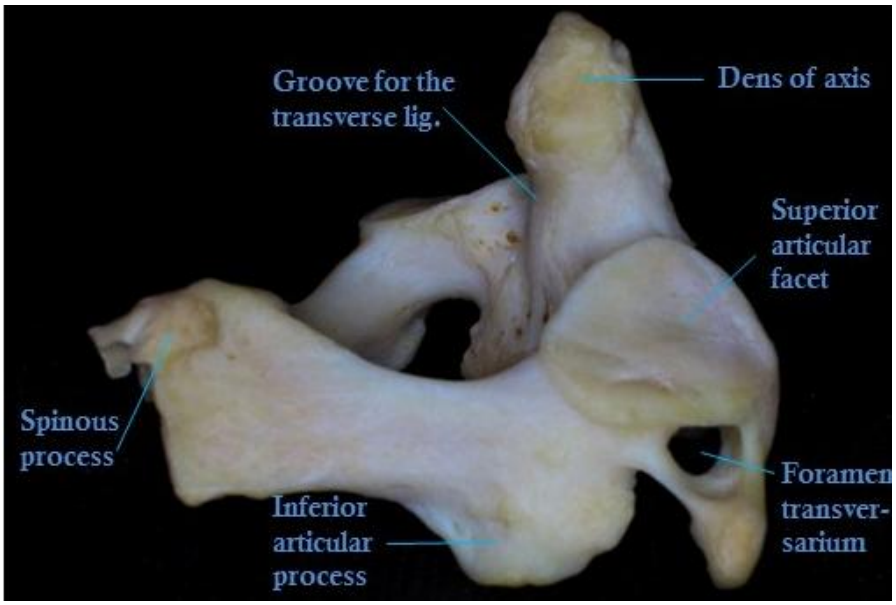



Fig. 6 C
*Axis from the lateral view.*

**Vertebra prominens (CVII)**

This vertebra is named according prominent – long, thick, not bifid, and almost horizontally directed spinous process which is easily palpable through the skin.

**THORACIC VERTEBRAE (TI – TXII)**

All thoracic vertebrae are characterized by the joints with the ribs. It means they have **facets (articular surfaces) for the ribs - costal facets** at the both sides of the bodies and at both transverse processes.

**The body** of a typical thoracic vertebra has transverse diameter equal to the anteroposterior diameter.

**Spinous processes** are slender, long and dorsocaudally directed. Spinous processes of TV to TIX overlap similarly like tiles at the roof.

**Transverse processes** of thoracic vertebrae are long and strong and they arise from the vertebral arch behind the articular processes. Transverse processes show the **costal facet** for the articulation with the tubercle of the rib.

**Articular processes** have articular facets oriented almost in frontal plane.

**Vertebral foramen** of thoracic vertebrae is oval.

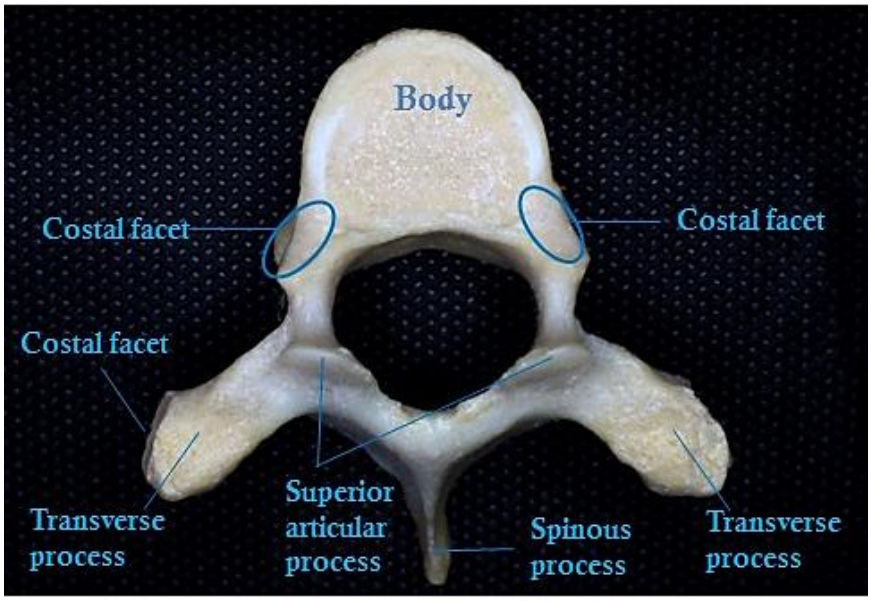



Fig. 7 A
*Thoracic vertebra from the superior view.*

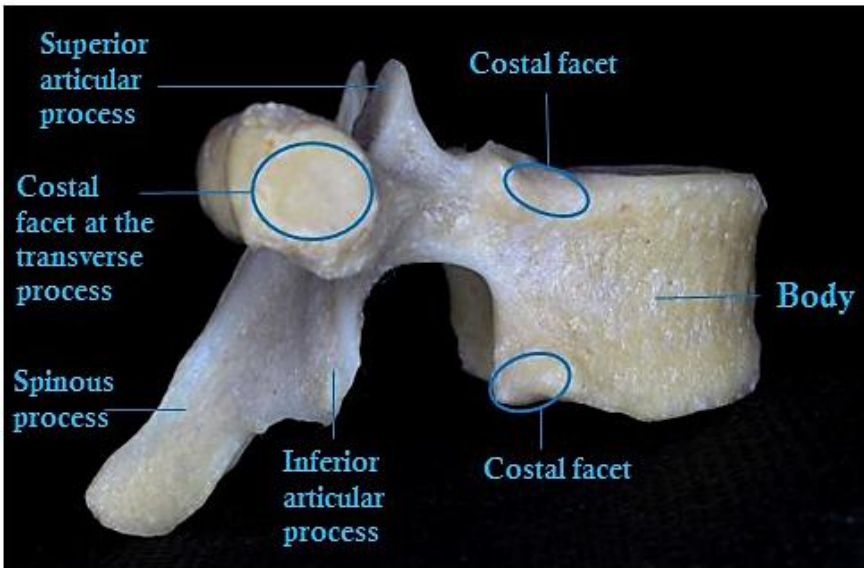
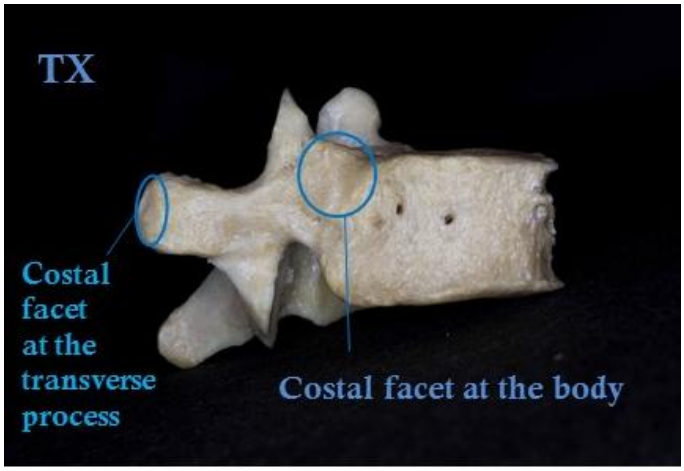
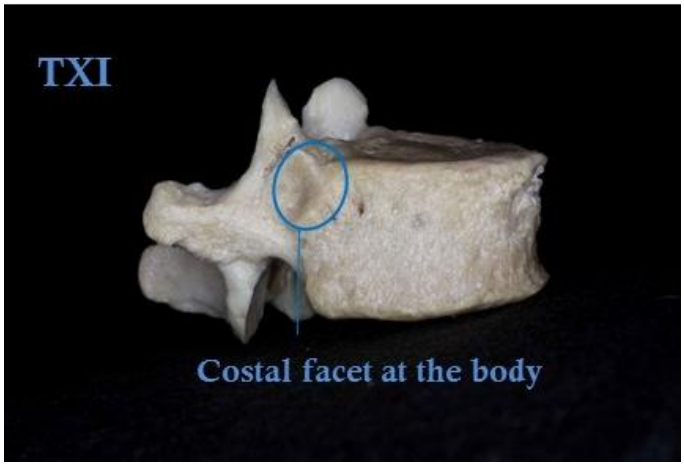
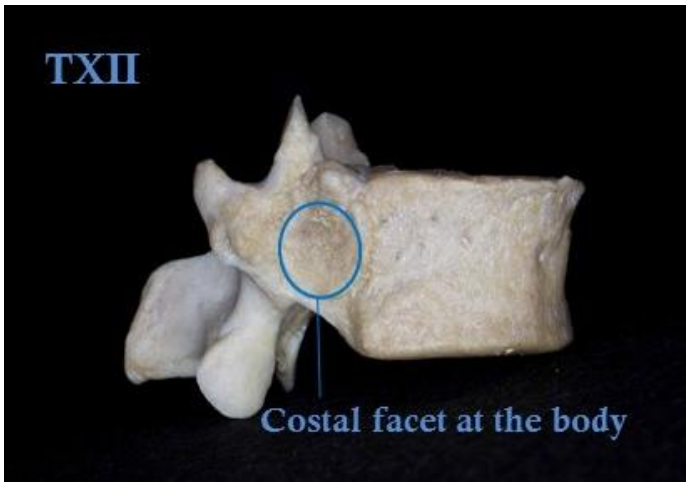



Fig. 7 B
*Thoracic vertebra from the lateral view.*

All thoracic vertebrae articulate with the ribs. The head of the rib articulates with the costal facets of two adjacent vertebrae and intervertebral disc between them. The tubercle of the rib articulates with the costal facet at the transverse process. TI – TIX have two costal facets on each side of the body and costal facets at both transverse processes.




TX, TXI and TXII have special arrangement of the costal facets because of the different morphology of the free (floating) ribs. The eleventh and the twelveth ribs have small heads which articulate with only one vertebra (the heads of the 11th ribs with the costal facets on each side at the body of TXI, the heads of the 12th ribs with costal facets at the body of TXII) The eleventh and the twelveth ribs also have no tubercle (it means no costal facets at the processes of TXI and TXII). Thus, TX has one costal facet at each side of the body and costal facet at both transverse processes. TXI and TXII have only one costal facet at each side of the body and no costal facet at the transverse process (see Figure 8).

Fig. 8
*Costal facets at thoracic vertebra TX, TXI and TXII.*

**LUMBAR VERTEBRAE (LI – LV)**

Lumbar vertebrae have **large bodies** which are transversely wider than anteroposteriorly Terminal surfaces of the bodies are bean - shaped. Pedicles and laminae of the arch are strong and they border triangular **vertebral foramen**.

**Spinous process** of lumbar vertebra is like square plate, short and nearly horizontally directed.

**Transverse processes** are long and slender (they are homologous to the ribs). They arise from the vertebral arch in front of the articular processes.

**Articular surfaces** at articular processes are almost in sagittal plane. The fifth lumbar vertebra is the largest and its body is anteriorly higher than posteriorly.

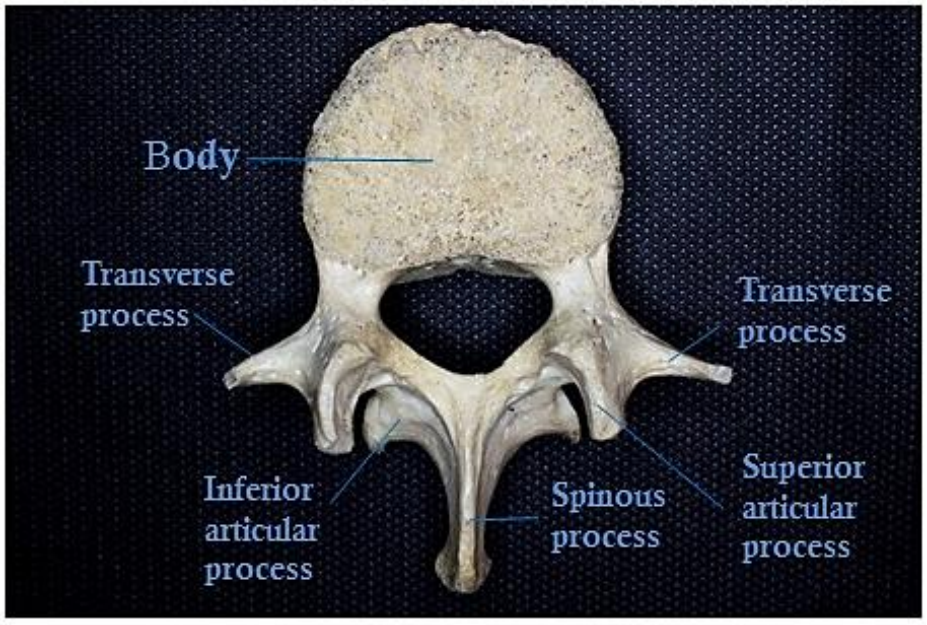



Fig. 9 A
*Lumbar vertebra from the superior view.*

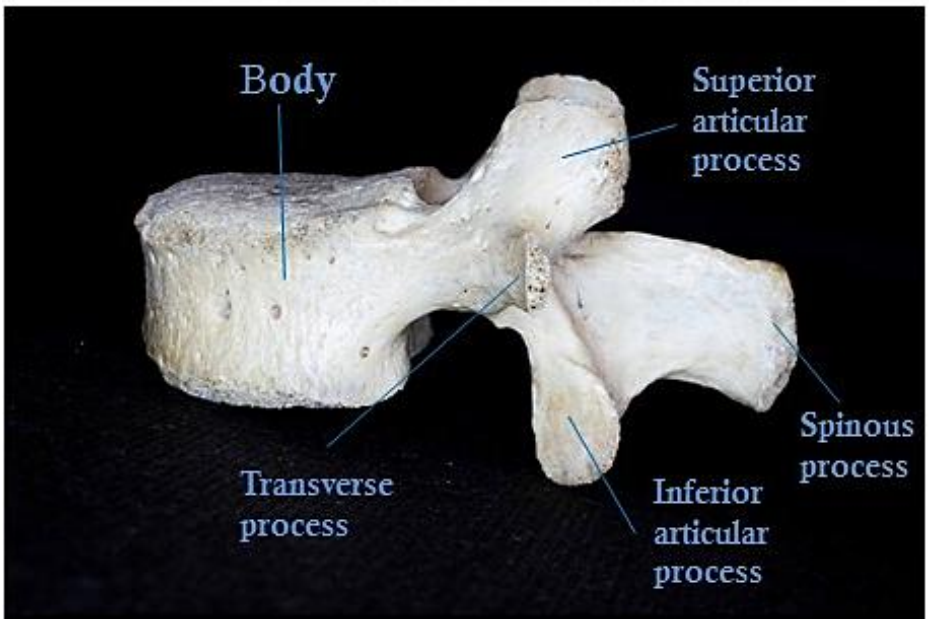



Fig. 9 B
*Lumbar vertebra from the lateral view.*

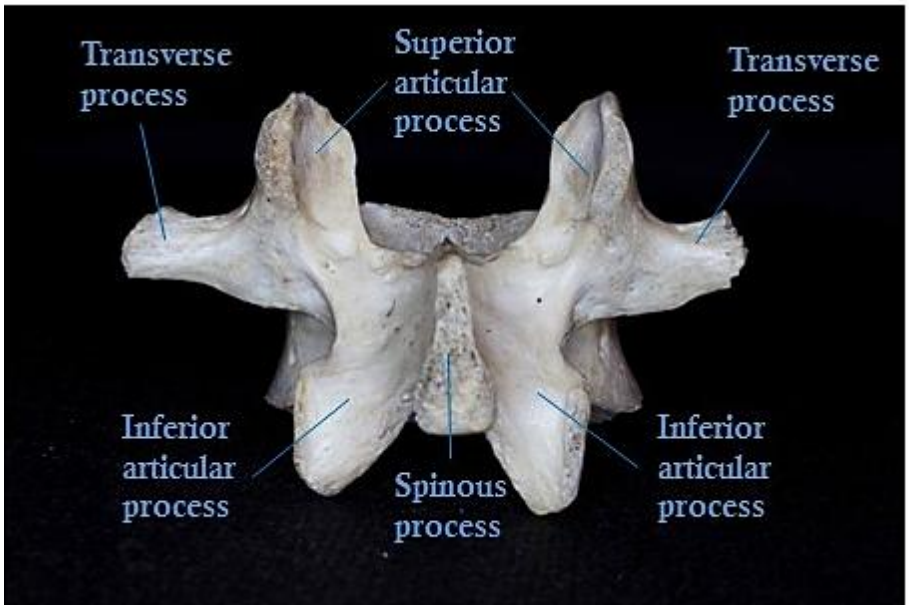



Fig. 9 C
*Lumbar vertebra from the posterior view.*

**SACRUM**

Sacrum is formed by the fusion of 5 sacral vertebrae. The upper wider part is the **base**, lowermost and narrow part is the **apex**. The base articulates with the fifth lumbar vertebra forming prominent **sacrovertebral angle**. The apex is connected with the coccyx.

A**nterior (pelvic) surface** of sacrum is ventrally concave and smooth, showing 4 pairs of **anterior (pelvic) sacral foramina**. Between these foramina there are **transverse ridges** which correspond with the borders between the fused vertebral bodies of sacral vertebrae. Piriformis muscle and a part of iliacus muscle originate from the anterior surface of sacrum. **Dorsal surface of sacrum** is convex and shows 4 pairs of **dorsal sacral foramina** which are together with anterior sacral foramina analogous to the intervertebral foramina.

Bodies and laminae of fused sacral vertebrae form the **sacral canal**, the continuation of vertebral canal. The caudal opening of the sacral canal - **sacral hiatus** is bordered by **sacral cornua** (horns).

Processes of fused sacral vertebrae display as the crests: **median sacral crest** (fused spinous processes), **intermediate sacral crests** (fused articular processes except the superior articular processes of the first sacral vertebra which articulate with the facets on the inferior processes of the fifth lumbar vertebra) and **lateral sacral crests** (fused transverse processes).

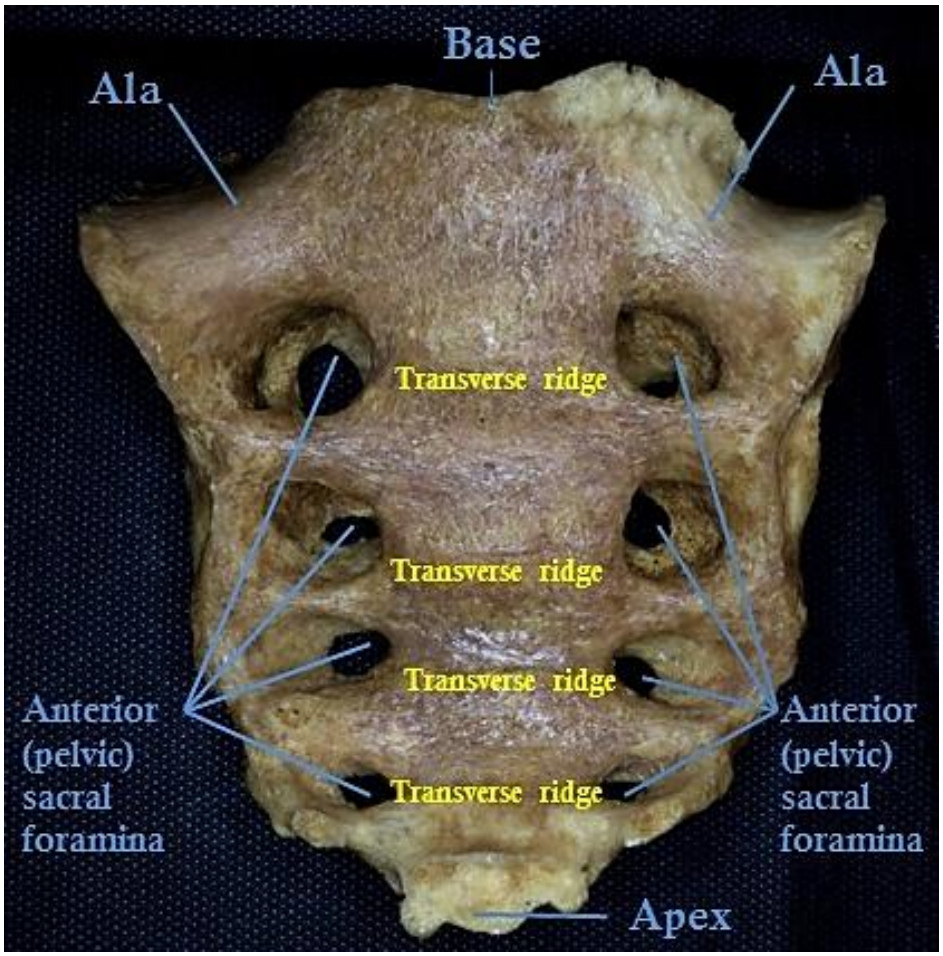



Fig. 10 A *Anterior (pelvic) surface of the sacrum.*

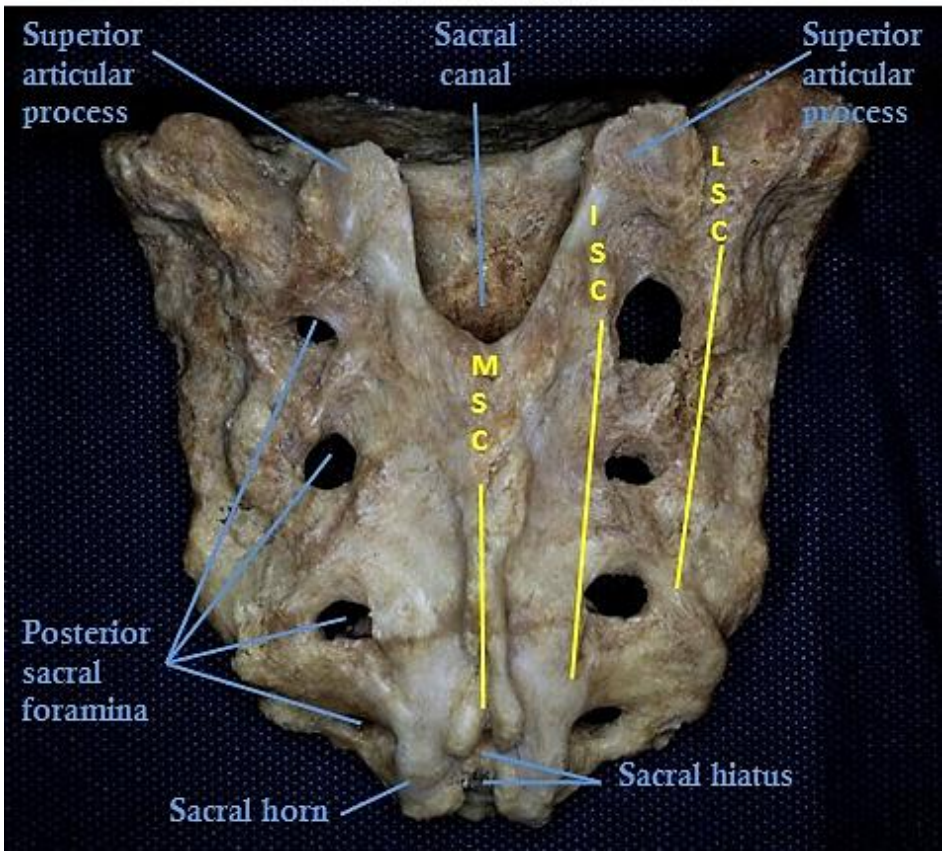



Fig. 10 B *Posterior surface of the sacrum. MSC – median sacral crest ISC – intermediate sacral crest, LSC – lateral sacral crest*

On both sides of sacrum there is the lateral surface. Its upper part bears ear-shaped– **auricular surface**, which is the articular surface for the connection with ilium (sacroiliac joint). Behid the auricular surface there is the **sacral tuberosity** - rough and uneven area for the attachment of sacroiliac ligaments.

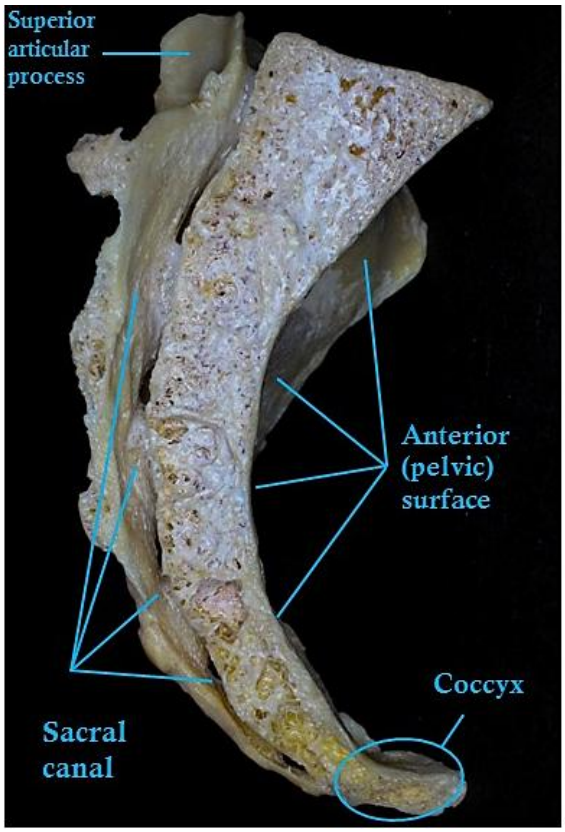



Fig. 10 C *Sagittal section of the sacrum.*

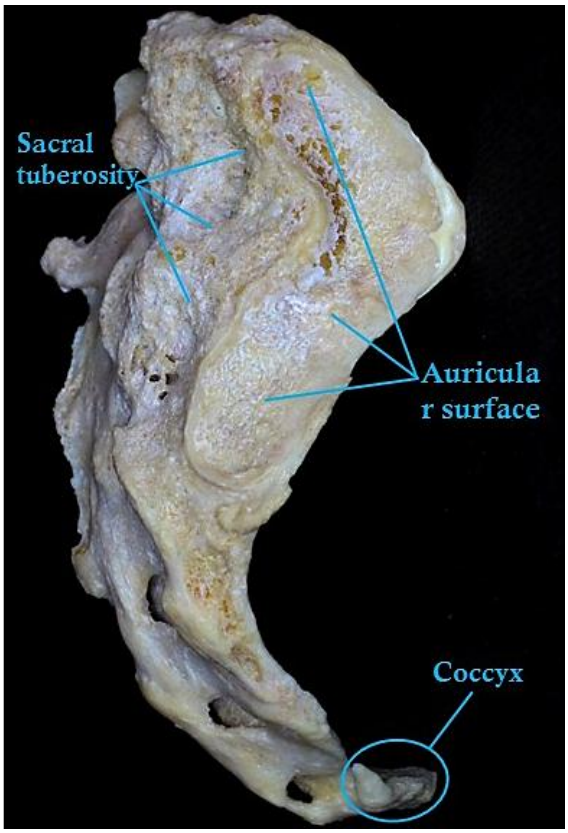



Fig. 10 D *Sacrum from the lateral view.*

## COCCYX

Usually 3-5 coccygeal vertebrae fuse to form the lowermost part of the vertebral column – **coccyx.** Coccygeal rudimentary vertebrae are avoided of arches and spinous processes. Coccyx is triangular in shape with wider upper part – **base** and inferiorly directed and narrower - **apex**. **Coccygeal cornua** (horns) arise superiorly from the base. They are rudimentary superior articular processes of the first coccygeal vertebra. **Coccygeus muscle and levator ani muscle are attached to the anterior surface of coccyx. Small part of gluteus maximus and sphincter ani externus muscle originate from the posterior surface.*

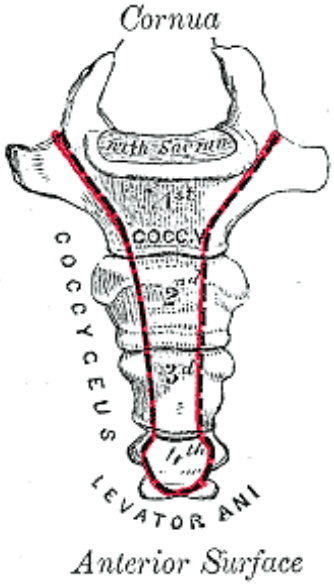



Fig.11 Coccyx anterior surface
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

## SKELETON OF THE THORAX

Bony thorax is conical in shape, being narrower superiorly and broader inferiorly, anteroposteriorly flattened. This osteocartilagineous cage serves as a mechanical protection for the thoracic organs (lungs, heart, trachea, bronchi, large vessels etc.). Skeleton of the thorax contains **sternum, ribs** and **thoracic vertebrae**.

## STERNUM

**Sternum** (breast bone) is flat bone forming a part of the anterior thoracic wall. It consists of 3 parts: **manubrium, body** and **xiphoid process.**

**Manubrium** is broad upper part of sternum. It has anterior and posterior surfaces which meet in superior, inferior and lateral borders. Superior border is thick and shows **jugular notch** in the middle and **clavicular notches** more laterally. **Costal notches** (costal facets) for the first and second ribs are situated **at the lateral borders**. Some fibres of sternocleidomastoideus muscles are inserted to the ventral surface of manubrium.

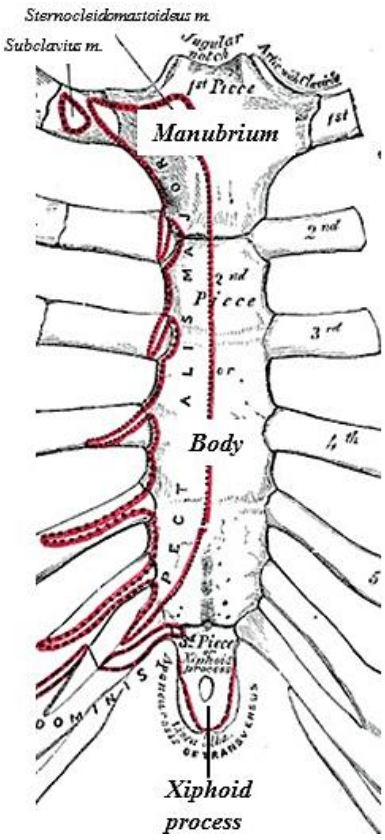



Fig. 12 A *Anterior surface of sternum*

*Retrieved from public domein Gray's Anatomy of human Body (1918) at Bartleby.com*

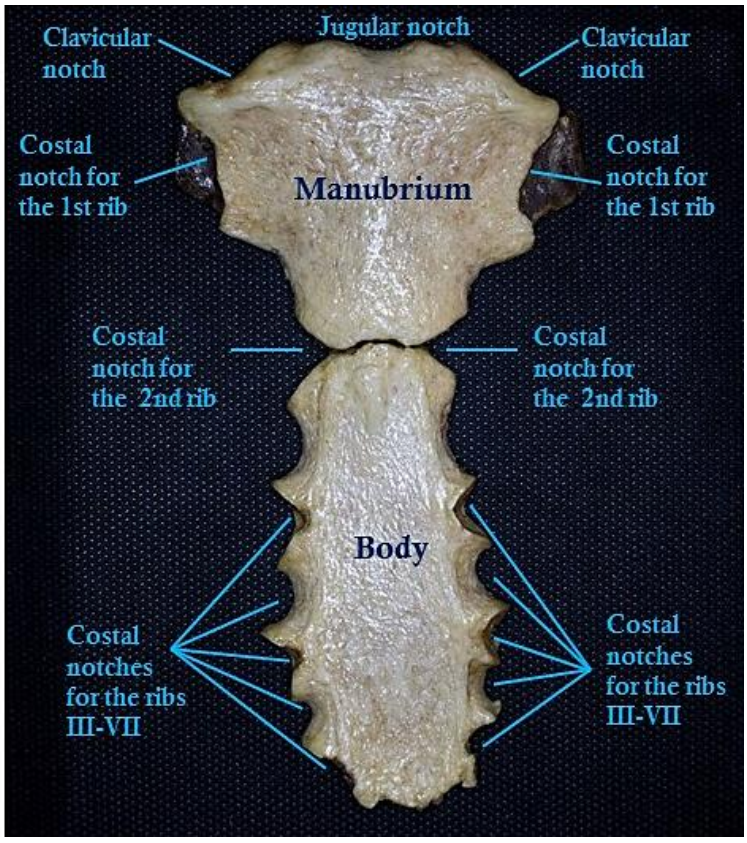



Fig. 12 B *Manubrium and body of sternum from anterior view.*

**Inferior border of manubrium** connects with the **superior border of the body** forming the **sternal angle**.

**The body** of sternum is thinner and narrower than manubrium. Its lateral borders are marked by costal notches (costal facets) for the cartilages of the 2nd to the 7th ribs (costal notch for the 2nd rib is at the border between the manubrium and body of sternum).

Inferior border of the body connects with the **xiphoid process** which is very variable in shape.

## RIBS

### General characteristics of the rib

Each rib consists of **vertebral (posterior) end**, the **shaft** and **sternal (anterior) end**.

**At the vertebral end** there is the **head of the rib** articulating with the vertebral column. The **articular surface** of the head is subdivided by the **crest** to smaller superior facet (demifacet) which articulates with the inferior costal facet on the vertebral body above, and greater inferior facet which articulates with the superior costal facet on the corresponding vertebral body. The crest at the costal head gives insertion to the intraarticular ligament which continues to the intervertebral disc. The t**ubercle** of the rib projects posteriorly and contains the area for the attachment of ligaments (nonarticular surface) and the articular surface for the articulation with the costal facet at the transverse process of corresponding vertebra (thus, for example: the head of rib IV articulates with the inferior costal facets of TIII and superior costal facet of TIV, tubercle of rib IV articulates with the costal facet at the transverse process of TIV). The head and tubercle are separated by the **neck**, short and narrow part of the rib.

The **shaft** of the rib is curved and flattened. It has the internal and external surfaces, rounded superior border and sharp inferior border.

**Costal groove** runs along the inferior border on the internal surface of the rib. The shaft of the rib curves forward forming the angle of the rib.

**Sternal end** of each rib terminates in costal cartilage.

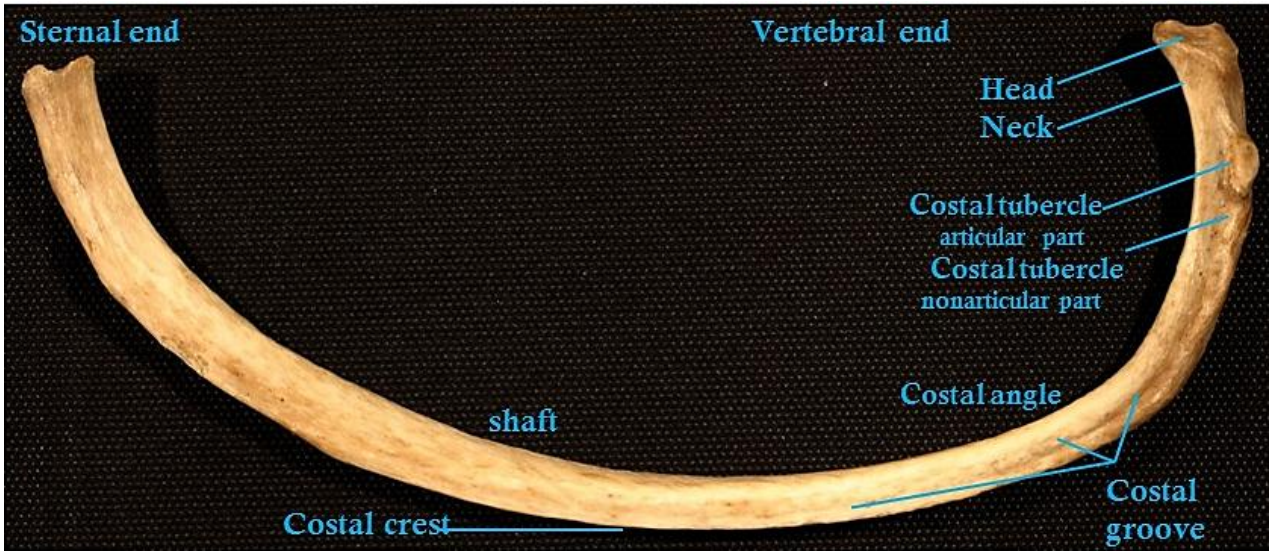



Fig. 13 *General characteristics of the rib*

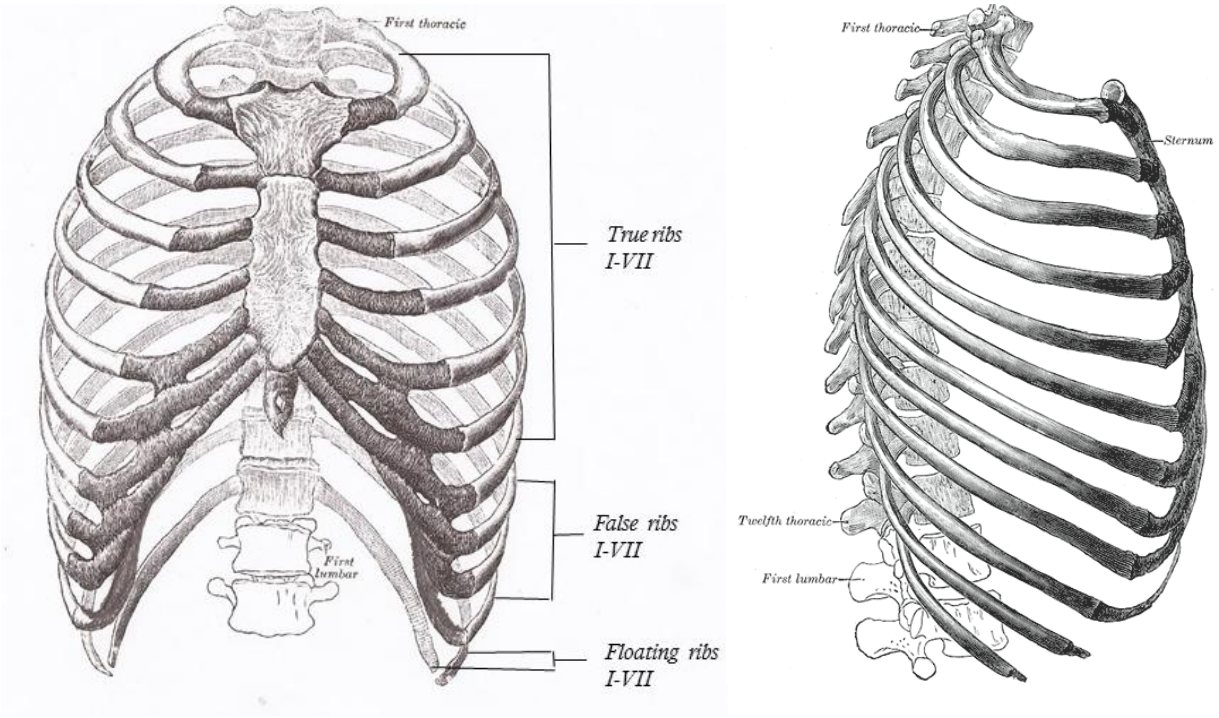



Fig.14 Thorax from anterior and lateral view.

*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

First seven pairs of ribs are **true ribs** because they directly articulate with sternum by their costal cartilages. Ribs VIII to X are **false ribs** because their costal cartilages articulate with the costal cartilages of the ribs above. Ribs XI and XII are **floating (free) ribs** and they have no connection with sternum or other costal cartilages.

**Rib I**

The first rib is the shortest and the most curved. It is flattened almost in horizontal plane with broad superior and inferior surface. It has small head but large and **prominent tubercle**. At its superior surface there are: the **groove for subclavian vein**, **scalene tubercle** and the **groove for subclavian artery**.

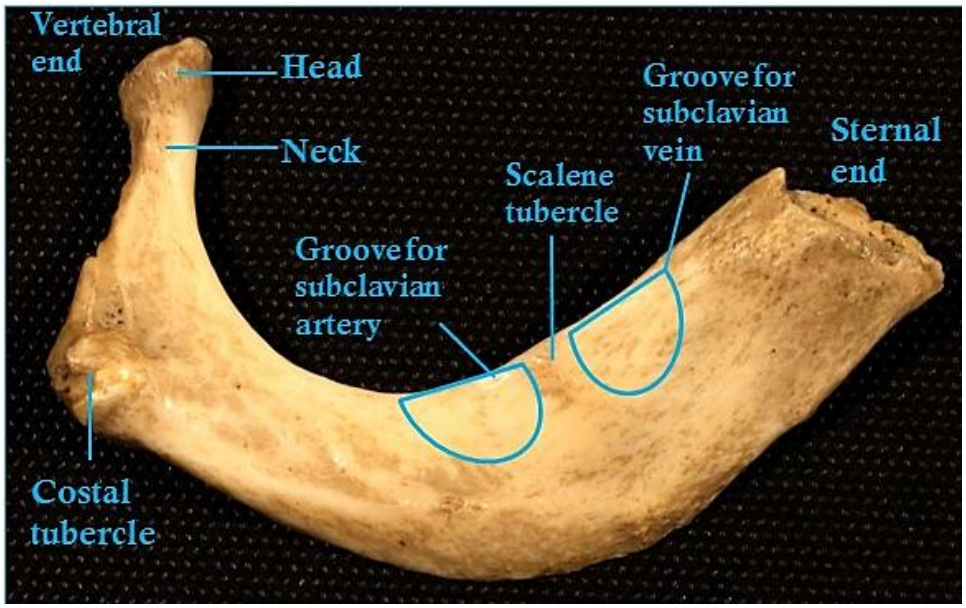



Fig. 15 *The first rib from the superior view.*

**Rib XI and XII**

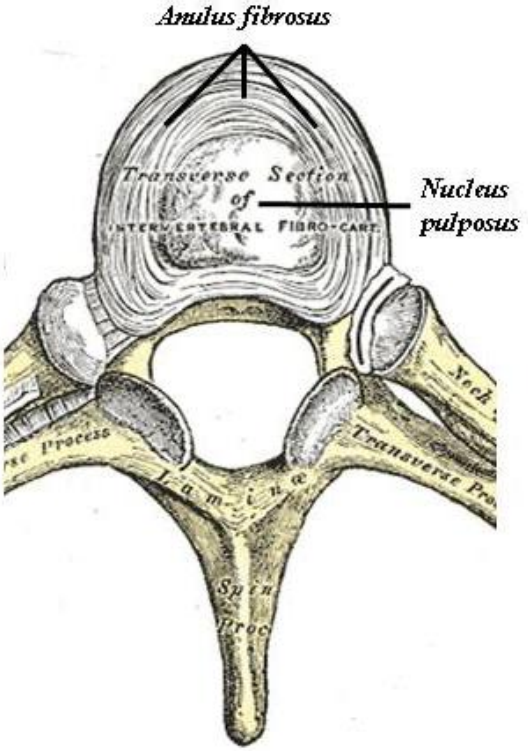
Both floating ribs have only small heads and they have no tubercle, no neck and no angle. The rib XI articulates only with the costal facet at the body of TXI, rib XII only with the costal facet at the body of TXII.

## JOINTS OF THE VERTEBRAL COLUMN

At the vertebral column all types of the joints can be found: cartilagineous, fibrous, osseous and synovial.

### Cartilagineous joints

**Intervertebral discs** are **symphyses** (joints by fibrous cartilage) between adjacent vertebral bodies**.** The first intervertebral disc is situated between CII and CIII, the last one between LV and SI. The size and shape of intervertebral disc corresponds with the shape and size of adjacent vertebral bodies to it.




Each intervertebral disc consists of:

- **anulus fibrosus** - outer lamellated portion formed by external ring of collagen and wide zone of fibrocartilage;
- **nucleus pulposus** – inner gelatinous portion which absorbs compression forces between vertebrae, it allows to vertebral bodies to roll over the incompressible gel.

Fig. 16 *Transverse section of the intervertebral disc between thoracic vertebrae.*
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

With aging the intervertebral discs undergo a degeneration, nucleus pulposus becomes dehydrated and anulus fibrosus becomes weaker. This leads to decreased ability of the disc to absorb the shocks.

**Synchondroses,** joints where connecting medium is a hyaline cartilage, can be found between sacral and coccygeal vertebrae during the growth period, in adulthood they are replaced by bones.

**Fibrous joints**

**Ligaments of the vertebral column** connect the bodies, arches and processes of vertebrae. The system of longitudinal and short ligaments controlls stability of the vertebral column and reinforces and supports the other joints of the vertebral column.

**Anterior longitudinal ligament** extends from the base of the skull (basilar part of the occipital bone) to the anterior surface of the sacrum, connecting anterior surfaces of the vertebral bodies and intervertebral discs. It adheres more firmly to the vertebral bodies than the intervertebral discs. At the sacrum it continues as **anterior sacrococcygeal ligament.**

**Posterior longitudinal ligament** runs along the posterior surfaces of the vertebral bodies and intervertebral discs inside the vertebral canal. It adheres more firmly to the intervertebral discs than the vertebral bodies. The upper part of this ligament connecting CII to the intracranial surface of the occipital bone is called **tectorial membrane.** Caudally posterior longitudinal ligament continues within the sacral canal as the **deep posterior sacrococcygeal ligament**.

Along the dorsal surface of the sacrum **superficial posterior sacrococcygeal ligament** runs. It extends from the median sacral crest to sacral and coccygeal horns closing the sacral hiatus.

Short ligaments connect the vertebral laminae and processes of adjacent vertebrae.

**Ligamenta flava** pass between the laminae of the adjacent vertebrae. The name of these ligaments is derived from their yellowish color, because they are predominantly formed by yellow elastic tissue.

**Interspinous ligaments** connect spinous processes of adjacent vertebrae. Anteriorly they reach ligamenta flava, posteriorly they blend with the supraspinous ligament.

**Supraspinous ligament** connects the tips of the spinous processes from CVII to LIII - LIV. **Ligamentum nuchae** extends like triangular membrane from spinous processes of CVII to the cranial base in the area from foramen magnum to the external occipital protuberance.

**Intertransverse ligaments** pass between adjacent transverse processes.

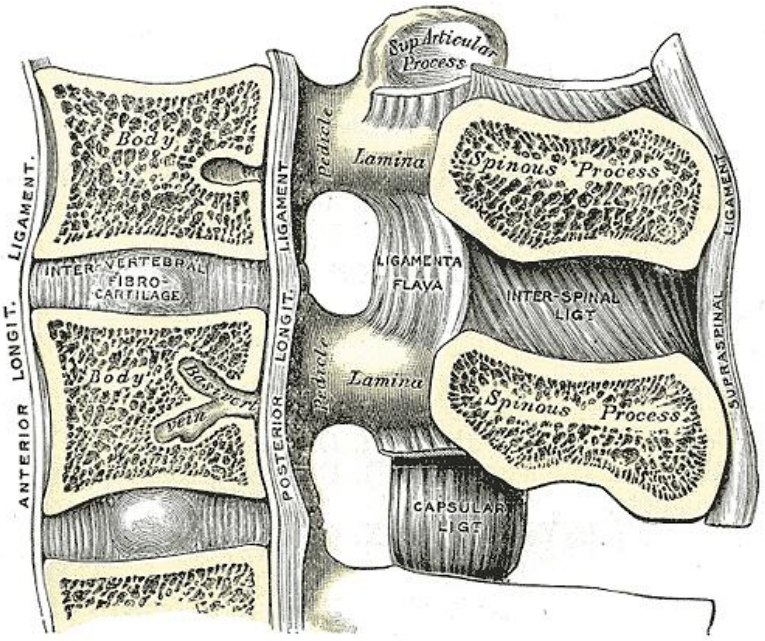



Fig. 17 *Ligaments of the vertebral column seen in transverse sectio in sagittal plane.*
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

**Osseous joint**

Synchondroses between the sacral and coccygeal vertebrae are replased by osseous joints in adulthood forming the sacrum and coccyx.

**Synovial joints**

Adjacent vertebrae are connected by their articular processes (superior articular processes of the lower vertebra join inferior articular processes of vertebra directly above it) forming synovial **zygapophysial joints (intervertebral joints or facet joints).** These joints are plane synovial joints which allow limited gliding movements. They stabilize the spinal column, guide and limit excessive movements. Zygapophysial joints have different orientation in different parts of vertebral column.

In the cervical part the facets of superior articular processes direct posteriorly, facets of inferior articular process posteriorly, futhermore, both face 45 degrees to the transverse plane and they are parallel to the coronal plane. **Zygaphophysial joints in cervical part** allow **flexion, extension, lateral ductions and rotation.**

The superior articulating facets in thoracic vertebrae direct posteriorly, superiorly and laterally and they are angled at 60 degrees to the transverse plane and almost parallel to the

coronal plane. **In thoracic part zygapohysial joints** allow **only rotation and lateral ductions**.

The articular facets at the lumbar vertebrae lie almost in sagittal plane, superior direct medially, inferior laterally. **Zygapophysial joints in lumbar part** allow **flexion and extension**.

**Craniovertebral joints**

Craniovertebral joints include:

- **atlantooccipital joint**
- **median atlantoaxial joint**
- **lateral atlantoaxial joints**

**Atlantooccipital joint** is the articulation between the occipital condyles (they are convex) and superior articular surfaces of the atlas (they are concave). It is **synovial elipsoid joint** which allows flexion, extension and lateral ductions but no rotation. The joint is strenghtened by **anterior** and **posterior atlantooccipital membrane**.

**Median atlantoaxial joint** is a **pivot synovial joint** between the articular surface at the dens of axis and facet for the dens at anterior arch of atlas. The dens is fixed to the anterior arch of atlas by **transverse ligament** running behind the dens and attached to the lateral masses of the atlas. Posterior aspect of the dens is also covered by vertically running fibres (they attach upwards to the basilar part of the occipital bone, downwards to the body of axis). The whole system is named **cruciforme ligament.** It is closely related to **membrana tectoria** (upward continuation of the posterior longitudinal ligamnet). Median atlantoaxial joint allows **rotation,** which is limited by the **alar ligaments** running from the dens of axis to the medial sides of the occipital condyles**.**

**Lateral atlantoaxial joints** are plane synovial joint between the inferior articular facets of the atlas and superior articular facets of the axis. Articular capsules of the joints are thick and loose strenghtened by accessory ligaments posteriorly nad medially. These joints allow rotation that is combined with the movement in median atlantoaxial joint.

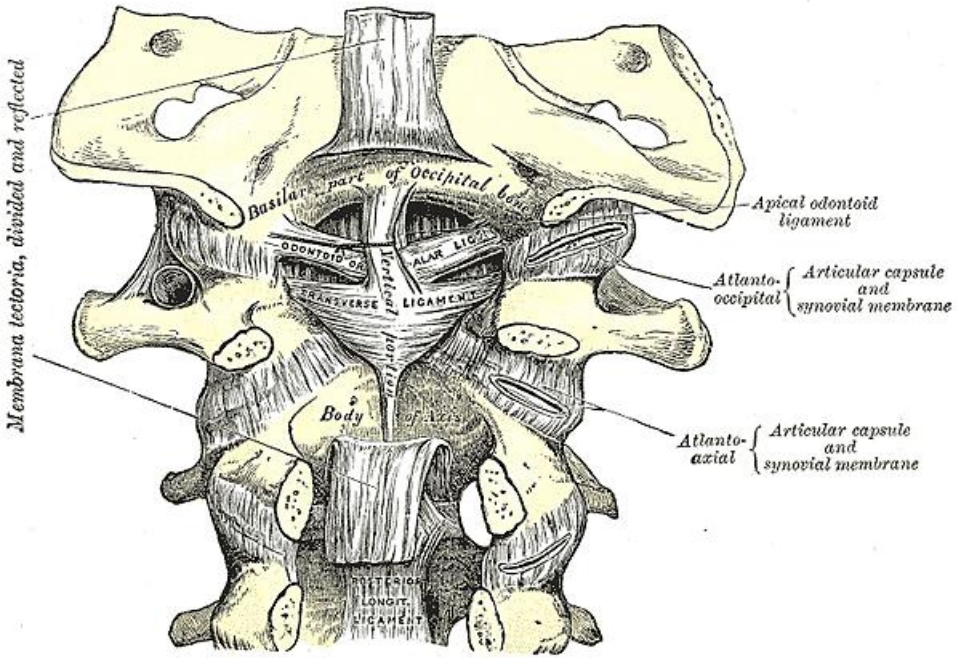
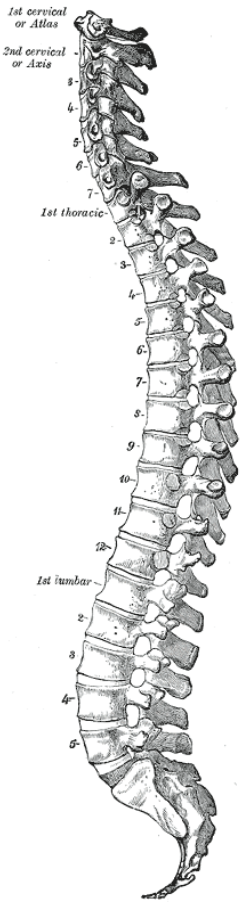



Fig. 18 *Craniovertebral joints. Posterior view.*
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

**Curvatures of the vertebral column**




Vertebral column is supported by the ligaments and muscles which are essential for the structural integrity of the spine. **In the sagittal plane** vertebral column shows **physiologic curvatures** in **cervical, thoracic and lumbar and sacrococcygeal part**.

The thoracic and sacrococcygeal curvatures are established during the intrauterine development, however, **cervical and lumbar curvatures** are developed during the childhood. Thus, vertebral column in newborn semms to be C – shaped with anteriorly concave **thoracic curvature - physiologic thoracic kyphosis** and anteriorly concave **sacrococcygeal curvature - physiologic sacrococcygeal kyphosis**. The cervical curvature is posteriorly concave - **physiologic cervical lordosis** and develops as a child starts to hold a head upright. When child begins to sit and walk upright, posteriorly concave **lumbar curvature** - **physiologic lumbar lordosis** is formed.

Some congenital defects and degenerative diseases can cause development of abnormal curvature in sagittal plane but also in frontal plane (scoliosis).

*Fig. 19 Vertebral column from the sagittal view.*
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

## JOINTS OF THE THORAX

### Costovertebral joints

All **costovertebral joints** are **plane synovial joints**.

They include following types of joints:

- **Joint of the costal head** - the head of the rib (subdivided by the crest into two facets) articulates with superior and inferior costal facet on adjacent vertebral bodies. This joint consists of two synovial compartments separated by intraarticular ligament, which runs from the crest at the costal head to the intervertebral disc**.** Articular capsule of this joint is firm and surrounded by radiate ligaments.

  ** The heads of rib I, X, XI and XII have only one simple articular surface without the crest and they articulate with only one single costal facet, that´s why in these joints there is only one synovial compartment.*
- **Costotransverse joint –** articular surface at the costal tubercle articulates with the costal facet at the transverse process. The joint has firm articular capsule strengthened by **costotransverse ligaments** passing in three stripes.

  **Rib XI and XII have no tubercle that´s why they form no costotransverse joint.*

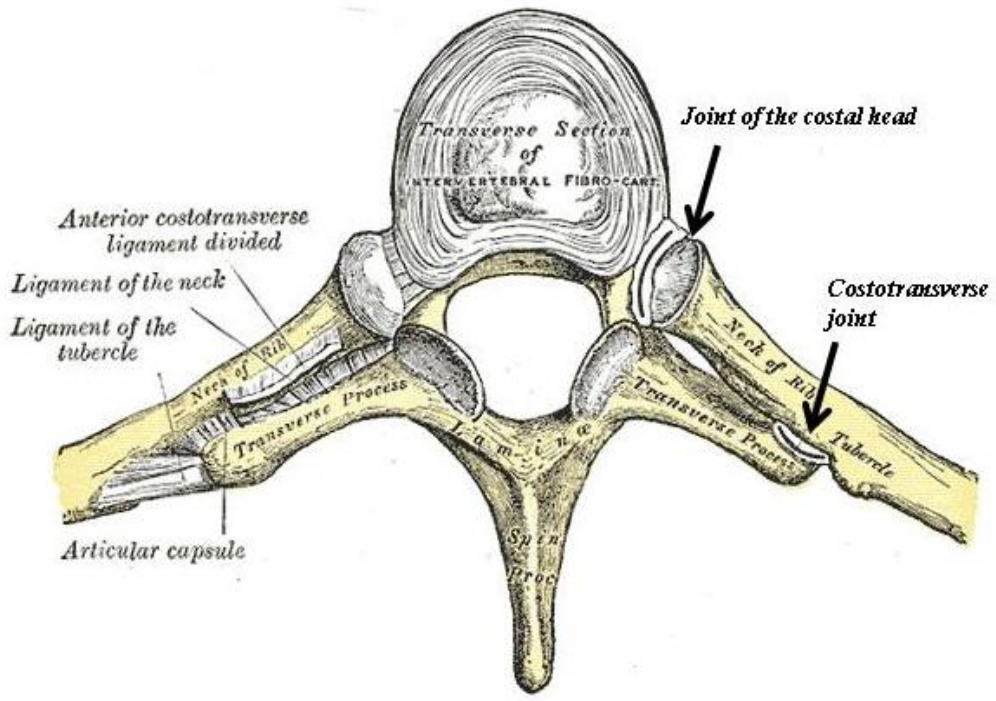
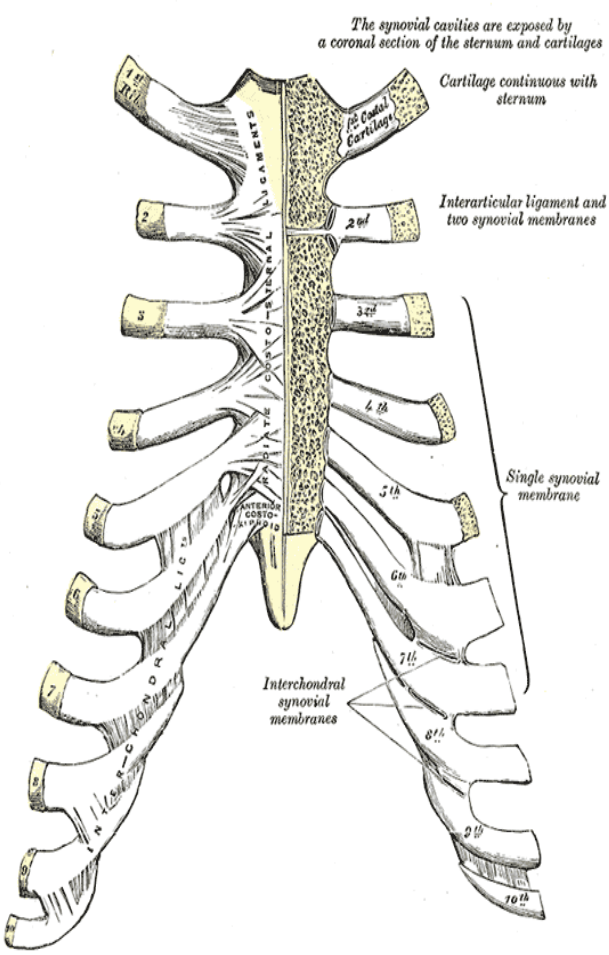



Fig. 22 *Costovertebral joints. Superior view.*
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

**Sternocostal joints**

Costal cartilages of rib I to VII connect with the costal notches on the lateral borders of sternum forming - **sternocostal joints**.




**The first rib** is connected to sternum by **cartilagineous joint – synchodrosis**.

Joints between the **rib II to VII** and sternum are **plane synovial joints**. Articular capsule of the joints is stabilized by **radiate sternocostal ligaments** passing from the costal cartilages to the anterior and posterior surface of sternum.

**Interchondral joints** are developed in the areas of mutual connections between adjacent cartilages of rib VII to X. They are usually plane synovial joints providing indirect docking to sternum.

Fig. 22 *Sternocostal joints. Anterior view.*
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

**SKULL**

The skull forms the complex bony skeleton of the head. In young adults it consists of 28 separate bones including auditory (ear) ossicles and mandible (lower jaw), some of these bones are are paired, the bones situated in the median plane are single.

Excluding the mandible, which is connected to the the temporal bone by the synovial joints, the other bones of the skull are connected by sutures and synchondroses to form **cranium.**

**Cranium** is usually subdivided into two components:

- **neurocranium** – encloses the brain with meninges and special sense organs of olfaction, vision, hearing and balance; its upper part - the roof of the cranial cavity is the **skull vault** or **calvaria** (formed by parts of frontal bone, parietal bones, temporal bones and occipital bone), the floor is **the cranial base** (formed by parts of frontal bone, ethmoid bone, sphenoid bone, temporal bones and occipital bone).

- **viscerocranium (splanchnocranium)** or the **facial skeleton** – forms the skeleton of the face, nasal and oral cavities (lacrimal bones, nasal bones, palatine bones, maxillae, zygomatic bones, inferior nasal conchae, mandible and vomer); these bones are developed from pharyngeal arches.

Majority of the cranial vault bones are flat bones. They consists of two plates of compact bone enclosing a layer of spongy bone (**diploe**). The internal plate of compact bone is thinner and more brittle while the external plate tends to be thicker and more resilient. These bones are developed by intramembranous ossification, however, the bones of the cranial base are developed by enchodral ossification.

The cranial bones have different thickness. In the regions where they are covered by the muscles they are thin and delicate (e.g. facial bones, squama of the temporal bone). In the sites of the muscle attachment the bones are thicker (e.g. protuberance at the external surface of the occipital bone).

The skull shows numerous openings and gateways which are transmitted by important nerves and vessels which enter or exit the skull. During the trauma not only

bones can be fractured but neurovascular structures can be damaged as a result of this trauma too. The openings of the skull which contain the vessels (especially those containing the emissary veins) can be a route of the infection spreading from the extracranial to the intracranial space what can result in serious clinical complications.

## INDIVIDUAL CRANIAL BONES

### FRONTAL BONE

**Frontal bone** consists of free parts: **squama, orbital part and nasal part**.

#### Squama of the frontal bone

**Squama** of the frontal bone forms the forehead. It has external surface which is slightly convex. It forms **supraorbital margin** – the upper border of the orbital opening. At its medial third the **supraorbital notch** or foramen is situated. Medially to it a frontal notch or foramen can be developed, however, it can be also absent. Laterally the supraorbital margine continues to the **zygomatic process of the frontal bone** which connects with the frontal process of the zygomatic bone.

Above the supraorbital margines there are **superciliary arches**. They are situated at the level of eyebrows and they are more prominent in males than females. Between the superciliary arches there is a small depression – **glabella**.

**Frontal tuberosities** are elevations approximately 2cm above the superciliary arches. They are more obvious in females.

**The inner surface** of frontal squama is concave. In the median plane it shows foramen caecum, **frontal crest** (for the attachment of the dural partition - falx cerebri, which separates the cerebral hemispheres) and **groove for superior sagittal sinus** (dural venous sinus)**.**

Posterior or parietal margin of frontal squama connects with parietal bones forming the **coronal suture**.

Laterally the squama forms the temporal surface - a part of the anteromedial wall of temporal fossa, and connects with the greater wing of the sphenoid bone.

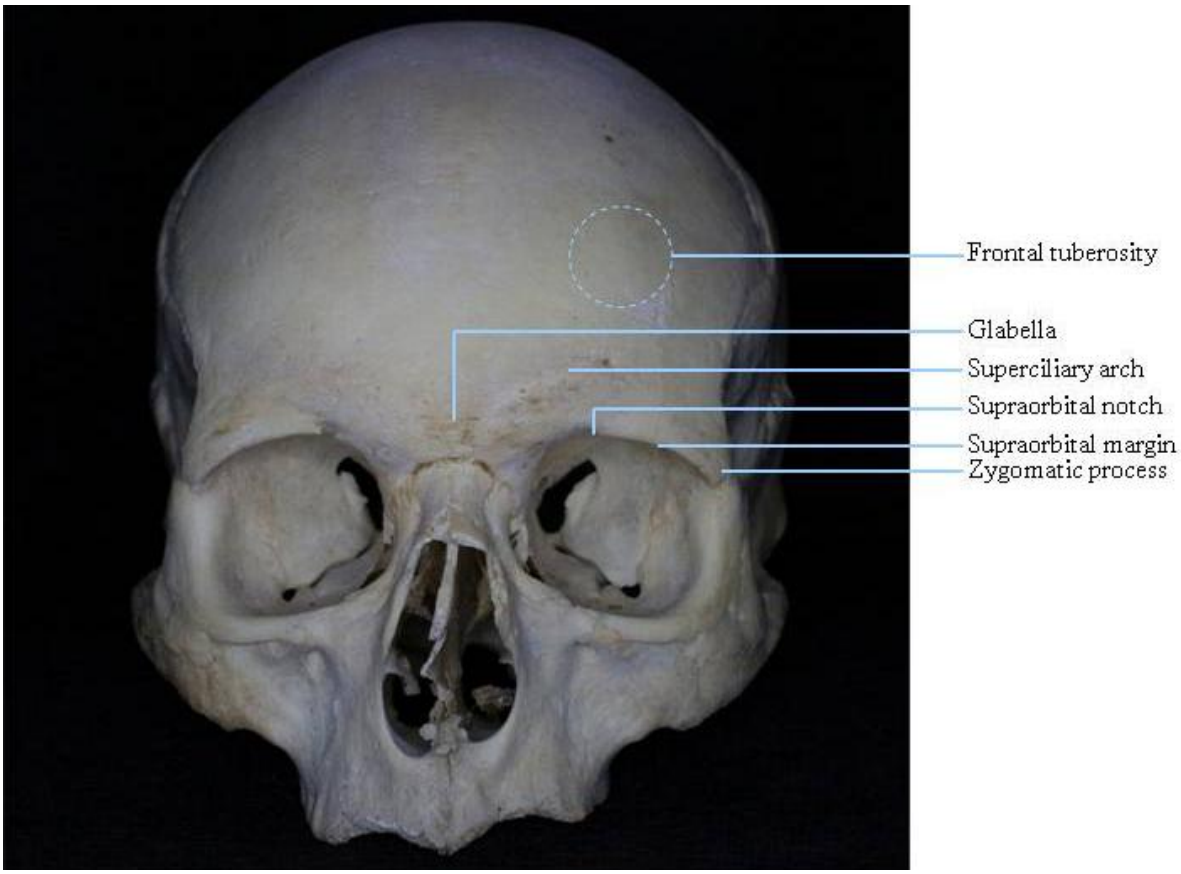



Fig. 23 *Anterior view of the skull – structures of the frontal bone*.

**Orbital parts of the frontal bone**

**Orbital parts** of the frontal bone are oriented almost in horizontal plane. They form the roofs of the orbits (cavities for the eyeballs) and they are separated by the **ethmoidal notch** (ethmoid bone is embeded in it). **The inferior or orbital surface** of orbital parts is smooth with concavity on the lateral side of the roof of the orbit – **fossa for the lacrimal gland** (the gland which produces the tears). **Superior or cerebral surface** of the orbital parts is convex and uneven because of **impressions of cerebral gyri** (a folded ridge of the cerebral cortex). Posterior borders of orbital parts articulate with the lesser wings of the sphenoid bone.

**Nasal part of the frontal bone**

The **nasal part** of the frontal bone is the area between the supraorbital margines. Inferiorly it joins the nasal bone, frontal process of maxilla and lacrimal bone of each side.

**Frontal sinuses**

Frontal bone is a pneumatic bone. Especially in the squama of the frontal bone there are air filled cavities - **frontal sinuses,** situated between the laminae of the bone. The sinus is absent at the birth, well developed in 7-8 years, with full size after the puberty. The size and shape of the sinus varies among the idividuals, usually they have larger volume in males. The frontal sinuses open into the nasal cavity - its middle nasal meatus through frontonasal canal.

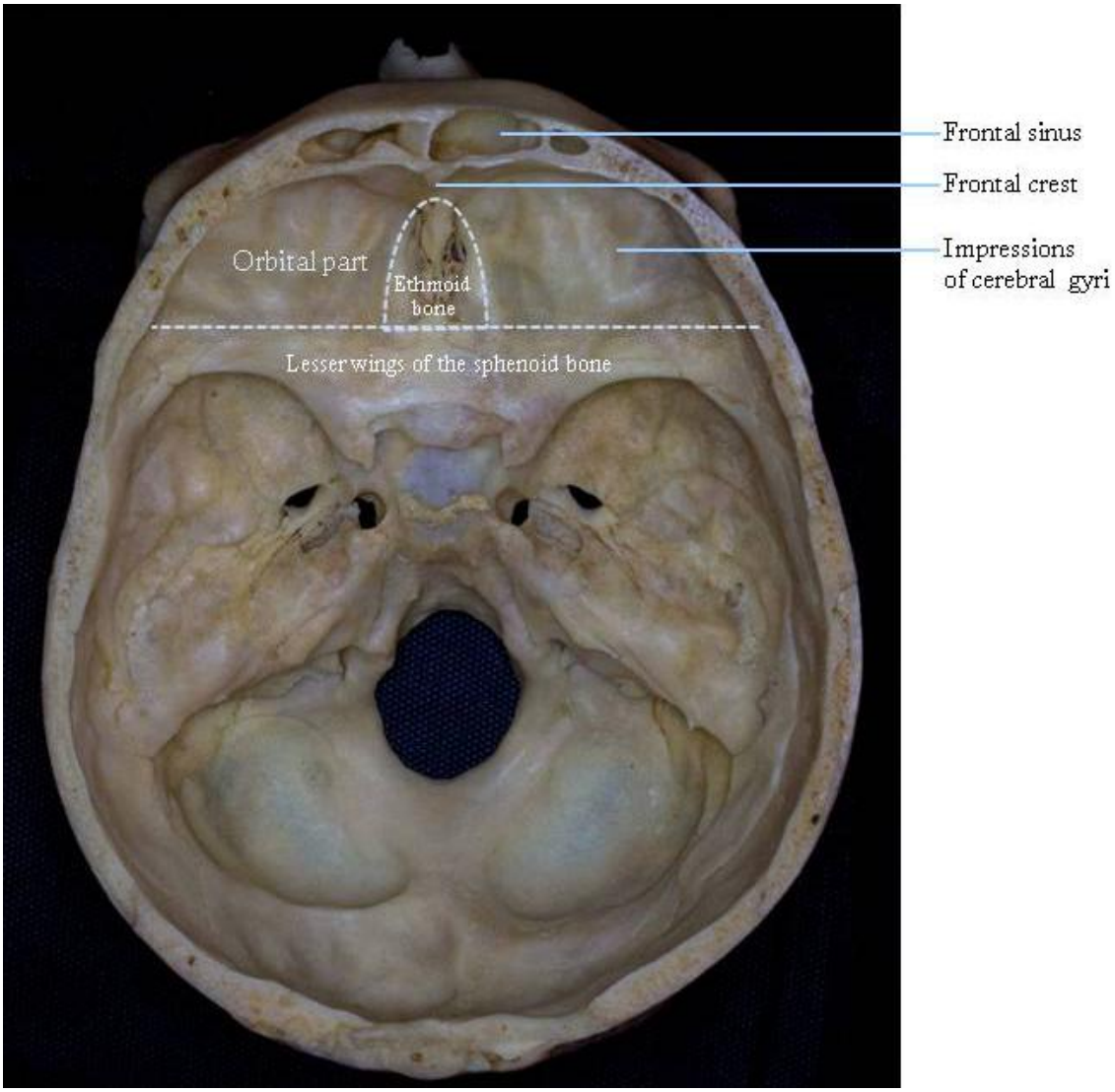



Fig. 24 *Internal cranial base – structures of the frontal bone.*

**Table 1: Frontal bone – summary.**

| parts of the bone | surfaces | structures |
|---|---|---|
| **squama** | external | supraorbital margines<br>supraorbital notches<br>superciliary arches<br>glabella<br>frontal tuberosities<br>zygomatic processes |
| | internal | groove for superior sagittal sinus<br>frontal crest<br>foramen caecum |
| **Orbital** | orbital | fossa for the lacrimal gland |
| | cerebral | impressions of cerebral gyri |
| **nasal** | | |
| **frontal sinus** | | |

**PARIETAL BONE**

Parietal bone is a paired bone. Both parietal bones form majority of the calvaria. They are irregulary quadrangular with

- **four margines:**

**frontal** - connects with the squama of the frontal bone forming the coronal suture

**sagittal** - connects with the parietal bone from the other side forming the sagittal suture

**occipital** - connects with the squama of the occipital bone forming the lambdoid suture

**squamous** - connects with the squama of the temporal bone forming the squamous suture.

- **four angles**

**frontal** - between sagittal and frontal margine

**occipital** - between sagittal and occipital margine

**sphenoid** - between squamous and frontal margine, it articulates with the greater wing of sphenoid bone

**mastoid** - between squamous and occipital margine, it articulates with the mastoid process of the temporal bone

**The external surface** of parietal bone is convex and smooth. In the central part there is a **parietal tuberosity**. From the lateral view **superior and inferior temporal lines** are visible. These curved lines mark the attachments of the temporalis fascia (superior temporal line) and temporalis muscle (inferior temporal line). Posteriorly next to the sagittal margine there is **parietal foramen**.

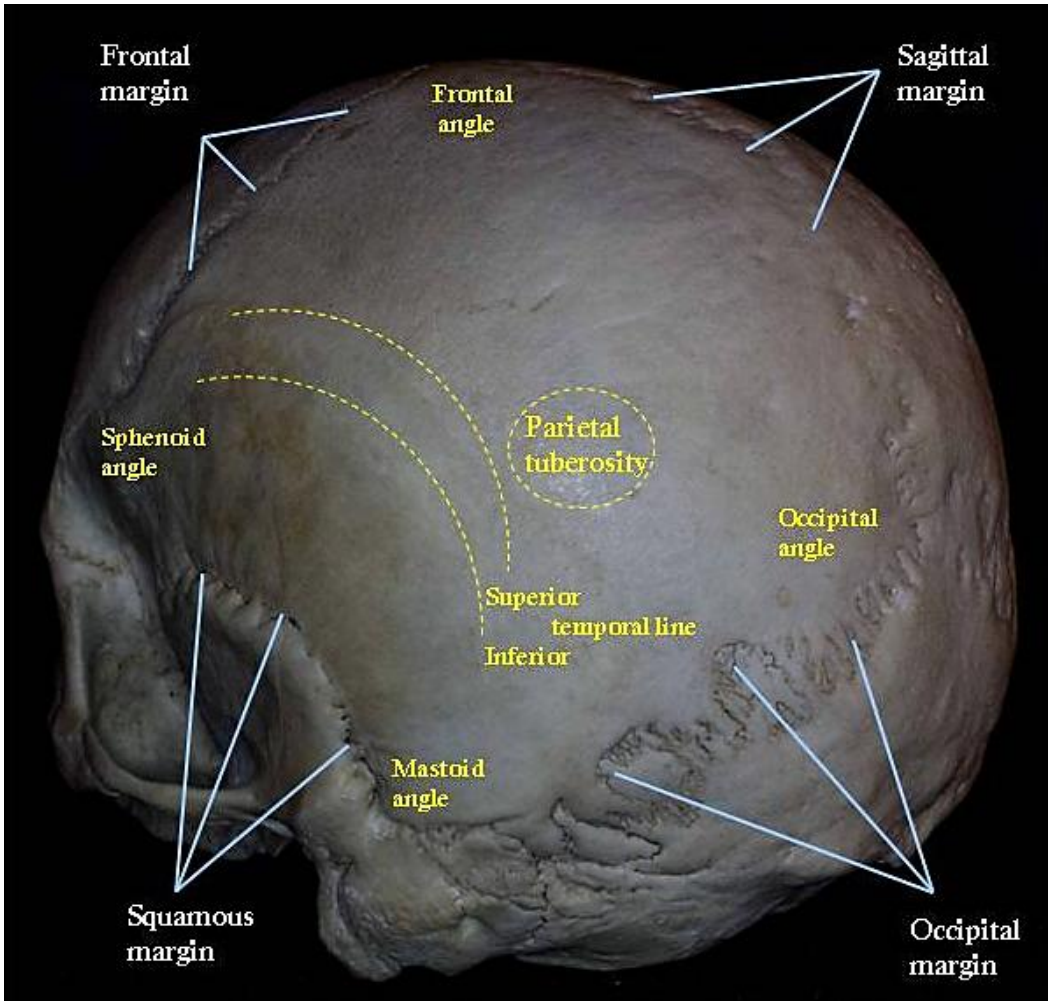



Fig. 25 E*xternal surface of the parietal bone*.

**The internal surface** of parietal bone is concave and shows numerous narrow **sulci (grooves) for middle meningeal artery**. Along the internal aspect of the sagittal suture there is the continuation of the **sulcus (groove) for superior sagital sinus** which continues from the squama of frontal bone to the squama of the occipital bone.

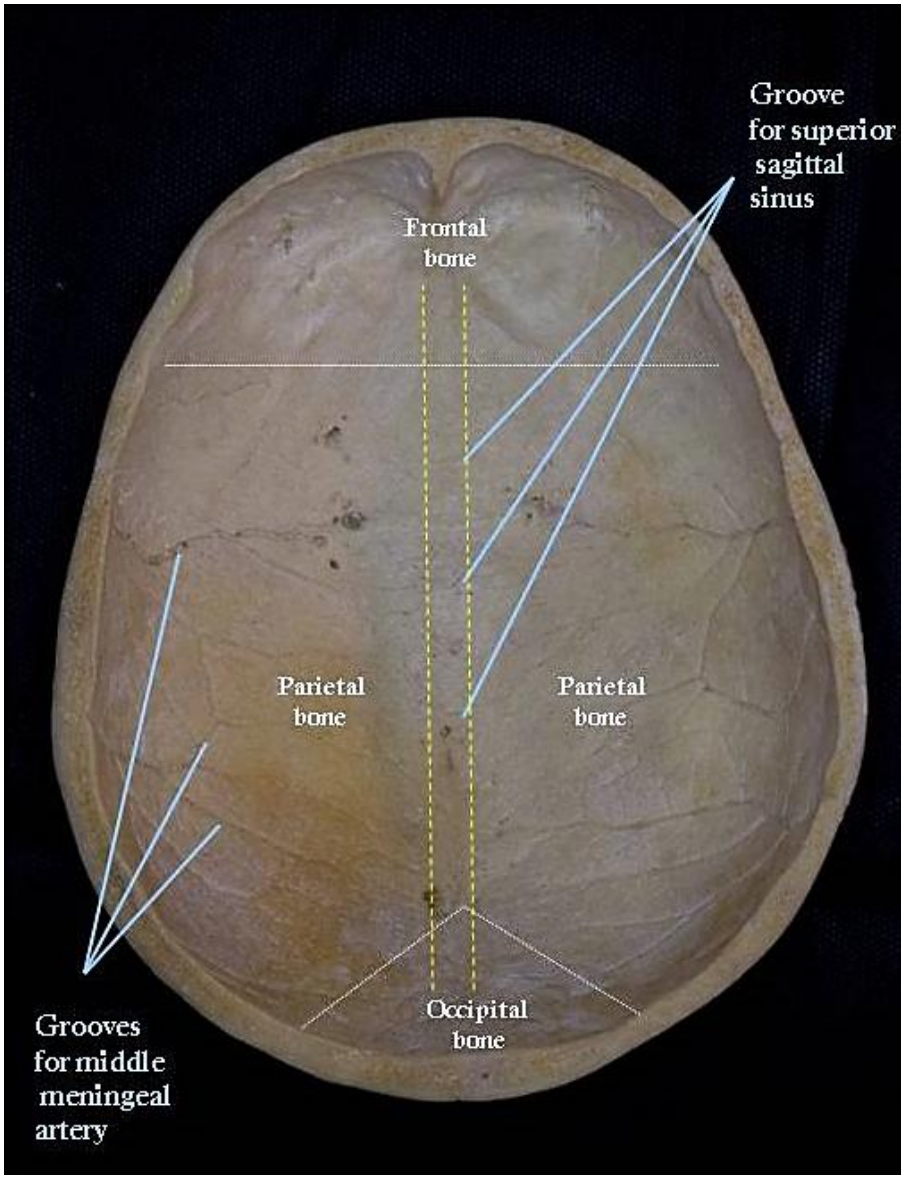



Fig. 26 *Internal surface of the cranial vault – structures at the parietal bone.*

**Table 2: Parietal bone – summary.**

| **surfaces** | **structures** |
|---|---|
| **external** | parietal tuberosity<br>parietal foramen<br>superior temporal line<br>inferior temporal line |
| **internal** | groove for the superior sagittal sinus<br>grooves for middle meningeal artery |
| | |
| **margines**:<br>**frontal, sagittal, occipital, squamous** | **angles:**<br>**frontal, sphenoid, occipital, mastoid** |

## OCCIPITAL BONE

Occipital bone forms posterior part of calvaria and cranial base. It consists of three parts **squama, basilar part and lateral parts** which are situated around the largest foramen of the skull - **foramen magnum.** Foramen magnum transmits medulla oblongata with its meninges, vertebral arteries, spinal root of the accessory nerve and membrana tectoria.

### Squama of the occipital bone

**Squama** of the occipital bone is situated **behind foramen magnum.** Its **external surface** is convex with e**xternal occipital protuberance** at the centre. This midline protrusion is the site for the attachment of the nuchal ligament and trapezius muscle. Curved lines which extends laterally from the external occipital protuberance are called **superior nuchal lines (**trapezius, occipitalis and splenius muscles are attached to them). Above the superior nuchal lines there are **highest nuchal lines** (the epicranial aponeurosis is attached to them) and below the superior nuchal lines there are **inferior nuchal lines. External occipital crest** (median nuchal line) extends downwards from the external occipital protuberance to the foramen magnum and gives attachment to the nuchal ligament.

**The internal surface** of the occipital squama is concave and presents a bony prominence in the midline – **internal occipital protuberance** from which the **internal occipital crest** runs downwards for the attachment of falx cerebelli (dural partition which separates the hemispeheres of the small brain). **Sulcus (groove) for the superior sagittal sinus** is visible at the upper part of the squama. Laterally from the internal occipital protuberance **sulcus (groove) for the transverse sinus** continues at both sides.

### Basilar part of the occipital bone

**Basilar part** of the occipital bone extends anteriorly from foramen magnum. **Its superior surface** is slightly concave and forms **clivus** (slope) where medulla oblongata and pons lie. The basilar part articulates anteriorly with the sphenoid bone and laterally with the petrous part of the temporal bone. At the border between the basilar part of the

occipital bone and petrous part of the temporal bone there is a **sulcus (groove) for inferior petrosal sinus**. At the **inferior surface of the basilar part** there is a **pharyngeal tubercle** for the attachment of pharyngeal raphe.

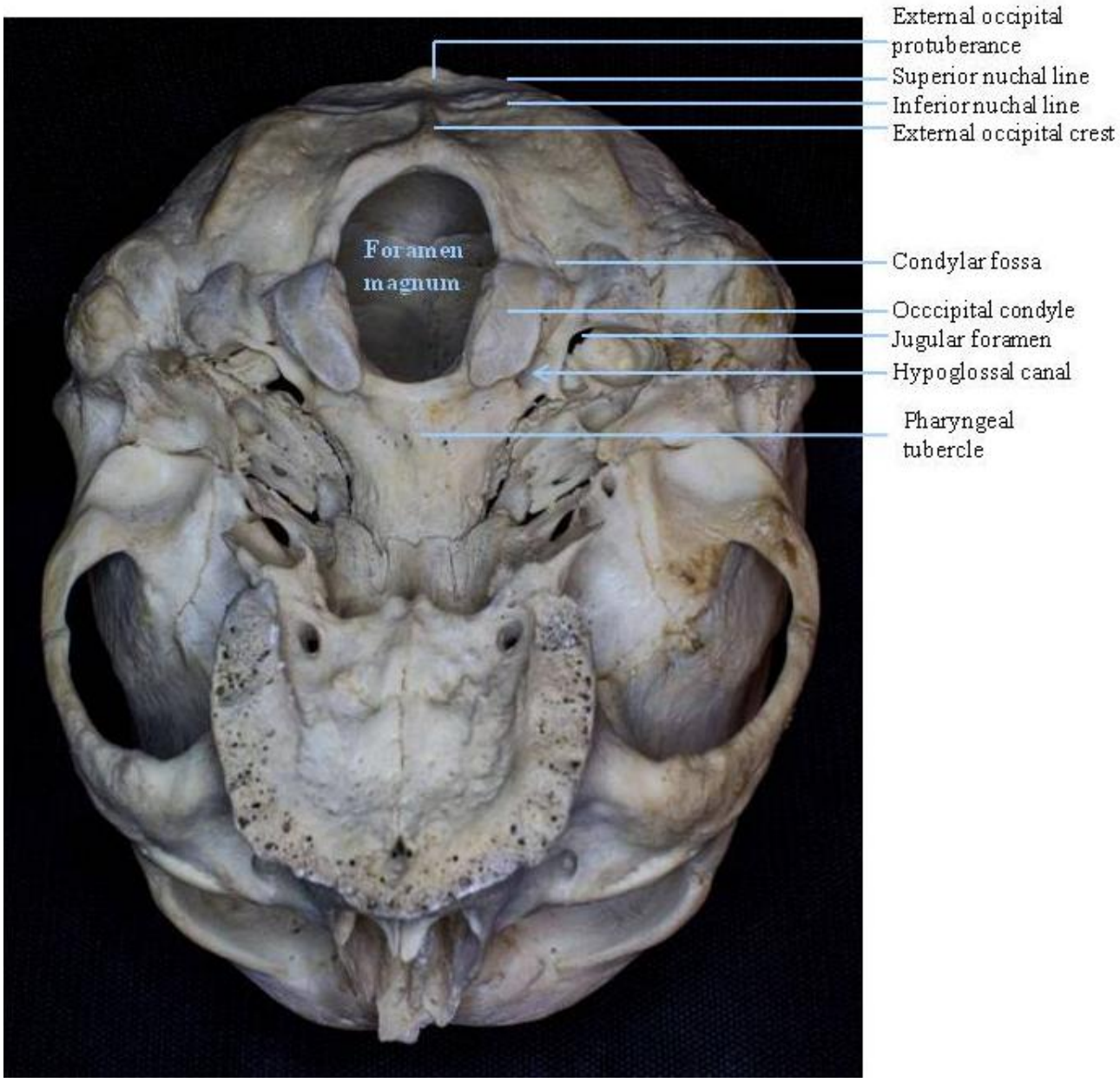



Fig. 27 E*xternal surface of the cranial base –structures at the occipital bone*.

**Lateral parts of the occipital bone**

**Lateral parts** of the occipital bone are situated at both sides of foramen magnum. At the external surface there are the occipital condyles, articular surfaces for the articulation with the atlas.

**Hypoglossal canal** traverses the occipital condyle and transmits the hypoglossal nerve at both sides. Behind each occipital condyle there is **condylar fossa** which leads into the **condylar canal** containing the emissary veins.

Between the lateral part of the occipital bone and petrous part of the temporal bone there is a **jugular foramen** that is formed by the **jugular notch of the occipital bone** and **jugular notch at the temporal bone**. Jugular foramen can be partially subdivided by intrajugular processes forming smaller anteromedial part and larger posterolateral part. It gives transmission for internal jugular vein (its initial part), glossopharyngeal nerve, vagus nerve and accessory nerve and some meningeal branches from occipital and ascending pharyngeal arteries.

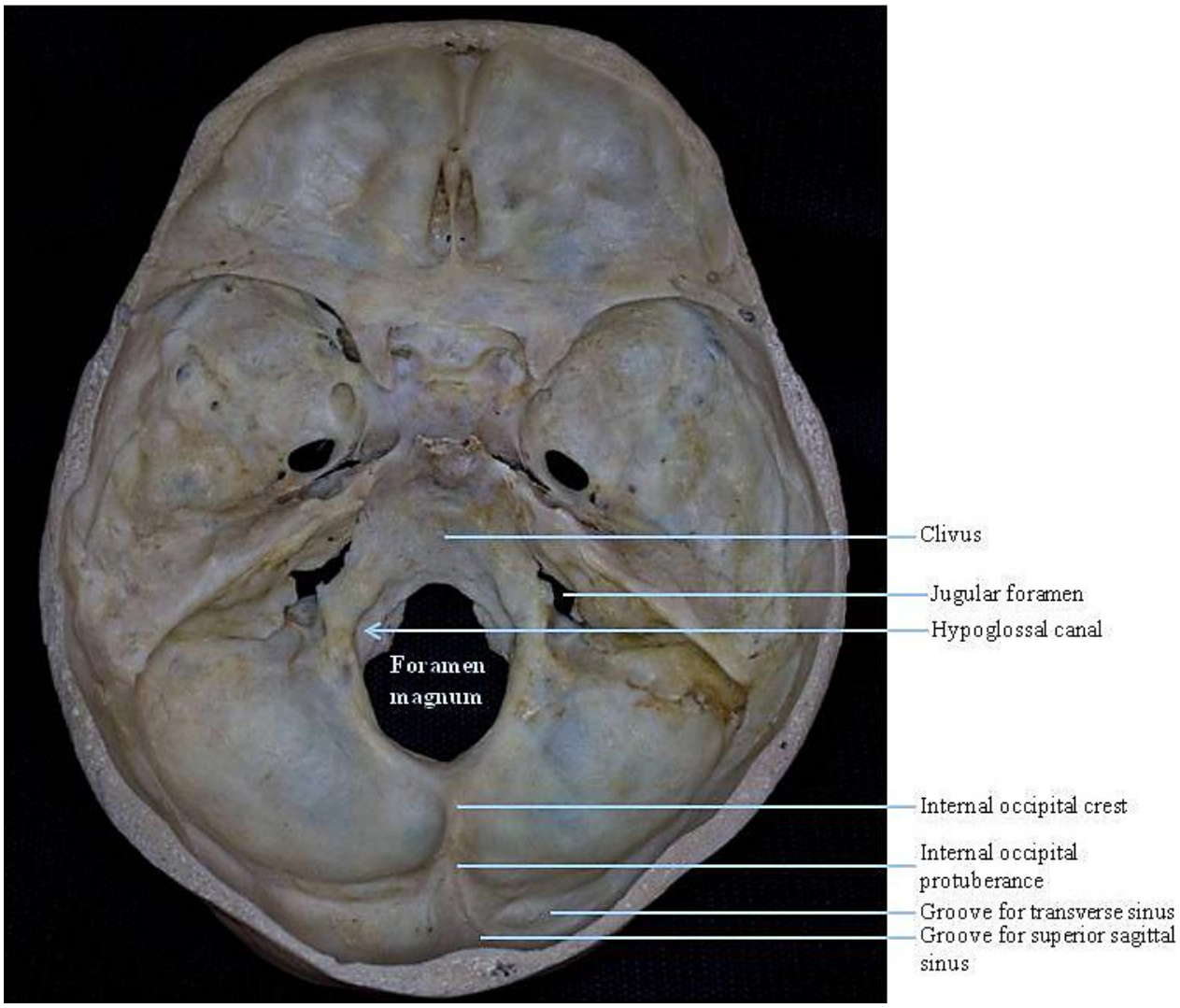



Fig. 28 *Internal surface of the cranial base – structures at the occipital bone.*

**Table 3: Occipital bone – summary.**

| part | surface | structures |
|---|---|---|
| **squama** | **external** | external occipital protuberance<br>superior nuchal lines<br>inferior nuchal lines<br>external occipital crest |
| | **internal** | internal occipital protuberance<br>internal occipital crest<br>groove for the superior sagittal sinus<br>groove for the transverse sinus |
| **lateral** | **external** | occipital condyles<br>condylar fossae<br>jugular notches<br>hypoglossal canals |
| | **internal** | hypoglossal canals<br>jugular notches |
| **basilar** | **external** | pharyngeal tubercle |
| | **internal** | clivus |

## SPHENOID BONE

**Sphenoid bone** forms the central part of the cranial base. It consists of the **body, lesser wings, greater wings and pterygoid processes**.

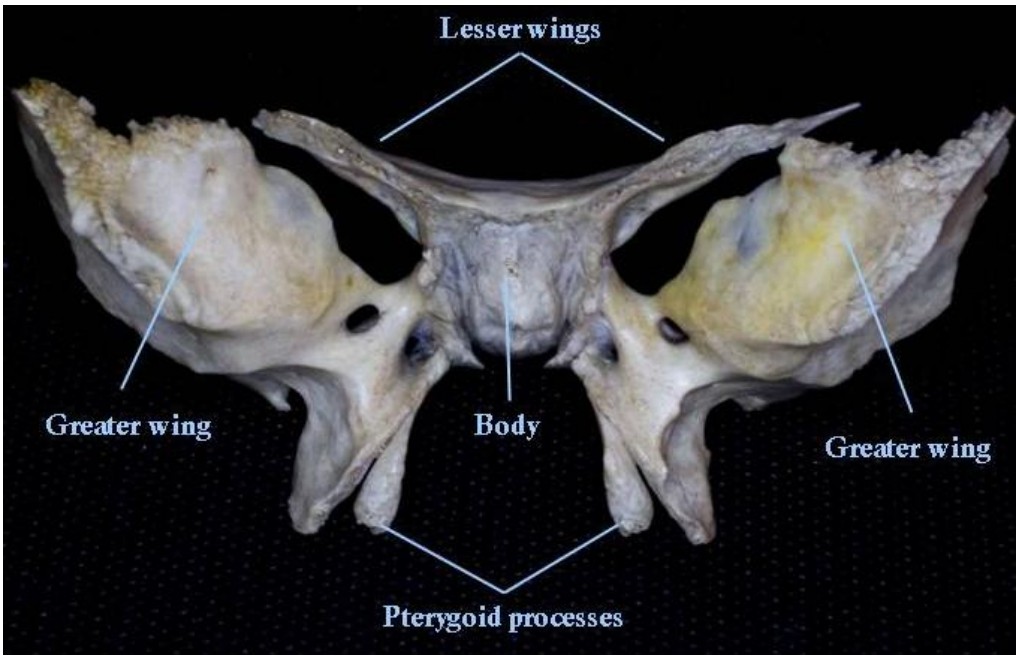



Fig. 29 *Sphenoid bone from anterior view.*

**The body of the sphenoid bone**

**The body of the sphenoid bone** is situated in the midline and it has a cuboidal shape with **sphenoid sinuses** inside.

**Superior or cerebral surface** presents concavity – **hypophysial fossa** for the hypophysial (pituitary) gland. Dorsally the surface elevates forming the **dorsum sellae** with **posterior clinoid processes** for the attachment of tentorium cerebelli (dural partition which separates cerebellum from the occipital lobes). **Hypophysial fossa** and **dorsum sellae** are commonly called **sella turcica**, because this saddle – shaped depression has similar shape as Turkish seat. In front of the hypophysial fossa there are the optic canals and chiasmatic sulcus (sulcus chiasmaticus or prechiasmaticus). **Optic canal** leads anterolaterally into the orbit (optic nerve and ophthalmic artery run through it). **Chiasmatic sulcus** is a transverse groove between the optic canals (some fibres of the optic nerve cross here). Anterior edge of chiasmatic sulcus forms the border between the body and lesser wings of the sphenoid bone.

**Anterior surface** of the sphenoid body directs into the nasal cavity. In the midline it forms a **sphenoidal crest** which articulates with the perpendicular plate of the ethmoid bone (the upper part of bony nasal septum). At both sides of the sphenoidal crests there are openings of sphenoid sinuses.

**Inferior surface** of the sphenoid body bears a sphenoidal rostrum which articulates with the vomer.

**Laterally** the sphenoid body connects with the greater wings and pterygoid processes. Lateral surface is posteriorly grooved by **carotid sulcus** at both sides (it is impression of internal carotid artery which exits from carotid canal here).

**Sphenoid sinuses** are air – filled cavities inside the body. They are usually asymetrical and subdivided by complete or incomplete bony septa. Sometimes they can extend into the greater or lesser wings as well. At the birth they have very small volume and just after the puberty they reach the final size. They open into the nasal cavity – into superior nasal meatus.

Fig. 25 E*xternal surface of the parietal bone*.

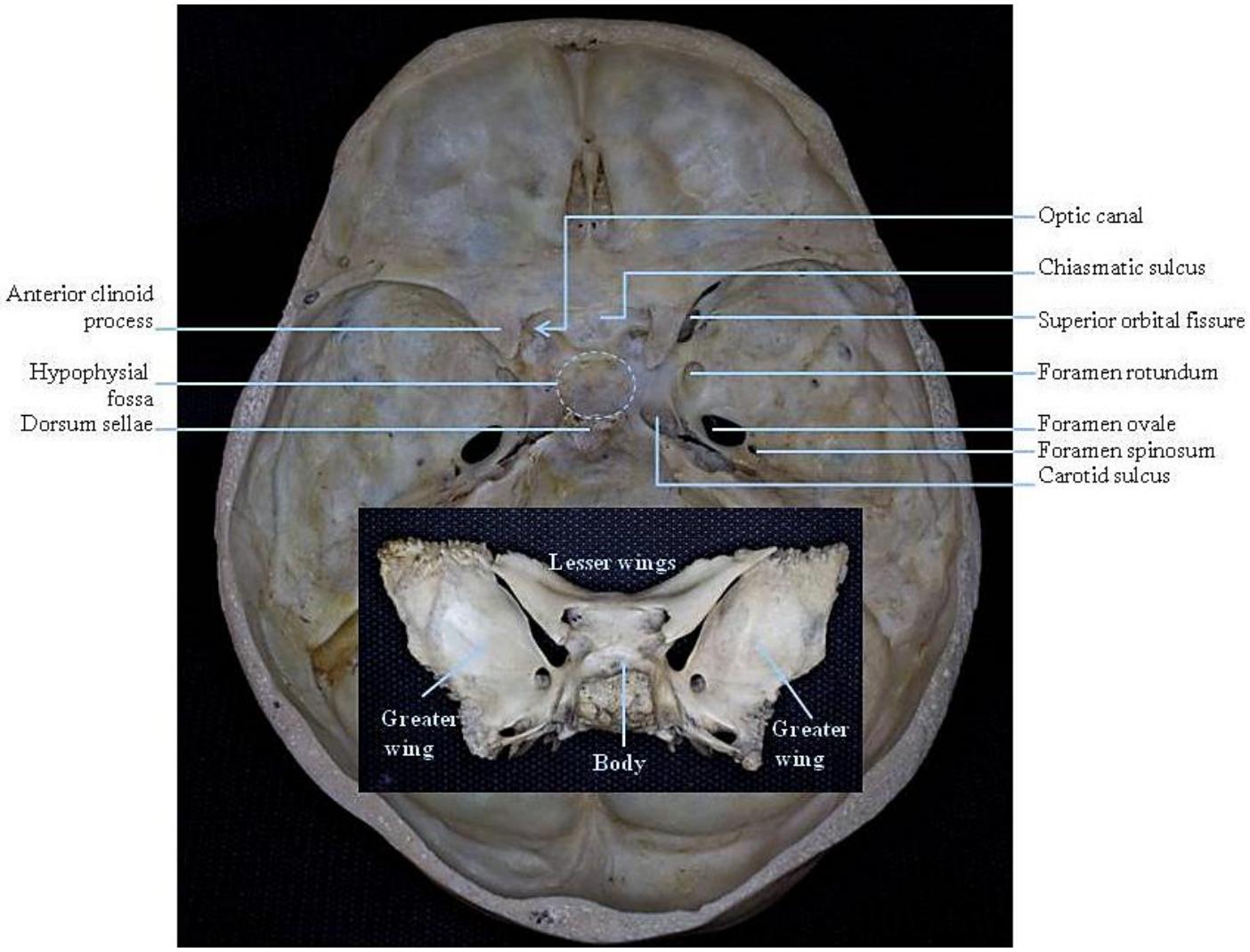



Fig. 30 *Internal surface of the cranial base - structures at the sphenoid bone.*

**Lesser wings of the sphenoid bone**

**Lesser wings** project anterolaterally from the sphenoid body. They are almost in horizontal plane showing the **cerebral (superior) surface and orbital (inferior) surface**. Cerebral surface is related to the frontal lobes of the brain. Inferior surface forms the roof of the orbit and with the greater wings they border the **superior orbital fissure**. This fissure is a main pathway between the middle cranial fossa and the orbit through which the oculomotor, trochlear, abducens and ophthalmic nerves and ophthalmic veins run. Anteriorly lesser wings articulate with the cribriform plate of the ethmoid bone and orbital parts of the frontal bone. Dorsally they have free margines which medially protrude into the **anterior clinoid processes** which give attachment to the anterior ends of tentorium cerebelli (dural partition which separates cerebellum from the occipital lobes).

**Greater wings of the sphenoid bone**

**Greater wings** project laterally from the sphenoid body into both sides. They are curved and inserted between the squamous and petrous parts of the temporal bone of each side.

Each **greater wing** forms several surfaces: **cerebral, orbital, lateral (subdivided into temporal and infratemporal) and maxillary surface.**

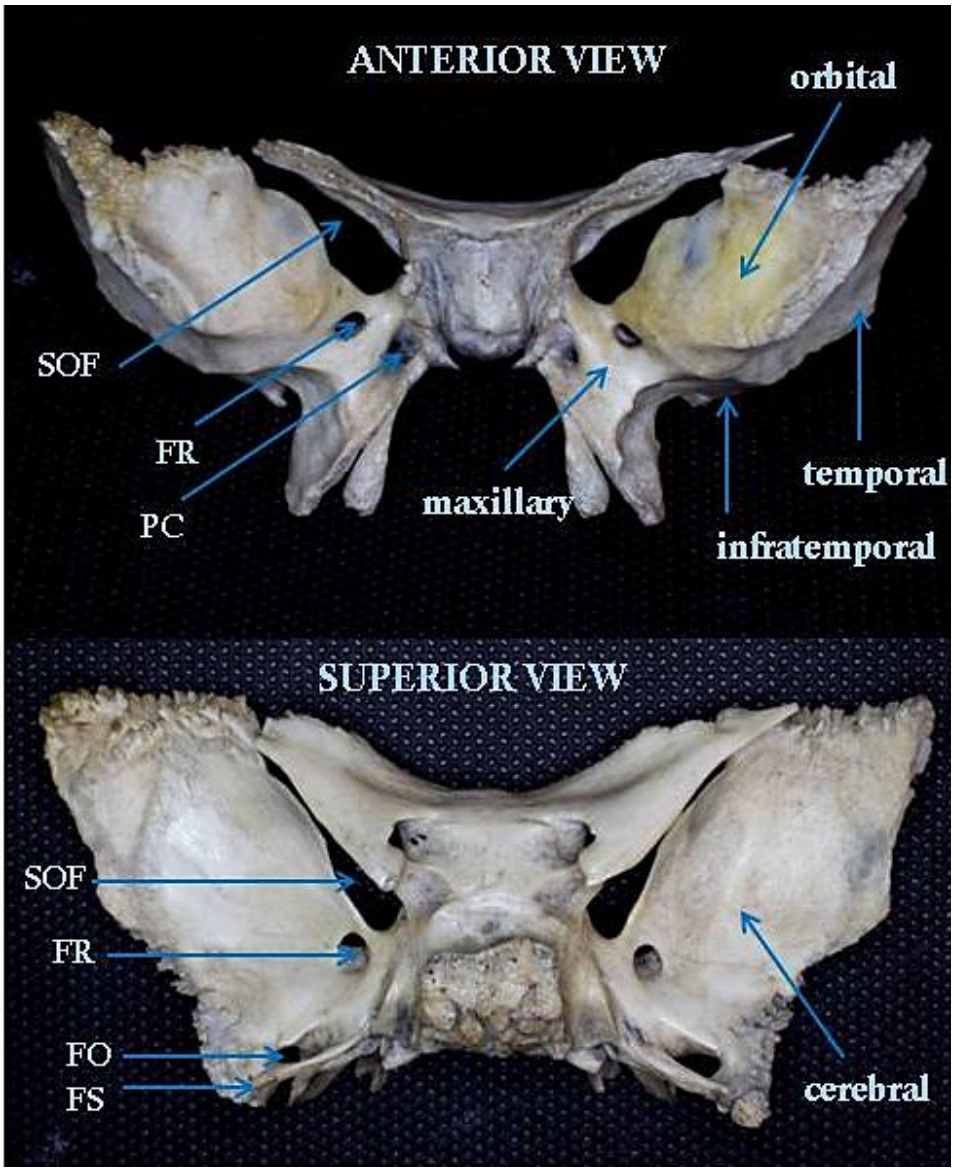



Fig. 31

*Surfaces of the greater wing from the anterior and superior view.*

*SOF – superior orbital fissure*
*FR – foramen rotundum*
*FO – foramen ovale*
*FS – foramen spinosum*
*PC – pterygoid canal*

**The cerebral surface** of the greater wing is related to the temporal lobe of the brain. Anteriorly it borders the superior orbital fissure together with the lesser wing of the sphenoid bone. Anteromedially at this surface there is **foramen rotundum** for the maxillary nerve. Posterolaterally to foramen rotundum there is **foramen ovale** for the mandibular nerve, accessory meningeal artery, lesser petrosal nerve and emissary vein. Posterolaterally to foramen ovale there is **foramen spinosum** which transmits the middle meningeal artery and meningeal branch of mandibular nerve.

**The orbital surface** of the greater wing is quadrangular and forms the lateral wall of the orbit. Superiorly it articulates with the orbital plate of the frontal bone and anteriorly with the zygomatic bone.

**The lateral surface** of the greater wing is subdivided by the **infratemporal crest into the temporal and infratemporal surfaces.** The **temporal surface** is almost in sagittal plane and gives attachment to the temporalis muscle. The **infratemporal surface** is oriented almost horizontally and shows foramen **ovale, foramen spinosum and sphenoid spine** behind foramina. The temporal and infratemporal surface form the walls of temporal and infratemporal fossa, respectively.

**The maxillary surface** of the greater wing forms the wall of the pterygopalatine fossa and presents **foramen rotundum**.

**Pterygoid processes of the sphenoid bone**

**Pterygoid processes** arise from the junction between the sphenoid body and greater wings and run vertically downwards. They are formed by the medial and lateral plates. Medial plate is narrower and inferiorly ends like hook projection - the **pterygoid hamulus**. Lateral plate is wider and thin. Between the medial and lateral plate of pterygoid process there is V – shaped **pterygoid fossa**. It contains medial pterygoid muscle and tensor veli palatini muscle. Above the pterygoid fossa there is smaller scaphoid fossa from which tensor veli palatini originates. The anterior surface of pterygoid process forms the posterior border of pterygopalatine fossa and superiorly presents the opening of the **pterygoid canal** (vidian canal) which transmits the nerve, artery and vein of pterygoid canal from the middle cranial fossa to the pterygopalatine fossa.

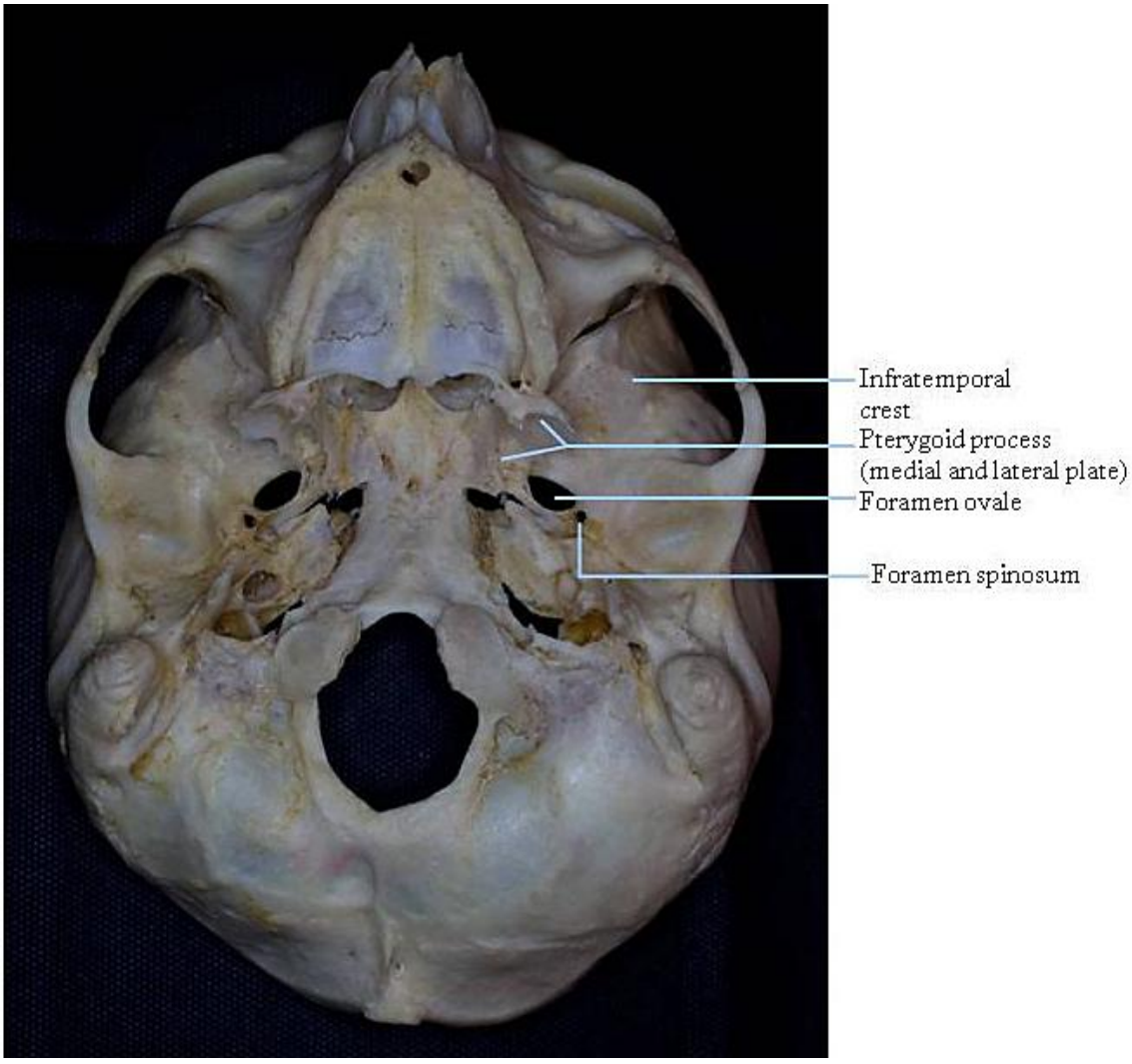



Fig. 32 *External surface of the cranial base - structures at the sphenoid bone.*

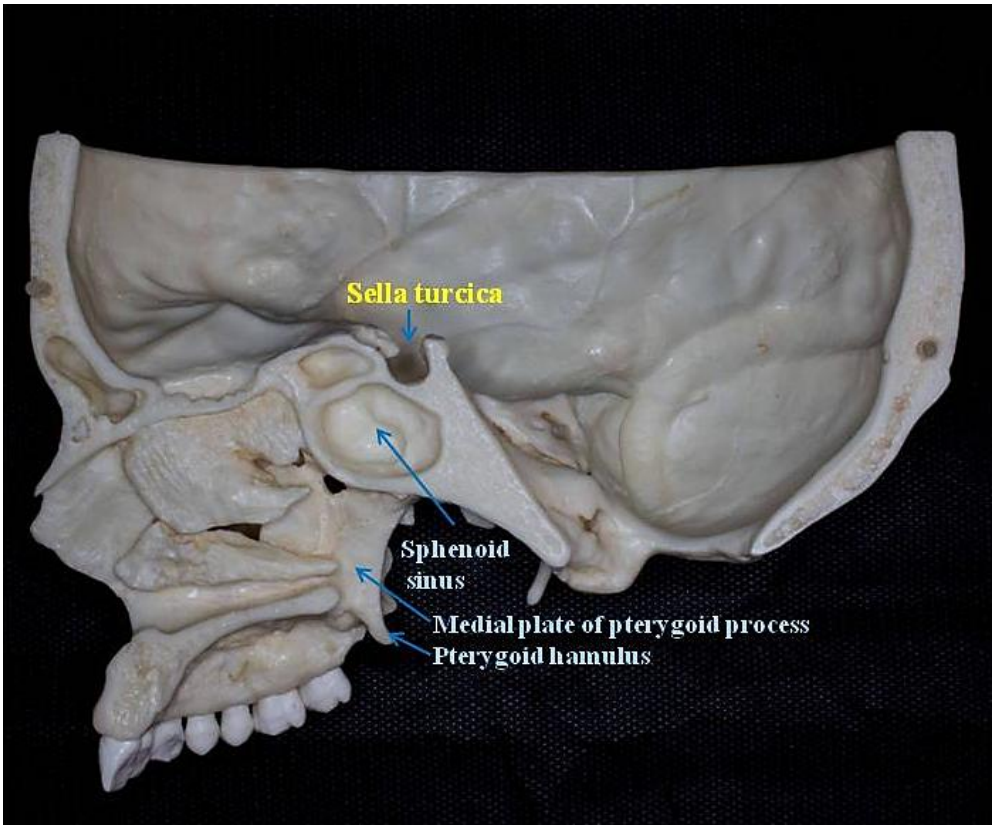



Fig. 33

*Sagittal section of the skull – structures at the sphenoid bone.*

**Table 4: Sphenoid bone – summary.**

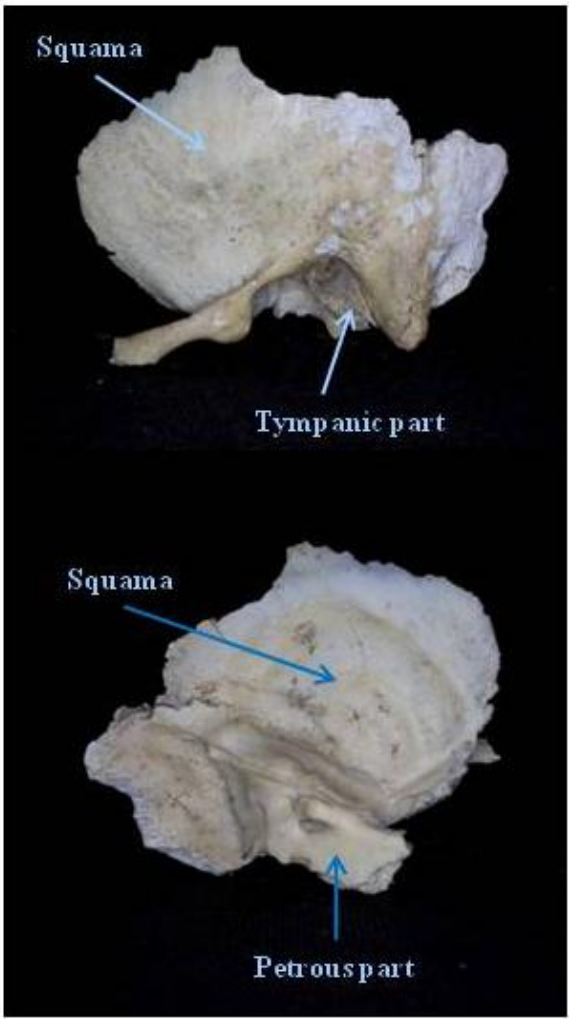
| part | surface | structures |
|---|---|---|
| **body** | **superior – cerebral** | hypophysial fossa<br>dorsum sellae<br>optic canal<br>chiasmatic sulcus (groove) |
| | **anterior** | sphenoidal crest<br>apertures of sphenoidal sinuses |
| | **inferior** | rostrum |
| **lesser wings** | **superior – cerebral** | anterior clinoid processes |
| | **inferior - orbital** | |
| **greater wings** | **cerebral** | foramen rotundum<br>foramen ovale<br>foramen spinosum |
| | **orbital** | |
| | **temporal** | |
| | **infratemporal** | infratemporal crest<br>foramen ovale<br>foramen spinosum |
| | **maxillary** | foramen rotundum |
| **pterygoid processes** | **medial plate** | pterygoid hamulus<br>pterygoid fossa |
| | **lateral plate** | |
| **sphenoidal sinus** | | |

## TEMPORAL BONE

Temporal bone is a paired bone situated laterally from the sphenoid bone and in front of the occipital bone. Each temporal bone is composed of the **squama, petrous part with styloid and mastoid processes and tympanic part**.

### Squama of the temporal bone

**Squama** forms the wall of temporal fossa and gives origin for temporalis muscle. Its internal (cerebral) surface is marked by **impressions of cerebral gyri and grooves for middle meningeal artery** (they continue to the parietal bone). Superiorly it articulates




with the squamous margine of the parietal bone. Inferiorly it bears **zygomatic process** of the temporal bone which connects with the temporal process of the zygomatic bone. Together they create the **zygomatich arch**. Deep concavity at the inferior aspect of the squama is **mandibular fossa,** anteriorly limited by the **articular tubercle**. Mandibular fossa serves as a socket for the head of mandible and articular disc in the temporomandibular joint.

Fig. 34
*Temporal bone. Lateral and medial view.*

**Petrous part of the temporal bone**

**Petrous part** has a **pyramidal** shape with three **surfaces** (anterior, posterior and inferior) and the **apex** directing anteromedially to the angle between the posterior border of the greater wing of sphenoid bone and basilar part of the occipital bone. Petrous part contains the **auditory apparatus and carotid canal** inside. Internal carotid artery runs through the carotid canal entering it in external opening at the inferior surface of the petrous part and exiting it in internal opening next to the apex of the petrous part.

**Anterior surface** of the petrous part forms a part of the floor of middle cranial fossa. Next to the apex there is a **trigeminal impression,** small depression for the trigeminal nerve ganglion. Posterolateraly to it there is an elevation - **arcuate eminence**, raised by the anterior semicircular canal of the internal ear. **Tegmen tympani** is a small area next to the temporal squama which forms the roof of the tympanic cavity (a part of the middle ear). Anteriorly to the arcuate eminence there are two narrow grooves - groove for

the lesser petrosal nerve (more laterally) and groove for the greater petrosal nerve (more medially).

**Posterior surface** of the petrous part faces backwards and forms a part of posterior cranial fossa. The border between the anterior and posterior surface of the petrous part is created by the **superior margine** of the petrous part (pyramidal crest). Along this margine a **groove for the superior petrosal sinus** runs. Almost in the centre of the posterior surface there is the **internal acoustic meatus** (porus acusticus internus) providing a passage for the facial and vestibulocochlear nerves. Posterior surface inferiorly ends as the inferior margine which articulates with the occipital bone. It is interrupted by **jugular foramen** which is formed by the jugular notches of the temporal and occipital bones. Along the inferior margine of the petrous part the **groove for the inferior petrosal sinus** runs.

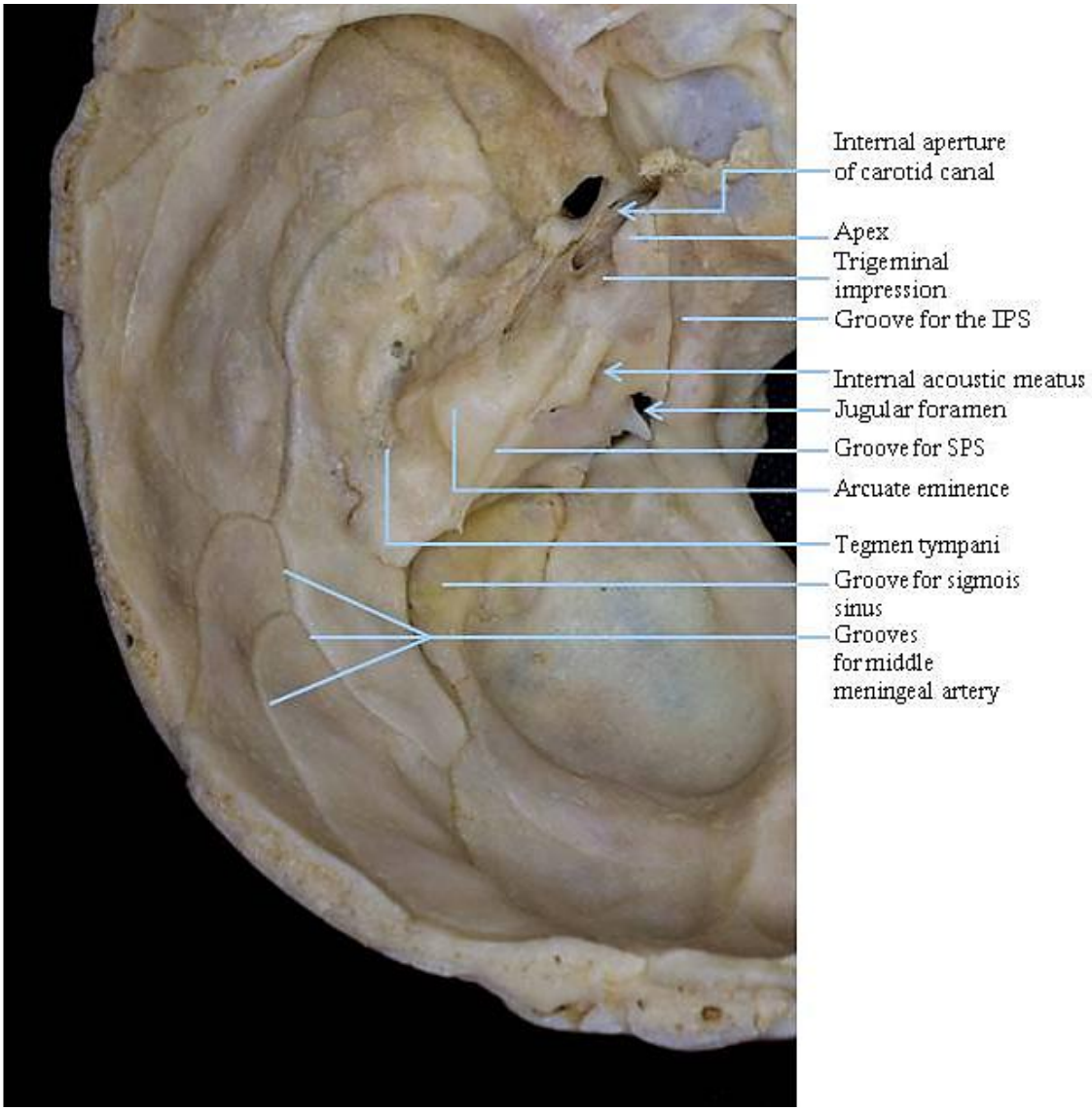



Fig. 35 *A part of internal surface of the cranial base - structures at the temporal bone.*

**Inferior surface of the petrous part** is situated at the external surface of the cranial base. It presents a large circular aperture - the **external opening of the carotid canal** for the entrance of the internal carotid artery. Posteriorly to it there is a jugular fossa in which the bulb of the internal jugular vein is hidden.

*Between the jugular fossa and the external opening of the carotid canal there are some small openings: canaliculus for the tympanic nerve a branch from the glossopharyngeal nerve, mastoid canaliculus for the auricular branch of the vagus nerve.*

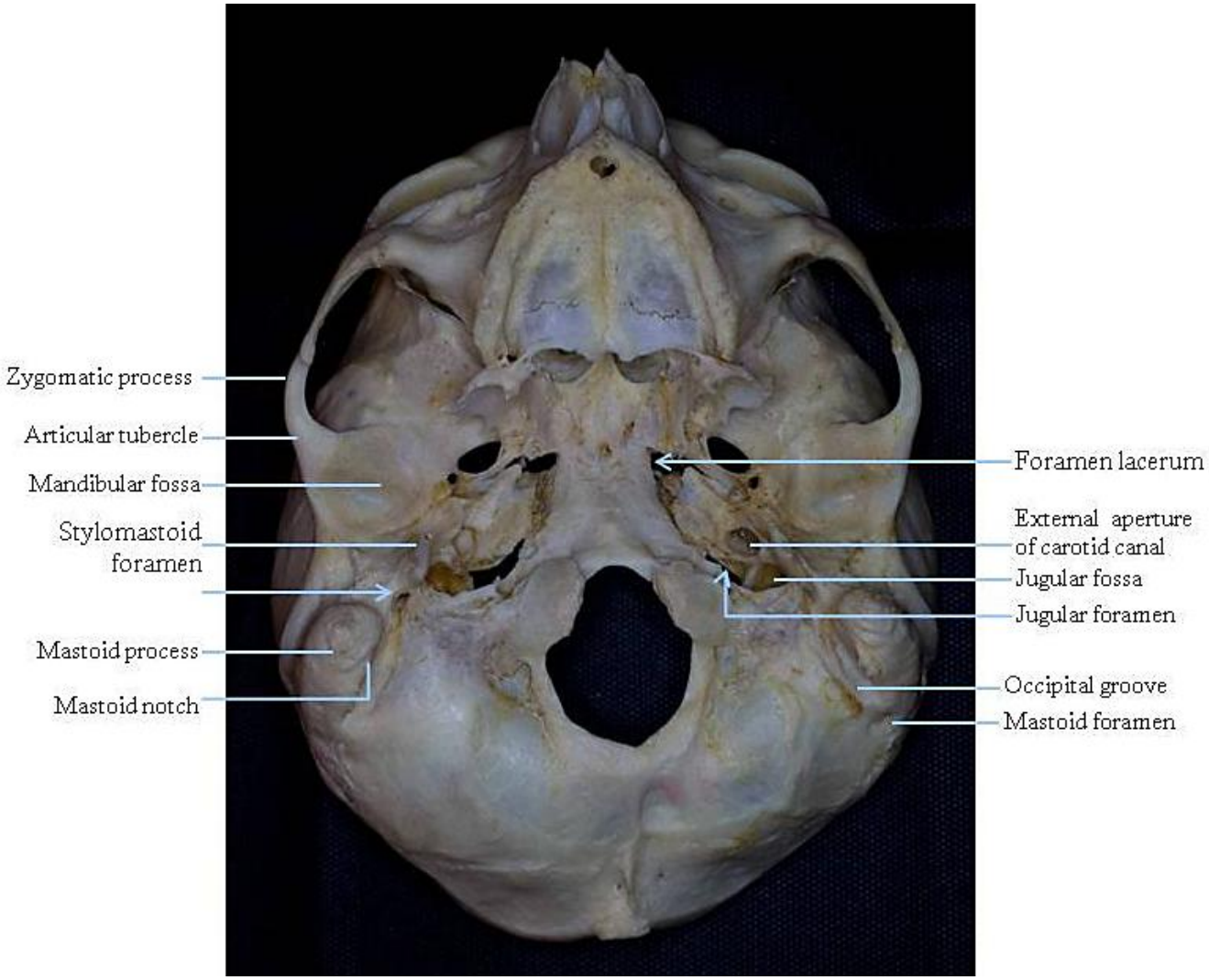



Fig. 36 *External surface of the cranial base - structures at the temporal bone.*

**Mastoid process** is a robust protrusion posterolaterally to the styloid process and behind the external acustic meatus. Its external surface is roughed by the attachments of the muscles. At its posterior aspect it bears a mastoid foramen for the emissary vein. Medially it presents the deep and narrow **mastoid notch** for the origine of the posterior

belly of the digastric muscle and shalow **occipital groove** for the occipital artery. Internal surface of the mastoid process shows the groove for sigmoid sinus (it is a continuation of the groove for the transverse sinus). The mastoid process is a pnematic bone. It contains the air cells – **mastoid cells** which communicate with the tympanic cavity of middle ear.

**Styloid process** is a long slender process projecting downwards which gives attachment to the muscles (e.g. stylohyoid muscle, stylopharyngeus musle) and ligaments. Posteriorly to styloid process there is the **stylomastoid foramen** that gives transmission for the facial nerve.

### Tympanic part of the temporal bone

**Tympanic part** is a curved U – shaped plate of bone situated below the squama and in front of the mastoid process. It forms a walls of the external acoustic meatus. Medially on its internal surface there is a tympanic sulcus for the attachment of the tympanic membrane.

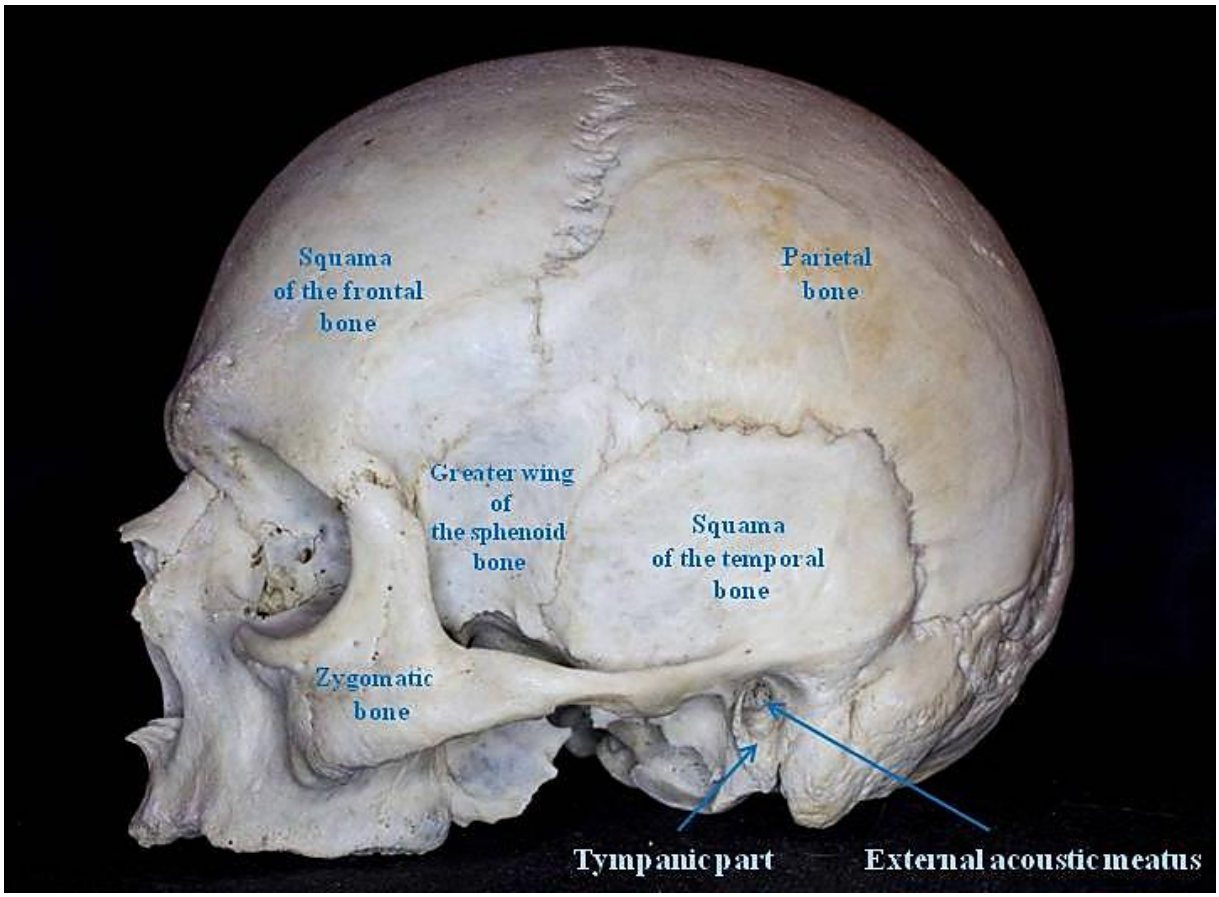



Fig. 37 *Lateral view of the skull - structures at the temporal bone.*

**Table 5: Temporal bone – summary.**

| part | surface | structures |
|---|---|---|
| **squama** | **external** | mandibular fossa<br>articular tubercle<br>zygomatic process |
| | **internal** | impressions of cerebral gyri<br>grooves for the middle meningeal artery |
| **petrous** | **anterior** | trigeminal impression<br>arcuate eminence<br>tegmen tympani<br>internal opening of the carotid canal<br>groove and hiatus for the greater petrosal nerve<br>groove and hiatus for the lesser petrosal nerve |
| | **posterior** | groove for superior petrosal sinus<br>internal acoustic meatus<br>jugular notch<br>groove for inferior petrosal sinus |
| | **inferior** | external opening of carotid canal<br>jugular fossa |
| **mastoid process** | **external** | mastoid notch<br>occipital groove<br>mastoid foramen<br>stylomastoid foramen |
| | **internal** | groove for sigmoid sinus |
| **styloid process** | | |
| **tympanic** | **internal**<br>**external** | tympanic sulcus |

## ETHMOID BONE

**Ethmoid bone** forms skeletal framework of the nasal cavity and a part of anterior cranial fossa. Usually it is subdivided into three parts: **cribriform plate, perpendicular plate and ethmoidal labyrinths** (ethmoidal air cells or sinuses).

## Cribriform plate of the ethmoid bone

**Cribriform plate** is horizontally oriented thin bony plate with numerous openings – **cribriform foramina**. Sometimes it is described as sieve – like structure. The inferior surface of cribriform plate forms a part of the roof of the nasal cavity, superior surface forms a part of skeletal framework of the anterior cranial fossa. Thus, cribriform foramina are openings between the nasal cavity and anterior cranial fossa and they are traversed by the oflactory filaments that are axons of bipolar olfactory receptor cells situated at the olfactory region of nasal mucosa. Within the anterior cranial fossa the olfactory filaments enter the olfactory bulbs. **Crista galli** is a sagittally oriented triangular lamina which ascends from the cribriform plate. Falx cerebri (dural partition which separates the cerebral hemispheres) is attached to it.

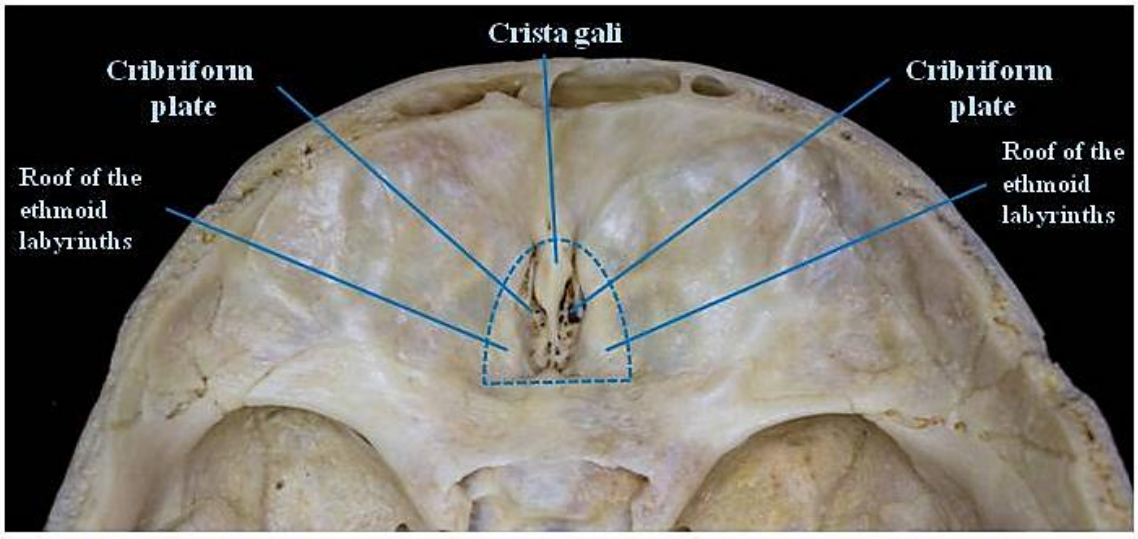



Fig. 38 *A part of internal surface of the cranial base - structures at the ethmoid bone.*

## Perpendicular plate of the ethmoid bone

**Perpendicular plate** is vertically oriented lamina, which descends from the cribriform plate of the ethmoid bone in median plane. Inferiorly it is connected with the vomer forming the bony nasal septum. Anteriorly it connects with the septal cartilage.

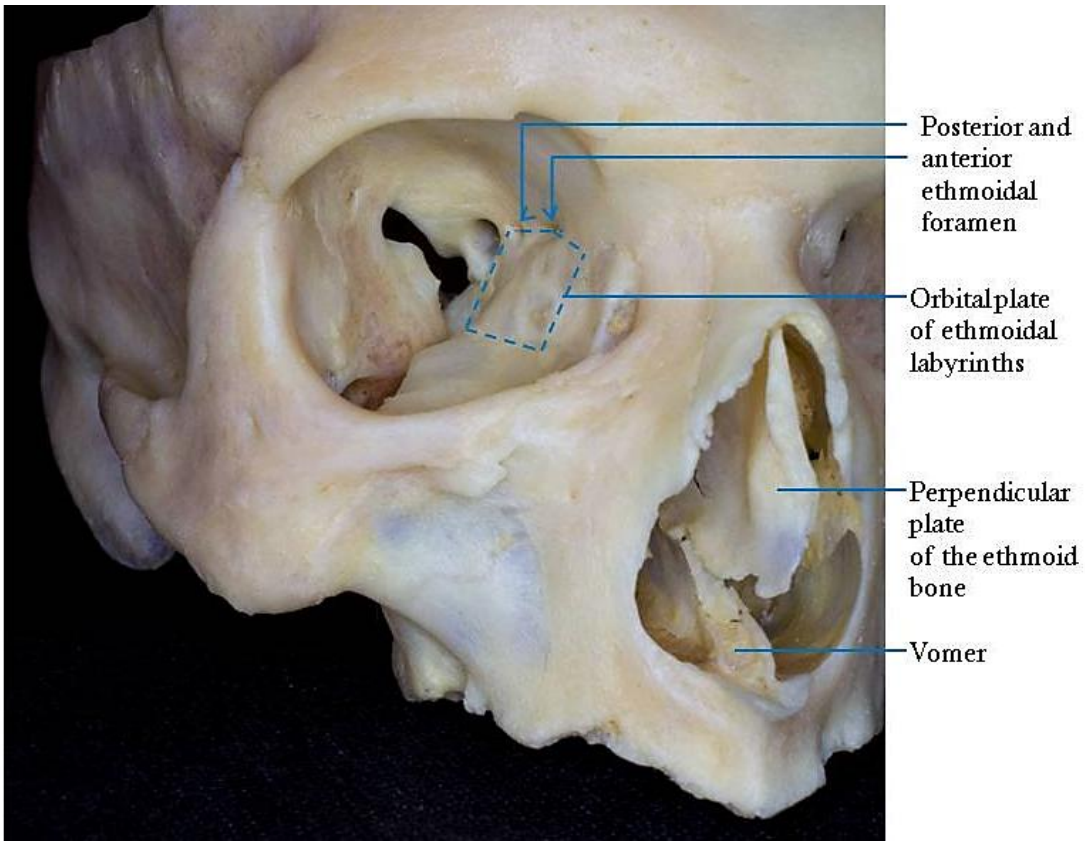



Fig. 39 *Anterior view of the skull - structures at the ethmoid bone.*

**Ethmoidal labyrinths**

**Ethmoidal labyrinths** or **sinuses** are air – filled cells situated between the nasal cavity and the orbits. The number of the air - cells (cavities) varies from 3 large to 18 small cavities on each side forming labyrinths of the air – cells.

**The lateral wall of** the labyrinths is formed by the **orbital plate** inserted in the medial wall of the orbit. This plate is extremly thin often termed as lamina papyracea and because of that it is only a poor barrier to infection which can spread into the orbit. The orbital plate articulates with frontal bone (superiorly), lacrimal bone (anteriorly), maxilla (inferiorly) and sphenoid bone (posteriorly). Between the orbital plate of the ethmoid and frontal bone there are two foramina: **anterior ethmoidal foramen** (it leads into the orbitocranial canal and subsequently into the anterior cranial fossa) and **posterior ethmoidal foramen** (it enters the posterior ethmoidal air - cells).

**The medial wall** of the labyrinths forms a part of the lateral wall of the nasal cavity and presents two projections (turbinates) – **superior nasal concha** (smaller upper one) and

**middle nasal concha** (larger lower one). They are thin and inferomedially curved plates separating the nasal cavity into the nasal meatuses. Irregular inferiorly projected extension – **uncinate process** descends to maxillary hiatus.

The ethmoidal sinuses are clinically subdivided into the **anterior and posterior air – cells**. In ech group the cells are separated by only incomplete thin bony septa. The anterior ethmoidal air – cells (up to 12 in number) open into the middle nasal meatus, posterior ethmoidal air – cells (up to 7 in number) into the superior nasal meatus. The ethmoidal sinuses are present at the birth, rapidly growing at the age between 6 and 8 years and finally developed after the puberty.

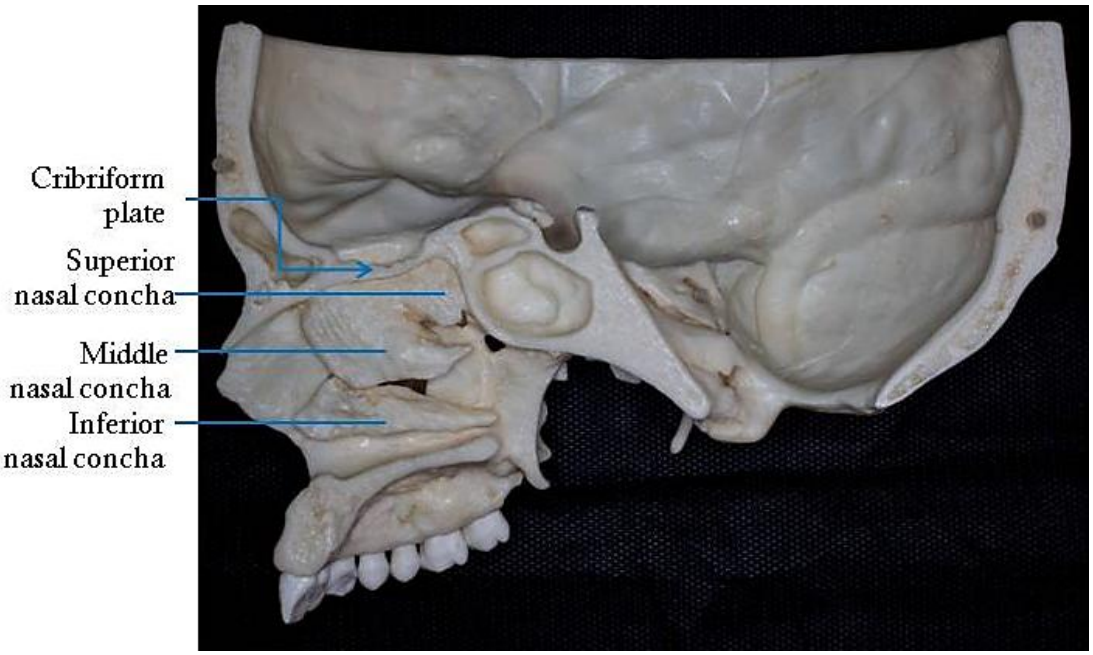



Fig. 40 *Sagittal section of the skull - structures at the ethmoid bone.*

**Table 6: Ethmoid bone - summary**

| **part** | **surface** | **structure** |
|---|---|---|
| **cribriform plate** | **superior – cerebral**<br>**inferior** | cribriform foramina<br>crista gali |
| **ethmoidal labyrinths sinuses** | **medial plate**<br><br><br><br>**lateral – orbital plate** | superior nasal concha<br>middle nasal concha<br>uncinate process<br><br>anterior ethmoidal foramen<br>posterior ethmoidal foramen |
| **perpendicular plate** | | |

## INFERIOR NASAL CONCHA

**Inferior nasal concha** is a paired bone arising from the lateral walls of the nasal cavity below the middle nasal concha. It is curved inferomedially forming the convex medial surface and concave lateral surface. It articulates with the lacrimal bone, uncinate process of the ethmoid bone, conchal crest at the frontal process of maxilla and perpendicular plate of the palatine bone. Inferior nasal concha separates the middle nasal meatus and inferior nasal meatus.

## PALATINE BONE

**Palatine bone** is a paired bone which forms the posterior one third of the palate and a part of the lateral wall of the bony nasal cavity. It consits of **horizontal and perpendicular plates.**

**Horizontal plate** is anteriorly connected to the palatine process of maxilla in **transverse palatine suture** and medially it connects to the contralateral horizontal plate of palatine bone in **median palatine suture**. It is a flat bony lamina with superior (directed to the nasal cavity) and inferior (directed to the oral cavity) surfaces. At the inferior surface next to the connection with maxillary alveolar process there are **greater palatine foramen** and 2 or 3 **lesser palatine foramina.**

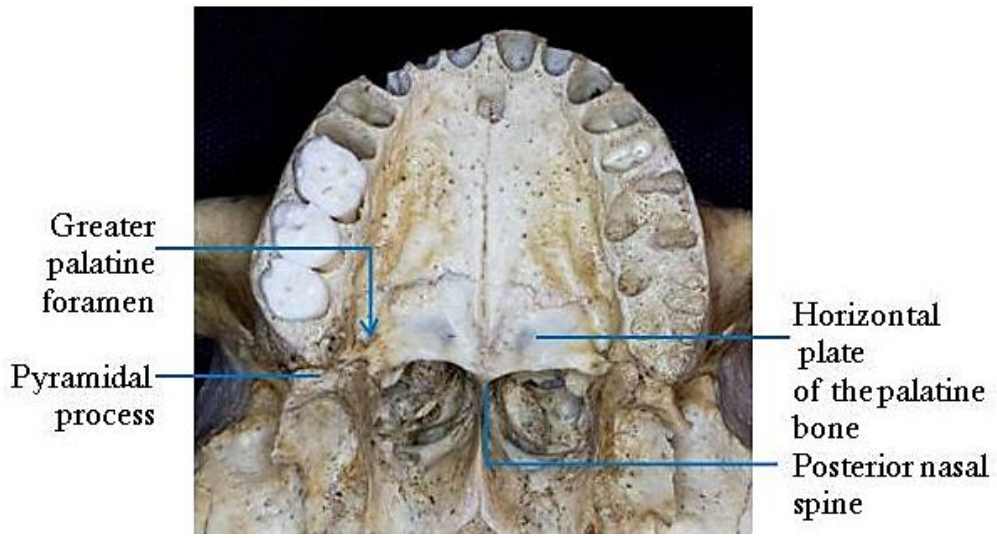



Fig. 41 *Bony palate – inferior view - structures at the palatine bone.*

They represent the exits from greater and lessere palatine canals for the palatine nerves and vessels which come from pterygopalatine fossa. At the posterior border of the horizontal plate in the median plane there is the **posterior nasal spine**.

**Perpendicular plate** is anteriorly connected to the maxillary body and posteriorly to the pterygoid process of the sphenoid bone. Cranially it forms two processes: **orbital and sphenoidal process**. These processes are separated by the **sphenopalatine notch** which creates the sphenopalatine foramen when it connects with the sphenoid. **Sphenopalatine foramen** is important communication between the pterygopalatine fossa and nasal cavity. Lateral surface of the perpendicular plate forms the medial wall of pterygopalatine fossa. Medial surface faces to the nasal cavity and shows the ridges: ethmoidal crest and conchal crest for the attachment of the middle nasal concha and inferior nasal concha, respectively. **Orbital process** forms a small triangular area at the floor of the orbit.

**Pyramidal process** descends posterolaterally from the junction of the horizontal and perpendicular plates. This process is angled between the pterygoid plates of the sphenoid bone.

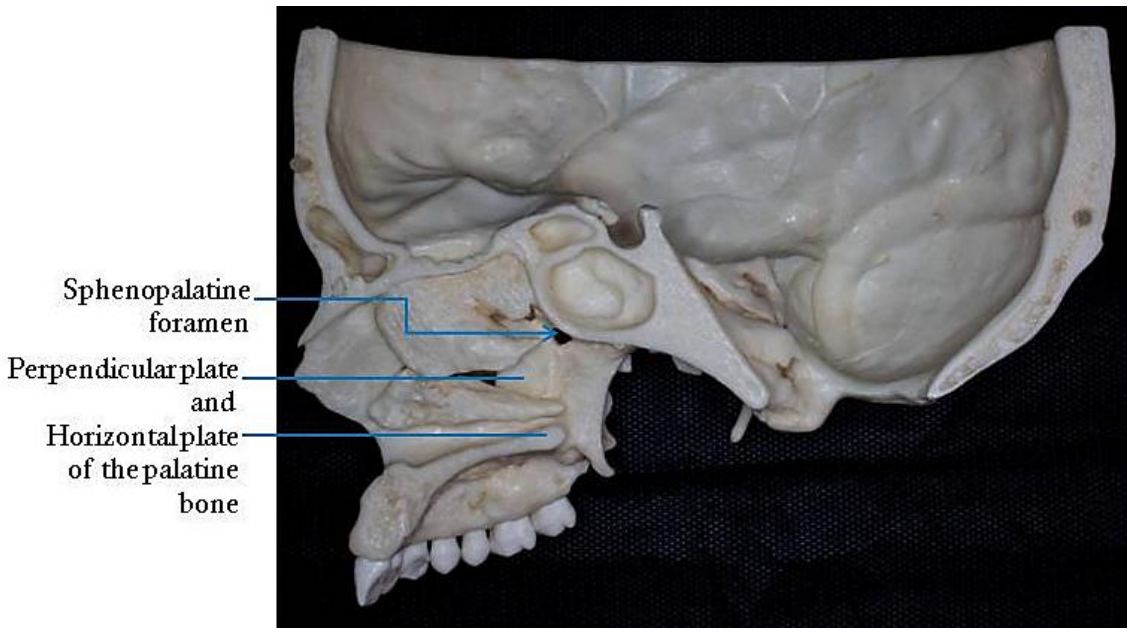



Fig. 42 *Sagittal section of the skull - structures at the palatine bone.*

## LACRIMAL BONE

**Lacrimal bone** is a small paired and fragile bone situated at the medial wall of the orbit. It articulates with the orbital part of frontal bone (superiorly), frontal process of maxilla (anteriorly), maxillary body (inferiorly) and orbital plate of the ethmoid bone (posteriorly). Lacrimal bone has the orbital and nasal surface. **At the orbital surface** there is a vertical ridge - **posterior lacrimal crest,** which forms the posterior edge of the **lacrimal sulcus** which continues into the **lacrimal fossa** containing the lacrimal sac. Lacrimal fossa communicates with the nasal cavity through the **nasolacrimal canal** which opens into the inferior nasal meatus.

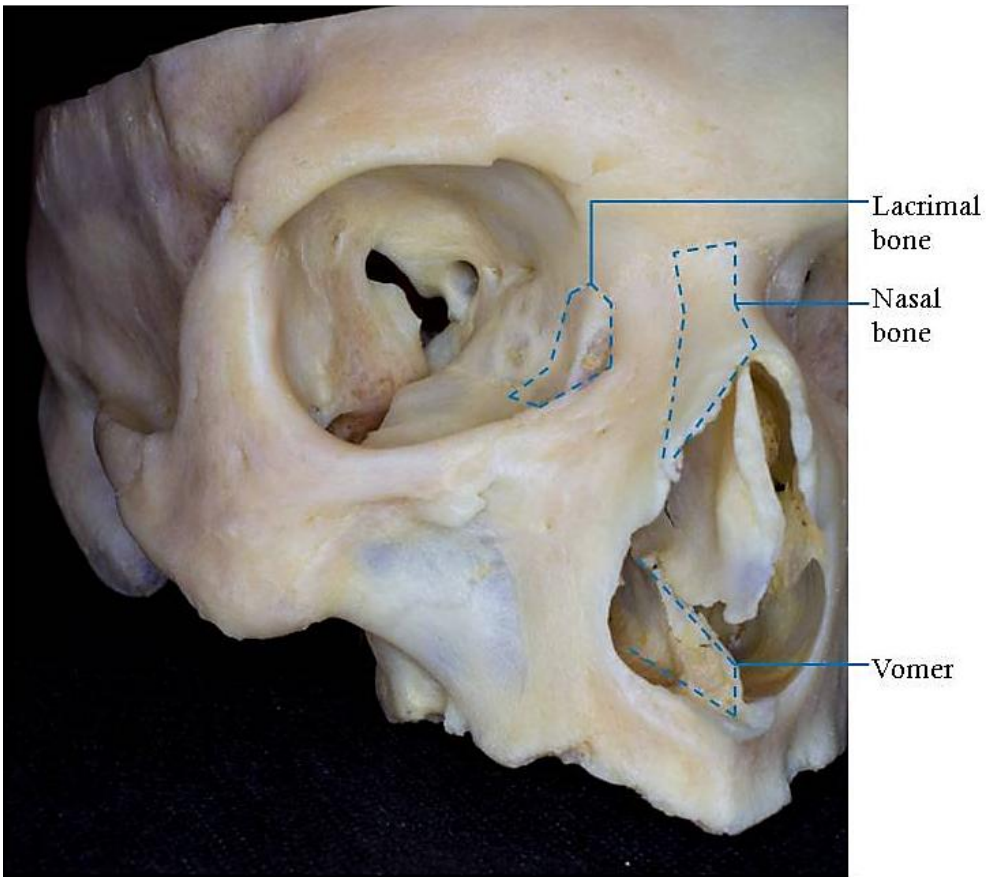



Fig. 43 *Anterior view of the skull – lacrimal bone, nasal bone and vomer.*

## NASAL BONE

**Nasal bone** is a paired bone which forms the root of the external nose. It joins the frontal bone superiorly, maxilla laterally, contralateral nasal bone medially, perpendicular plate of the ethmoid bone inferiorly and lateral nasal cartilage anteroinferiorly. Each nasal

bone has external surface covered with the muscles (procerus and nasalis muscles) and concave internal surface forms a part of the nasal roof.

## VOMER

**Vomer** is sagitally oriented flat bone. It creates the dorsocaudal part of the bony nasal septum. It has four margines and two surfaces. Superior border is thick with a groove separating two alae (wings) of the vomer. Alae join the rostrum and inferior surface of the sphenoid body. Anterior border articulates with perpendicular plate of the ethmoid bone, inferior border with the nasal crest of the maxila and palatine bone. Surfaces of the vomer presents a thin grooves for the vessels and nerves.

## ZYGOMATIC BONE

**Zygomatic bone** is a paired bone which creates the prominence of the cheek, forms a part of skeletal framework of the temporal and infratemporal fossa and the orbit. It has three **surfaces - orbital, lateral and temporal** and **three processes - frontal, maxillary and temporal**.

**Orbital surface** creates a part of the inferior rim and floor of the orbit. It contains a small opening - **zygomaticoorbital foramen** for the zygomatic nerve. This foramen leads into the canals which open at the zygomaticotemporal and zygomaticofacial foramina.

**Lateral (facial) surface** is convex and directs ventrolaterally. Almost at the centre it is perforated by **zygomaticofacial foramen** which gives transmission for the zygomaticofacial vessels and nerves. This surface gives the attachment to the zygomaticus major and minor muscle.

**Temporal surface** is slightly concave and faces dorsomedially into the temporal fossa. Next to the base of the frontal process it usually bears z**ygomaticotemporal foramen** containing zygomaticotemporal nerve.

**Processes of the zygomatic bone** articulate with neighbouring bones.

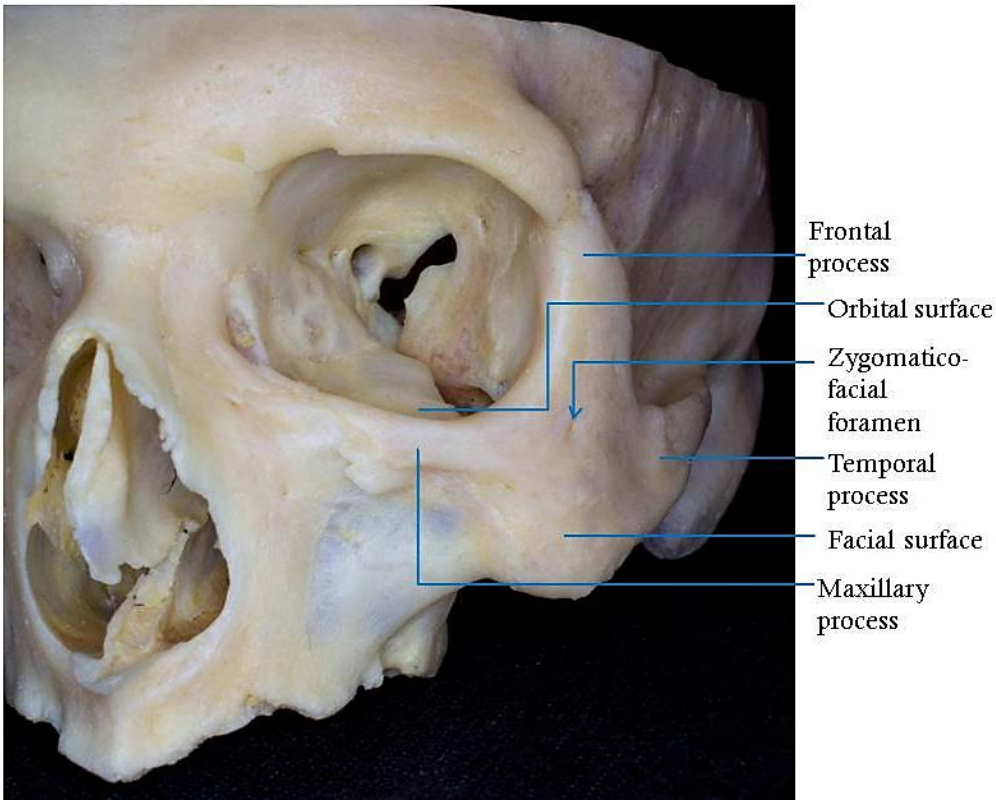


Fig. 44 *Anterior view of the skull – structures at the zygomatic bone.*

**Frontal process of the zygomatic bone** articulates with the zygomatic process of the frontal bone and together they form the lateral rim of the orbital opening (orbital entrance or aditus orbitae). **Maxillary process of the zygomatic bone** joins the zygomatic process of the maxilla and they form the inferior rim of the orbital opening. **Temporal process of the zygomatic bone** connects with the zygomatic process of the temporal bone forming the zygomatic arch.

## MAXILLA

The area of the face between the orbits and upper dental arch is formed by paired bones - **maxillae.** Each maxilla (upper jaw) consits of **the body** and four **processes - frontal, zygomatic, palatine and alveolar**.

### The body of maxilla

**Maxillary body** is more or less pyramidal in shape with the air - filled cavity - **maxillary sinus** inside. It has four **surfaces: orbital, anterior, nasal and infratemporal**.

**Orbital surface** of the maxillary body forms a triangular area at the floor of the orbit. It is grooved by **infraorbital sulcus** (groove) which leads into the **infraorbital canal** for the infraorbital vessels and nerve.

Infraorbital canal ends in **infraorbital foramen** at the **anterior surface** of maxillary body. More inferiorly at the anterior surface there is a **canine fossa** and **canine eminence** (above the socket for the caninus root). Medially it forms the **nasal notch** which terminates as **anterior nasal spine**.

**Nasal surface** of maxillary body shows large **maxillary hiatus** leading into the maxillary sinus.

**Infratemporal surface** directs posteriorly and looks at the pterygolalatine and infratemporal fossae. It is perforatted by 2 or 3 minute openings – **alveolar foramina** leading into the **alveolar canals** for the posterior superior alveolar vessels and nerves.

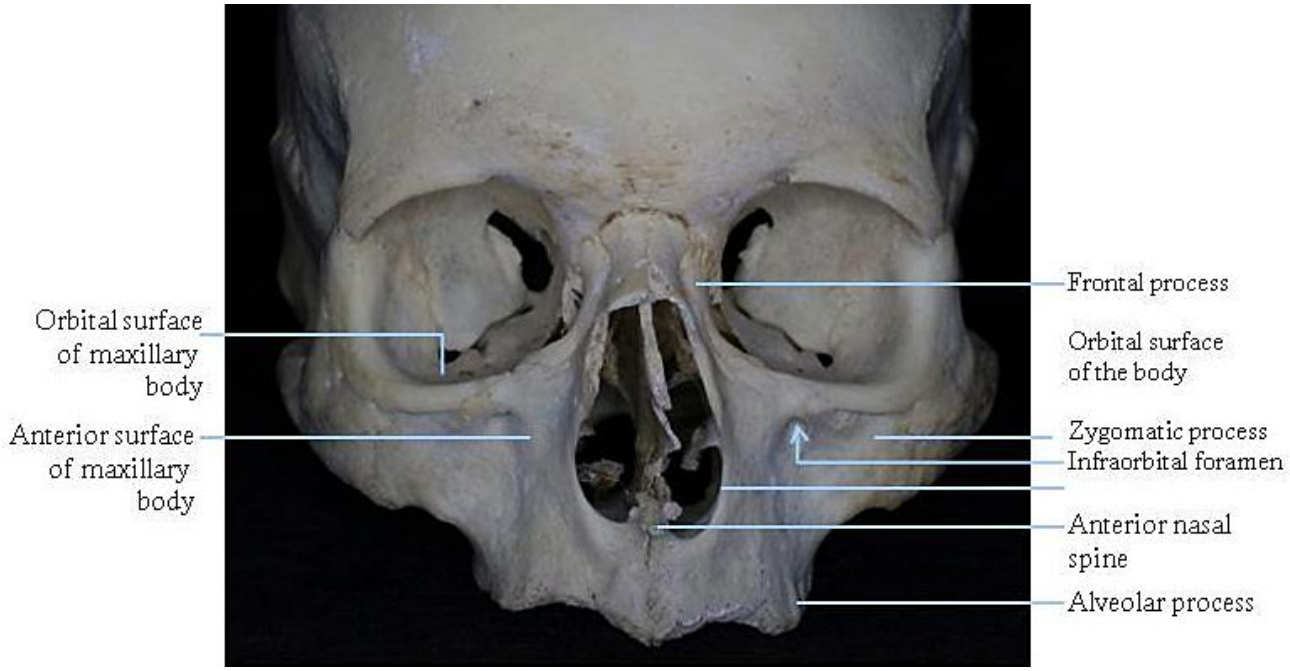



Fig. 45 *Anterior view of the skull – structures at maxilla.*

**Maxillary sinus** (antrum of Highmore)

This sinus is situated within the body of maxilla. It is the largest of all paranasal sinuses. The floor of the maxillary sinus extends more inferiorly than the floor of the nasal cavity and is related to the roots of the premolar and molar teeth (especially second premolar and first molar). The roof of the sinus is related to the floor of the orbit. Posterior wall is related to the infratemporal fossa. The opening for the drainage of the maxillary

sinus – maxillary hiatus leads into the middle nasal meatus. Hiatal opening is reduced by the attachment of uncinate process of the ethmoid bone and inferior nasal concha. It contains infraorbital canal and alveolar canals. Maxillary sinus is developed at the birth and rapidly grows at the age of 0-3 years and then 6-12 years.

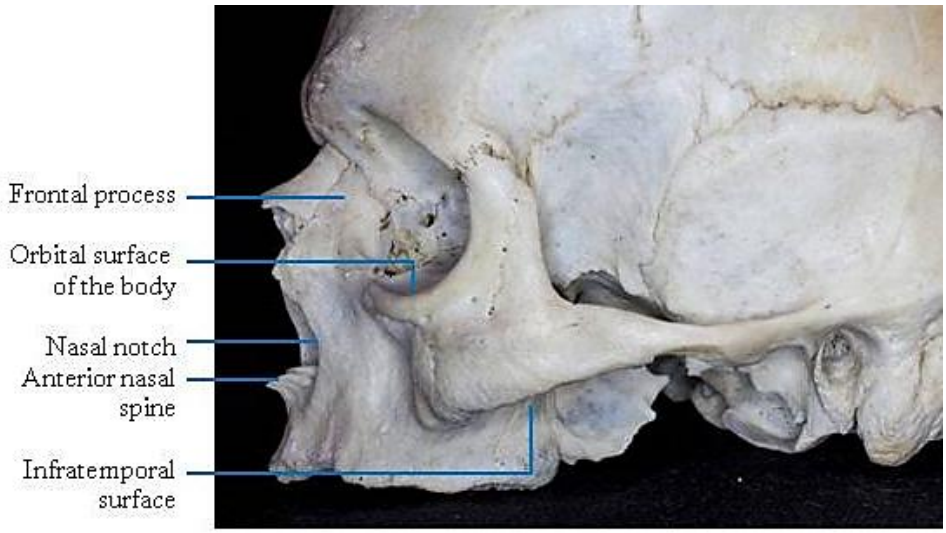



Fig. 46 *Lateral view of the skull – structures at maxilla.*

**Processes of maxilla**

**Zygomatic process** of maxilla projects laterally from the maxillary body and articulates with the maxillary process of the zygomatic bone.

**Frontal process** ascends to join the frontal bone, posteriorly it articulates with the lacrimal bone. Its lateral surface forms the anterior part of the medial orbital wall and shows **anterior lacrimal crest** which creates the anterior edge of the lacrimal sulcus. Medial surface of the frontal process looks at the nasal cavity and bears the **ethmoidal crest** for the articulation with the middle nasal concha.

**Palatine process** is horizontally oriented bony plate which forms the ventral 2/3 of the bony palate (hard palate). Posteriorly it connects with the horizontal plate of the palatine bone, medially it articulates with the contralateral palatine process in median palatine suture. Superior surface faces into the nasal cavity. Inferior surface is concave and directs to the oral cavity. Behind the incisors there is a small depression - the incisive fossa with **incisive foramen** in the centre. The whole palatine process is marked by the numerous small foramina for the vessels and nerves of the hard palate and little depresions for palatine glands.

**Alveolar process** brings the sockets (alveoli) for the upper dental arch (upper teeth). The sockets for the molar teeth are the largest and subdivided by septa into three canals for the dental roots (upper molars have three roots). The socket for the caninus tooth is usually the deepest one. With the loss of the teeth the alveolar process undergoes resorption.

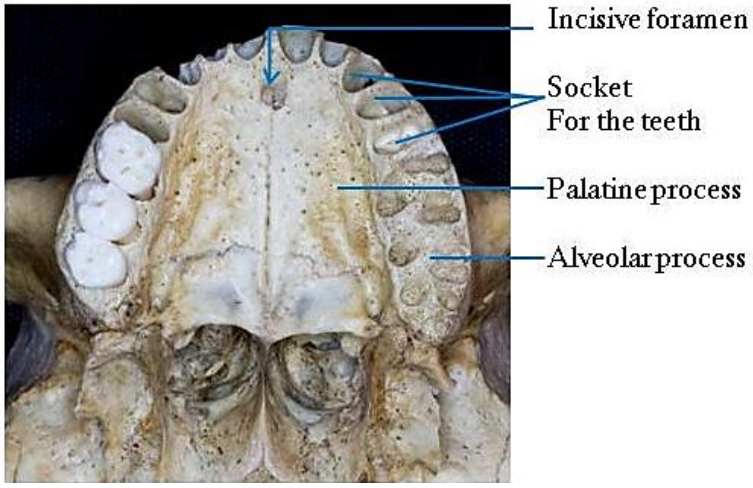



Fig. 47 *bony palate – structures at the palatine process of maxilla.*

**Table 7: Maxilla - summary.**

| **parts** | **surfaces** | structures |
|---|---|---|
| **body** | **orbital** | infraorbital groove |
| | **anterior** | infraorbital foramen<br>canine fossa<br>canine eminence<br>nasal notch |
| | **nasal** | maxillary hiatus |
| | **infratemporal** | alveolar foramina |
| **frontal process** | **orbital**<br>**nasal** | anterior lacrimal crest |
| **zygomatic process** | | |
| **palatine process** | **nasal** | |
| | **oral** | incisive fossa with incisive foramen |
| **alveolar process** | | socket for the teeth |
| **maxillary sinus** | | |

## MANDIBLE

**Mandible** (lower jaw) forms the lowermost part of the face, borders the infratemporal fossa and bears lower dental arch (lower teeth). Mandible consists of U-shaped **body and two rami** ascending posteriorly.

### Body of the mandible

**Mandibular body** has two surfaces – external and internal.

**External surface** bears a midline triangular protrusion – **mental protuberance** with lateral elevations – **mental tubercles**. Laterally to mental protuberance there is **mental foramen** at both sides. Usually it is situated below the first or second premolar teeth. External surface of the mandibular body gives attachment to the facial muscles (mentalis muscle, depressor labii inferioris, depressor anguli oris, platysma or buccinator muscle).

Internal surface of the body marked by **the mylohyoid line** which gives attachment for mylohyoid muscle (forms the floor of the oral cavity). In the midline it shows **mental spines** for the origine of the genioglossus and geniohyoideus muscle. Inferiorly to it there is oval **digastric fossa** on each side for the origine of the anterior belly of digastric muscle. Laterally to the mental spine and above the mylohyoid line there is triangular depression - **sublingual fossa** for the sublingual salivary gland. **Submandibular fossa** is situated more posteriorly and below the mylohyoid line and adjoins the submandibular lymph nodes and submandibular salivary gland. Upper border of the mandibular body is formed by the **alveolar part**. It contains the sockets (alveoli) for the lower teeth. Depending on the number of the dental roots the sockets are subdived by septa into one or two canals.

Mandibular body and rami meet in **angles**. Medial surface of the mandibular angle is roughened by the **ptergoid tuberosity** for the attachment of medial pterygoid muscle, lateral surface is marked by the **masseter** tuberosity for the insertion of masseter muscle. Both pterygoid and masseter muscles are important masticatory (chewing) muscles.

**Mandibular ramus** is almost quadrangular with two superiorly projected processes – **condylar** and **coronoid process**.

**Condylar process** is enlarged at the top forming the **head of mandible** which articulates with mandibular fossa of temporal bone, with the articular disc in between. Below the head there is the **neck** and **pterygoid fovea** (attachment for the lateral pterygoid muscle). Coronoid and condylar processes are separated by **mandibular notch**.

Medial surface of the ramus presents the **mandibular foramen** which leads into the mandibular canal. Inferiorly to mandibular foramen there is a mylohyoid groove which extends ventrocaudaly bellow the mylohyoid line. It contains mylohyoid vessels and nerve. **Mandibular canal** runs from mandibular foramen to mental foramen and gives transmission for inferior alveolar vessels and nerves.

**Coronoid process** is situated in front of the condylar process and gives insertion to temporalis muscle (another masticatory muscle).

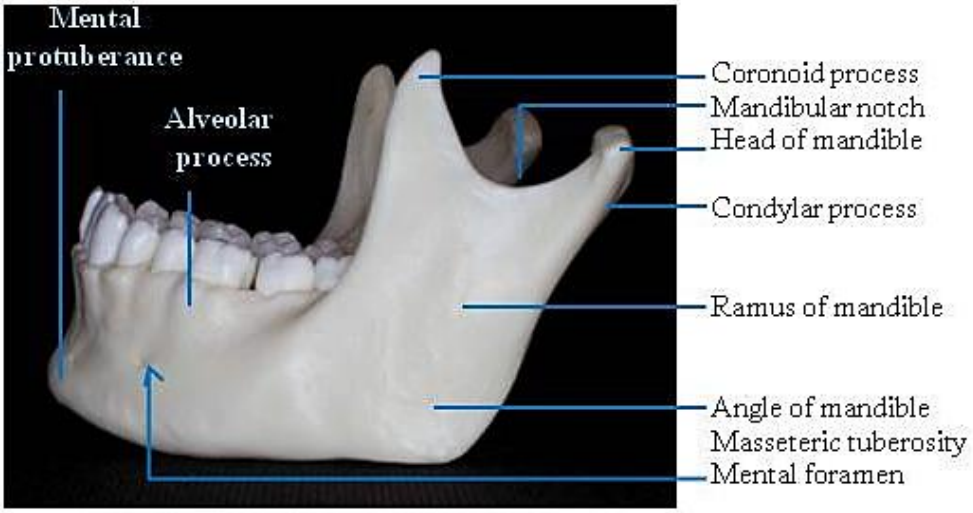



Fig. 48 *X Mandible from the lateral view.*

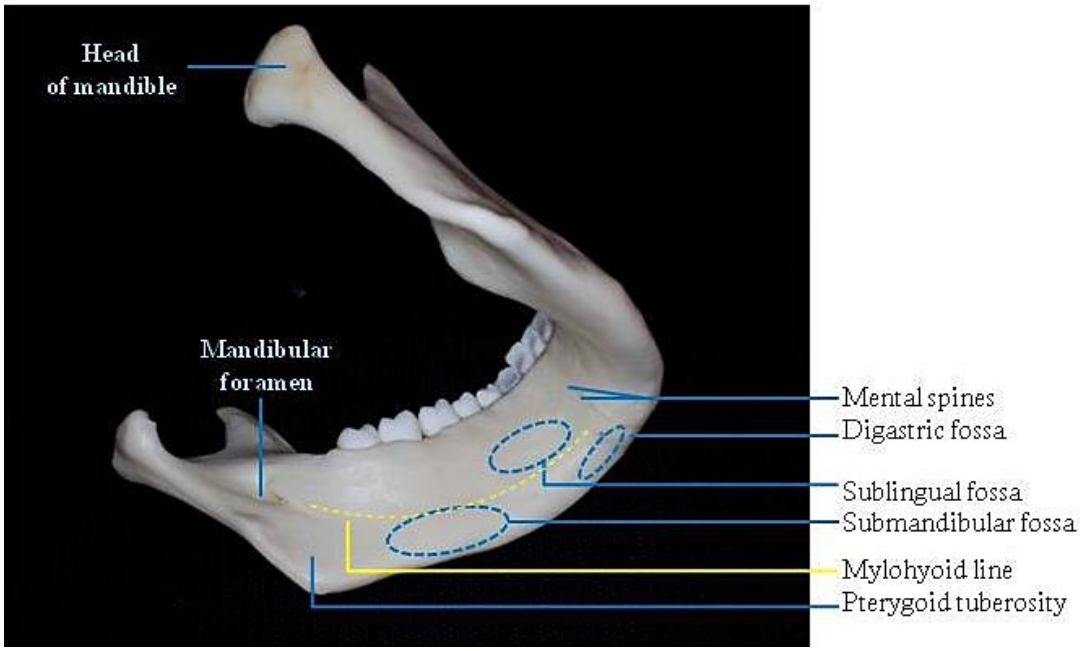



Fig. 49 *Mandible –from the inferolateral view.*

**Table 8: Mandible - summary.**

| parts | surfaces | structures |
|---|---|---|
| **body** | **external** | mental protuberance<br>mental foramina |
| | **internal** | mental spines<br>mylohyoid lines<br>digastric fossae<br>sublingual fossae<br>submandibular fossae |
| **rami** | **medial**<br>**lateral** | mandibular foramen |
| **condylar process** | | head<br>neck<br>pterygoid fovea |
| **coronoid process** | | mandibular notch |
| **angles** | **medial**<br>**lateral** | pterygoid tuberosity<br>masseteric tuberosity |

## SPACES OF THE SKULL

### CALVARIA (cranial vault)

**Calvaria** forms the roof of the cranial cavity. It is a dome – like structure formed by squamous part of frontal bone anteriorly, both parietal bones and temporal bones in the middle and squamous part of the occipital bone posteriorly.

These bones are connected by the sutures:

- **coronal suture** – serrate suture between the frontal bone and parietal bones
- **sagittal suture** – serrate suture between both parietal bones
- **lambdoid suture** – serrate suture between the parietal bones and occipital bone
- **squamous sutures** – lap (squamous) suture between the temporal and parietal bones.

Internal surface of calvaria is concave and marked by grooves (**groove for superior sagital sinus, grooves for middle meningeal artery**), minute opening for perforating vessels (diploic or emissary veins) and small irregular depressions **granular foveolae** (for arachnoid granulations) especially along the groove for superior sagittal sinus. Anteriorly it bears **frontal crest** which gives attachment for the falx cerebri (dural partition separating the cerebral hemispheres).

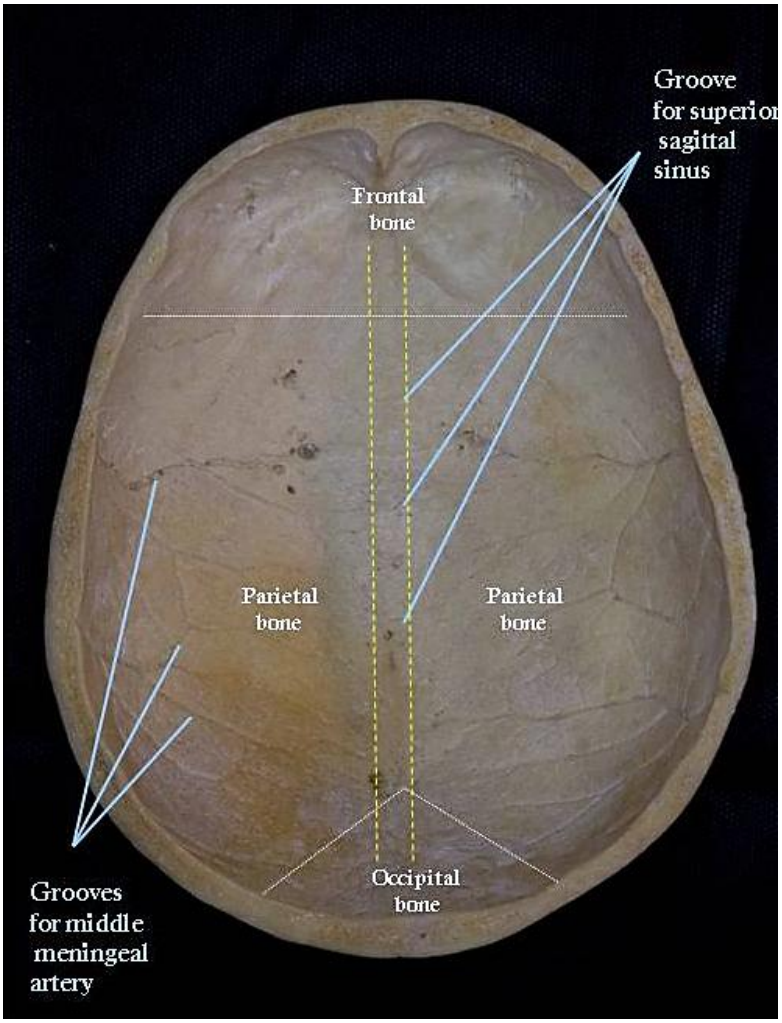



Fig. 50
*Internal surface of the cranial vault.*

**INTERNAL SURFACE OF THE CRANIAL BASE**

The floor of the cranial cavity is subdivided into three cranial fossae:

- **anterior cranial fossa**
- **middle cranial fossa**
- **posterior cranial fossa**

**The border between anterior and middle cranial fossa** is formed by posterior margin of the lesser wings and anterior edge of the chiasmatic sulcus.

**The border between middle and posterior cranial fossa** is created by superior margin of the petrous part of the temporal bone and dorsum sellae.

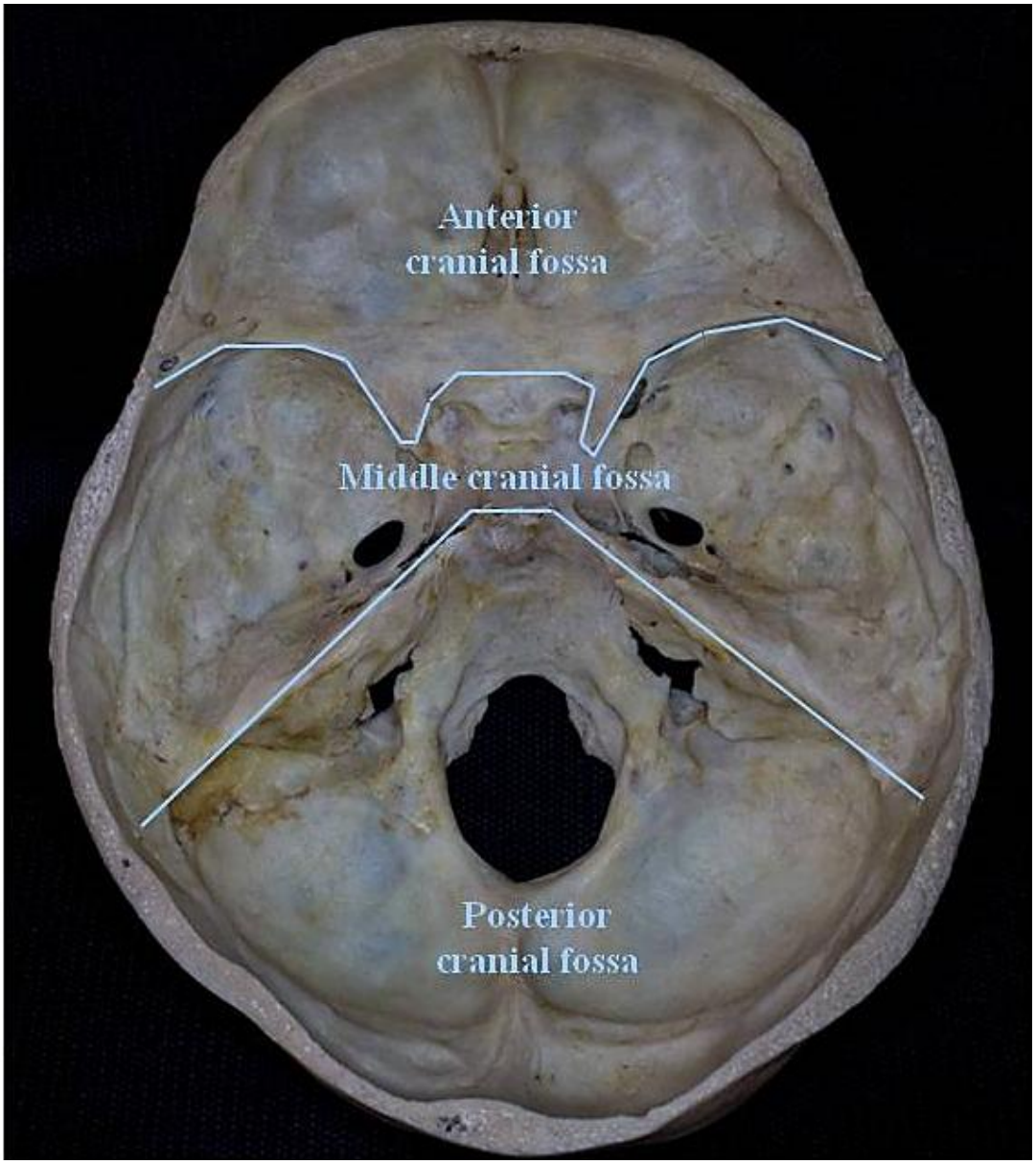



Fig. 51 *Internal surface of the cranial base. Anterior, middle and posterior cranial fossae.*

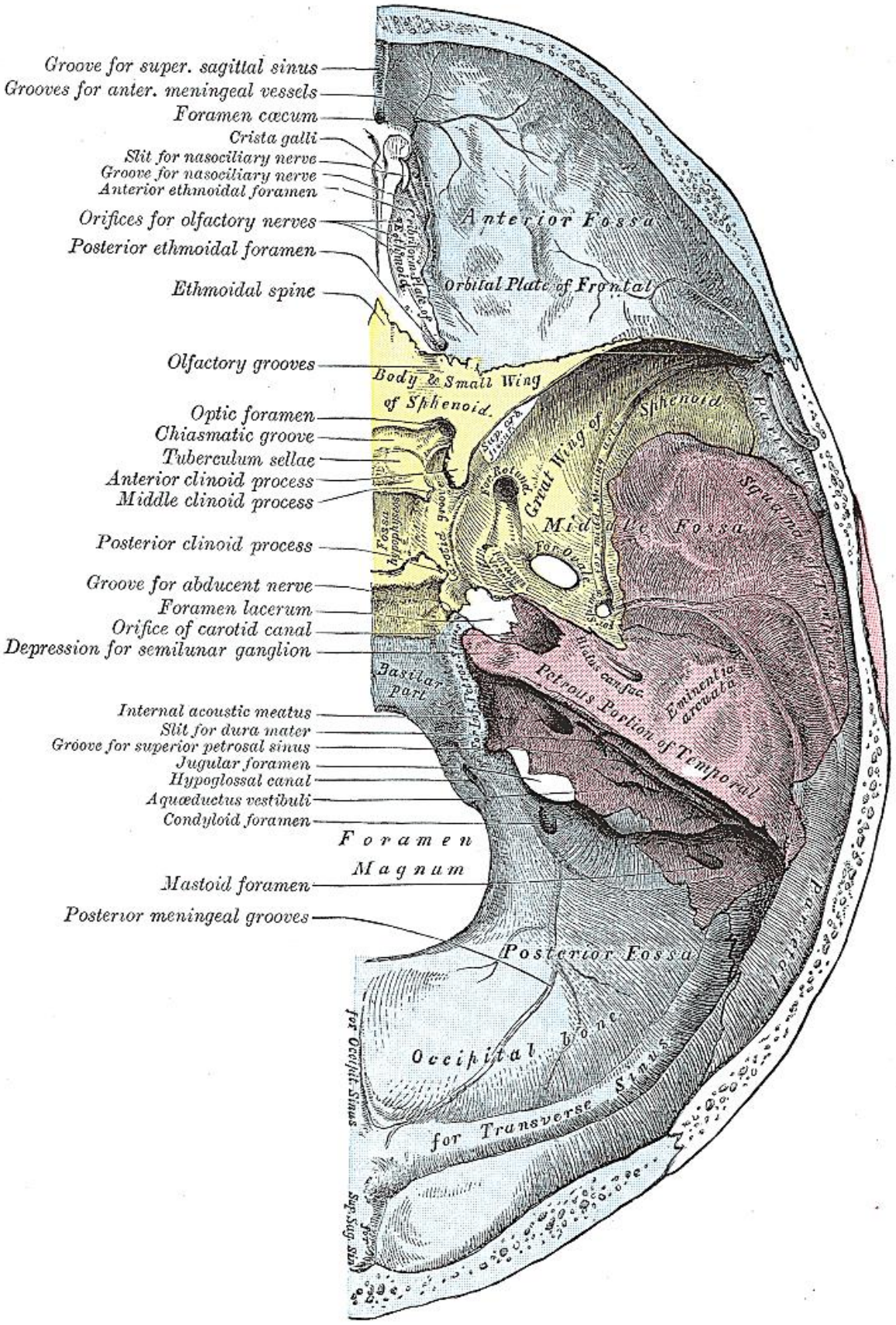



Fig. 52 *Internal surface of the cranial base.*
*Retrieved from public domein Gray´s Anatomy of human Body (1918) at Bartleby.com*

## ANTERIOR CRANIAL FOSSA

The floor of the **anterior cranial fossa** is at the highest level (above the middle and posterior cranial fossae) situated above the nasal cavity and the orbits. It is related to the frontal lobes of the brain.

**Skeletal framework of the anterior cranial fossa is formed by :**

- **frontal bone - superior surfaces of the orbital parts**
- **ethmoid bone - cribriform plate with crista gali**
- **sphenoid bone – cerebral surface of the lesser wings.**

It is perforated by the openings for the vessels and nerves (see table 9).

**Table 9 : Openings of the anterior cranial fossa.**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **foramen caecum** | anterior cranial fossa ↔nasal cavity | emissary vein (it connects the veins of the nasal cavity and superior sagittal sinus) |
| **cribriform foramina** | anterior cranial fossa ↔nasal cavity | olfactory filaments of olfactory nerves (n.I) |

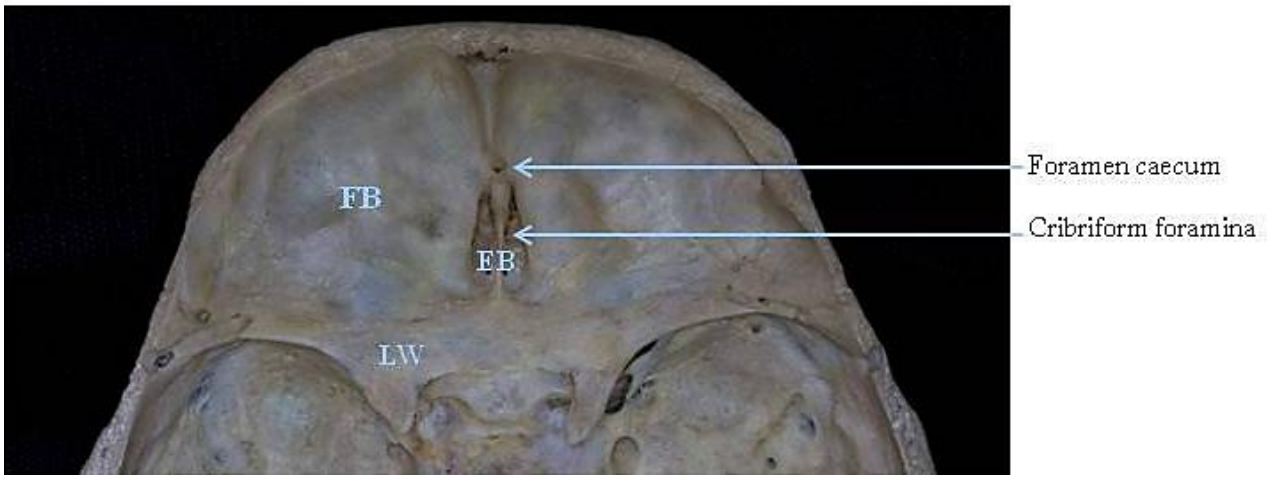



Fig. 53 *Anterior cranial fossa.*
*FB – orbital part of the frontal bone*
*EB – cribriform plate of the ethmoid bone*
*LW – lesser wing of the sphenoid bone*

## MIDDLE CRANIAL FOSSA

The floor of the **middle cranial fossa** is situated lower than the anterior cranial fossa but higher than posterior cranial fossa. It forms the middle part of the cranial base and contains the temporal lobes of the brain.

**Skeletal framework** is formed by following bones**:**

- **sphenoid bone**
  - **superior surface of the body** (chiasmatic groove, sella turcica)
  - **cerebral surface of greater wings**
- **temporal bone**
  - **anterior surface of the petrous part** (trigeminal impression, arcuate eminence, tegmen tympani)
- **squamous part of the temporal bone** (impressions for cerebral gyri, grooves for middle meningeal artery)

Middle cranial fossa presents following openings for the vessels and nerves (see table 10).

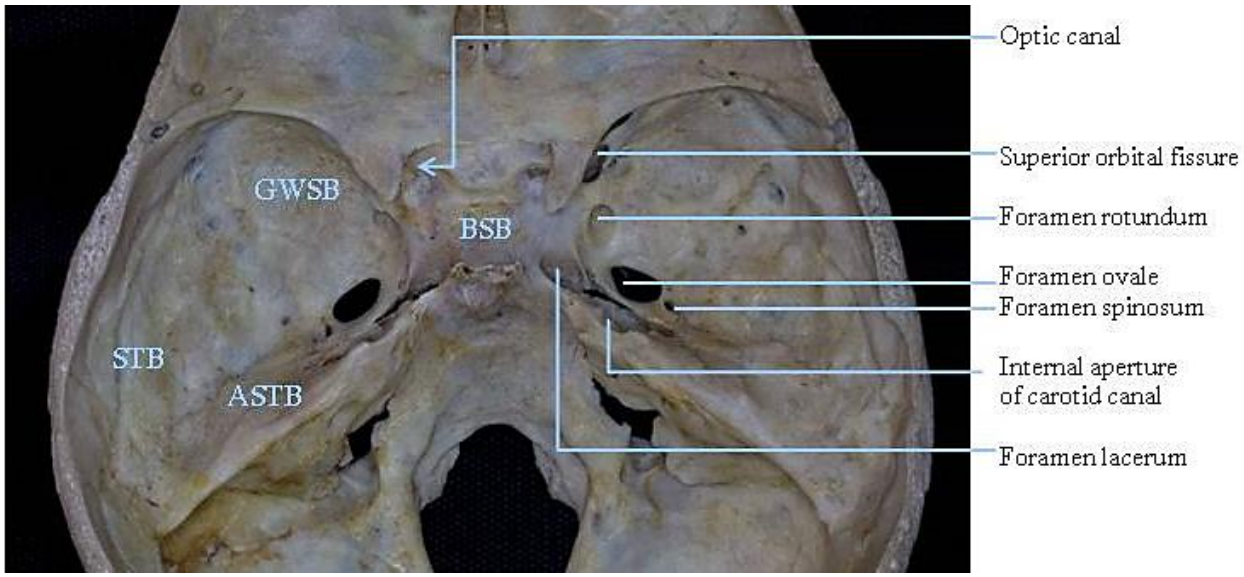



Fig. 54 *Middle cranial fossa.*

*BSB - body of the sphenoid bone*
*GWSB – greater wing of sphenoid bone*
*STB – squama of the temporal bone*
*ASTB – anterior surface of the petros part of the temporal bone*

**Table 10 : Openings of the middle cranial fossa.**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **optic canal** | middle cranial fossa ↔ orbit | optic nerve (n.II)<br>ophthalmic artery |
| **superior orbital fissure** | middle cranial fossa ↔ orbit | oculomotor nerve (n.III)<br>trochlear nerve (n.IV)<br>ophthalmic nerve (n.V1)<br>abducent nerve (n.VI)<br>ophthalmic veins |
| **foramen rotundum** | middle cranial fossa ↔ pterygopalatine fossa | maxillary nerve (n. V2) |
| **foramen ovale** | middle cranial fossa ↔ infratemporal fossa | mandibular nerve (n.V3)<br>lesser petrosal nerve<br>accessory middle meningeal artery<br>emissary veins (they connect pterygoid plexus and cavernous sinus) |
| **foramen spinosum** | middle cranial fossa ↔ infratemporal fossa | middle meningeal artery<br>meningeal branch from mandibular nerve |
| **carotid canal** | middle cranial fossa ↔ external surface of the cranial base | internal carotid artery |
| **foramen lacerum** | closed by cartilage | deep petrosal nerve, greater petrosal nerve |
| **hiatus for greater petrosal nerve** | middle cranial fossa ↔ facial canal | greater petrosal nerve<br>superficial perosal artery |
| **hiatus for lesser petrosal nerve** | middle cranial fossa ↔ tympanic cavity | lesser petrosal nerve<br>superior tympanic artery |

## POSTERIOR CRANIAL FOSSA

Posterior cranial fossa is the largest and deepest of all cranial fossae. It supports the cerebellum, medulla oblongata, pons, midbrain and occipital lobes of the brain.

**Skeletal framework** is composed from:

- **temporal bone**
  - **posterior surface of the petrous part**
  - **internal surface of mastoid process**
- **occipital bone**
  - **superior surface of the basilar part** (clivus)
  - **superior surface of the lateral parts**

- **internal surface of the squama** (internal occipital crest, internal occipital protuberance).

Posterior cranial fossa is grooved by impressions of dural venous sinuses: groove for the superior sagital sinus, groove for the transverse sinus, groove for the sigmoid sinus, groove for the superior and inferior petrosal sinuses.

Floor of posterior cranial fossa is perforated by following foramina for the vessels, nerves and spinal cord.

**Table 11 : Openings of the posterior cranial fossa.**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **internal acoustic meatus** | posterior cranial fossa ↔ internal ear ↔ facial canal ↔ stylomastoid foramen | labyrinthine artery and veins<br>vestibulocochlear nerve (n.VIII)<br>facial nerve (n.VII) |
| **jugular foramen** | posterior cranial fossa ↔ external surface of cranial base | glossopharyngeal nerve (n.IX)<br>vagus nerve (n.X)<br>accessory nerve (n.XI)<br>internal jugular vein formed by sigmoid sinus and inferior petrosal sinus<br>posterior meningeal branches |
| **foramen magnum** | posterior cranial fossa ↔ external surface of cranial base | Medulla oblongata with meninges<br>vertebral arteries, emissary veins<br>spinal root of accessory nerve (n.XI) |
| **hypoglossal canal** | posterior cranial fossa ↔ external surface of cranial base | hypoglossal nerve (n.XII)<br>meningeal branch of ascending pharyngeal artery |
| **condylar canal** | posterior cranial fossa ↔ external surface of cranial base – condylar fossa | emissary vein (it connects occipital veins and sigmoid sinus) |

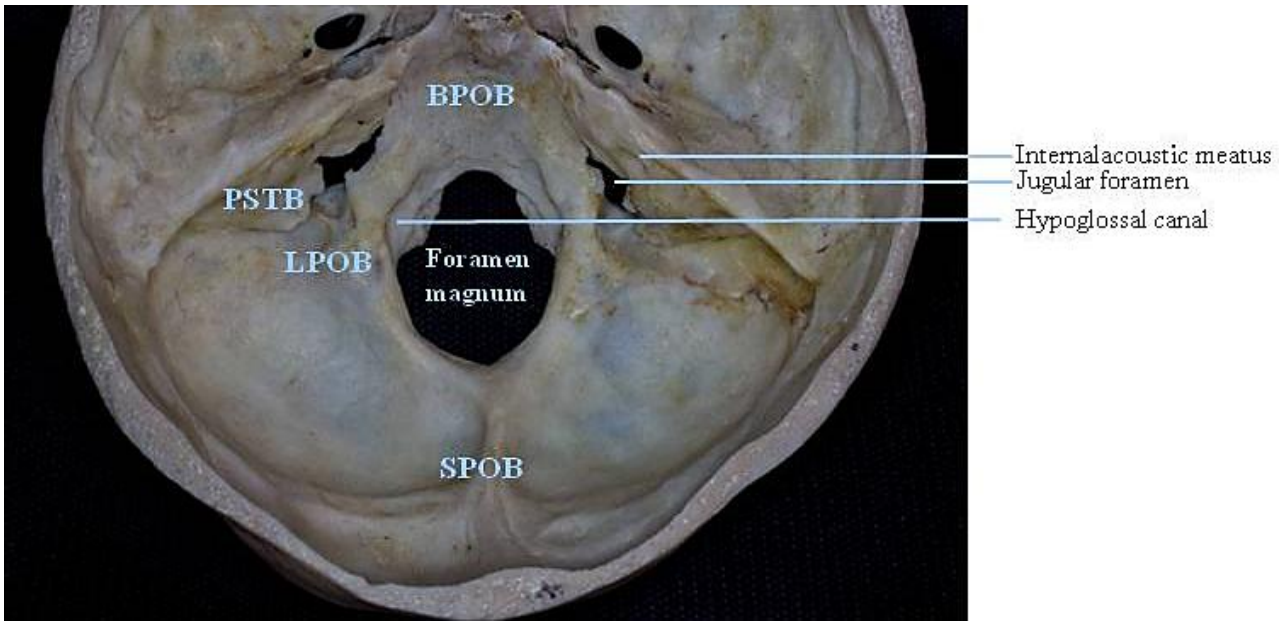



Fig. 55 *Posterior cranial fossa*

*BPOB – basilar part of the occipital bone*
*LPOB – lateral part of the occipital bone*
*PSTB – posterior surface of the temporal bone*

## EXTERNAL SURFACE OF THE CRANIAL BASE – NORMA BASALIS

The external surface of cranial base is usually divided into three parts:

- **anterior part** – formed by alveolar process with the teeth and hard palate (palatine processes of maxillae, horitontal plates of palatine bones)
- **middle part** – from the posterior margine of the hard palate to the anterior edge of foramen magnum (inferior surface of the sphenoid body, infratemporal surface of the greater wings of the sphenoid bone, pterygoid processes of the sphenoid bone, vomer, squama of the temporal bones, inferior surfaces of petrous parts of the temporal bones, basilar part of the occipital bone)
- **posterior part** – from behind the anterior edge of foramen magnum to superior nuchal lines (lateral and squamous part of the occipital bone, inferior surfaces of the petrous parts of the temporal bones, tympanic parst of the temporal bones).

**Table 12 : Openings visible at the external surface of the cranial base – norma basalis.**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **incisive foramen / canal** | bony palate / oral cavity ↔ nasal cavity | nasopalatine nerve<br>branch of greater palatine artery |
| **greater and lesser palatine foramina** | bony palate /oral cavity ↔ pterygopalatine fossa | greater and lesser palatine nerves<br>descending palatine artery and vein |
| **canalis pterygoideus** | pterygopalatine fossa ↔ middle cranial fossa fossa | nerve of pterygoid canal<br>artery and vein of pterygoid canal (Vidian nerve, artery and vein) |
| **foramen lacerum** | external surface of cranial base ↔ middle cranial fossa<br>filled by cartilage | deep petrosal nerve, greater petrosal nerve |
| **external aperture of the carotid canal** | external surface of cranial base ↔ middle cranial fossa | internal carotid artery |
| **foramen ovale** | infratemporal fossa ↔ middle cranial fossa fossa | mandibular nerve (n.V3)<br>lesser petrosal nerve<br>accessory middle meningeal artery<br>emissary veins (they connect pterygoid plexus and cavernous sinus) |
| **foramen spinosum** | infratemporal fossa ↔ middle cranial fossa fossa | middle meningeal artery<br>meningeal branch from mandibular nerve |
| **jugular foramen** | external surface of cranial base ↔ posterior cranial fossa | glossopharyngeal nerve (n.IX)<br>vagus nerve (n.X)<br>accessory nerve (n.XI)<br>internal jugular vein formed by sigmoid sinus and inferior petrosal sinus<br>posterior meningeal branches |
| **petrotympanic fissure** | external surface of cranial base ↔ tympanic cavity | chorda tympani<br>anterior tympanic artery |
| **stylomastoid foramen** | external surface of cranial base ↔ facial canal | facial nerve (n. VII)<br>stylomastoid artery |
| **hypoglossal canal** | external surface of cranial base ↔ posterior cranial fossa | hypoglossal nerve (n.XII)<br>meningeal branch of ascending pharyngeal artery |
| **condylar canal** | external surface of cranial base ↔ posterior cranial fossa | emissary vein (it connects suboccipital veinous plexus and sigmoid sinus) |
| **mastoid foramen** | external surface of cranial base ↔ posterior cranial fossa | emissary vein (it connects posterior auricular veins and sigmoid sinus) |

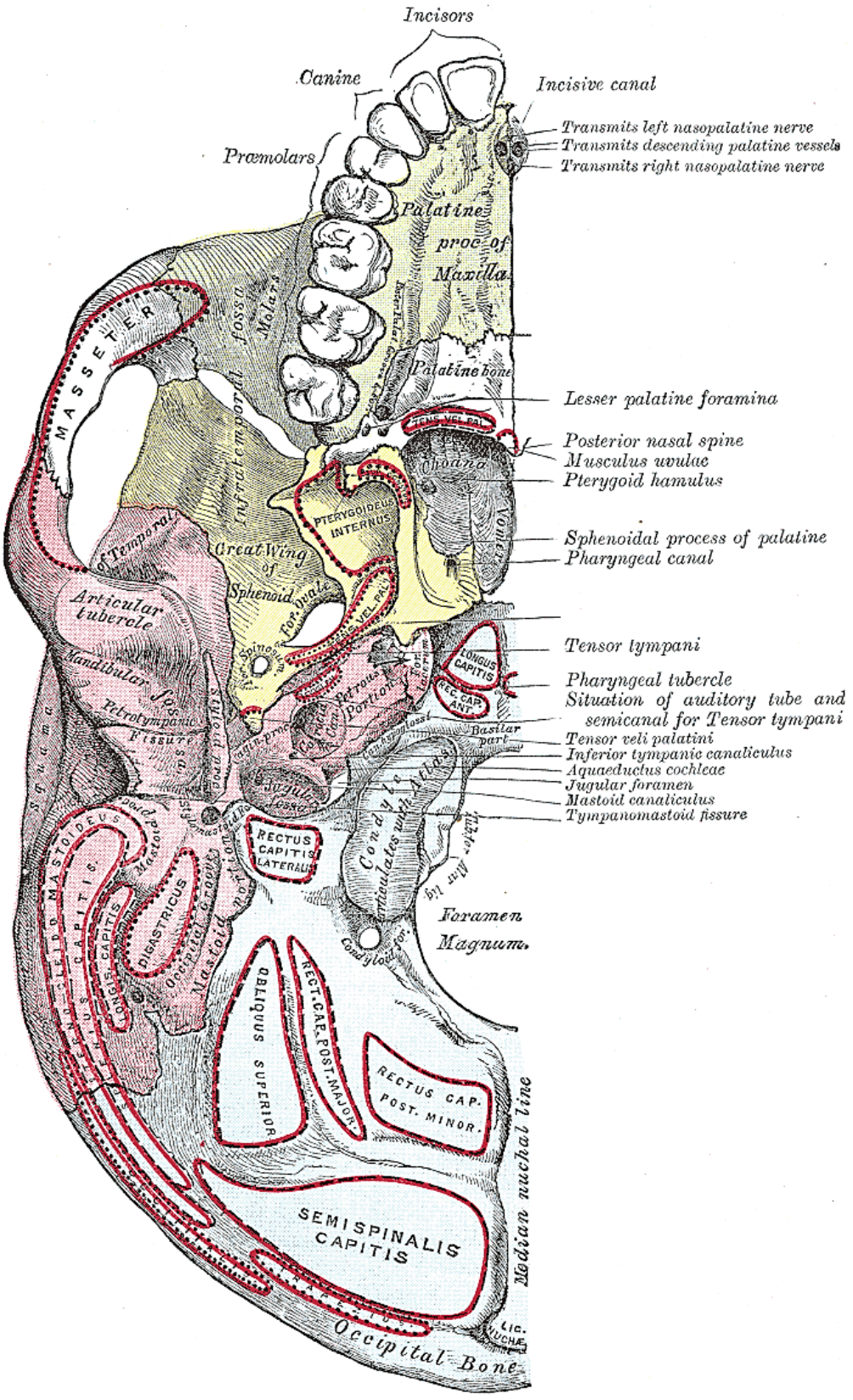



Fig. 55 *External surface of the cranial base.* *Retrieved from public domein Gray's Anatomy of human Body (1918) at Bartleby.com*

## ORBIT

**Orbits** are the bony cavities for the eyeballs and accessory visual apparatus (extraocular muscles, orbital fat, lacrimal gland) and vessels and nerves supplying this region.

**Orbit** has a shape of four - walled pyramid with the **roof, floor, medial and lateral walls**. Its axis directs posteromedialy to the **apex** situated **next to the optic canal**.

The base is at the **orbital opening** (orbital entrance or aditus orbitae) bordered by the supraorbital margine of the frontal bone superiorly (it bears supraorbital notch), frontal process of maxilla medially, frontal process of zygomatic bone laterally and maxilla and zygomatic bone inferiorly.

**Skeletal framework** of the orbit consits of seven bones.

**The roof** is formed by the **orbital parts of the frontal bone** with laterally situated gentle concavity – fossa for the lacrimal gland. Posteriorly it shelves to the apex connecting the **lesser wing of the sphenoid bone**. The roof of the orbit is related to the anterior cranial fossa.

**The floor** of the orbit roofs the maxillary sinus. It is formed by the **zygomatic bone** anterolaterally, and mostly by the **orbital surface of maxillary body** grooved by infraorbital sulcus. A small triangular area next to the apex at the border between the floor and medial wall is made up by **orbital process of palatine bone**.

Majority of **the medial wall of the orbit** is formed by **the orbital plate of the ethmoidal labyrints (lamina papyracea),** which posteriorly connects with sphenoid **body**. Superiorly the ethmoid orbital plate articulates with the orbital part of the frontal bone forming the suture interrupted by two foramina – **anterior and posterior ethmoidal foramina**. Anterior part of the medial wall of the orbit is formed by the **frontal process of maxilla and lacrimal bone.** The ridges at these bones (anterior and posterior lacrimal crests) border the lacrimal groove and lacrimal fossa (for the lacrimal sac) leading into nasolacrimal canal. Medial walls of both orbits are paralel they separate the orbits from nasal cavity.

**Lateral wall** of the orbit is anteriorly formed by the **zygomatic bone** (here it shows a minute opening **zygomaticoorbital foramen**) and behind there is the **orbital surface of the sphenoid greater wing**. This wall separates the orbit from infratemporal fossa.

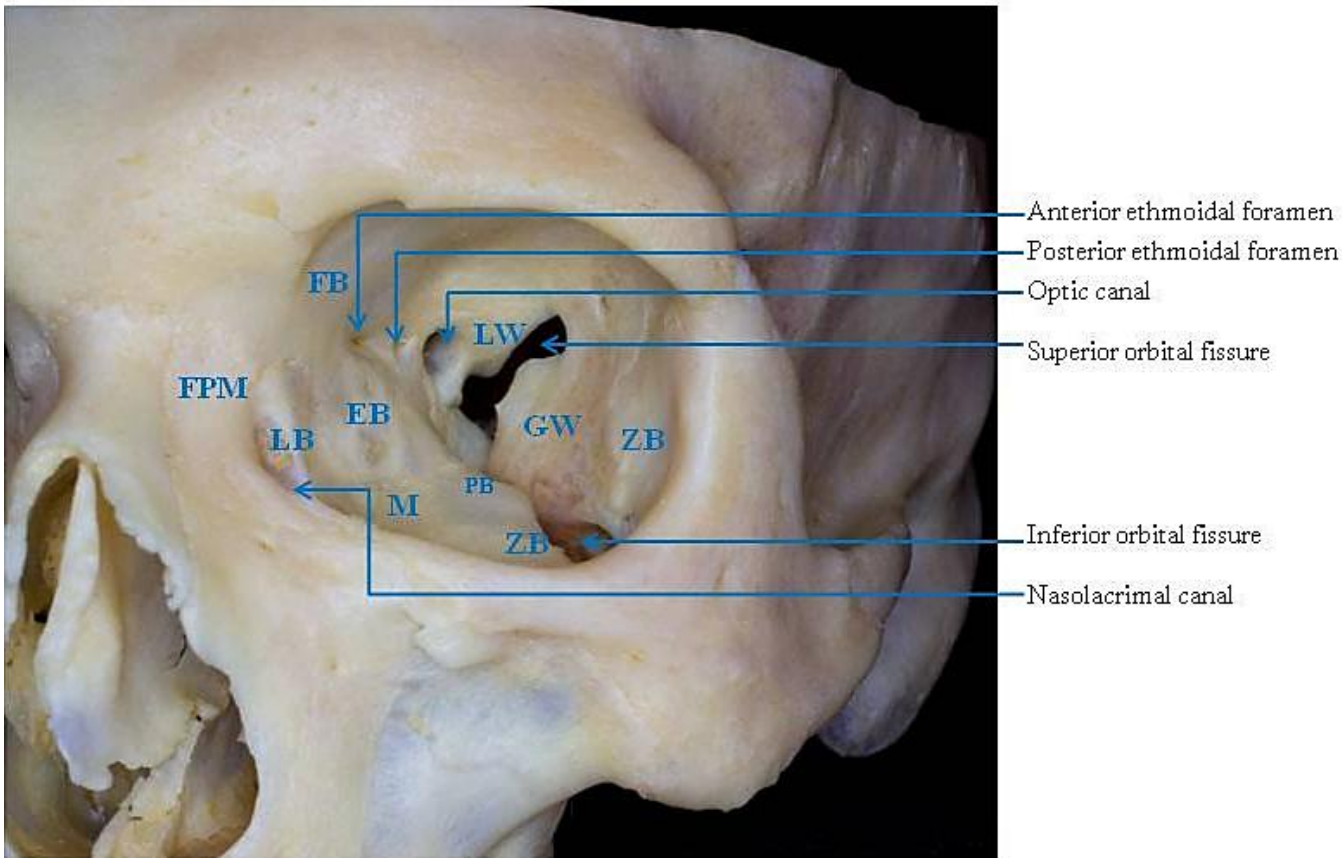



Fig. 56 *Left orbit.*

*FB – orbital part of the frontal bone*
*LW – lesser wing of the sphenoid bone*
*GW – greater wing of the sphenoid bone*
*ZB – zygomatic bone*
*PB – orbital process of the palatine bone*
*EB – ethmoid bone*
*LB – lacrimal bone*
*FPM – frontal process of maxilla*
*M - Maxilla*

The orbit communicates with the anterior and middle cranial fossa, pterygopalatine fossa, temporal and infratemporal fossa and nasal cavity through following openings (see table 13).

**Table 13 : Openings of the orbit.**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **optic canal** | orbit ↔ middle cranial fossa | optic nerve (n.II)<br>ophthalmic artery |
| **superior orbital fissure** (between the greater and lesser wing of sphenoid bone) | orbit ↔ middle cranial fossa | oculomotor nerve (n.III)<br>trochlear nerve (n.IV)<br>ophthalmic nerve (n.V1)<br>abducent nerve (n.VI)<br>superior ophthalmic vein |
| **inferior orbital fissure** (between the greater wing and maxilla) | orbit ↔ pterygopalatine fossa /infratemporal fossa | zygomatic nerve<br>infraorbital nerve<br>infraorbital vessels<br>inferior ophthalmic vein |
| **nasolacrimal canal** | orbit ↔ nasal cavity (inferior nasal meatus) | nasolacrimal duct |
| **infraorbital canal** | orbit ↔ anterior surface of maxillary body | infraorbita nerve<br>infraorbital artery |
| **anterior ethmoidal foramen** | orbit ↔ orbitocranial canal ↔anterior cranial fossa | anterior ethmoidal nerve<br>anterior ethmoidal artery and vein |
| **posterior ethmoidal foramen** | orbit ↔ posterior ethmoidal cells | posterior ethmoidal nerve<br>posterior ethmoidal artery and vein |

## BONY NASAL CAVITY

Bony nasal cavity is irregular space anteriorly opened through **anterior nasal aperture or piriform aperture**. This pear – shaped opening is superiorly bordered by the nasal bones and inferolaterally by nasal notches of maxillae.

Posteriorly the nasal cavity communicates with nasopharynx via **posterior nasal apertures or choanae** separated in the midline by the vomer. Choanae are superiorly bordered by the sphenoid body, inferiorly by the horizontal plate of the palatine bones, and laterally at both sides by the medial plate of the pterygoid processes of the sphenoid bone.

**Bony nasal septum** subdivides the nasal cavity into the right and left parts. It is composed from the perpendicular plate of the ethmoid bone anterosuperiorly and vomer posteroinferiorly.

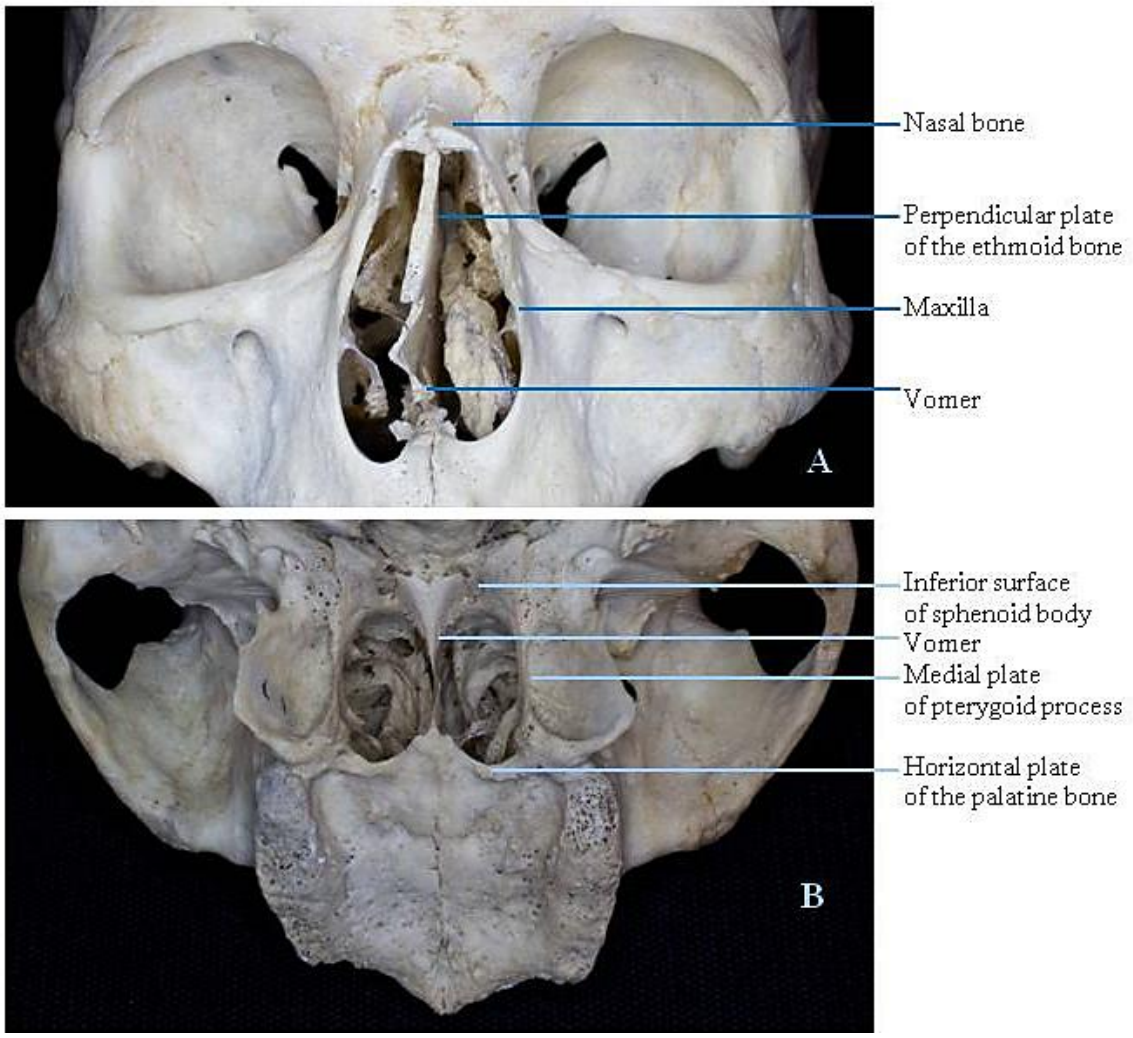



Fig. 57 A Anterior nasal aperture – piriform aperture.
B Posterior nasal apertures – choanae.

**The roof of the bony nasal cavity** is anteroposteriorly formed by **: nasal bones, nasal part of the frontal bone, cribriform plate of the ethmoid bone and the body of sphenoid**. The roof is uneven - in the cetre horizontally oriented, anteriorly and posteriorly it slopes downwards.

**The floor of the bony nasal cavity** is smooth and slightly transversely concave. Major anterior part is formed by **the palatine processes of maxillae**, posterior third by **horizontal plates of the palatine bones**. The floor shows the nasal crest in the midline, that articulates with the vomer (dorsocaudal part of bony nasal septum).

**The lateral wall of the nasal cavity** is composed from the **nasal surface of maxillary body, frontal process of maxilla, nasal bone, lacrimal bone, medial plate of the ethmoidal labyrinths, perpendicular plate of the palatine bone and inferior nasal**

**concha**. This wall contains three shelves of bone projecting medially across the nasal cavity **– superior and middle nasal concha** (parts of the ethmoid bone) and **inferior nasal concha** (independend bone). Nasal conchae increase the surface area of contact between nasal mucosa and respired air.

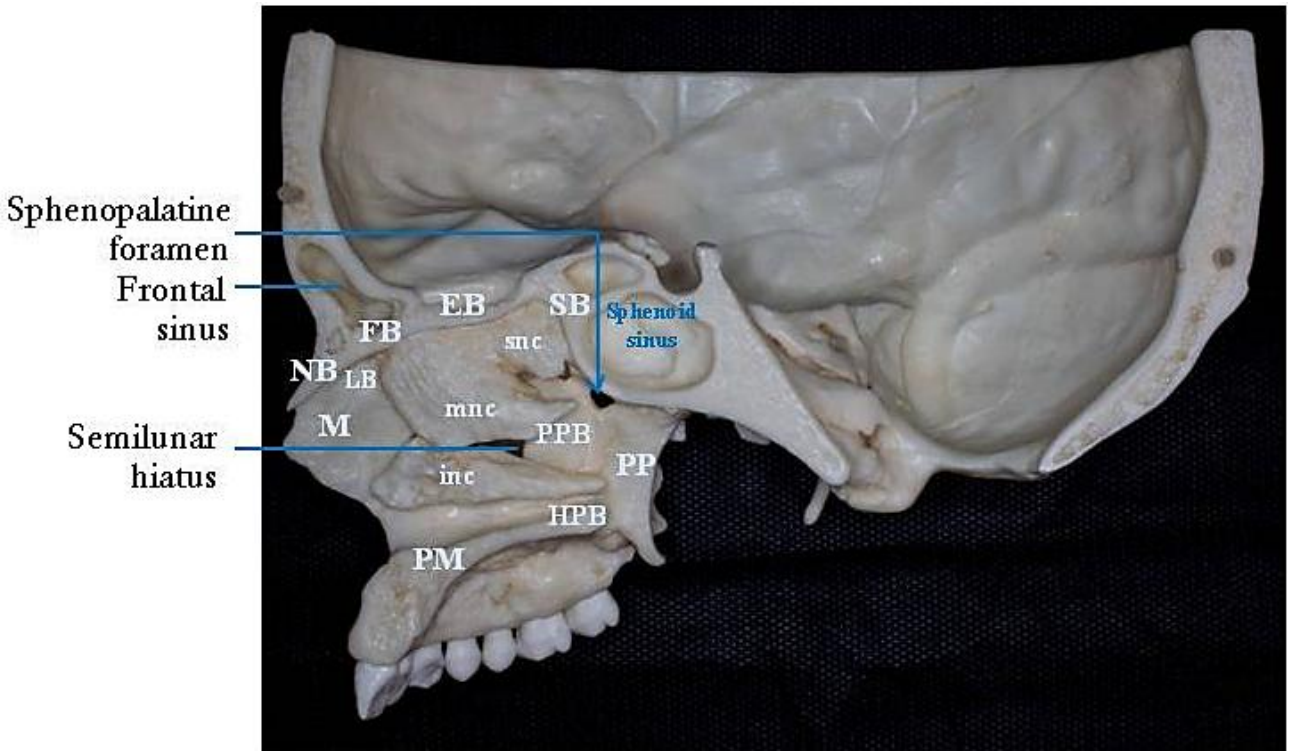



Fig. 58 *Nasal cavity – lateral wall, section of the roof and floor*.

*NB – nasal bone*
*LB – lacrimal bone*
*FB – frontal bone – nasal part*
*EB – cribriform plate of the ethmoid bone*
*SB – body of the sphenoid bone*
*PP –medial plate of pterygoid process*
*PPB – perpendicular plate of the palatine bone*
*HPB – horizontal plate of the palatine bone*
*PM – palatine process of maxilla*
*M – nasal surface of the maxillary body*

*snc – superior nasal concha*
*mnc – middle nasal concha*
*inc – inferior nasal concha*

**Superior nasal concha** is the smallest usually visible only from the posterior view to the nasal cavity, inferior nasal concha is the largest one. **Middle and inferior nasal conchae** subdivide the nasal cavity into three channels: **superior, middle and inferior nasal meatus**.

**Superior nasal meatus** is the space above the middle nasal concha. It contains the openings of the **sphenoidal sinus and posterior ethmoidal air – cells**. The area between the superior nasal concha and the nasal roof is called **sphenoethmoidal recess**.

**Middle nasal meatus** is bordered by the middle nasal concha superiorly and inferior nasal concha inferiorly. The **frontal sinus, maxillary sinus and anterior ethmoidal air – cells** are drained into it.

**Inferior nasal meatus** is situated between the inferior nasal concha and the floor of the nasal cavity. It is  the largest meatus containing the opening of the **nasolacrimal canal**. Nasolacrimal duct passing through it drains the tears from the eye to the nasal cavity.

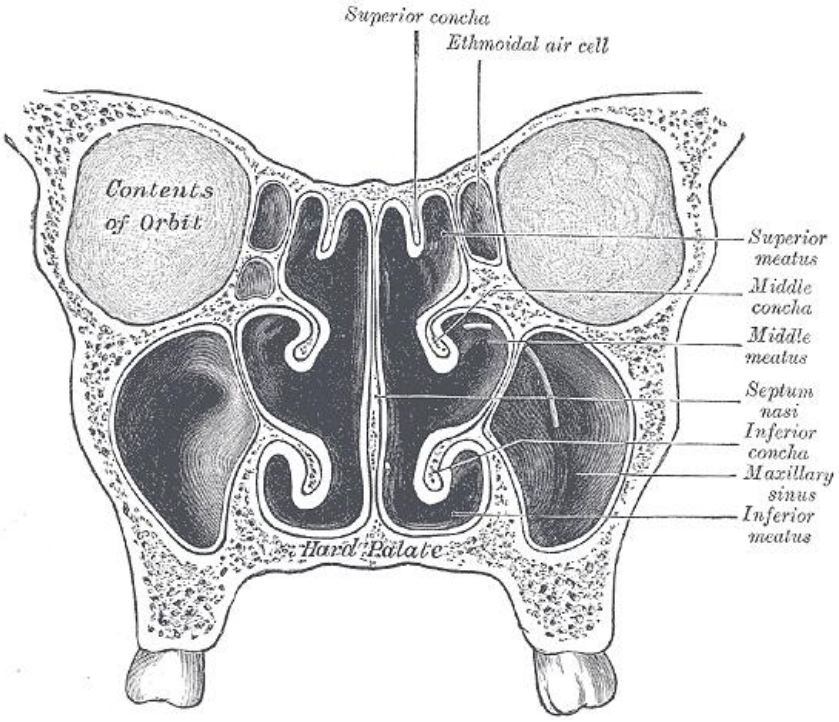



Fig. 59 *Nasal meatuses. Frontal section*.
*Retrieved from public domein Gray's Anatomy of human Body (1918) at Bartleby.com*

Nasal cavity is laterally related to the orbits and maxillary sinus, superiorly to the anterior cranial fossa and inferiorly to the oral cavity.

Bony nasal cavity communicates with the anterior cranial fossa, pterygopalatine fossa, orbit and oral cavity through following openings (see table 14).

**Table 14 : Openings of the bony nasal cavity.**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **sphenopalatine foramen** | nasal cavity ↔ pterygopalatine fossa | nasopalatine nerves<br>posterior superior lateral nasal nerve<br>sphenopalatine artery and vein |
| **cribriform foramina** | nasal cavity ↔ anterior cranial fossa | olfactory filaments of olfactory nerves (n.I) |
| **incisive foramen / canal** | nasal cavity ↔ oral cavity | nasopalatine nerve<br>branch of greater palatine artery |
| **nasolacrimal canal** | nasal cavity ↔ orbit | nasolacrimal duct |

## PARANASAL SINUSES

**Paranasal sinuses** are air – filled cavities develop as outgrowths (pneumatic diverticula) from the nasal cavity and erode into surrounding bones – frontal, sphenoid, ethmoid bones and maxillae.

Respiratory epithelium of the nasal cavity spreads through apertures (openings) to sinuses and lines their cavities, however, it allows the spreading of the infection as well. Sinus mucosa is thinner and less vascular. Most sinuses are absent or very small at the birth but rapidly grow during the permanent teeth eruption and puberty.

The function of paranasal sinuses is not fully understood but it is known that they increase resonance of the voice, humidify and heat inhaled air and decrease the relative weight of the skull (especially facial bones).

### Frontal sinuses

These sinuses are absent at the birth, well developed in 7-8 years, with full size after the puberty. The size and shape of the sinus varies among the individuals, usually they have larger volume in males. The frontal sinuses open into middle nasal meatus through frontonasal canal.

*Because of the close relation of the frontal sinus to the frontal lobe, the infection in the frontal sinus (e.g. untreated frontal sinusitis) can spread to the frontal lobe of the brain resulting in abscess of the frontal lobe. The fractures of the frontal bone involving the sinus*

*can lead to the arteficial communication between the frontal sinus and subarachnoid space that results in cerebrospinal fluid rhinorhoea (leakage into the nasal cavity).*

**Sphenoid sinuses**

They are usually asymetrical and subdivided by bony septa and situated inside the body of sphenoid bone. Rarely they can extend into the greater or lesser wings of the sphenoid bone. At the birth they have very small volume and just after the puberty they reach the final size. They are drained into superior nasal meatus.

*Only thin bony plates separate the sphenoid sinus from the nasal cavity (anteriorly) and hypophysial fossa (superiorly), thus the hypophysis (pituitary gland) can be surgically approached (for example. in patients with pituitary tumours) through the sphenoid sinuses (transsphenoidal approach).*

**Ethmoidal sinuses**

Ethmoidal sinuses are air – filled cells situated at both sides of the cribriform plate, between the nasal cavity and the orbits. The ethmoidal sinuses are clinically subdivided into the anterior and posterior groups of the air – cells. In ech group the cells are separated by only incomplete thin bony septa forming the ethmoidal labyrinth. The anterior ethmoidal air – cells open into the middle nasal meatus, posterior ethmoidal air – cells into the superior nasal meatus. The ethmoidal sinuses are present at the birth, rapidly growing at the age between 6 and 8 years and finally developed after the puberty.

*The infection of the ethmoidal air-cells may result in frontal abscess similarly like in frontal sinusitis, and ethmoidal fracture may cause the cerebrospinal rhinorhoea (leakage into the nasal cavity).*

**Maxillary sinuses** (antrum of Highmore)

Maxillary sinus is the largest of all paranasal sinuses. The floor of the maxillary sinus extends more inferiorly than the floor of the nasal cavity and is related to the roots of the premolar and molar teeth (especially second premolar and first molar). The roof of the sinus is related to the floor of the orbit. Posterior wall is related to the infratemporal fossa. The opening for the drainage of the maxillary sinus – maxillary hiatus leads into the middle nasal meatus. Hiatal opening is reduced by the attachment of uncinate process of the ethmoid bone and inferior nasal concha. Maxillary sinus is developed at the birth and rapidly grows at the age of 0-3 years and then 6-12 years.

## TEMPORAL FOSSA

**Temporal fossa** is a narrow fan – shaped space situated at the lateral side of the skull. Its skeletal framework is formed by following bones:

- **medial wall**: parietal bone, squamous part of the temporal and frontal bones, temporal surface of greater wing of the sphenoid bone
- **anterior wall**: posterior surfaces of the frontal process of the zygomatic bone and zygomatic process of the frontal bone
- **superior border**: superior and inferior temporal lines chat run from the zygomatic process of the frontal bone to the supramastoid crest of the temporal bone
- **inferior border**: zygomatic arch laterally and infratemporal crest at the greater wing of sphenoid bone medially

The floor of the temporal fossa is opened and medially continues into the infratemporal fossa.

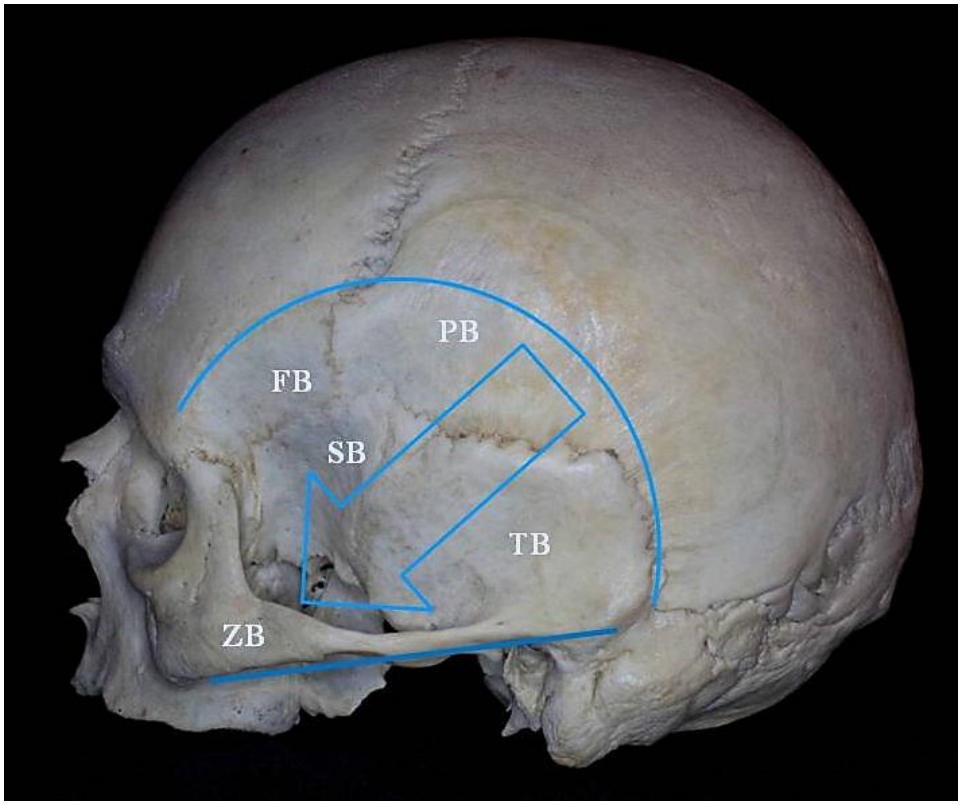



Fig. 60 *Temporal fossa from the lateral view.*

*FB – squama of the frontal bone*
*PB – parietal bone*
*TB – squama of the temporal bone*
*SB – greater wing of the sphenoid bone*
*ZB – zygomatic bone*

**Temporal fossa contains**:

- temporalis muscle (chewing musle)
- deep temporal vessels and nerves, superficial temporal artery
- zygomaticotemporal nerve which exits from the **zygomaticotemporal foramen** at the anterior wall
- superficial and deep temporal fascia
- temporal par of corpus adiposum buccae.

## INFRATEMPORAL FOSSA

Infratemporal fossa is situated inferomedially to temporal fossa. It is a wedge - shaped space made up by following bones:

- **roof**: infratemporal (inferior) surface of the **greater wing of sphenoid bone**
- **lateral wall**: medial surface of the **ramus of mandible**
- **medial wall**: **lateral plate of pterygoid process of the sphenoid bone**
- **anterior wall**: **infratemporal** (posterior) **surface of maxilla**

Posteroinferiorly infratemporal fossa opens to the neck and craniomedially to pterygopalatine fossa through pterygomaxillary fissure.

Infratemporal fossa presents numerous openings at its walls (see table 15).

**Table 15 : Openings of the infratemporal fossa.**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **foramen ovale** | infratemporal fossa ↔ middle cranial fossa fossa | mandibular nerve (n.V3)<br>lesser petrosal nerve<br>accessory middle meningeal artery<br>emissary veins (they connect pterygoid plexus and cavernous sinus) |
| **foramen spinosum** | infratemporal fossa ↔ middle cranial fossa fossa | middle meningeal artery<br>meningeal branch from mandibular nerve |
| **mandibular foramen** | infratemporal fossa ↔ mandibular canal | inferior alveolar nerve<br>inferior alveolar artery and vein |
| **alveolar foramina at the maxillary tuberosity** | infratemporal fossa ↔ alveolar canals for the upper teeth | posterior superior alveolar nerves<br>posterior superior alveolar arteries and veins |

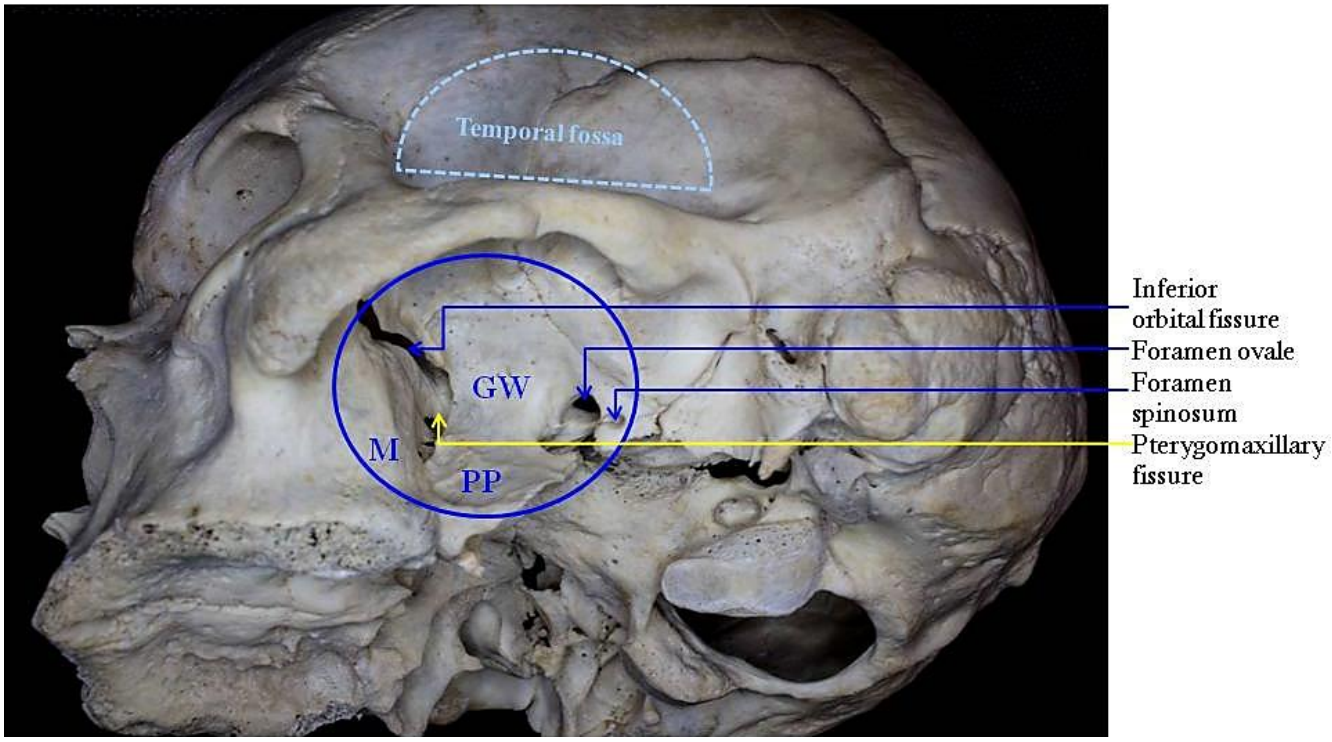



Fig. 61 *Infratemporal fossa without the mandible. Inferolateral view.*

*M – infratemporal surface of maxilla*
*PP – lateral plate of the pterygoid process of the sphenoid bone*
*GW – infratemporal surface of greater wing of the sphenoid bone*

**The infratemporal fossa contains:**

- sphenomandibular ligament (extracapsular ligament of temporomandibular joint)
- medial and lateral pterygoid muscles (chewing muscles)
- maxillary artery and its branches
- mandibular nerve and its branches
- branches of the facial and glossopharyngeal nerves
- venous pterygoid plexus and retromandibular vein.

## PTERYGOPALATINE FOSSA

**Pterygopalatine fossa** is a narrow and small pyramidal space situated craniomedially to infratemporal fossa. Its skeletal framework is formed by following bones:

- **anterior wall**: **infratemporal (posterior) surface of maxilla**
- **medial wall**: **lateral surface of perpendicular plate of the palatine bone**
- **posterior wall and the roof**: **greater wing and pterygoid process of the sphenoid bone**

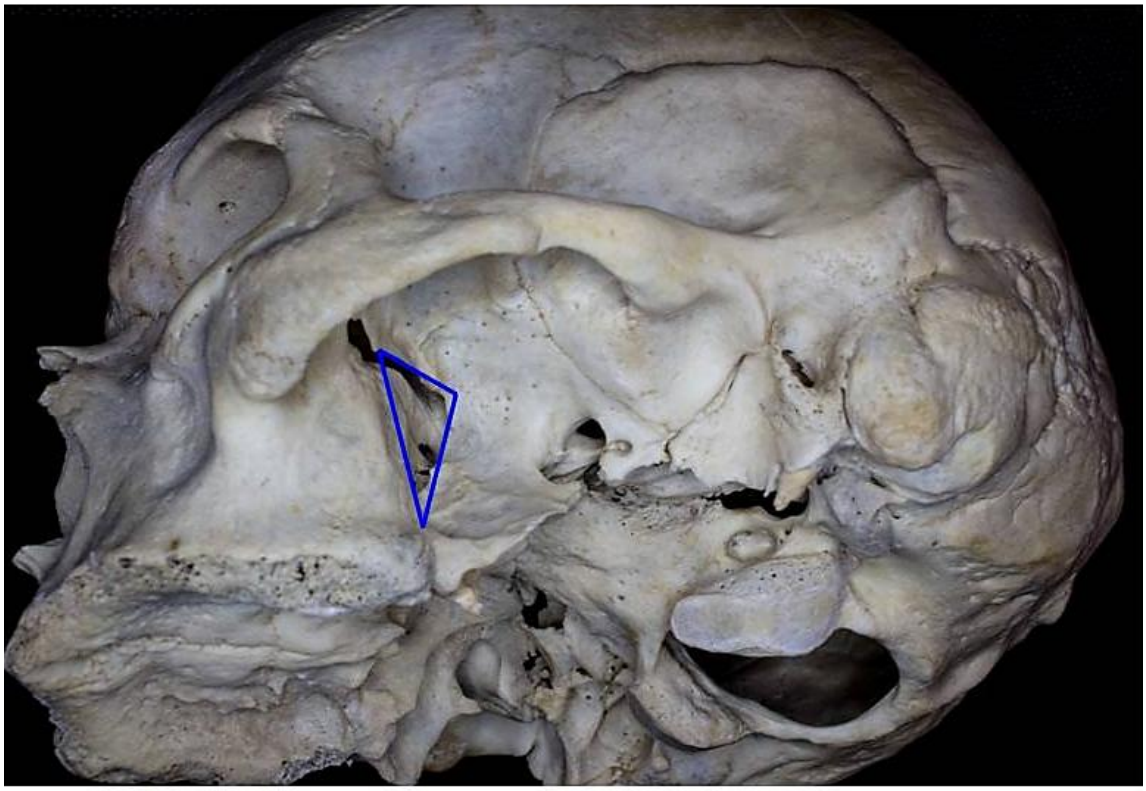


Fig. 62 *Pterygopalatine fossa from the inferolateral view.*

Pterygopalatine fossa is strategic in position because through the openings and fissure it communicates with middle cranial fossa, infratemporal fossa, orbit, nasal cavity, and oral cavity (see table 16).

**Table 16 : Openings of the pterygopalatine fossa**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **inferior orbital fissure** | pterygopalatine fossa ↔ orbit | zygomatic nerve<br>infraorbital nerve<br>infraorbital vessels<br>inferior ophthalmic vein |
| **foramen rotundum** | pterygopalatine fossa ↔ middle cranial fossa fossa | maxillary nerve (n. V2) |
| **sphenopalatine foramen** | pterygopalatine fossa ↔ nasal cavity | nasopalatine nerves<br>posterior superior lateral nasal nerve<br>sphenopalatine artery and vein |
| **palatine canals** | pterygopalatine fossa ↔ oral cavity (greater and lesser palatine foramina) | greater and lesser palatine nerves<br>descending palatine artery and vein |
| **pterygoid canal** | pterygopalatine fossa ↔ middle cranial fossa fossa | nerve of pterygoid canal<br>artery and vein of pterygoid canal (Vidian nerve, artery and vein) |

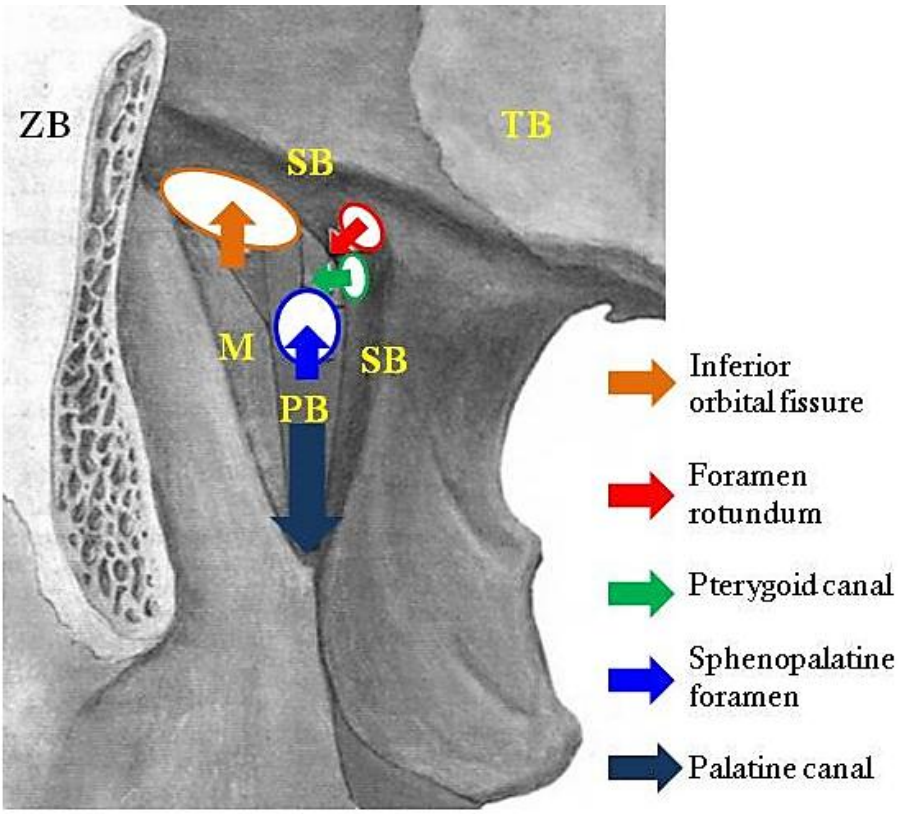



Fig. 63 *Pterygopalatine fossa from the left side –redrawn according Čihák (2011).*
*SB – sphenoid bone*
*TB – temporal bone*
*PB – perpendicular plate of palatine bone*
*M – infratemporal surface of maxilla*
*ZB – zygomatic bone*

**Pterygopalatine fossa contains** these important neurovascular structures:

- pterygopalatine ganglion
- terminal part of maxillary artery
- terminal distribution of maxillary nerve.

## BONY (HARD) PALATE

The **bony palate or hard palate** is horizontally oriented bony plate that forms the roof of the oral cavity. Its anterior 2/3 are formed by the palatine processes of maxillae and posterior 1/3 by horizontal plates of the palatine bones. These bones articulate in the midline in median palatine suture and transversely in the transverse palatine suture. The hard palate is bounded by the alveolar processes of maxillae anteriorly and laterally. Posteriorly it continues to the soft palate.

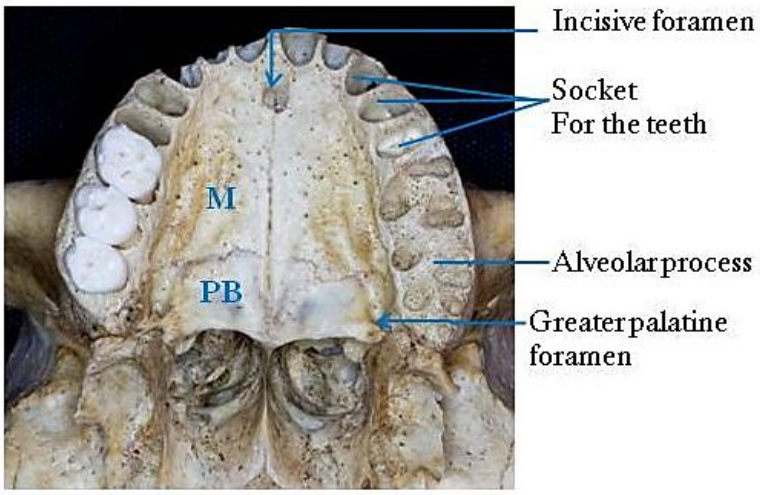



*Fig.64*
*Hard palate from inferior view.*
*M – palatine process of maxilla*
*PB – horizontal plate of the palatine bone*

**Table 17 : Openings of the hard palate**

| opening | spaces communicating through the opening | structures passing through the opening |
|---|---|---|
| **greater and lesser palatine foramina** | bony palate /oral cavity ↔ pterygopalatine fossa | greater and lesser palatine nerves<br>descending palatine artery and vein |
| **incisive foramen / canal** | Bony palate / oral cavity ↔ nasal cavity | nasopalatine nerve<br>branch of greater palatine artery |

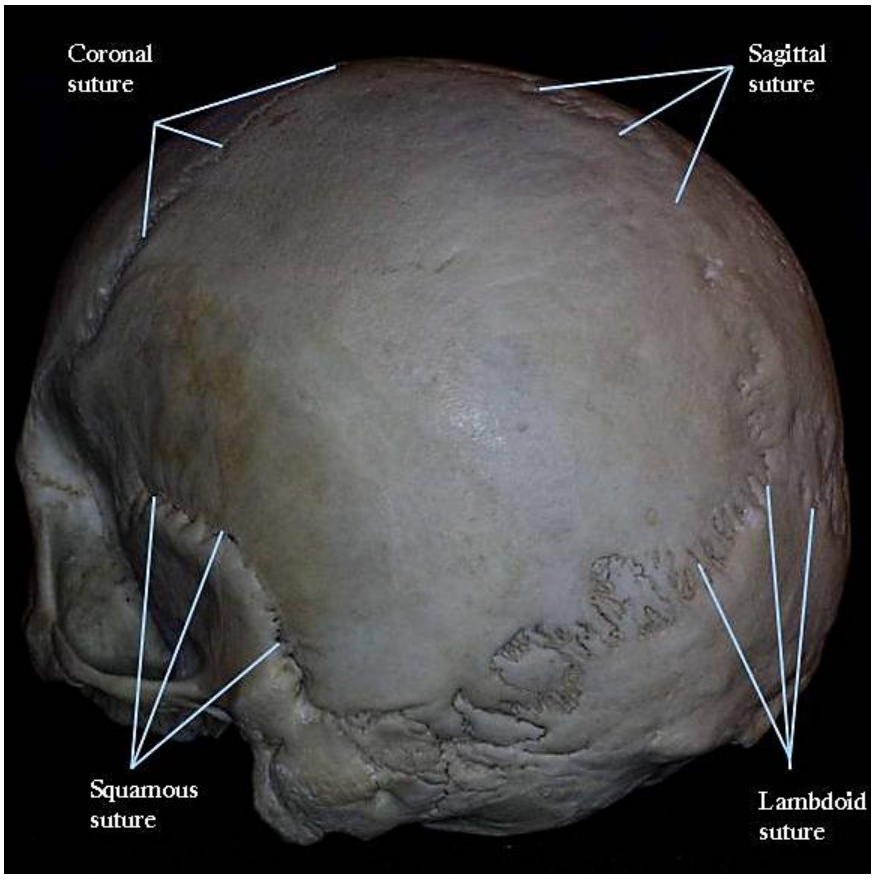
## JOINTS OF THE SKULL

The skull is the most complex bony structure in human body. The bones of the skull are connected by **sutures, synchondroses, ligaments, and temporomandibular joint**.

### Sutures

Sutures are fibrous joints which held together majority of the skull bones. These immoveable joints can be found only at the skull and in the developing and growing skull allow enlargment of the bones. There are three types of suture:

- **serrate suture** – the mrtgines of the bones present numerous projections that interlock, giving a serrated appearance like in coronal, sagittal or lambdoid suture
- **squamous (lap) suture** - the border of one bone overlaps the other for example the squamous suture between the parietal bone and temporal bone
- **plane suture** - the bones meet end-to-end, giving a simple suture e.g. median palatine suture.




The most visible sutures are at the cranial vault: **coronal suture** (serrate suture between the frontal bone and parietal bones), **sagittal suture** (serrate suture between both parietal bones), **lambdoid suture** (serrate suture between the parietal bones and occipital bone) and **squamous sutures** (lap suture between the temporal and parietal bones).

Fig. 65 *Sutures at the cranial vault.*

Sutures are wide in newborns and with growing they become narrower. During the third and fourth decades they are replaced by synostosis. This process of fusion starts on the internal surface and proceeds externally. Sagittal suture is usually the first affected by fusion, in reverse zygomaticofacial suture is rarely fused. Early fusion of sutures in growing period can result in various abnormalities.

**Synchondroses**

The bones at the base of the skull are formed by the enchodral ossification and joints between them are primary cartilagineous. There are two synchondroses which are permanent (present during the whole life): **sphenopetrous synchondrosis** and **petrooccipital synchondrosis**. During the growing period we can see also anterior and posterior intraoccipital synchondrosis (persistent till 4-7 years), intrasphenoidal synchondrosis (persistent during the first year) and sphenooccipital synchondrosis (persistent till 18-20 years).

**Ligaments**

At the skull there are these important ligaments: **pterygospinal ligament** (between the lateral plate of pterygoid process of the sphenoid bone and sphenoid spine**)**, **stylohyoid ligament** (between the stylohyoid process and lesser horns of the hyoid bone) and **ligaments of the temporomandibular joint** (see below).

**Temporomandibular joint**

**Temporomandibular joint** is a synovial joint which allows opening and closing of the mouth and complex chewing movements of mandible.

The **articular surfaces** of this joint are the head of the mandible inserted into concavity formed by mandibular fossa and articular tubercle at the squamous part of the temporal bone. Between the articular surfaces which are lined by fibrocartilage there is an articular disc completely subdividing the articular cavity into two parts: upper and lower. The articular disc has thick margine - peripheral anulus and central depression in its lower surface that surrounds mandibular head.

The upper part of the joint allows the head of the mandible to move forward (protrusion of the mandible) and backward (retraction of the mandible). The lower part of the joint allows depression and elevation of the mandible.

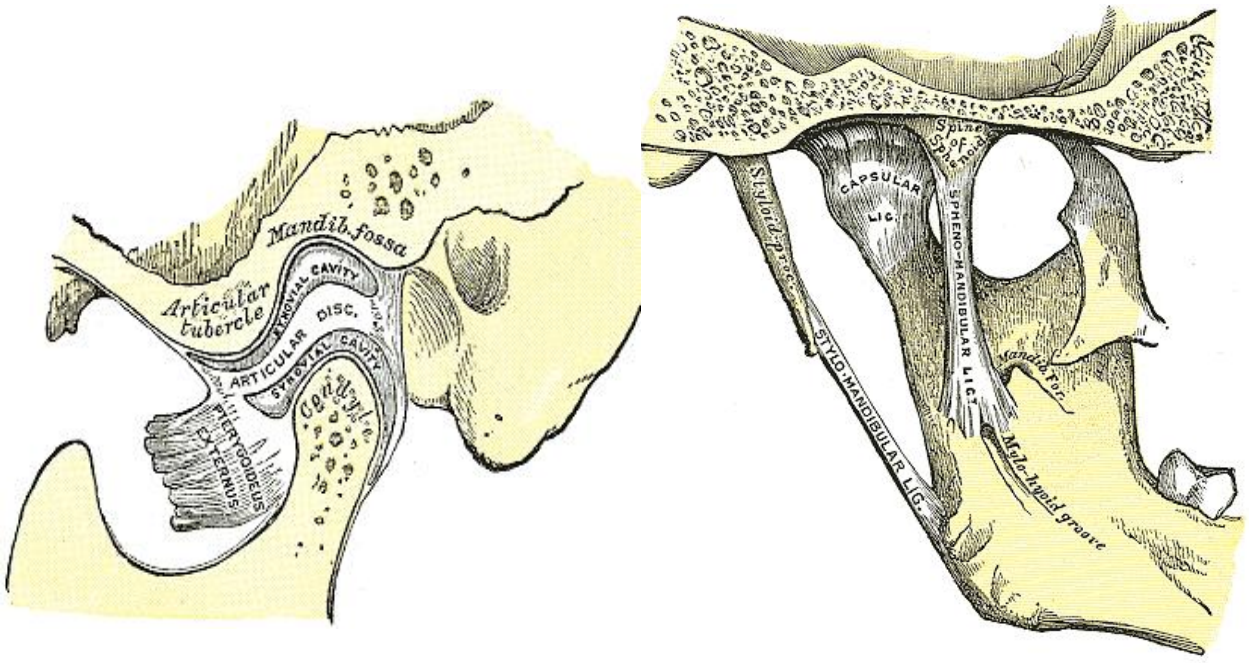



Fig. 66 *Temporomandibular joint and ligaments around the joint.*
*Retrieved from public domein Gray's Anatomy of human Body (1918) at Bartleby.com*

**Articular capsule** of the temporomandibular joint lines all non-articular compartments of the upper and lower part of the joint and attaches to the margines of the articular disc.

Tempomandibular joint is stabilzed by three ligaments:

- **sphenomandibular ligament** – this flat ligament runs medially to the articular capsule from the sphenoid spine to lingula at the medial surface of the mandibular ramus
- **stylomandibular ligament** – it passes from the styloid process to the posterior margine and angle of the mandible.
- **lateral temporomandibular ligament** – it is attached above to the articular tubercle and extends downwards to the lateral surface of the mandibular neck.

**Movements in the temporomandibular joint** at one side are coordinated with reciprocal movements at the temporomandibular joint of the other side. Movements of the mandible **elevation, depression, protrusion and retraction** are produced by the actions of the principal masticatory (chewing) muscles.

## THE SKULL AT THE BIRTH (NEONATAL SKULL)

It is important to remember that the newborn or infant body is not miniture adult body. There are typical features which distinguish infant and adult body sytems.

The neonatal skull has several characteristics:

- The skull at the birth is **relatively larger in proportion to the other parts of the skeleton**.
- The neonatal **neurocranium is larger** and **facial skeleton is smaller** they are in the ratio 8:1, however in adults it is 1:1. Especially maxilla and mandible have unfinished development because the teeth are unerupted.
- Neonatal bones of the cranial vault are **unlaminar and lack diploe**.
- Glabella, superciliary arches and mastoid processes are not developed.
- **Ossification** in some newborn skull bones **is incomplete**. Some parts of frontal bone, maxilla, and occipital bone are not united, they consist of several elements connected by fibrous tissue or cartilage.
- Neonatal skull presents wide sutures and membranous gaps within the angles between the sutures termed **fontanelles**. The **anterior** (greater or major) **fontanell** is the largest, diamond – shaped, situated between the frontal and parietal bones. It should be closed till the age of 18 month after the birth. **Posterior** (smaller or minor) **fontanell** is triangular in shape, situated between the occipital and parietal bones. It ossifies during the third month after the birth. The sphenoidal and mastoid fontanells are situated at each sides at the sphenoidal and mastoid angles of parietal bones.They are usually only small, irregular and closed during the first months.
- **Paranasal sinuses** (except the maxillary sinus) are **absent or miniature** at the birth.

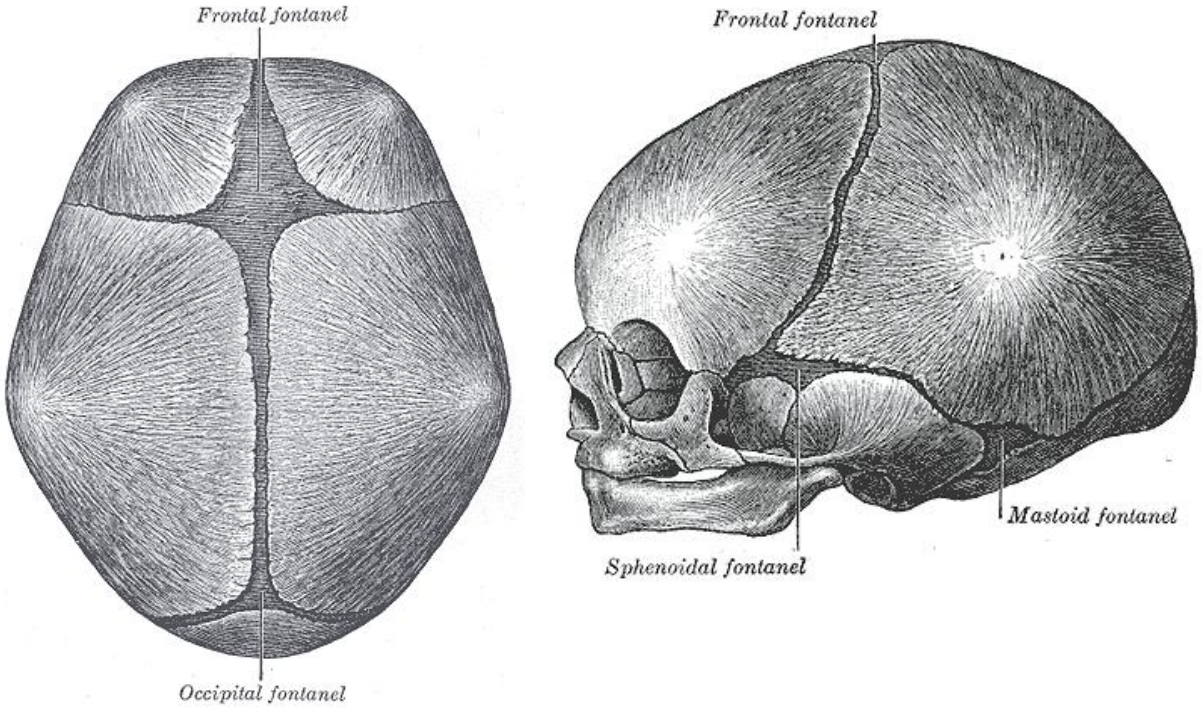



Fig. 67 *Neonatal skull.*
*Retrieved from public domein Gray's Anatomy of human Body (1918) at Bartleby.com*

During the parturition the skull is compressed in the birth canal. Sometimes the pressure in the birth canal may mold head because the fontanells and the width of the sutures allow the bones of the cranial vault to overlap.

Postnatal growth of the cranial vault, cranial base and facial skeleton is largely independent.

Growth of the cranial vault is rapid especially during the first year. It is influenced by the maturation of the brain.

The facial skeleton reacts on the development of the teeth and masticatory muscles. It quickly grows during the first year, continues to puberty when it shows a growth spurt associated with hormonal influence and secondary sexual alteration.

## GENDER DIFFERENCES IN THE SKULL

Sexual dimorphism can be seen in the skull similarly like in the other parts of the human skeleton. The most typical features are reviewed in the table 18.

**Table 18 : Gender differences in the skull**

| feature | male | female |
|---|---|---|
| **size and architecture of the skull** | larger and more robust | smaller and more gracile |
| **forehead** | lower<br>steeper<br>more prominent supercilary arches | higher<br>more vertical<br>more prominent frontal tuberosities |
| **parietal tuberosity** | smaller | larger |
| **mastoid process** | larger more robust | smaller and gracile |
| **temporal lines**<br>**nuchal lines**<br>**occipital protuberances** | more prominent | less marked |
| **orbits** | squared<br>rounded supraorbital margines | rounded<br>sharp supraorbital margines |
| **mandible** | larger | smaller |

## REVIEW QUESTIONS

## SKELETON AND JOINTS OF THE VERTEBRAL COLUMN

**Atlas CI:**
a/ it has no body
b/ it has bifid spinous process
c/ it has the groove for vertebral artery at its posterior arch
d/ inferior articular surfaces (facets) are elongated and concave
e/ its transverse processes are perforated by transverse foramina (foramina transversaria)

**Cervical vertebrae (CIII-CVII):**
a/ they have triangular vertebral foramen
b/ they have facets for the ribs on the bodies
c/ their transverse processes are perforated by foramen transversarium
d/ they have small bodies which are transversely wider than anteroposteriorly
e/ CVII is vertebra prominens

**Thoracic vertebrae:**
a/ they have triangular vertebral foramen
b/ they have the costal processes
c/ they have foramen transversarium at the transverse processes
d/ they have bifid spinous process
e/ vertebra TXII has no costal facets at the transverse processes

**Lumbar vertebrae:**
a/ they have triangular vertebral foramina
b/ they have bifid spinous processes
c/ they have costal facets at the bodies
d/ they have transverse foramina at the transverse processes
e/ LV is vertebra prominens

**Sacrum:**
a/ it has wider upper part - base
b/ it has concave and smooth dorsal surface
c/ its lateral sacral crest is formed by the fusion of transverse processes of sacral vertebrae
d/ its median sacral crest is formed by the fusion of articular processes of sacral vertebrae
e/ inferiorly it connects with the coccyx

**Joints of the vertebral column:**
a/ intervertebral (zygapophysial) joints are synovial joints
b/ the first intervertebral disc is situated between CII and CIII
c/ the last intervertebral disc is situated between LIV and LV
d/ ligamenta flava connect spinous processes
e/ posterior longitudinal ligament runs in vertebral canal

**Ligaments of the vertebral column**:
a/ anterior longitudinal ligament runs within the vertebral canal
b/ ligamenta flava connect vertebral arches (laminae)
c/ posterior longitudinal ligament connects spinous processes of the vertebrae
d/ ligamentum nuchae connects spinous processes in the lumbar part of the vertebral column
e/ supraspinous ligament connects apices of the spinous processes in the cervical part of the vertebral column

**Atlantooccipital joint:**
a/ it is a synovial joint
b/ it is a pivot joint
c/ it allows rotation
d/ in this joint the occipital condyles join with the inferior articular surfaces (facets) of the atlas
e/ this joint contains an articular disc

**Median atlantoaxial joint:**
a/ it is a synovial joint
b/ it is a pivot joint
c/ it is multiaxial joint
d/ it is the joint between the articular processes of CI and CII
e/ it allows rotation

## SKELETON AND JOINTS OF THE THORAX

**Ribs:**
a/ floating ribs are connected to sternum
b/ the 1st rib is connected to manubrium sterni
c/ the 2nd rib is the most curved
d/ the 11th rib has big tubercle
e/ the 12th rib has no angle

**the 1st rib:**
a/ it has no tubercle
b/ it is the most curved rib
c/ groove for subclavian artery is situated at its superior surface
d/ groove for subclavian vein is situated at its inferior surface
e/ it is connected to the body of sternum

**Floating ribs:**
a/ they are connected to the body of sternum
b/ they have no tubercle
c/ they have no costal cartilage
d/ they have no costal angle
e/ their heads are connected to the transverse processes of the thoracic vertebrae TXI and TXII

**SKULL – INDIVIDUAL BONES**

**Frontal bone:**
a/ its squamous part forms a part of calvaria
b/ its orbital parts form the roof of the orbits
c/ its orbital parts form the middle cranial fossa
d/ frontal sinus opens into the superior nasal meatus
e/ frontal bone forms a part of the roof of the bony nasal cavity

**Orbital parts of the frontal bone:**
a/ they are situated in the middle cranial fossa
b/ they form the roof of the orbits
c/ orbital surface of the orbital parts shows fossa for the lacrimal gland
d/ the cerebral surface of the orbital parts is marked by the sulci of middle meningeal artery
e/ the cerebral surface of the orbital parts is marked by cribriform foramina

**Body of the sphenoid bone:**
a/ it is situated in the posterior cranial fossa
b/ hypophysial fossa is situated at its inferior surface
c/ vomer is attached to its inferior surface
d/ posteriorly it is connected with the basilar part of the occipital bone
e/ it contains air-filled sinus

**Greater wings of sphenoid bone:**
a/ they form a part of the lateral wall of the orbit
b/ they form the floor of anterior cranial fossa
c/ they project laterally from the body
d/ they form anterior clinoid processes
e/ they form the roof of the nasal cavity

**Lesser wings of the sphenoid bone:**
a/ ventrally they are connected with the orbital parts of the frontal bone
b/ they form the roof of the nasal cavity
c/ they form the floor of the orbits
d/ their posterior margins form a part of boundary between the anterior and middle cranial fossa
e/ they are situated behind the sphenoid body

Pe**trous part of the temporal bone:**
a/ it contains carotid canal
b/ its anterior and posterior surfaces are separated by the inferior margin
c/ trigeminal impression is situated at its anterior surface
d/ tegmen tympani is situated at its anterior surface
e/ stylomastoid foramen is situated at its posterior surface

**Ethmoid bone:**
a/ its cribriform plate is situated in the middle cranial fossa
b/ its perpendicular plate forms a part of bony nasal septum
c/ posterior ethmoid air cells (labyrinths) are opened into the middle nasal meatus
d/ inferior nasal concha arises from the medial wall of the ethmoid labyrinths
e/ lateral wall of the ethmoid labyrinths forms a part of the lateral wall of the orbit

**Ethmoidal labyrinths**:
a/ lateral wall of the labyrinths forms the lateral wall of the orbit
b/ medial wall of the labyrinths forms a part of the lateral wall of bony nasal cavity
c/ posterior ethmoidal air cells are opened into the inferior nasal meatus
d/ anterior ethmoidal air cells are opened into the superior nasal meatus
e/ inferior nasal concha arises from the medial wall of the labyrinths

**Palatine bone:**
a/ its perpendicular plate forms the lateral border of the piriform aperture
b/ its perpendicular plate forms the lateral wall of the nasal cavity
c/ its horizontal plate forms the bony palate
d/ its horizontal plate forms the inferior border of the piriform aperture
e/ perpendicular plates of the right and left palatine bones are connected by the median suture

**Maxilla:**
a/ maxilla borders the posterior nasal aperture - choanae
b/ maxillary body forms a part of the lateral wall of the bony nasal cavity
c/ alveolar foramina are situated at the nasal surface of the maxillary body
d/ maxillary sinus is opened into the middle nasal meatus
e/ palatine processes of maxillae form the ventral part of the bony palate

**Mandible:**
a/ its coronoid process bears the head of mandible
b/ masseter tuberosity is situated at the lateral (external) surface of the mandibular angle
c/ the ramus of mandible forms the lateral border of the infratemporal fossa
d/ mental protuberance is situated at the internal surface of the mandibular body
e/ sublingual fossa is situated at the internal surface of the mandibular body

**Mark correctly assigned structures:**
a/ occipital bone – groove for transverse sinus
b/ sphenoid bone – hypophysial fossa
c/ mandible – zygomatic process
d/ parietal bone – groves for middle meningeal artery
e/ maxilla – sublingual fossa

**Mark correctly assigned structures:**
a/ frontal bone – crista gali
b/ occipital bone – groove for transverse sinus
c/ maxilla – condylar process
d/ temporal bone – mandibular fossa
e/ ramus of the mandible – mental foramen

**Mark correctly assigned structures:**
a/ occipital bone – superior nuchal line
b/ temporal bone – mandibular fossa
c/ maxilla – orbital process
d/ parietal bone – sphenoid angle
e/ palatine bone – incisive foramen

**Mark correctly assigned structures:**
a/ ethmoid bone – cribriform plate
b/ occipital bone – groove for transverse sinus
c/ maxilla – supraorbital foramen
d/ ramus of mandible – mental foramen
e/ lateral part of occipital bone - clivus

## SKULL - SPACES

**Skeletal framework of the anterior cranial fossa is formed by:**
a/ body of the sphenoid bone
b/ basilar part of the occipital bone
c/ lesser wings of the sphenoid bone
d/ anterior surface of the petrous part of the temporal bone
e/ greater wings of the sphenoid bone

**Which of following structures are situated in the anterior cranial fossa:**
a/ tegmen tympani
b/ crista gali
c/ cribriform foramina
d/ impressions of cerebral gyri
e/ dorsum sellae

**Which of following structures are situated in the middle cranial fossa:**
a/ foramen ovale
b/ clivus
c/ jugular foramen
d/ internal acoustic meatus
e/ hypophysial fossa

**Skeletal framework of the posterior cranial fossa is formed by:**
a/ lesser wings of the sphenoid bone
b/ basilar part of the occipital bone
c/ greater wings of the sphenoid bone
d/ squamous part of the occipital bone
e/ inferior surface of the petrous part of the temporal bone

**Which of following structures are situated in the posterior cranial fossa:**
a/ occipital groove
b/ clivus
c/ occipital condyles
d/ jugular foramen
e/ internal acustic meatus

**Which of following structures are situated in norma basalis (external surface of the cranial base):**
a/ groove for the superior sagittal sinus
b/ pharyngeal tubercle
c/ occipital condyles
d/ posterior surface of the petrous part of the temporal bone
e/ styloid process of the temporal bone

**Skeletal framework of the orbit**:
a/ lacrimal bone forms a part of the medial wall
b/ perpendicular plate of the ethmoid bone forms a part of the medial wall
c/ zygomatic bone forms a part of the floor
d/ greater wing of the sphenoid bone forms a part of the lateral wall
e/ lesser wing of the sphenoid bone forms a part of the roof

**Orbit communicates with:**
a/ middle cranial fossa through the inferior orbital fissure
b/ pterygopalatine fossa through the superior orbital fissure
c/ posterior cranial fossa through the optic canal
d/ anterior cranial fossa through the anterior ethmoidal foramen and orbitocranial canal
e/ nasal cavity through the nasolacrimal canal

**Skeletal framework of the of the nasal cavity:**
a/ frontal bone forms a part of the roof
b/ body of the sphenoid bone forms a part of the roof
c/ perpendicular plate of the ethmoid bone forms a part of bony nasal septum
d/ lacrimal bone forms a part of the lateral wall
e/ horizontal plate of the palatine bone forms a part of the lateral wall

**Roof of the bony nasal cavity is formed by:**
a/ body of the sphenoid bone
b/ greater wings of the sphenoid bone
c/ cribriform plate of the ethmoid bone
d/ lacrimal bone
e/ perpendicular plate of the ethmoid bone

**Lateral wall of the bony nasal cavity is formed by**:
a/ perpendicular plate of the ethmoid bone
b/ lacrimal bone
c/ body of maxilla
d/ frontal process of maxilla
e/ vomer

**Nasal cavity communicates through the openings in its walls with**:
a/ anterior cranial fossa
b/ temporal fossa
c/ pterygopalatine fossa
d/ oral cavity
e/ posterior cranial fossa

**Superior nasal meatus:**
a/ it is situated above the middle nasal concha
b/ frontal sinus is opened into the superior nasal meatus
c/ sphenoid sinus is opened into the superior nasal meatus
d/ maxillary sinus is opened into the superior nasal meatus
e/ nasolacrimal canal is opened into the superior nasal meatus

**Skeletal framework of the temporal fossa is formed**:
a/ inferiorly by the zygomatic arch
b/ ventrally by the zygomatic process of the frontal bone
c/ ventrally by the frontal process of the zygomatic bone
d/ laterally by the maxilla
e/ floor opens medially to the infratemporal fossa

**Skeletal framework of the infratemporal fossa is formed**:
a/ dorsally by maxillary body
b/ superiorly by the infratemporal surface of the greater wing of the sphenoid bone
c/ medially by the lateral plate of the pterygoid process
d/ ventrally by perpendicular plate of the palatine bone
e/ laterally by the ramus of mandible

**Which of following openings are situated in the walls of the infratemporal fossa:**
a/ mandibular foramen
b/ zygomaticotemporal foramen
c/ foramen spinosum
d/ alveolar foramina
e/ infraorbital foramen

**Which of following openings are situated in infratemporal fossa:**
a/ hypoglossal canal
b/ mandibular foramen
c/ foramen ovale
d/ stylomastoid foramen
e/ foramen spinosum

**Infratemporal fossa communicates**:
a/ with the oral cavity through the sphenopalatine foramen
b/ with the orbit through superior orbital fissure
c/ with middle cranial fossa through foramen ovale
d/ with anterior cranial fossa through anterior ethmoidal foramen
e/ with mandibular canal through mandibular foramen

**Skeletal framework of the pterygopalatine fossa is formed**:
a/ superiorly by the lesser wing of the sphenoid bone
b/ ventrally by the maxillary body
c/ inferiorly by the sphenoid body
d/ medially by the perpendicular plate of the palatine bone
e/ posteriorly by the pterygoid process of the sphenoid bone

**Which of following openings are situated in pterygopalatine fossa**:
a/ inferior orbital fissure
b/ foramen ovale
c/ foramen spinosum
d/ foramen rotundum
e/ sphenopalatine foramen

**Pterygopalatine fossa communicates through the openings in its walls with**:
a/ anterior cranial fossa
b/ middle cranial fossa
c/ posterior cranial fossa
d/ nasal cavity
**e/** oral cavity

**Pterygopalatine fossa communicates**:
a/ with the nasal cavity through the palatine canals
b/ with the orbit through the inferior orbital fissure
c/ with the middle cranial fossa through foramen ovale
d/ with the anterior cranial fossa through pterygoid canal
e/ with the posterior cranial fossa through foramen rotundum

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