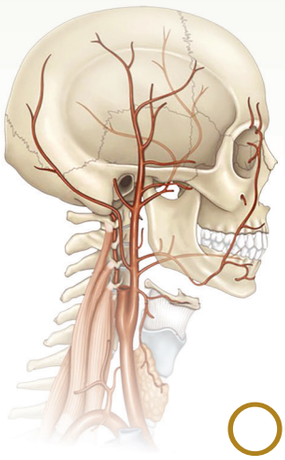


Chapter

1

Osteology of Head and Neck

The *head* is the globular uppermost part of the body, which is connected with the trunk by the *neck*. The *face* is the anterior aspect of head and the muscles present here express facial movements. The *scalp* overlies the lateral, posterior and superior aspects of skull.

Functions of Head and Neck

The head and neck region performs the following functions:

1. Protection to brain, endocrine glands and special senses.
2. Gives passage to food and air and connects their upper parts to their respective lower parts.
3. Produces voice for communication.

Peculiar Features of Human Head and Neck

1. The head comprises skull and lodges the brain covered by meninges, hypophysis cerebri, special senses, teeth and blood vessels. Brain is the highest seat of intelligence.
2. To accommodate the increased volume of nervous tissue, the cranial cavity had to enlarge.
3. Correspondingly, the lower jaw or mandible had to retract.
4. The eyes also had come more anteriorly, on each side of the nose.
5. The external nose also became prominent.
6. The external ear becomes vestigial and chin is pushed forwards to accommodate the broad tongue.
7. Tongue, the organ for speech, is securely placed in the oral cavity for articulation of words, i.e. speech.
8. The vocalisation centre is big to articulate various words and speak distinctly. Speech is a special and chief characteristic of the human.

Regions of Head and Neck

For study purposes, the head and neck are divided into the following regions:

1. ***Frontal region:*** Lies in front of skull.
2. ***Parietal region:*** Lies on top of skull, formed chiefly by the parietal bones. It is seen from the top.
3. ***Occipital region:*** Forms back of skull.
4. ***Temporal region:*** It is the area above the ears.
5. ***Ocular region:*** It is the region around the large orbital openings, containing the precious eyeball, muscles to move the eyeball, nerves and blood vessels to supply these muscles.
6. ***Auricular region:*** The region of the external ear with external auditory meatus comprises the auricular region.
7. ***Nasal region:*** The region of the external nose, its muscles and the associated cavity comprise the nasal region. Sense of smell is perceived from this region.
8. ***Oral region:*** Comprises upper and lower lips and the angle of the mouth, where the lips join each side. Numerous muscles are present here, to express feelings and emotions. These are parts of the muscles of facial expression. They show feelings, without words.
9. ***Oral cavity:*** It houses the organ of speech and taste. Tongue itself is not swallowed, though everything put on the tongue passes downwards.
10. ***Parotid region:*** Lies on the side of the face. It contains the biggest serous parotid salivary gland, which lies around the external auditory meatus.
11. ***Neck:*** Each half of the neck comprises two triangles between anterior median line and posterior median line.
    a. ***Posterior triangle:*** Lies between sternocleidomastoid, the *neck and chin turning muscle*; trapezius, *the shrugging muscle* and middle one-third of the clavicle. It contains spinal root of accessory nerve, proximal parts of the important brachial plexus, subclavian vessels with its branches and tributaries. Its apex is above and base is below.
    b. ***Anterior triangle:*** Lies between the anterior median line and the anterior border of sternocleidomastoid muscle. Its apex is in lower part of neck, close to sternum and base above. It contains the common carotid artery and branches of external carotid artery, last four cranial nerves, lymph nodes.

Competency:
AN26.1 Demonstrate anatomical position of skull, identify and locate individual skull bones in skull.

Bones of Head and Neck

The bones of head and neck include:
1. Skull, i.e. cranium with mandible
2. Seven cervical vertebrae
3. Hyoid
4. Six ossicles of the ear.

SKULL

The skeleton of the head is called the *skull*. It consists of several bones that are joined together to form the ***cranium***. The term skull also includes the mandible or lower jaw, which is a separate bone. However, the two terms, skull and cranium, are often used synonymously (Plate 1.1).

Parts of Skull

The skull can be divided into two main parts:
1. ***Calvaria*** or *brain box/neurocranium* is the upper part of the cranium, which encloses the brain. It consists of a skull cap/vault (intramembranous ossification) and a base (intracartilaginous ossification).
2. ***Facial skeleton***/viscerocranium constitutes the rest of the skull and includes the mandible.

Bones of the Skull

The skull consists of 28 bones, including 6 ear ossicles.
1. **Calvaria** or brain box is composed of 14 bones, including three paired ear ossicles.

Paired	*Unpaired*
1. Parietal	1. Frontal
2. Temporal	2. Occipital
3. Malleus	3. Sphenoid
4. Incus	4. Ethmoid
5. Stapes	

2. ***Facial skeleton*** is composed of 14 bones.

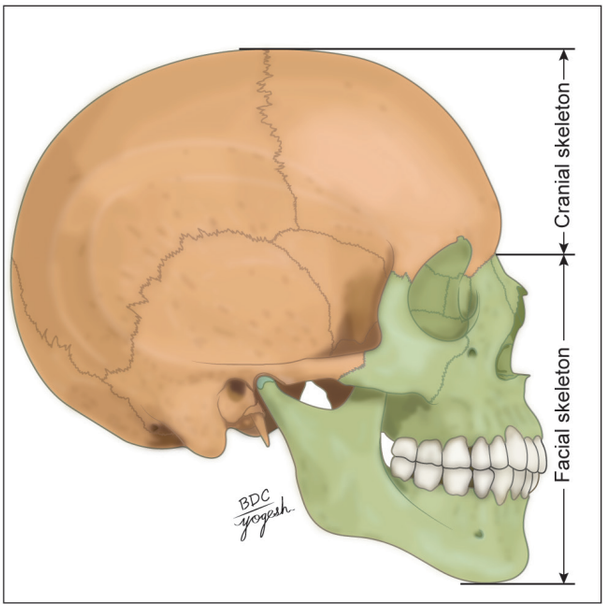
Paired	*Unpaired*
1. Maxilla	1. Mandible
2. Zygomatic	2. Vomer
3. Nasal	
4. Lacrimal	
5. Palatine	
6. Inferior nasal concha	

Skull Joints

The joints in the skull are mostly ***sutures***, a few primary cartilaginous joints and three pairs of synovial joints. The sutures can be classified into:
1. Plane suture — edges of bone are flat, e.g. internasal suture.
2. Serrate suture, e.g. coronal suture.
3. Denticulate suture, e.g. lambdoid suture.
4. Squamous suture, e.g. parietotemporal suture.
5. Schindylesis, e.g. palatomaxillary suture.

Movable joints of skull: Two pairs of synovial joints are present between the ossicles of middle ear. One pair is the largest *temporomandibular joint*.

Plate 1.1: Cranial and facial skeleton



Anatomical Position of Skull

Hold the skull in both the hands so that (Fig. 1.1):
1. The orbital cavities are directed forwards
2. The lower margin of the orbit and upper margin of the external acoustic meatus lie in the same horizontal plane (called ***Frankfurt's plane***).

Note: ***Reid's base line*** is a horizontal line obtained by joining the infraorbital margin to the centre of external acoustic meatus, i.e. auricular point (Fig. 1.1). It is used in conventional radiography when performing CT imaging.

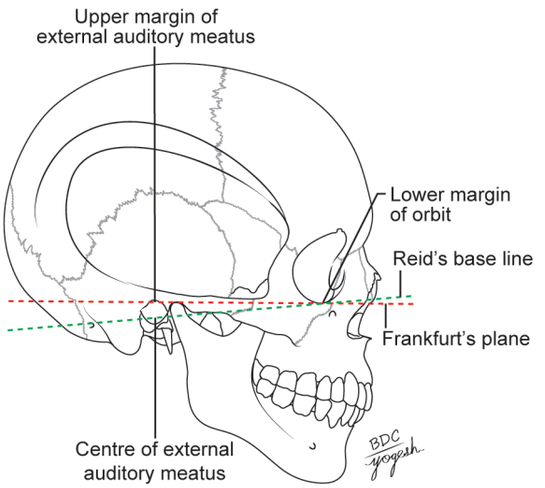


Fig. 1.1: Anatomical position of skull

Methods of Study of the Skull

The skull can be studied as a whole. The whole skull can be studied from the outside or externally in different views:

1. Superior view — norma verticalis
2. Posterior view — norma occipitalis
3. Anterior view — norma frontalis
4. Lateral view — norma lateralis
5. Inferior view — norma basalis.

The whole skull can be studied from the inside or internally after removing the roof of the calvaria or skull cap:

a. Internal surface of the ***cranial vault***.
b. Internal surface of the ***cranial base*** that shows a natural subdivision into anterior, middle and posterior cranial fossae.

Competency:
AN27.2 Describe emissary veins with its role in spread of infection from extracranial route to intracranial venous sinuses

Peculiarities of Skull Bones

1. Base of skull ossifies in cartilage, while the skull cap ossifies in membrane.
2. At birth, skull comprises one table only. By 4 years or so, two tables are formed. Between the two tables, there are *diploes* (Greek *double*), i.e. spaces containing red bone marrow forming RBCs, granular series of WBCs and platelets. Four diploic veins on each side drain the formed blood cells into neighbouring veins.
3. At birth, the 4 angles of parietal bone have membranous gaps or fontanelles. These allow overlapping of bones during vaginal delivery, if required. These also allow skull bones to increase in size after birth, for housing the delicate brain.
4. Some skull bones have air cells in them and are called pneumatic bones, e.g. frontal and maxilla.
   a. They reduce the weight of skull.
   b. They maintain humidity of inspired air.
   c. They give resonance to voice.
   d. These may get infected resulting in sinusitis.
5. Skull bones are united mostly by sutures.
6. Skull has foramina for 'emissary veins', which connect intracranial venous sinuses with extracranial veins. These try to relieve raised intracranial pressure. Infection may reach through the emissary veins into cranial venous sinuses as these veins are valveless (Table 1.1).
7. Petrous temporal is the densest bone of the body. It lodges internal ear, middle ear, including three ossicles, i.e. malleus, incus and stapes. Ossicles are 'bones within the bone' and are fully formed at birth.
8. Skull lodges brain, meninges, CSF, glands like hypophysis cerebri and pineal, venous sinuses, teeth, special senses like retina of eyeball, taste buds of tongue, olfactory epithelium, cochlear and vestibular nerve endings.

Competency:
AN26.2 Describe the features of norma frontalis, verticalis, occipitalis, lateralis and basalis.

EXTERIOR OF THE SKULL

NORMA VERTICALIS

Shape

When viewed from above, the skull is usually oval in shape. It is wider posteriorly than anteriorly. The shape may be more nearly circular (Fig. 1.2, Flowchart 1.1).

Bones

1. Frontal bone anteriorly.
2. Occipital bone posteriorly.
3. Parietal bone on each side.

Sutures

1. ***Coronal suture*** is placed between the frontal and the two parietal bones. The suture crosses the cranial vault from side-to-side (Fig. 1.2).
2. ***Sagittal suture*** is placed in the median plane between the two parietal bones.
3. ***Lambdoid suture*** lies posteriorly between the occipital and the two parietal bones. It is labda-shaped, hence the name.

Note: ***Metopic*** (Latin *forehead*) ***suture*** is occasionally present in about 3% to 8% of individuals. It lies in the median plane and separates the two halves of the frontal bone. Normally, it fuses at 6 years of age.

TABLE 1.1: The emissary veins of the skull

Name	*Foramen of skull*	*Veins outside skull*	*Venous sinus*
1. Parietal emissary vein	Parietal foramen	Veins of scalp	Superior sagittal sinus
2. Mastoid emissary vein	Mastoid foramen	Veins of scalp	Sigmoid sinus
3. Emissary vein	Hypoglossal canal	Internal jugular vein	Sigmoid sinus
4. Condylar emissary vein	Posterior condylar foramen	Suboccipital venous plexus	Sigmoid sinus
5. 2–3 emissary veins	Foramen lacerum	Pharyngeal venous plexus	Cavernous sinus
6. Emissary vein	Foramen ovale	Pterygoid venous plexus	Cavernous sinus
7. Emissary vein	Foramen caecum	Veins from upper part of nose	Superior sagittal sinus

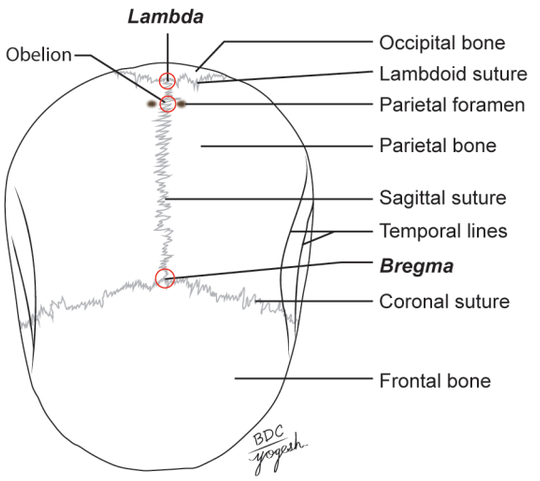
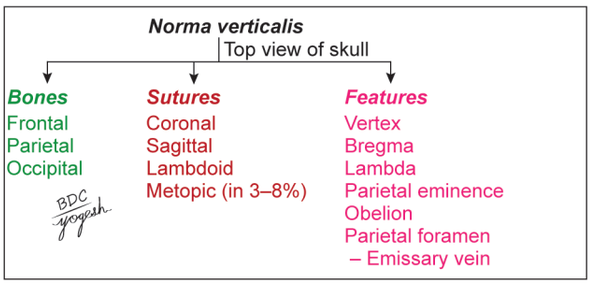


Fig. 1.2: Norma verticalis

Flowchart 1.1: Features of norma verticalis



Features (Fig. 1.2)

1. ***Vertex*** is the highest point on sagittal suture.
2. ***Vault*** of skull is the arched roof for the dome of skull.
3. ***Bregma*** is the meeting point between the coronal and sagittal sutures. In the foetal skull, this is the site of a membranous gap, called the *anterior fontanelle*, which closes at 18 to 24 months of age. It allows growth of brain.
4. ***Lambda*** is the meeting point between the sagittal and lambdoid sutures. In the foetal skull, this is the site of the *posterior fontanelle*, which closes at birth—2 to 3 months of age.
5. ***Parietal tuber*** *(eminence)* is the area of maximum convexity of the parietal bone. This is a common site of fracture of the skull.
6. ***Parietal foramen***, one on each side, pierces the parietal bone near its upper border, 2.5 to 4 cm in front of the lambda. The parietal foramen transmits an emissary vein from the veins of scalp to superior sagittal sinus.
7. ***Obelion*** is the point on the sagittal suture between the two parietal foramina.
8. ***Temporal lines*** begin at the zygomatic process of the frontal bone, arch backwards and upwards and cross the frontal bone, the coronal suture and the parietal bone. Over the parietal bone, there are two lines—superior and inferior. Traced anteriorly, they fuse to form a single line. Traced posteriorly, the superior line fades out over the posterior part of the parietal bone, but the inferior temporal line continues downwards and forwards with zygomatic arch.
9. A pair of anterolateral/sphenoidal fontanelle and a pair of posterolateral or mastoid fontanelles are also present. These fontanelles close within 3–4 months after birth.

NORMA OCCIPITALIS

Norma occipitalis is convex upwards and on each side and is flattened below (Fig. 1.3, Flowchart 1.2).

Bones

1. Parietal bones above.
2. Squamous part of the occipital bone below.
3. Mastoid part of the temporal bone on each side.

Sutures

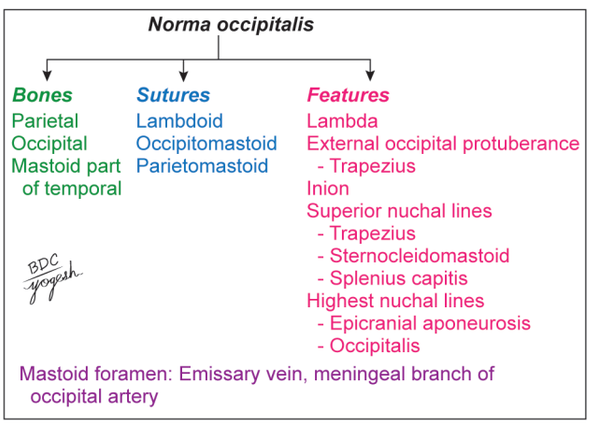
1. ***Lambdoid suture*** lies between the occipital bone and the two parietal bones. Sutural or wormian bones are common along this suture.
2. ***Occipitomastoid suture*** lies between the occipital bone and mastoid part of the temporal bone.
3. ***Parietomastoid suture*** lies between the parietal bone and mastoid part of the temporal bone.

   The posterior part of the ***sagittal suture*** is also seen.

Features

1. *Lambda, parietal foramina* and *obelion* have been examined in the norma verticalis.
2. ***External occipital protuberance*** is a median prominence in the lower part of this norma. It marks the junction of the head and the neck. The most prominent point on this protuberance is called the *inion*.
3. ***Superior nuchal lines*** are curved bony ridges passing laterally from the protuberance. These also mark the junction of the head and the neck. The area below the superior nuchal lines will be studied with the norma basalis.
4. ***Highest nuchal lines*** are not always present. They are curved bony ridges situated about 1 cm above the superior nuchal lines. They begin from the upper part of the external occipital protuberance and are more arched than the superior nuchal lines.

Flowchart 1.2: Features of norma occipitalis



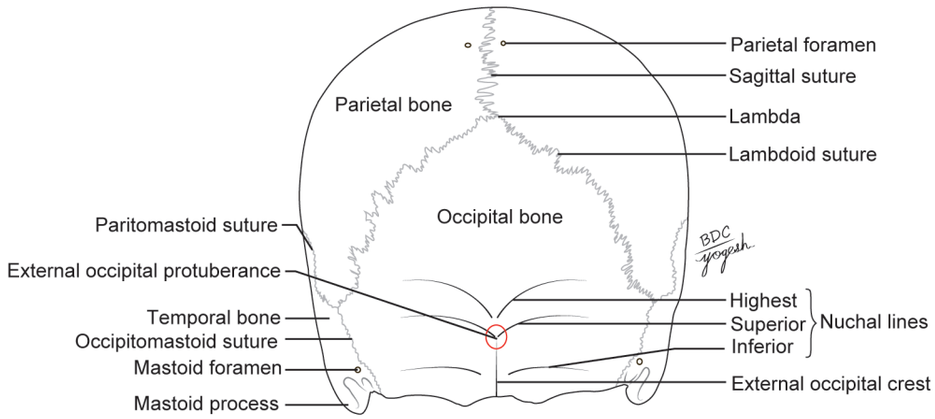


Fig. 1.3: Norma occipitalis

5. ***Occipital point*** is a median point, a little above the inion. It is the point farthest from the glabella.
6. ***Mastoid*** (Greek *breast*) ***foramen*** is located on the mastoid part of the temporal bone at or near the occipitomastoid suture. Internally, it opens at the sigmoid sulcus. The mastoid foramen transmits an emissary vein (Table 1.1) and the meningeal branch of the occipital artery.

Note: ***Interparietal bone*** (inca bone) is occasionally present. It is a large triangular bone located at the apex of the squamous occipital. This is not a sutural or accessory bone but represents the membranous part of the occipital bone which has failed to fuse with the rest of the bone.

Attachments

1. The upper part of the external occipital protuberance gives origin to the trapezius, and the lower part gives attachment to the upper end of the ligamentum nuchae.
2. The medial 1/3rd of the superior nuchal line gives origin to the trapezius, and the lateral part provides insertion to the sternocleidomastoid above and to the splenius capitis below.
3. The highest nuchal lines, if present, provide attachment to the epicranial aponeurosis medially, and give origin to the occipitalis or occipital belly of occipitofrontalis muscle laterally. In case of absence of highest nuchal lines, these structures are attached to superior nuchal lines.

NORMA FRONTALIS

The norma frontalis is roughly oval in outline, being wider above than below (Plate 1.2, Fig. 1.4, Flowchart 1.3).

Bones

1. *Frontal* bone forms the forehead. Its upper part is smooth and convex, but the lower part is irregular and is interrupted by the orbits and by the anterior bony aperture of nose.
2. Right and left *maxillae* form the upper jaw.
3. Right and left *nasal* bones form the bridge of the nose.
4. *Zygomatic* (Greek *yoke*) bones form the bony prominence of the superolateral part of the cheeks.
5. *Mandible* forms the lower jaw.

Descriptive Subdivisions

The *norma frontalis* can be studied under the following heads.

1. Frontal region
2. Orbital openings
3. Anterior nasal aperture
4. Lower part of the face.

Frontal Region

The frontal region presents the following features:

1. ***Superciliary arch*** is a rounded, curved elevation situated just above the medial part of each orbit. It overlies the frontal sinus and is better marked in males than in females.

Flowchart 1.3: Features of norma frontalis

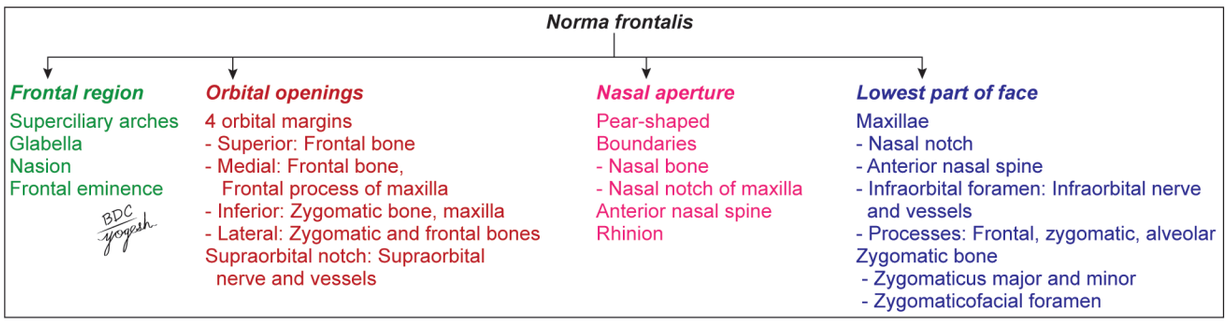
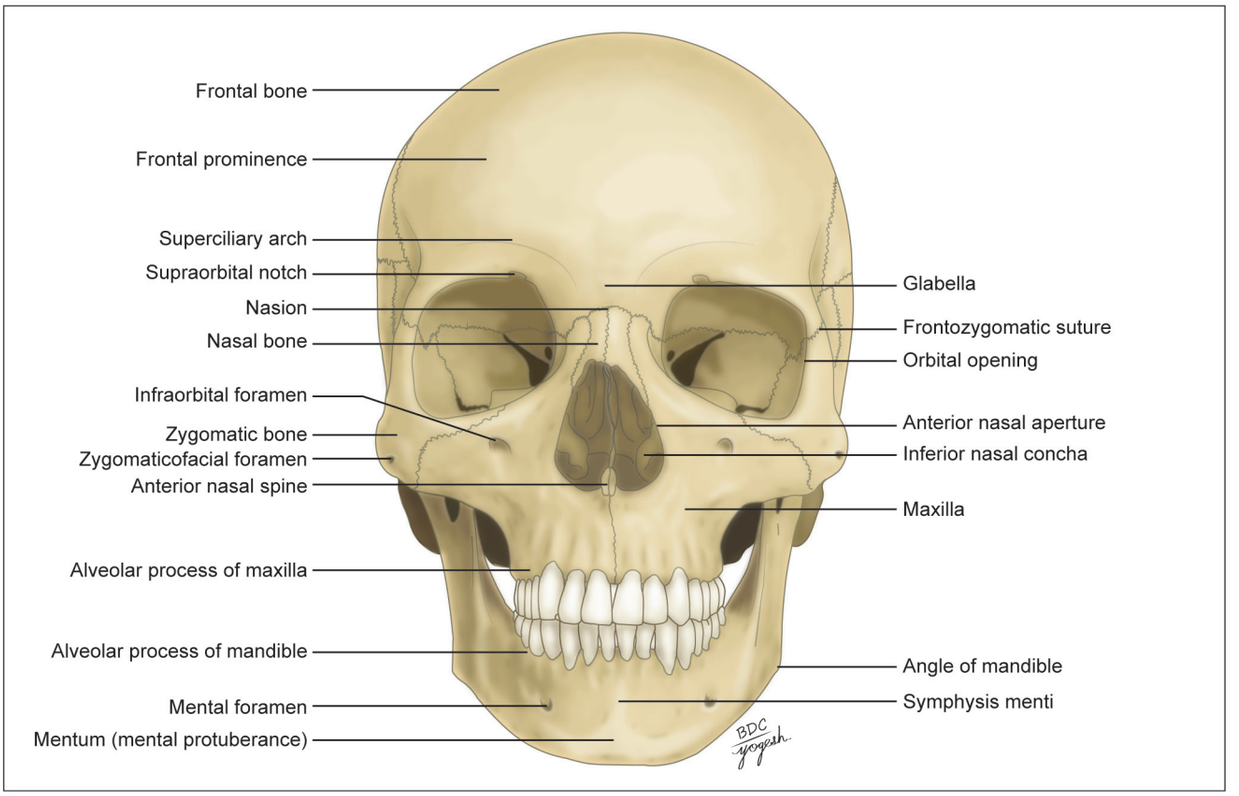


Plate 1.2: Norma frontalis



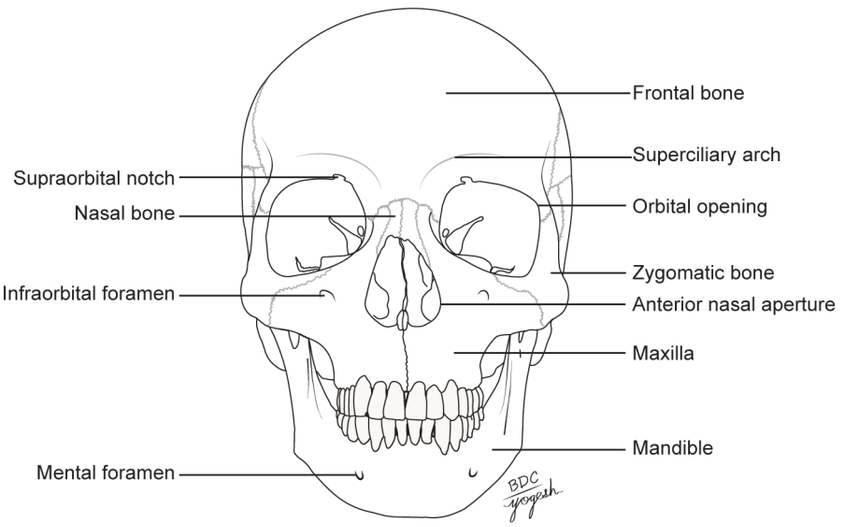


Fig. 1.4: Norma frontalis: Walls of orbit, nasal aperture and lower part of face

2. ***Glabella*** is a median elevation connecting the two superciliary arches. Below the glabella, the skull recedes to frontonasal suture at root of the nose.
3. ***Nasion*** is a median point at the root of the nose where the internasal suture meets with the frontonasal suture.
4. ***Frontal tuber*** or *eminence* is a low rounded elevation above the superciliary arch – one on each side. It is more prominent in females and in children.

Orbital Openings

Each orbital (Latin *circle*) opening is quadrangular in shape and is bounded by the following four margins.

1. ***Supraorbital margin*** is formed by the frontal bone. At the junction of its lateral 2/3rd and its medial 1/3rd, it presents the supraorbital notch or foramen.
2. ***Infraorbital margin*** is formed by the zygomatic bone laterally, and maxilla medially.

3. ***Medial orbital margin*** is ill-defined. It is formed by the frontal bone above, and by the lacrimal crest of the frontal process of the maxilla below.
4. ***Lateral orbital margin*** is formed mostly by the frontal process of zygomatic bone but is completed above by the zygomatic process of frontal bone. *Frontozygomatic suture* lies at their union.

Anterior Nasal Aperture

The anterior bony aperture of the nose is pear-shaped, being wide below and narrow above.

Boundaries

Above: By the lower border of the nasal bones.

Below: By the nasal notch of the body of maxilla on each side.

Features

1. *Articulations of the nasal bone:*
   Anteriorly — with the opposite bone at the internasal suture.
   Posteriorly — with the frontal process of the maxilla.
   Superiorly — with the frontal bone at the frontonasal suture.
   Inferiorly — the upper nasal cartilage is attached to it.
2. ***Anterior nasal spine*** is a sharp projection in the median plane in the lower boundary of the piriform aperture.
3. ***Rhinion*** is the lowermost point of the internasal suture.

Lower Part of the Face

The lower part of the face is formed by the following bones:

1. Maxilla forms upper jaw.
2. Zygomatic bone forms malar prominences.
3. Mandible forms lower jaw.

Maxilla

Maxilla contributes a large share in the formation of the facial skeleton. The anterior surface of the body of the maxilla presents:

1. N*asal notch* medially
2. *Anterior nasal spine*
3. ***Infraorbital foramen***, 1 cm below the infraorbital margin
4. ***Incisive fossa*** above the incisor teeth
5. ***Canine fossa*** lateral to the canine eminence.

In addition, three out of four ***processes of the maxilla*** are also seen in this norma.

1. ***Frontal process*** *of the maxilla* is directed upwards. It articulates anteriorly with the nasal bone, posteriorly with the lacrimal bone and superiorly with the frontal bone (Fig. 1.7).
2. ***Zygomatic process*** *of the maxilla* is short but stout and articulates with the zygomatic bone.
3. ***Alveolar process*** *of the maxilla* bears sockets for the upper teeth.

Zygomatic Bone (Malar Bone)

1. Zygomatic bone forms the prominence of the cheek.
2. ***Zygomaticofacial foramen*** is seen on its surface.

Mandible (Lower Jaw Bone)

Mandible (Latin *to chew*) forms the lower jaw. Its following features are seen in norma frontalis:

1. *Upper border* or *alveolar arch* lodges the lower teeth.
2. *Lower border* or *base* is rounded.
3. Middle point of the base is called the *mental point or* ***gnathion***.
4. The point on the angle of mandible is called ***gonion***.
5. A*nterior surface* of the body of the mandible presents:
   a. *Symphysis menti*, the *mental protuberance* and the *mental tubercles*, anteriorly.
   b. ***Mental foramen*** below the interval between the two premolar teeth, transmitting the *mental nerve and vessels*.
   c. ***Oblique line*** runs upwards and backwards from the mental tubercle to the anterior border of the *ramus* (Latin branch) of the mandible.

Sutures of the Norma Frontalis

1. Internasal
2. Frontonasal
3. Nasomaxillary
4. Lacrimomaxillary
5. Frontomaxillary
6. Intermaxillary
7. Zygomaticomaxillary
8. Zygomaticofrontal.

Attachments

1. The medial part of the superciliary arch gives origin to the corrugator supercilii muscle (Fig. 1.5).
2. Procerus muscle arises from the nasal bone near the median plane.
3. The orbital part of the orbicularis oculi arises from the frontal process of the maxilla and from the nasal part of the frontal bone.
4. Medial palpebral ligament is attached to the frontal process of the maxilla between the frontal and maxillary origins of the orbicularis oculi.
5. Levator labii superioris alaeque nasi arises from the frontal process of the maxilla in front of the orbicularis oculi.
6. Levator labii superioris arises from the maxilla between the infraorbital margin and the infraorbital foramen.
7. Levator anguli oris arises from the canine fossa.
8. Nasalis and the depressor septi arise from the surface of the maxilla bordering the nasal notch.
9. Incisivus labii superioris muscle arises from an area just below the depressor septi. It forms part of orbicularis oris.
10. Zygomaticus major and minor arise from the surface of the zygomatic bone. The zygomaticus minor

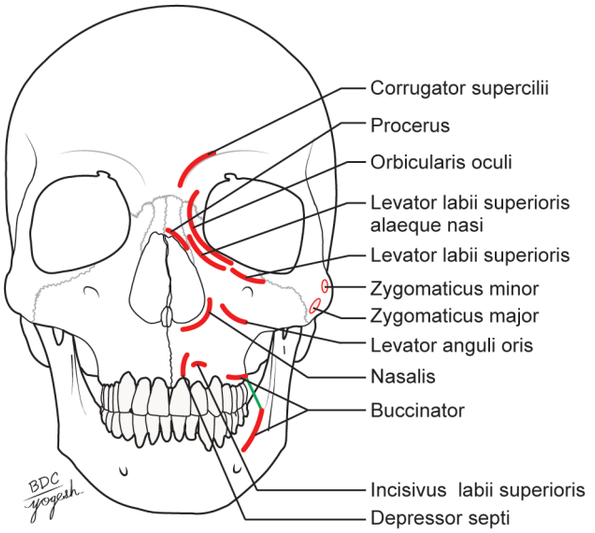


Fig. 1.5: Attachments of muscles to the norma frontalis

muscle arises below the zygomaticofacial foramen. The zygomaticus major arises lateral to the minor muscle.

11. Buccinator arises from maxilla and mandible opposite molar teeth and from *pterygomandibular raphe*. It also forms part of orbicularis oris.

Structures Passing Through Foramina

1. *Supraorbital notch or foramen* transmits the *supraorbital nerves and vessels*.
2. *External nasal nerve* emerges between the nasal bone and upper nasal cartilage.
3. *Infraorbital foramen* transmits the *infraorbital nerve* and *vessels*.
4. *Zygomaticofacial foramen* transmits the nerve of the same name, a branch of *maxillary nerve*.
5. *Mental foramen* on the mandible transmits the mental nerve and vessels.

CLINICAL ANATOMY

The *nasal bone is one of the most commonly fractured bones of the face*. Mandible and parietal eminence are the next bones to be fractured.

NORMA LATERALIS

Bones (Plate 1.3, Figs 1.6a and b, Flowchart 1.4)

1. Frontal
2. Parietal
3. Occipital
4. Temporal
5. Sphenoid
6. Zygomatic
7. Mandible
8. Maxilla
9. Nasal

Features

Temporal Lines

The *temporal lines* have been studied in the norma verticalis. The inferior temporal line, in its posterior part, turns downwards and forwards and becomes continuous with the ***supramastoid crest*** on the squamous temporal bone near its junction with the mastoid temporal. This crest is continuous anteriorly with the posterior root of the zygomatic arch (Flowchart 1.4, Plate 1.3, Figs 1.6a to c).

Zygomatic Arch or Zygoma

The *zygomatic arch* is a horizontal bar on the side of the head, in front of the ear, a little above the tragus. It is formed by the temporal process of the zygomatic bone in anterior 1/3rd and the zygomatic process of the temporal bone in posterior 2/3rd. The ***zygomaticotemporal suture*** crosses the arch obliquely downwards and backwards.

Features

1. The arch comprises 2 surfaces (medial and lateral) and 2 borders (upper and lower).
2. Medially, the arch is separated from the side of the skull by a gap, which is deeper in front than behind. The *lateral surface* of the arch is subcutaneous.
3. *Upper border* is continuous with temporal line in front and with supramastoid crest behind. The anterior end of the upper border is called the ***jugal point***.
4. The *posterior end* of the zygomatic arch is attached to the squamous temporal bone by *anterior* and *posterior roots*.
5. The ***tubercle of the root of the zygoma*** lies on its lower border at the junction of the anterior and posterior roots.

Flowchart 1.4: Features of norma lateralis

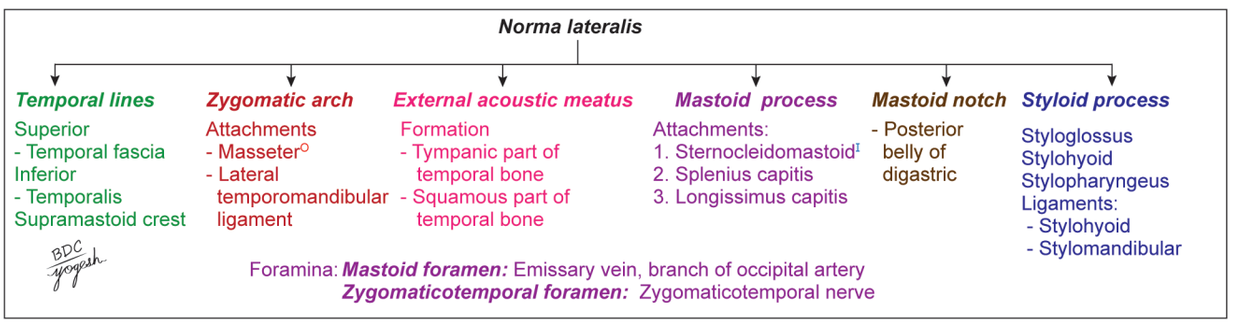
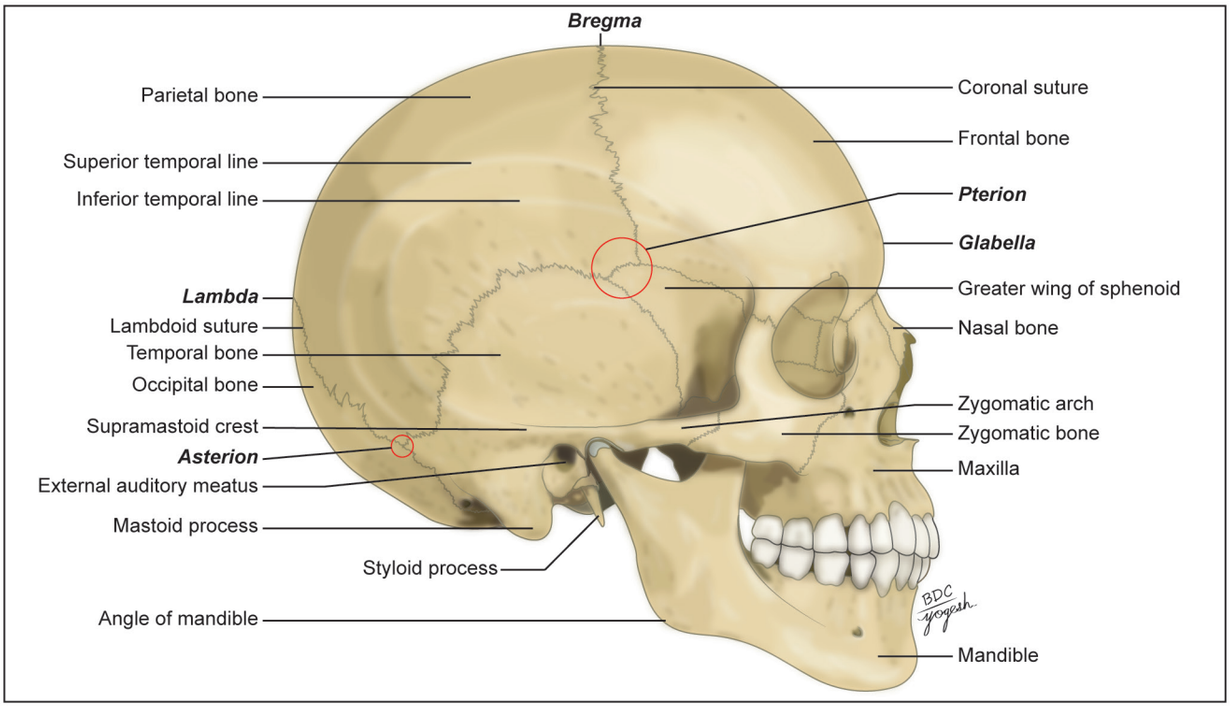
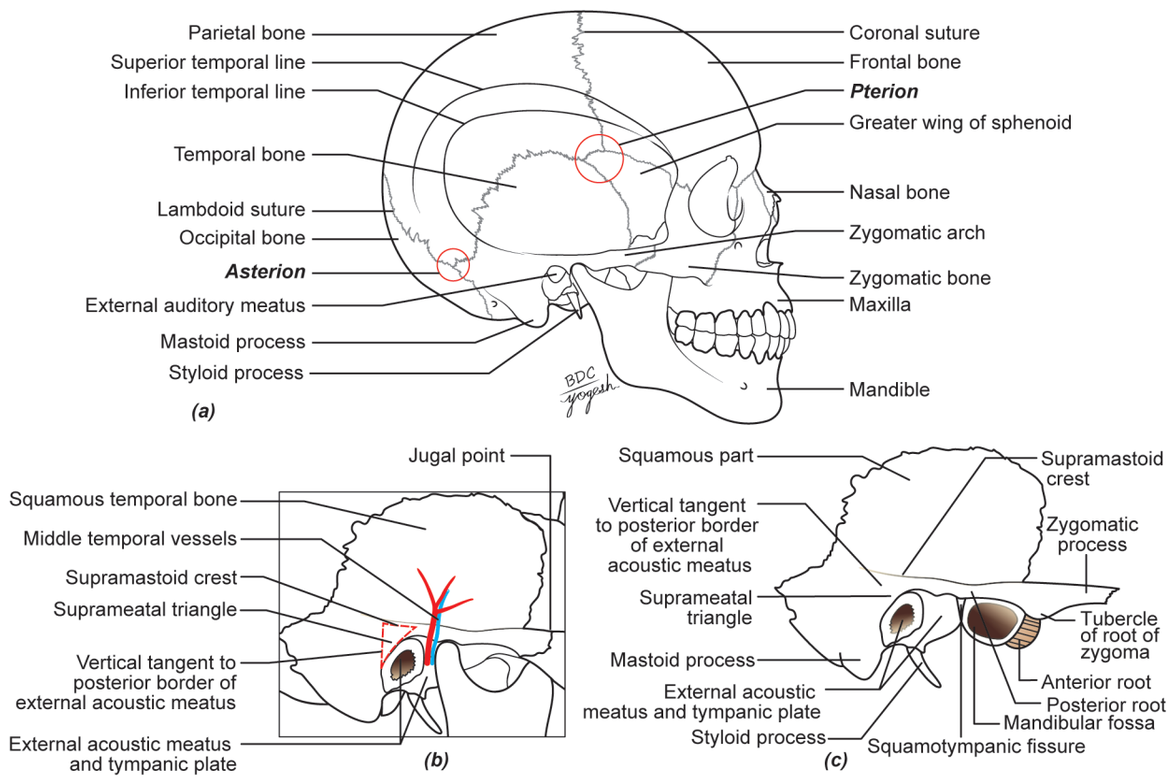


Plate 1.3: Norma lateralis





Figs 1.6a to c: (a) Norma lateralis, (b) bones forming norma lateralis, and (c) tympanic plate forming margins of external acoustic meatus

6. The ***anterior root*** (articular tubercle) passes medially in front of the *mandibular fossa*. The ***posterior root*** passes backwards along the lateral margin of the mandibular or articular fossa, then above the external acoustic meatus to become continuous with the supramastoid crest.

7. Two projections are visible in relation to these roots.
   a. One is ***tubercle of root of zygoma*** at its lower border.
   b. Another tubercle is visible just behind the mandibular or articular fossa and is known as ***postglenoid tubercle***.

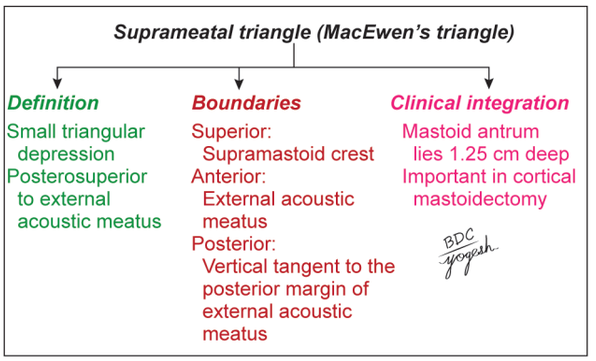
External Acoustic Meatus

1. The *external acoustic meatus* opens just below the posterior part of the posterior root of zygoma. Its anterior and inferior margins and the lower part of the posterior margin are formed by the tympanic plate, and the posterosuperior margin is formed by the squamous temporal bone. The margins are roughened for the attachment of auricular cartilage.
2. The ***suprameatal triangle*** *(triangle of Mc-Ewen)* is a small depression posterosuperior to the meatus. (Flowchart 1.5)
   Boundaries
   Superior: Supramastoid crest
   Anterior: Posterosuperior margin of external acoustic meatus
   Posterior: Vertical tangent to the posterior margin of the meatus.
   Clinical aspects: The triangle forms the lateral wall of the tympanic or mastoid antrum (Fig. 1.9c). The mastoid antrum lies 1.25 cm deep to the suprameatal triangle. This triangle is an important landmark in cortical mastoidectomy.
3. The ***suprameatal spine*** *(of Henle)* may be present on the anteroinferior margin of the triangle. It serves as a surgical landmark while performing middle ear surgeries.

Mastoid Part of the Temporal Bone

1. The *mastoid part of the temporal bone* lies just behind the external acoustic meatus.
2. The mastoid temporal bone articulates posterosuperiorly with the posteroinferior part of the parietal bone at the horizontal *parietomastoid suture*, and posteriorly with the squamous occipital bone at the *occipitomastoid suture*. These two sutures meet at the lateral end of the lambdoid suture. The ***asterion*** is the point where the parietomastoid, occipitomastoid and lambdoid sutures meet. In infants, the asterion is the site of the ***posterolateral*** **or** ***mastoid fontanelle***, which closes by 12 months (Fig. 1.3).

Flowchart 1.5: Suprameatal triangle



3. The ***mastoid process*** is a breast-like projection from the lower part of the mastoid temporal bone, posteroinferior to the external acoustic meatus. It appears during the 2nd year of life. The *tympanomastoid fissure* is placed on the anterior aspect of the base of the mastoid process. The *mastoid foramen* lies at or near the occipitomastoid suture (Fig. 1.5).

Styloid Process

The *styloid* (Latin *pen*) *process* is a needle-like thin, long projection from the temporal bone seen in norma basalis situated anteromedial to the mastoid process. It is directed downwards, forwards and slightly medially. Its base is partly ensheathed by the tympanic plate. The apex or tip is usually hidden from view by the posterior border of the ramus of the mandible.

Temporal Fossa

It is a shallow depression on the side of the skull.

Boundaries

1. *Above:* Superior temporal line.
2. *Below:* Upper border of the zygomatic arch laterally, and by the infratemporal crest of the greater wing of the sphenoid bone medially. Through the gap deep to the zygomatic arch, temporal fossa communicates with the infratemporal fossa.
3. *Anterior wall:* Formed by the zygomatic bone and by parts of the frontal and sphenoid bones. This wall separates the fossa from the orbit.
4. *Floor:* The anterior part of the floor is crossed by an H-shaped suture where four bones—frontal, parietal, greater wing of sphenoid and temporal adjoin each other. This area is termed the ***pterion***.

Note:

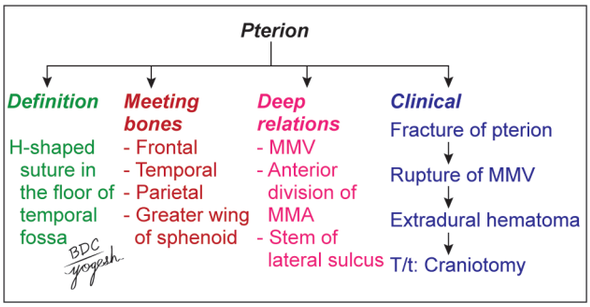
The ***pterion*** lies 4 cm above the midpoint of the zygomatic arch and 2.5 cm behind the frontozygomatic suture. Deep to the pterion lie, *middle meningeal vein*, *anterior division of the middle meningeal artery* and *stem of the lateral sulcus of brain (Sylvian point)* (Flowchart 1.6).

On the temporal surface of the zygomatic bone forming the anterior wall of the fossa, there is the *zygomaticotemporal foramen.*

Attachments (Fig. 1.7)

1. Temporal fascia is attached to the superior temporal line and to the area between the two temporal lines. Inferiorly, it is attached to the outer and inner lips of the upper border of the zygomatic arch.
2. Temporalis muscle arises from the whole of the temporal fossa.
3. The medial surface and lower border of the zygomatic arch give origin to the masseter.
4. Lateral ligament of the temporomandibular joint is attached to the tubercle of the root of the zygoma.
5. The sternocleidomastoid, splenius capitis and longissimus capitis are inserted from before backwards on the posterior part of the lateral surface of the mastoid process. Posterior belly of digastric arises from mastoid notch. The groove obliquely placed behind mastoid notch is due to occipital artery.

Flowchart 1.6: Pterion



(MAA: Middle meningeal artery, MMV: Middle meningeal vein)

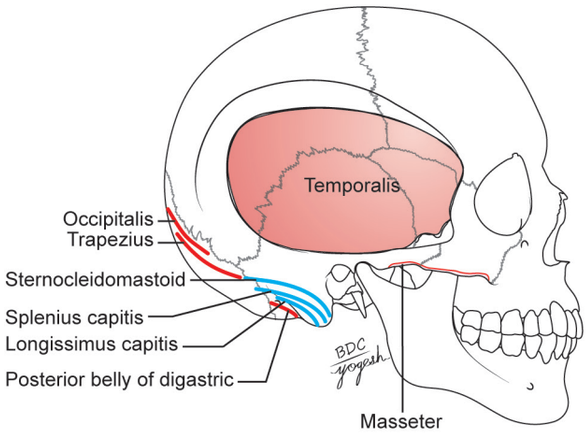


Fig. 1.7: Attachments of norma lateralis

6. The *gap* between the zygomatic arch and the side of the skull transmits:
   a. Tendon of the temporalis muscle
   b. Deep temporal vessels
   c. Deep temporal nerves
   d. Zygomaticotemporal vessels and nerve

Note: For infratemporal fossa, *see* Chapter 6. For pterygopalatine fossa, *see* Chapter 15.

Structures Passing Through Foramina

1. *Tympanomastoid fissure* on the anterior aspect of the base of the mastoid process transmits the *auricular branch* of *vagus nerve.*
2. Mastoid foramen transmits:
   a. *Emissary vein* connecting the *sigmoid sinus* with the *posterior auricular vein* (Table 1.1).
   b. Meningeal branch of the occipital artery.
3. *Zygomaticotemporal foramen* transmits the nerve of the same name and a minute artery.

CLINICAL ANATOMY

***Pterion**, the site of anterolateral fontanelle,* is the thin part of skull. In roadside accidents, the anterior division of middle meningeal artery at pterion (Fig. 1.8) may be ruptured, leading to clot formation between the skull bone and dura mater or extradural haemorrhage (Fig. 1.9). The clot compresses the motor area of brain, leading to paralysis of the opposite side. The clot must be sucked out at the earliest by trephining. The head must be protected by a helmet during driving a two-wheeler.

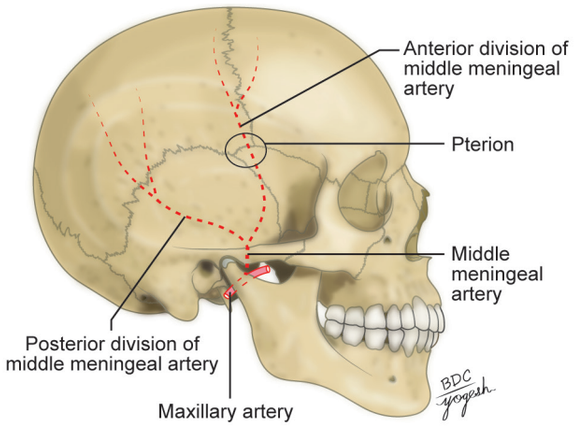


Fig. 1.8: Position of anterior division of middle meningeal artery against the pterion

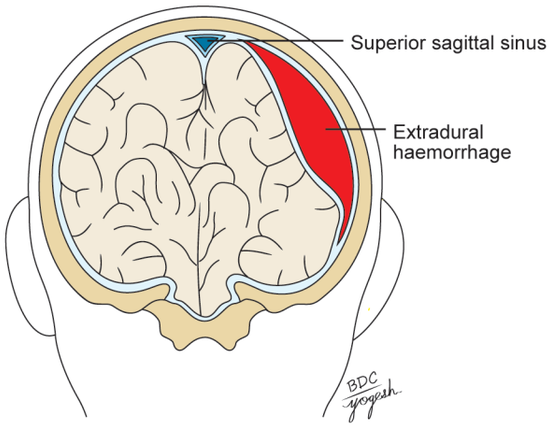


Fig. 1.9: Extradural haemorrhage

NORMA BASALIS

The inferior view of the skull is norma basalis. For the descriptive purposes, the norma basalis is divided into anterior, middle and posterior parts by two imaginary transverse lines:

1. ***Anterior transverse line:*** It passes along the posterior margin of the hard palate.
2. ***Posterior transverse line:*** It passes along the anterior margin of the foramen magnum (Plate 1.4, Fig. 1.10).

Anterior Part of Norma Basalis

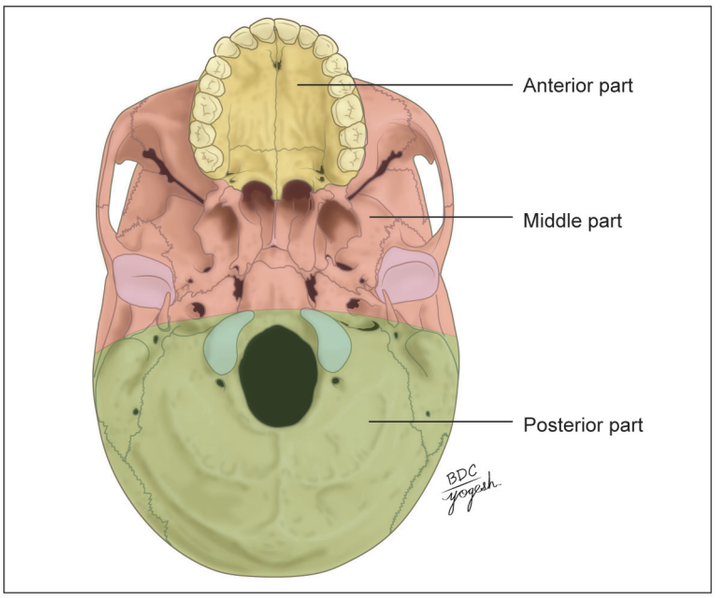
The anterior part of norma basalis consists of two parts (Plate 1.5, Flowchart 1.7):

1. Alveolar processes of maxillae or alveolar arch
2. Hard palate

Alveolar Arch

Alveolar processes of maxillae form U-shaped alveolar arch that bears sockets for the roots of the upper teeth.

Plate 1.4: Parts of norma basalis



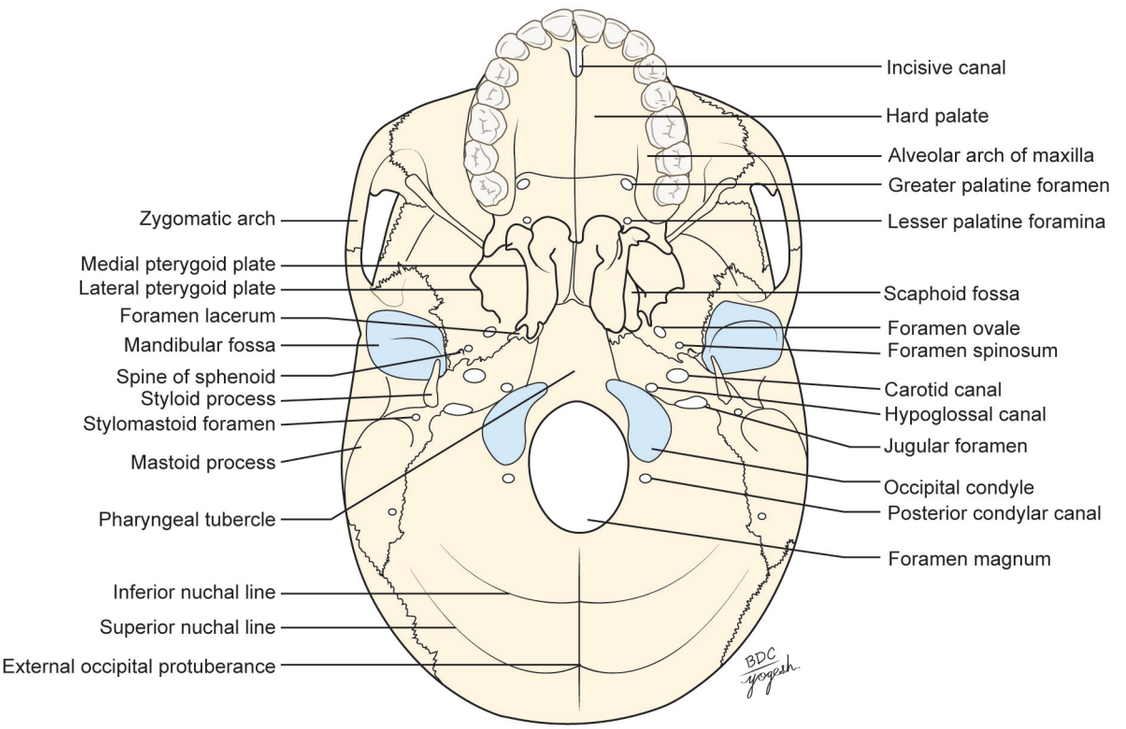
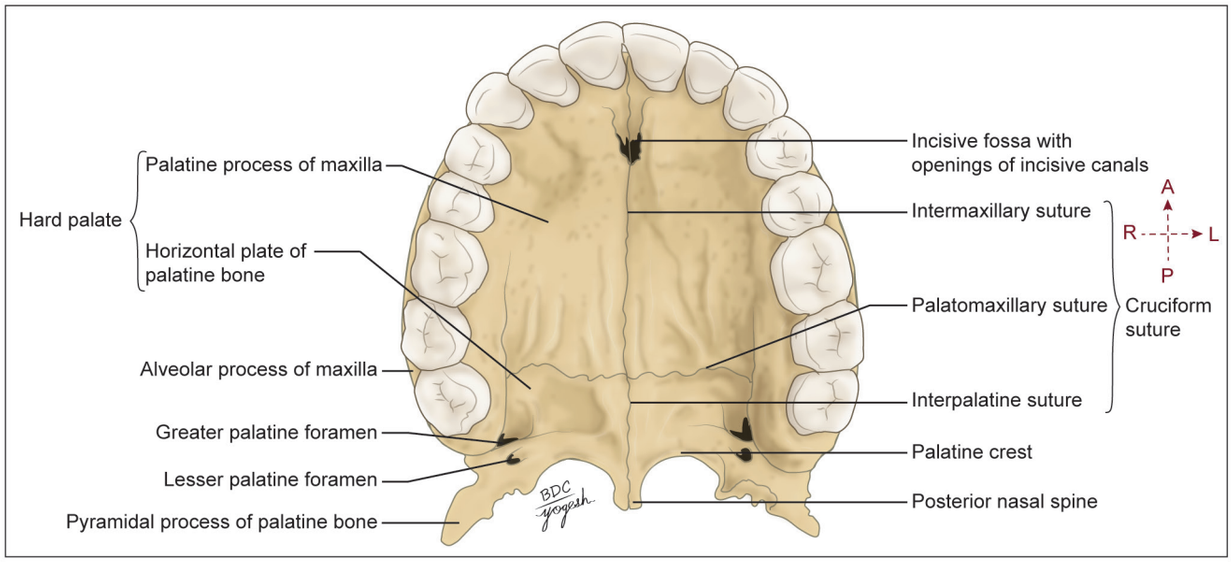


Fig. 1.10: Norma basalis

Hard Palate

1. *Formation:*
   a. Anterior 2/3rd, by the palatine processes of the maxillae.
   b. Posterior 1/3rd, by the horizontal plates of the palatine bones.
2. *Sutures:* The palate is crossed by a cruciform suture made up of intermaxillary, interpalatine and palatomaxillary sutures.
3. It is arched in all directions. It shows pits for the palatine glands.
4. The *posterior border* of the hard palate is free and presents the ***posterior nasal spine*** in the median plane.
5. The ***palatine crest*** is a curved ridge near the posterior border. It begins behind the greater palatine foramen and runs medially.
6. ***Incisive foramen*** is a deep fossa situated anteriorly in the median plane. Two ***incisive canals***, right and left,

Plate 1.5: Anterior part of norma basalis



Flowchart 1.7: Features of anterior part of norma basalis

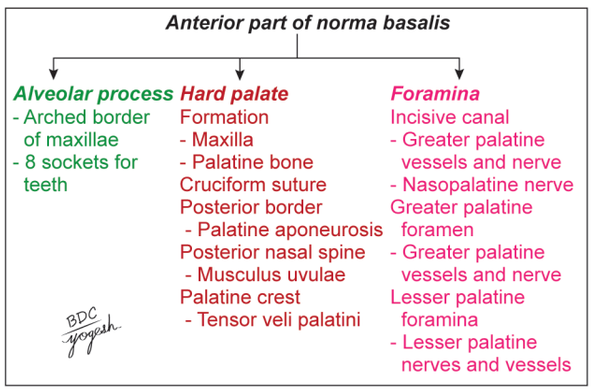
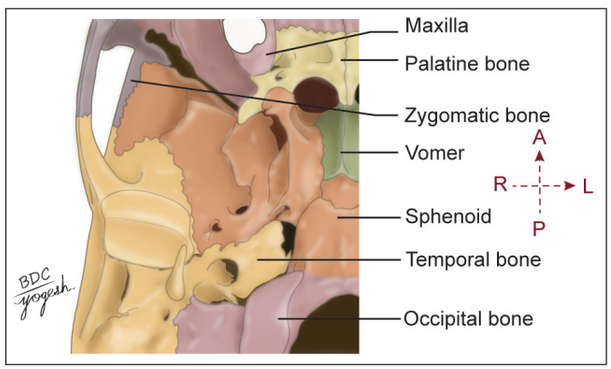


Plate 1.6: Bones of middle part of norma basalis



pierce the walls of the incisive foramen, usually one on each side, but occasionally in the median plane, the left being anterior and the right, posterior.

7. ***Greater palatine foramen***, one on each side, is situated just behind the lateral part of the palatomaxillary suture. A groove leads from the foramen towards the incisive fossa.
8. ***Lesser palatine foramina***, two or three in number on each side, lie behind the greater palatine foramen and perforate the pyramidal process of the palatine bone.

Middle Part of Norma Basalis

The middle part extends from the posterior border of the hard palate to the arbitrary transverse line passing through the anterior margin of the foramen magnum. Middle part of the norma basalis is studied as median and lateral areas (Plates 1.6 and 1.7).

Median Area

1. The median area shows (Flowchart 1.8):
   a. Posterior border of the *vomer*.
   b. A *broad bar of bone* formed by fusion of the posterior part of the body of sphenoid and the basilar part of occipital bone.
2. The ***vomer*** separates the two posterior nasal apertures. Its inferior border articulates with the bony palate. The superior border splits into two ***alae*** and articulates with the ***rostrum*** of the *sphenoid bone* (Fig. 1.11).

Flowchart 1.8: Features of median area of middle part of norma basalis

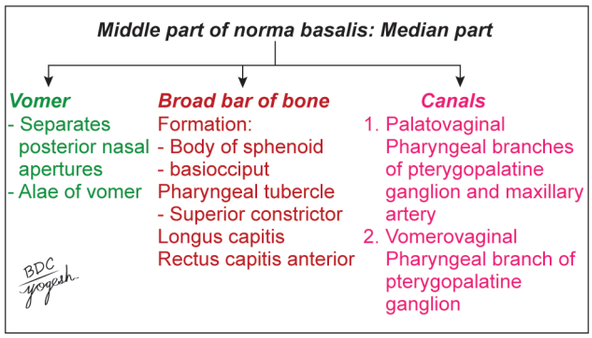
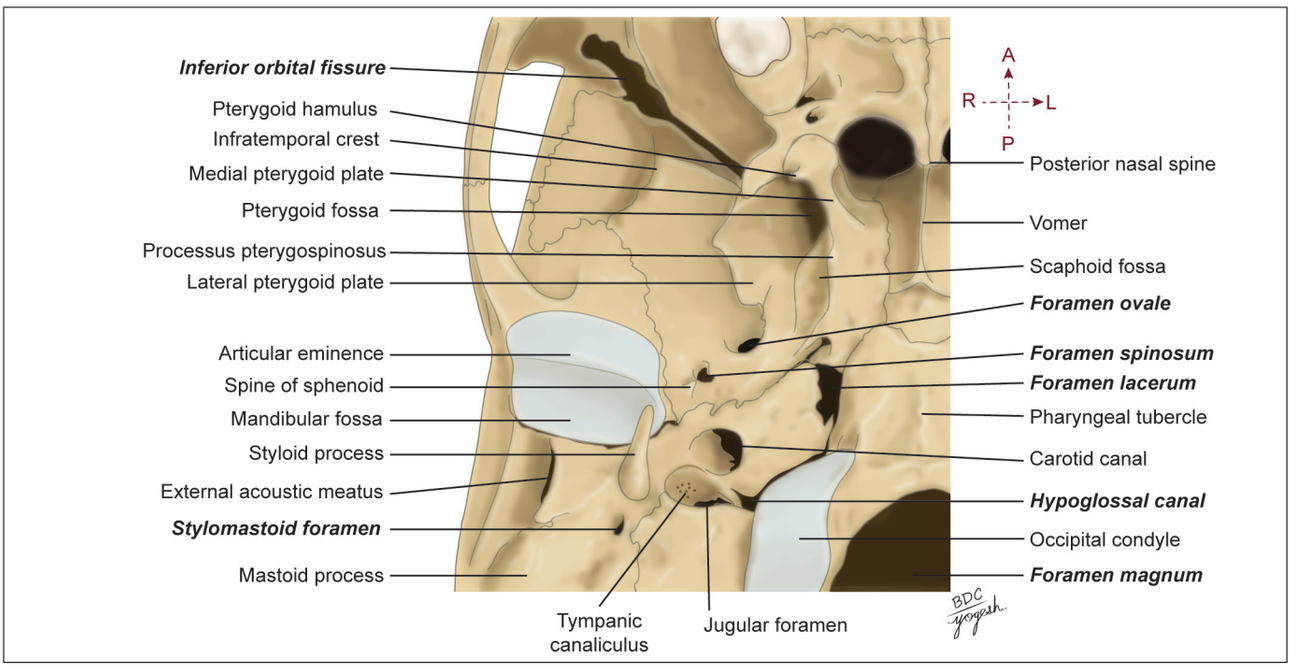


Plate 1.7: Features of middle part of norma basalis



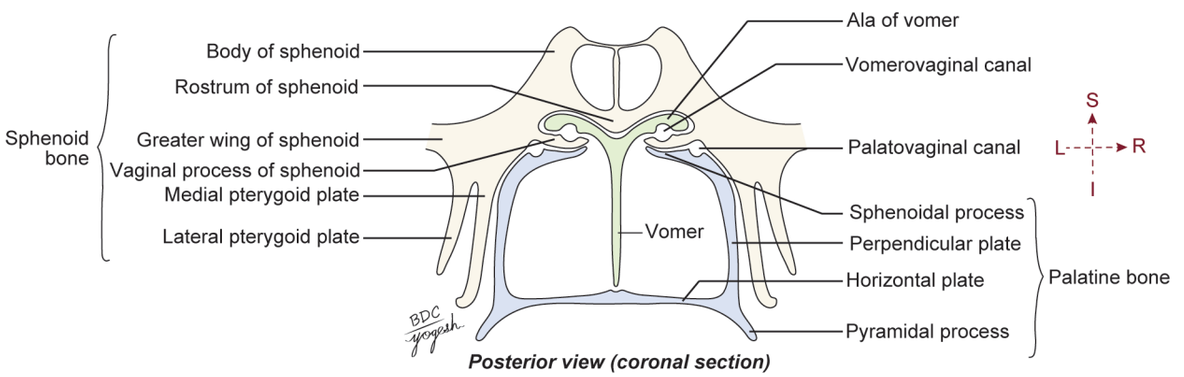


Fig. 1.11: Vomerovaginal and palatovaginal canals

3. The broad bar of the bone is marked in the median plane by the ***pharyngeal tubercle***, a little in front of the foramen magnum (Plate 1.8).

Note:

Palatinovaginal canal: The inferior surface of the vaginal process of the medial pterygoid plate is marked by an anteroposterior groove, which is converted into the palatinovaginal canal by the upper surface of the sphenoidal process of the palatine bone. The canal opens anteriorly into the posterior wall of the pterygopalatine fossa (Fig. 1.11).

Vomerovaginal canal: The lateral border of each ala of the vomer comes into relationship with the vaginal process of the medial pterygoid plate, and may overlap it from above to enclose the vomerovaginal canal (Fig. 1.11).

Lateral Area

The lateral area shows (Plate 1.8, Flowchart 1.9)

a. Two parts of the sphenoid bone — pterygoid process and greater wing.
b. Three parts of the temporal bone — petrous temporal, tympanic plate and squamous temporal.

1. **Pterygoid process** projects downwards from the junction of greater wing and the body of sphenoid behind the third molar tooth.

   Inferiorly, it divides into the *medial and lateral pterygoid plates*, which are fused together anteriorly, but are separated posteriorly by the V-shaped *pterygoid fossa.*

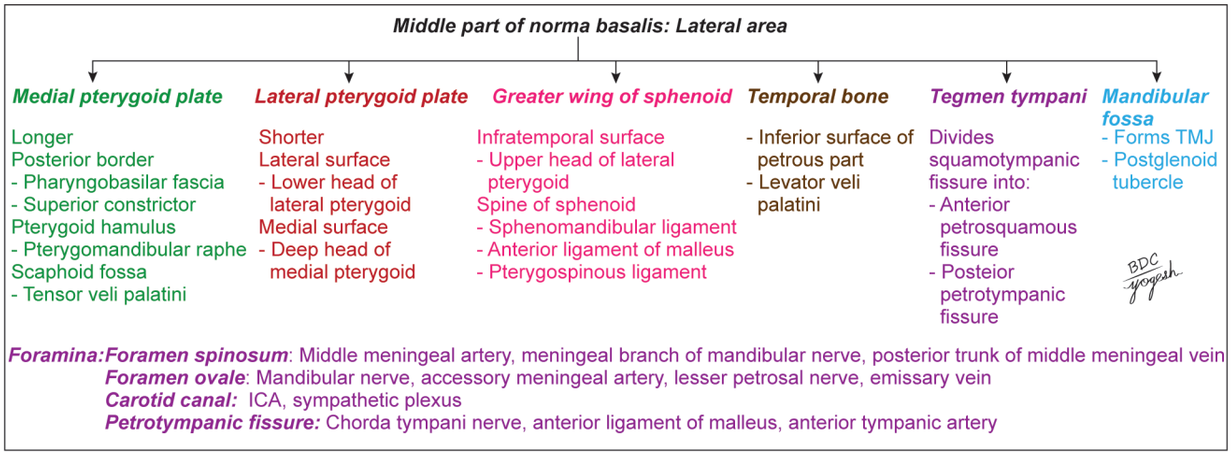
   The fused anterior borders of the two plates articulate medially with the perpendicular plate of the palatine bone, and are separated laterally from the posterior surface of the body of the maxilla by the *pterygomaxillary fissure*.

2. **Medial pterygoid plate**

   It is directed backwards. It has medial and lateral surfaces and a free posterior border.

   The upper end of posterior border divides to enclose a triangular depression called the ***scaphoid fossa***.

Flowchart 1.9: Features of lateral area of middle part of norma basalis



The lower end of the posterior border is prolonged downwards and laterally to form the ***pterygoid hamulus***.

3. **Lateral pterygoid plate**

   It is directed backwards and laterally. It has medial and lateral surfaces and a free posterior border.

   The posterior border sometimes has a projection at its middle called the *pterygospinous process*, which projects towards the spine of the sphenoid.

4. **Infratemporal surface of the greater wing of the sphenoid**

   It is pentagonal.

   It shows the following 4 foramina:

   a. ***Foramen ovale*** is large and oval. It is situated posterolateral to the upper end of the posterior border of lateral pterygoid plate.

   b. ***Foramen spinosum*** is small and circular in shape. It is situated posterolateral to the foramen ovale, and is limited posterolaterally by the spine of sphenoid.

   c. Sometimes, there is the ***emissary sphenoidal foramen*** *or foramen of Vesalius*. It is situated between the foramen ovale and the scaphoid fossa. Internally, it opens between the foramen ovale and the foramen rotundum.

   d. At times, there is a ***canaliculus innominatus*** situated between the foramen ovale and the foramen spinosum.

   There is a small, sharp, downward projection between the posterolateral and posteromedial margins called the ***spine of the sphenoid***.

   Sulcus tubae is the groove between the posteromedial margin of the greater wing of the sphenoid and the petrous temporal bone. It lodges the *cartilaginous part of the auditory tube*. Posteriorly, the groove leads to the bony part of the auditory tube, which lies within the petrous temporal bone.

5. **Inferior surface of the *petrous* part of the temporal bone** is triangular in shape with its apex directed forwards and medially (Greek petrous = *rock*). It lies between the greater wing of the sphenoid and the basiocciput.

   Its *apex* is perforated by the upper end of the carotid canal, and is separated from the sphenoid by the foramen lacerum. The *inferior surface* is perforated by the lower end of the *carotid canal* posteriorly.

   Carotid canal runs forwards and medially within the petrous temporal bone.

   Tegmen tympani: It is a part of the petrous temporal bone that is present in the middle cranial fossa. It has a down turned edge, which is seen in the *squamotympanic fissure* and divides it into the posterior *petrotympanic* and anterior *petrosquamous* fissures.

6. ***Foramen lacerum*** is a short, wide canal, 1 cm long.

   Its lower end is bounded posterolaterally by the apex of the petrous temporal, medially by the basiocciput and the body of the sphenoid and anteriorly by the root of the pterygoid process and the greater wing of the sphenoid bone (Fig. 1.13).

7. ***Tympanic part of the temporal bone****, also called the* ***tympanic plate****,* is a triangular curved plate, which lies in the angle between the petrous and squamous parts. Its apex is directed medially and lies close to the spine of the sphenoid.

   The *base or lateral border* is curved, free and roughened.

   Its *anterior surface* forms the posterior wall of the mandibular fossa. The *posterior surface* is concave and forms the anterior wall, floor and lower part of the posterior wall of the bony external acoustic meatus.

   Its *upper border* bounds the petrotympanic fissure.

   The *lower border* is sharp and free.

   Medially, the tympanic plate passes along the anterolateral margin of the lower end of the carotid canal. Laterally, it forms the anterolateral part of the *sheath of the styloid process*. Internally, the tympanic plate is fused to the petrous temporal bone.

8. ***Squamous part of the temporal bone*** forms:

   a. The anterior part of the mandibular/articular fossa, which articulates with the head of the mandible to form the temporomandibular joint.

b. The tubercle of root of zygoma, which is continuous with the anterior root of the zygoma.
c. A small posterolateral part of the roof of the infratemporal fossa.

Posterior Part of Norma Basalis

The posterior part of norma basalis is studied as median and lateral areas (Plate 1.8, Flowchart 1.10).

Median Area

The median area shows the following four features from before backwards:

1. Foramen magnum
2. External occipital crest
3. External occipital protuberance
4. Nuchal lines.

1. ***Foramen magnum*** (Latin *great*) is the largest foramen of the skull. It opens upwards into the posterior cranial fossa, and downwards into the vertebral canal. It is oval in shape, being wider behind than in front where it is overlapped on each side by the occipital condyles.
2. ***External occipital crest*** begins at the posterior margin of the foramen magnum and ends posteriorly and above at the external occipital protuberance.
3. ***External occipital protuberance*** is a projection located at the posterior end of the crest. It is easily felt in the living, in the midline, at the point where the back of the neck becomes continuous with the scalp.
4. ***Nuchal lines*****:** These are superior, inferior and the highest. The *superior nuchal lines* begin at the external occipital protuberance and the *inferior nuchal lines* at the middle of the crest. Both of them curve laterally and backwards and then laterally and forwards.
   Highest nuchal line is faded and seen above superior nuchal line (occasionally).

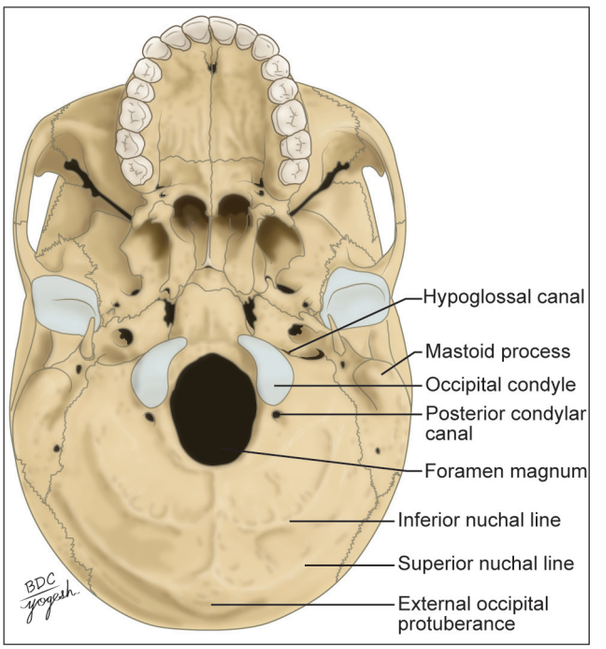
Lateral Area

The *lateral area* shows:

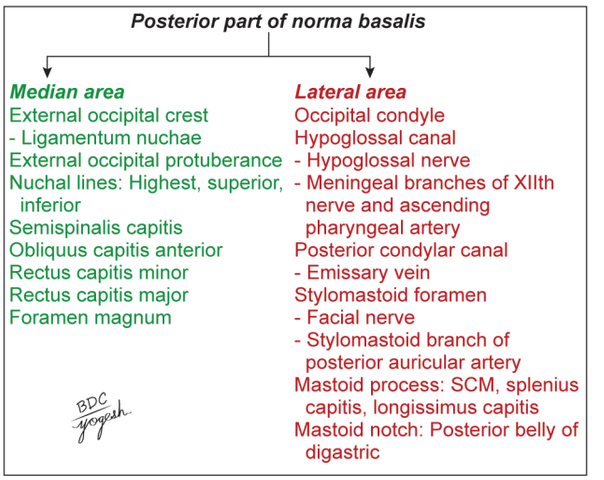
- Condylar part of the occipital bone
- Squamous part of the occipital bone
- Jugular foramen between the occipital and petrous temporal bones
- Styloid process of the temporal bone
- Mastoid part of the temporal bone.

1. ***Condylar or lateral part of the occipital bone*** presents the following features:
   - ***Occipital condyles*** are oval in shape and are situated on each side of the anterior part of the foramen magnum. Their long axis is directed forwards and medially. They articulate with the superior articular facets of the atlas vertebra to form the *atlanto-occipital joints*.
   - ***Hypoglossal canal*** or *anterior condylar canal* pierces the bone anterosuperior to the occipital condyle, and is directed laterally and slightly forwards.

Plate 1.8: Norma basalis – Posterior part labelled



Flowchart 1.10: Features of posterior part of norma basalis



- ***Condylar canal*** or *posterior condylar canal* is occasionally present in the floor of a condylar fossa present behind the occipital condyle. Superiorly, it opens into the sigmoid sulcus.
- ***Jugular process of the occipital bone*** lies lateral to the occipital condyle and forms the posterior boundary of jugular foramen.

2. ***Squamous part of occipital bone*** is marked by the superior and inferior nuchal lines mentioned above (Fig. 1.3).
3. ***Jugular foramen*** is large and elongated, with its long axis directed forwards and medially. It is placed at the posterior end of the petro-occipital suture.
4. ***Styloid process*** is described in Chapter 8, page 161. ***Stylomastoid foramen*** is situated between the anterior end of mastoid process and root of styloid process.

5. ***Mastoid process***, a component of mastoid part is a large conical projection located posterolateral to the stylomastoid foramen. It is directed downwards and forwards. It forms the lateral wall of the *mastoid notch*.

Note:

At the posterior end of the foramen, its anterior wall (petrous temporal) is hollowed out to form ***jugular fossa***, which lodges the superior bulb of the internal jugular vein. The fossa is larger on the right side than on the left.

The lateral wall of the jugular fossa is pierced by a minute canal, the ***mastoid canaliculus*** *(Arnold's canal)*. It transmits the auricular branch of vagus nerve or Arnold's nerve.

Near the medial end of the jugular foramen, there is the ***jugular notch***. At the apex of the notch, there is an opening that leads into the ***cochlear canaliculus***.

Tympanic canaliculus opens on or near the thin edge of bone between the jugular fossa and the lower end of the carotid canal.

Attachments (Fig. 1.12)

1. Palate
2. Posterior border of the hard palate provides attachment to the palatine aponeurosis. The posterior nasal spine gives origin to the musculus uvulae.

   Palatine crest provides attachment to a part of the tendon of tensor veli palatini muscle.
3. Inferior surface of the basiocciput:
   a. *Pharyngeal tubercle* gives attachment to the raphe, which provides insertion to the upper fibres of the superior constrictor muscle of the pharynx.
   b. The area in front of the tubercle forms the roof of the *nasopharynx* and supports the *pharyngeal tonsil*.
   c. Longus capitis is inserted lateral to the pharyngeal tubercle.
   d. Rectus capitis anterior is inserted a little posterior and medial to the hypoglossal canal.
4. Medial pterygoid plate:
   a. Lower part of the posterior border and the pterygoid hamulus give origin to the superior constrictor of the pharynx.
   b. Upper part of the posterior border is notched by the *auditory* tube.
   c. Pterygomandibular raphe is attached to the tip of the *pterygoid hamulus* at one end and to the mandible behind 3rd molar tooth at the other end.
5. Lateral pterygoid plate:
   a. Its lateral surface gives origin to the larger lower head of lateral pterygoid muscle.
   b. Its medial surface gives origin to the deep head of the medial pterygoid. The small, superficial head of this muscle arises from the *maxillary tuberosity* and the adjoining part of the pyramidal process of the palatine bone.
   c. Pharyngobasilar fascia is attached below to the processus tuberis.

      Processus tuberis/pterygospinous process (Civinini's ligament) is a triangular projection, which is present at the middle of the posterior border of lateral pterygoid plate. It supports the medial end of cartilaginous part of auditory tube.
   d. The pterygospinous process, which is present at the middle of lateral pterygoid plate gives attachment to the ligament of same name.

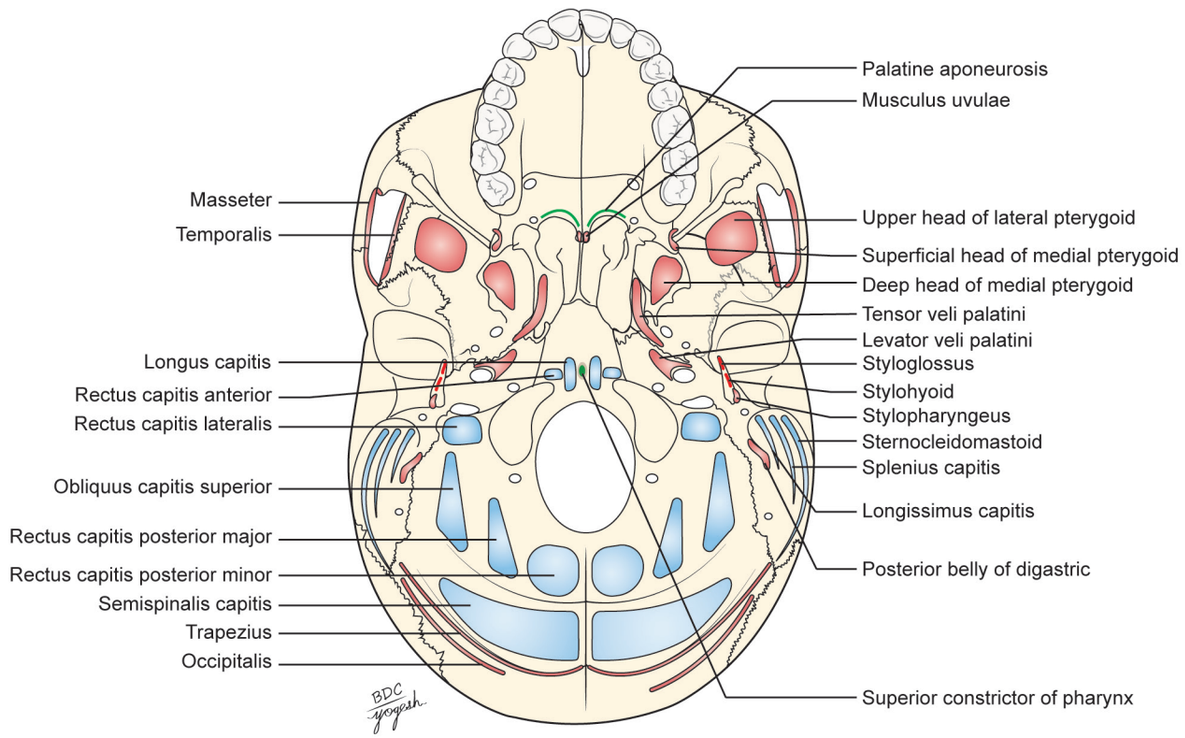


Fig. 1.12: Muscles attached to the base of skull

6. Infratemporal surface of the greater wing of the sphenoid: It gives origin to the upper head of the lateral pterygoid muscle, and is crossed by the deep temporal and masseteric nerves.
7. *Spine of the sphenoid:* It is related laterally to the auriculotemporal nerve, and medially to the chorda tympani nerve and auditory tube.

   Its *tip* provides attachment to sphenomandibular ligament, anterior ligament of malleus and pterygospinous ligament.

   Its *anterior aspect* gives origin to the most posterior fibres of the tensor veli palatini and tensor tympani muscles.
8. Inferior surface of petrous temporal bone: It gives origin to the levator veli palatini.
9. Margins of the foramen magnum: It provides attachment to:
   a. Anterior atlanto-occipital membrane, anteriorly.
   b. Posterior atlanto-occipital membrane, posteriorly.
   c. Alar ligaments on the roughened medial surface of each occipital condyle.
10. Ligamentum nuchae is attached to the external occipital protuberance and crest.
11. Rectus capitis lateralis is inserted into the inferior surface of the jugular process of the occipital bone
12. Squamous part of the occipital bone: The area between the superior and inferior nuchal lines provides insertion medially to the semispinalis capitis, and laterally to the obliquus capitis superior muscle.

    The area below the inferior nuchal line provides insertion medially to the rectus capitis posterior minor, and laterally to the rectus capitis posterior major.
13. Mastoid notch gives origin to the posterior belly of digastric muscle.

The structures passing through various foramina of skull are listed in Table 1.2.

TABLE 1.2: Structures passing through foramina of skull

Foramen	*Structures*
Incisive foramen	Terminal parts of the greater palatine vessels from the palate to the nose Terminal part of the nasopalatine nerve from the nose to the palate
Greater palatine foramen	Greater palatine vessels (Fig. 1.12) Anterior palatine nerve (both of which run forwards in the groove that passes forwards from the foramen)
Lesser palatine foramina	Middle and posterior palatine nerves
Palatinovaginal canal	Pharyngeal branch from the pterygopalatine ganglion A small pharyngeal branch of the maxillary artery
Vomerovaginal canal (if patent)	Pharyngeal branch from pterygopalatine ganglion and vessels
Foramen ovale	**M**andibular nerve (Fig. 1.11) **A**ccessory meningeal artery **L**esser petrosal nerve **E**missary vein connecting the cavernous sinus with the pterygoid plexus of veins Anterior trunk of middle meningeal vein (occasionally) [*Mnemonic*—**MALE]**
Foramen spinosum	Middle meningeal artery Meningeal branch of the mandibular nerve or nervus spinosus Posterior trunk of the middle meningeal vein
Emissary sphenoidal foramen (foramen of Vesalius)	Emissary vein connecting the cavernous sinus with the pterygoid plexus of veins
Canaliculus innominatus (if present)	Lesser petrosal nerve (in place of foramen ovale)
Carotid canal	Internal carotid artery Venous and sympathetic plexuses around the artery
Foramen lacerum (Fig. 1.13)	During life, the lower part of the foramen is filled with cartilage, and no significant structure passes through the whole length of the canal, except for the meningeal branch of the ascending pharyngeal artery and an emissary vein from the cavernous sinus. However, the upper part of the foramen is traversed by the internal carotid artery with venous and sympathetic plexuses around it. In the anterior part of the foramen, the greater petrosal nerve unites with the deep petrosal nerve to form the nerve of the pterygoid canal (Vidian's nerve), which leaves the foramen by entering the pterygoid canal in the anterior wall of the foramen lacerum (Figs 1.15a and b).

(*Contd.*)

TABLE 1.2: Structures passing through foramina of skull *(Contd.)*

Foramen	*Structures*
Medial end of the petrotympanic fissure	Chorda tympani nerve Anterior ligament of malleus Anterior tympanic artery
Foramen magnum (Fig. 1.14, Flowchart 1.11)	Through the narrow anterior part: a. Apical ligament of dens b. Vertical band of cruciate ligament c. Membrana tectoria Through wider posterior part: a. Lowest part of medulla oblongata b. Three meninges Through the subarachnoid space pass: a. Spinal accessory nerves b. Vertebral arteries with its sympathetic plexus c. Posterior spinal arteries d. Anterior spinal artery
Hypoglossal or anterior condylar canal	Hypoglossal nerve Meningeal branch of the hypoglossal nerve (These are the sensory fibres of first cervical spinal nerve supplying the dura mater of posterior cranial fossa) Meningeal branch of the ascending pharyngeal artery Emissary vein connecting the sigmoid sinus with the internal jugular vein
Posterior condylar canal	Emissary vein connecting the sigmoid sinus with suboccipital venous plexus
Jugular foramen *Note*: The glossopharyngeal notch near the medial end of the jugular foramen lodges the inferior ganglion of the glossopharyngeal nerve (Fig. 1.15, Flowchart 1.12)	Through the anterior part: a. Inferior petrosal sinus b. Meningeal branch of the ascending pharyngeal artery Through the middle part: IX, X and XI cranial nerves Through the posterior part: a. Internal jugular vein b. Meningeal branch of the occipital artery.
Mastoid canaliculus (Arnold's canal) (lies in the lateral wall of the jugular fossa)	Auricular branch of the vagus (Arnold's nerve)
Tympanic canaliculus (on the thin edge of partition between the jugular fossa and carotid canal)	Tympanic branch of glossopharyngeal nerve (Jacobson's nerve) to the middle ear cavity
Stylomastoid foramen	Facial nerve Stylomastoid branch of the posterior auricular artery
External nasal foramen	External nasal nerve
Inferior orbital fissure	Zygomatic nerve; orbital branches of pterygopalatine ganglion; infraorbital nerve and vessels
Infraorbital foramen	Infraorbital nerve and vessels
Petrotympanic fissure	Chorda tympanic nerve, anterior ligament of malleus and anterior tympanic artery
Pterygoid canal	Nerve to pterygoid canal and vessels
Pterygomaxillary fissure	Maxillary nerve
Pterygopalatine fossa	Pterygopalatine ganglion
Supraorbital foramen	Supraorbital nerve and vessels
Zygomatic foramen	Zygomatic nerve
Zygomaticofacial foramen	Zygomaticofacial nerve
Zygomaticotemporal foramen	Zygomaticotemporal nerve

Note: Auricular branch of the vagus (Arnold's nerve) passes laterally through the bone, crosses the facial canal and emerges at the tympanomastoid fissure. The nerve is extracranial at birth, but becomes surrounded by bone as the tympanic plate and mastoid process develop (also called Alderman's nerve).

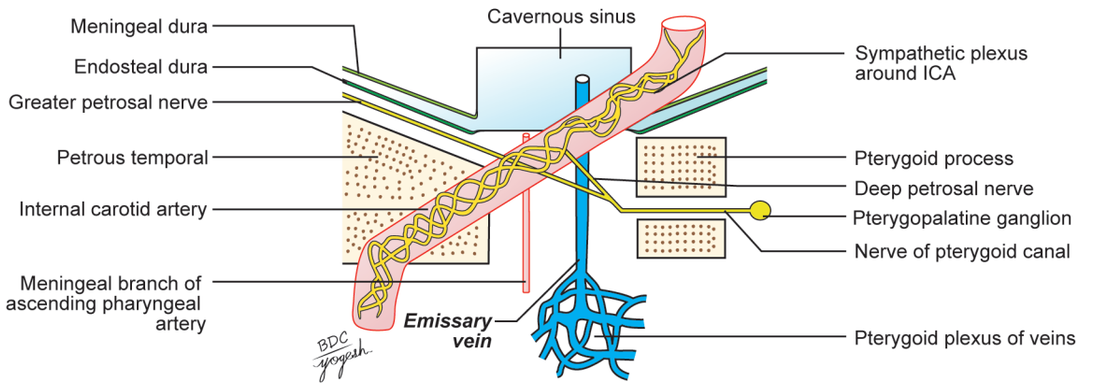


Fig. 1.13: Structures related to the foramen lacerum

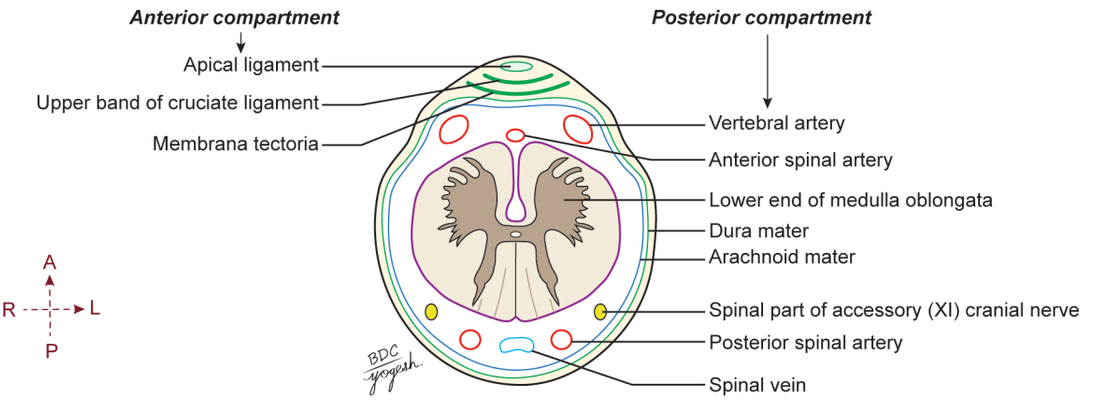
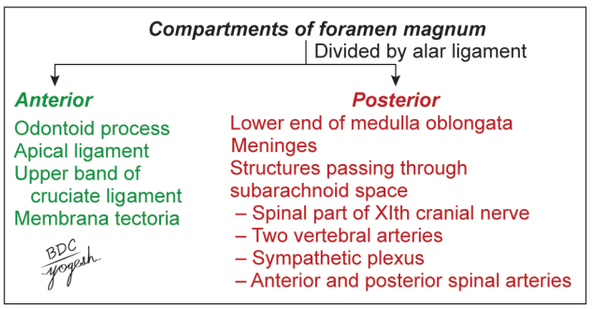
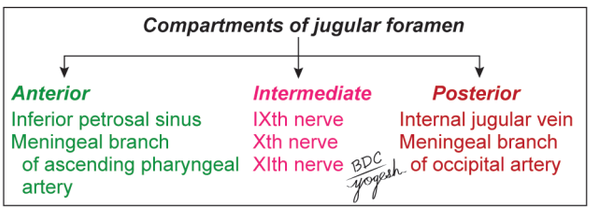


Fig. 1.14: Structures passing through foramen magnum

Flowchart 1.11: Foramen magnum



Flowchart 1.12: Jugular foramen



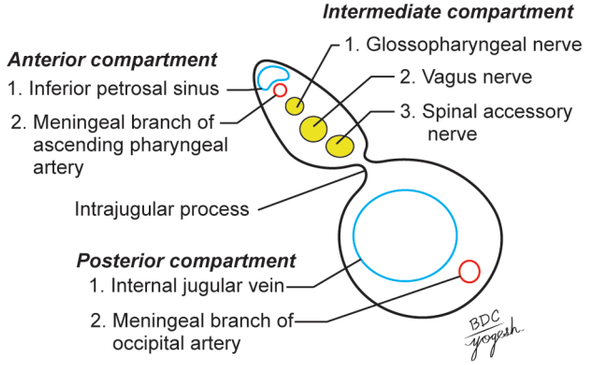


Fig. 1.15: Jugular foramen

INTERIOR OF THE SKULL

- The cranium is lined internally by ***endocranium***, which is continuous with the pericranium through the foramina and sutures (Plate 1.10, Fig. 1.16, Flowchart 1.13).
- The *thickness* of the cranial vault is variable. The bones covered with muscles, i.e. temporal and posterior cranial fossae, are thinner than those covered with scalp. Further, the bones are thinner in females than in males, and in children than in adults.
- Most of the cranial bones consist of:
  a. An *outer table* of compact bone, which is thick, resilient and tough.
  b. An *inner table* of compact bone, which is thin and brittle.
  c. The *diploe* that consists of spongy bone filled with red marrow, in between the two tables.

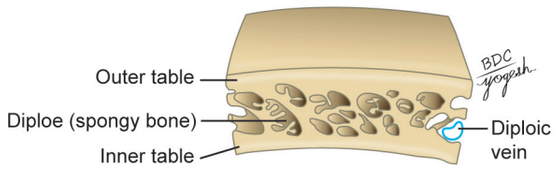


Fig. 1.16: Structure of cranial bones

Note: The skull bones derive their blood supply mostly from the meningeal arteries from inside and very little from the arteries of the scalp. Blood supply from the outside is rich in those areas where muscles are attached, e.g. the temporal fossa and the suboccipital region. The blood from the diploes is drained by four diploic veins on each side draining into venous sinuses (Table 1.3 and Fig. 1.17).

Many bones, like vomer (Latin *ploughshare*), pterygoid plates, do not have any diploe.

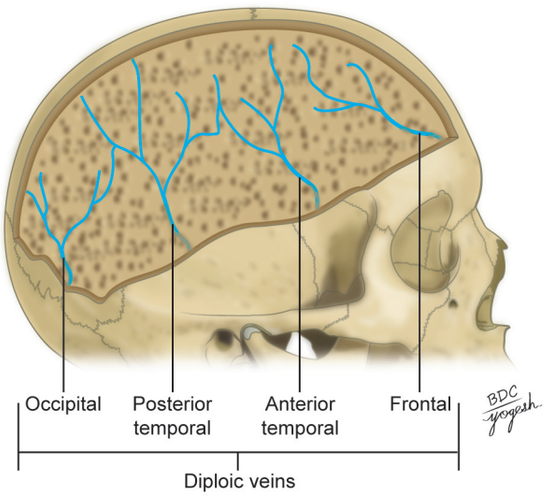


Fig. 1.17: Diploic veins

INTERNAL SURFACE OF CRANIAL VAULT

The shape, the bones present and the sutures uniting them have been described with the norma verticalis. It shows the following features (Plate 1.9):

1. The *inner table* is thin and brittle. It presents *markings* produced by meningeal vessels, venous sinuses, arachnoid granulations and to some extent by cerebral gyri. It also presents raised ridges formed by the attachments of the dural folds.
2. The ***frontal crest*** lies anteriorly in the median plane. It projects backwards.
3. The ***sagittal sulcus*** runs from before backwards in the median plane. It becomes progressively wider posteriorly. It lodges the superior sagittal sinus.
4. The ***granular foveolae*** are deep, irregular, large, pits situated on each side of the sagittal sulcus. They are formed by arachnoid granulations. They are larger and more numerous in aged persons.
5. ***Vascular markings:*** The groove for the anterior branch of the middle meningeal artery, and the accompanying vein runs upwards 1 cm behind the coronal suture. Smaller grooves for the branches from the anterior and posterior branches of the middle meningeal vessels run upwards and backwards over the parietal bone.
6. The ***parietal foramina*** open near the sagittal sulcus 2.5 to 3.75 cm in front of the lambdoid suture.
7. The *impressions for cerebral gyri* are less distinct. These become very prominent in cases of raised intracranial tension.

Competencies:
AN26.3 Describe cranial cavity, its subdivisions, foramina and structures passing through them.
AN30.1 Describe the cranial fossae and identify related structures.

INTERNAL SURFACE OF THE BASE OF SKULL

The interior of the base of skull presents natural subdivisions into the anterior, middle and posterior cranial fossae. The dura mater is firmly adherent to the floor of fossae and is continuous with pericranium through the foramina and fissures (Plate 1.10, Fig. 1.18, Flowchart 1.13).

Anterior Cranial Fossa

It is separated from the middle cranial fossa by the free *posterior border* of the *lesser wing of the sphenoid*, the *anterior clinoid process* and the *anterior margin of the sulcus chiasmaticus* (Plate 1.11).

Floor

It is formed by:

1. *Cribriform plate of the ethmoid bone*
2. *Body of the sphenoid or jugum sphenoidale*
3. *Orbital plate of the frontal bone*
4. *Lesser wing of the sphenoid*.

TABLE 1.3: Diploic veins

Vein	*Foramen*	*Drainage*
Frontal diploic vein	Supraorbital foramen	Drain into supraorbital vein
Anterior temporal or parietal diploic vein	In the greater wing of sphenoid	Sphenoparietal sinus or in anterior deep temporal vein
Posterior temporal or parietal diploic vein	Mastoid foramen	Transverse sinus
Occipital diploic vein (largest)	Foramen in occipital bone	Occipital vein or confluence of sinuses
Small unnamed diploic veins	Pierce inner table of skull close to the margins of superior sagittal sinus	Venous lacunae

Plate 1.9: Internal surface of the vault of the skull (calvaria or skull cap)

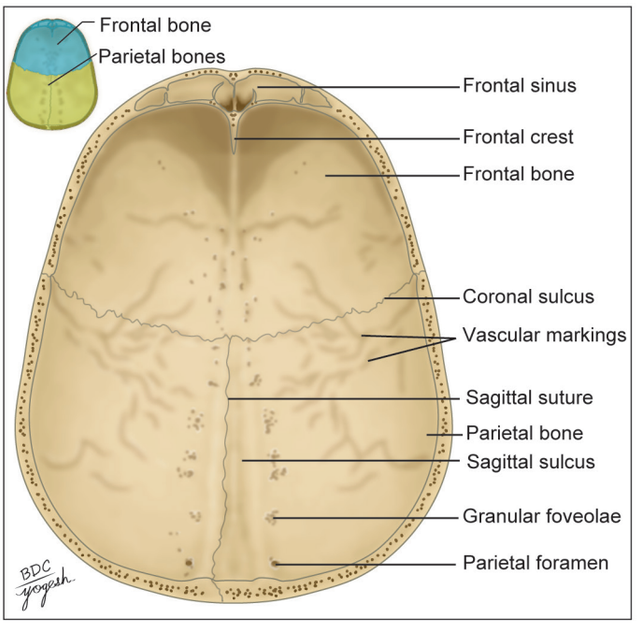
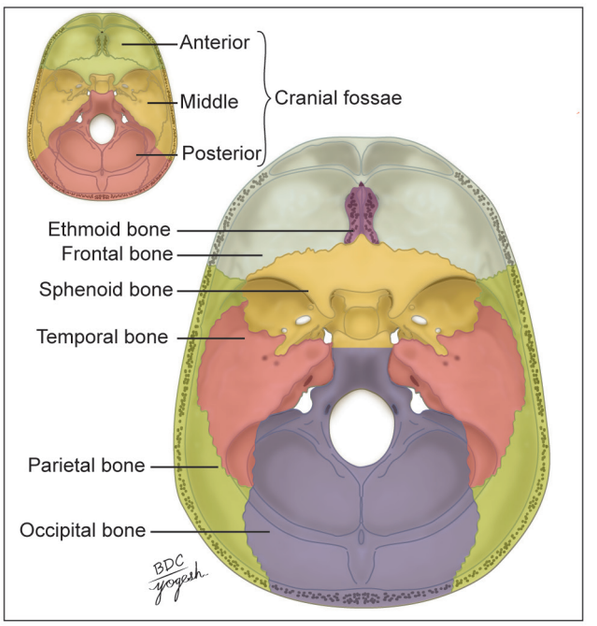


Plate 1.10: Cranial fossae and bones forming the interior of the skull



Flowchart 1.13: Features of interior of the base of skull

Anterior cranial fossa

Features	Foramina
Frontal crest - Falx cerebri Crista galli - Falx cerebri Jugum sphenoidale Cribriform plate of ethmoid Orbital plate of frontal bone Lesser wing of sphenoid - Free posterior border - Anterior clinoid process Free margin of tentorium cerebelli	Foramen caecum - Emissary vein Anterior ethmoidal canal - Anterior ethmoidal nerve and vessels Posterior ethmoidal canal - Posterior ethmoidal nerve and vessels Optic canal - Optic nerve - Ophthalmic artery

Superior orbital fissure

Lies between the greater and lesser wings of sphenoid bone
Divided into 3 parts by tendinous ring

Lateral part	Middle part	Medial part
Lacrimal nerve Frontal nerve Trochlear nerve Superior ophthalmic vein	Upper and lower divisions of oculomotor nerve Nasociliary nerve Abducent nerve	Inferior ophthalmic vein Sympathetic nerves

Median area of middle cranial fossa

Body of sphenoid

Features	Attachments	Foramen
Sulcus chiasmaticus Sella turcica - Occupies pituitary gland - Tuberculum sellae - Middle clinoid process - Dorsum sellae - Posterior clinoid process Carotid groove	Posterior clinoid process Tuberculum sellae and dorsum sellae - Diaphragma sellae	Optic canal - Optic nerve - Ophthalmic artery Carotid groove - Internal carotid artery

Lateral area of middle cranial fossa

Features	Foramina
Greater wing of sphenoid Groove for middle meningeal vessels Trigeminal impression Hiatus for greater and lesser petrosal nerves Arcuate eminence Tegmen tympani	Foramen spinosum: Middle meningeal artery, nervous spinosus Foramen ovale: Mandibular nerve, accessory meningeal artery, lesser petrosal nerve, emissary vein Foramen rotundum: Maxillary nerve Foramen lacerum: Emissary vein Superior orbital fissure

Median area of posterior cranial fossa

Features	Relations and foramina
Clivus Foramen magnum Internal occipital protuberance Internal occipital crest Vermian fossa Groove for transverse sinus Cerebellar fossa	Clivus: Related to pons, medulla, basilar venous plexus Attachments 1. Apical ligament of dens 2. Vertical band of cruciate ligament 3. Membrana tectoria Internal occipital crest 1. Falx cerebelli Foramen magnum

Lateral area of posterior cranial fossa

Features	Foramina
Condylar part of occipital bone - Jugular tubercle Posterior surface of petrous part of temporal bone Mastoid part of temporal bone - Sigmoid sulcus	Hypoglossal canal - 12th nerve - Meningeal branch of ascending pharyngeal artery - Emissary vein Condylar canal: Emissary vein Internal acoustic meatus - VII and VIII nerves - Labyrinthine vessels Jugular foramen Mastoid foramen: Emissary vein

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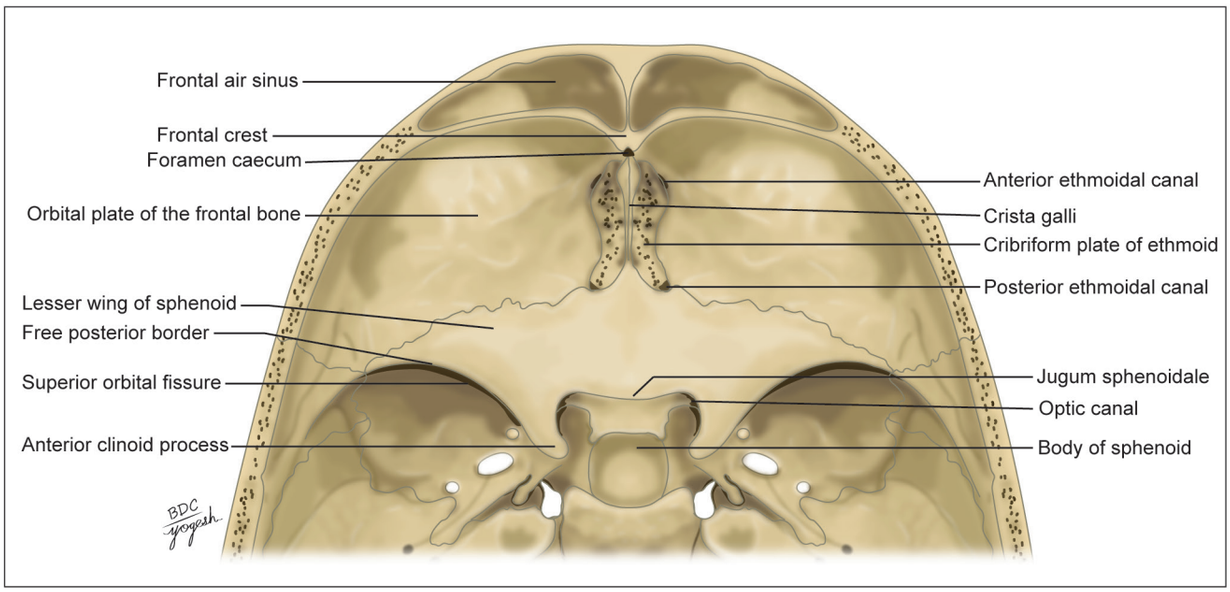
Plate 1.11: Features of anterior cranial fossa



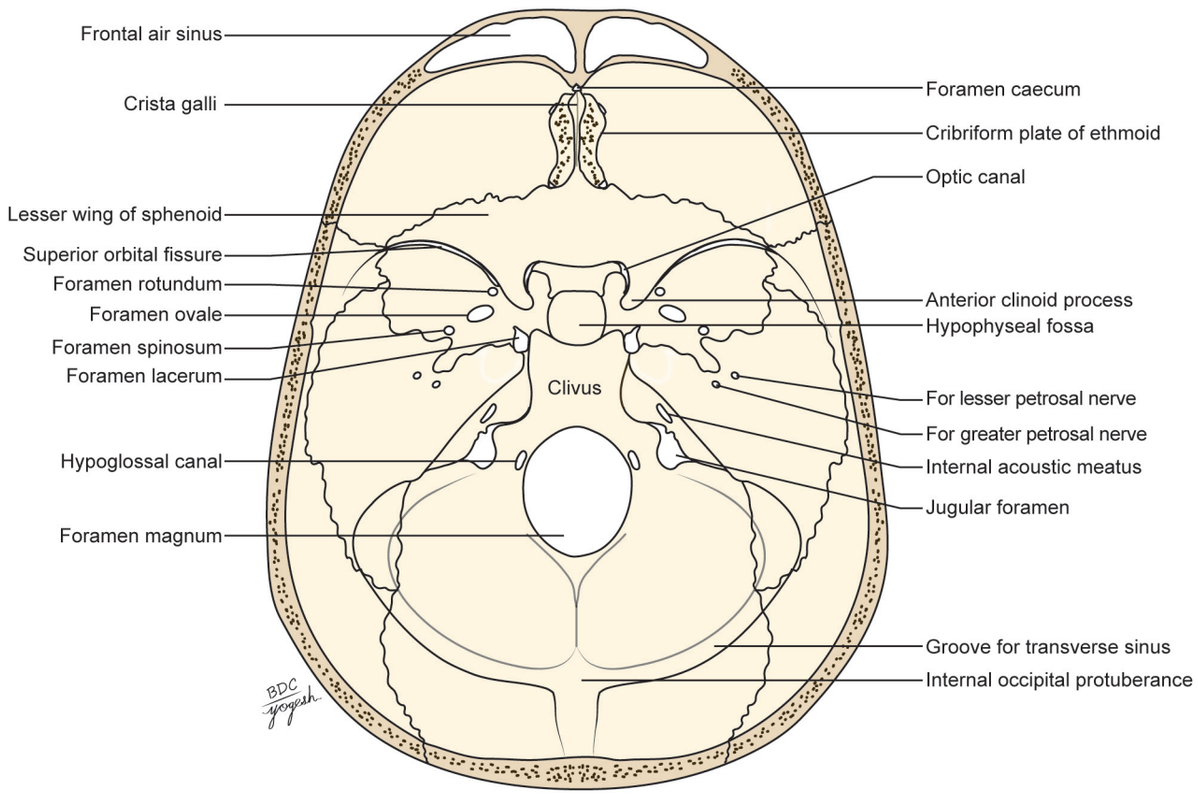


Fig. 1.18: Features of cranial fossae

Features

1. ***Cribriform plate of the ethmoid bone*** separates the anterior cranial fossa from the nasal cavity. It is quadrilateral in shape.
   a. *Anterior* margin articulates with the frontal bone at the *frontoethmoidal suture*, which is marked in the median plane by the ***foramen caecum***. This foramen is usually blind, but is occasionally patent.
   b. *Posterior margin* articulates with the jugum sphenoidale. At the posterolateral corners of cribriform plane, one sees the ***posterior ethmoidal canals***.

c. Its *lateral margins* articulate with the orbital plate of the frontal bone: The suture between them presents the ***anterior ethmoidal canal*** placed behind the crista galli.

Anteriorly, the cribriform plate has a midline projection called the ***crista galli*** (Latin *cock's comb*). On each side of the crista galli, there are foramina through which the *anterior ethmoidal nerve and vessels* pass to the nasal cavity. The plate is also perforated by *numerous foramina* for the passage of olfactory nerve rootlets.

2. ***Jugum sphenoidale*** separates the anterior cranial fossa from the sphenoidal sinuses.
3. ***Orbital plate of the frontal bone*** separates the anterior cranial fossa from the orbit. It supports the orbital surface of the frontal lobe of the brain, and presents reciprocal impressions. The *frontal air sinus* may extend into its anteromedial part.
4. ***Lesser wing of the sphenoid*** is broad medially where it is continuous with the jugum sphenoidale and tapers laterally. The free *posterior border* fits into the *stem of the lateral sulcus of the brain*. It ends medially as a prominent projection, the ***anterior clinoid process***. Inferiorly, the posterior border forms the upper boundary of the *superior orbital fissure*. Medially, the lesser wing is connected to the body of the sphenoid by ***anterior and posterior roots***, which enclose the ***optic canal***.

CLINICAL ANATOMY

Fracture of the anterior cranial fossa may cause bleeding and discharge of cerebrospinal fluid through the nose. It may also cause a condition called *black eye*, which is produced by seepage of blood into the eyelid, as frontalis muscle has no bony origin.

Middle Cranial Fossa

It is deeper than the anterior cranial fossa, and is shaped like a butterfly, being narrow and shallow in the middle; and wide and deep on each side. It is separated from the posterior cranial fossa by the superior border of the petrous temporal bone, and the dorsum sellae of the sphenoid (Plate 1.12).

Floor

Floor is formed by body of sphenoid in the median region and by greater wing of sphenoid, squamous temporal and anterior surface of petrous temporal on each side.

Features

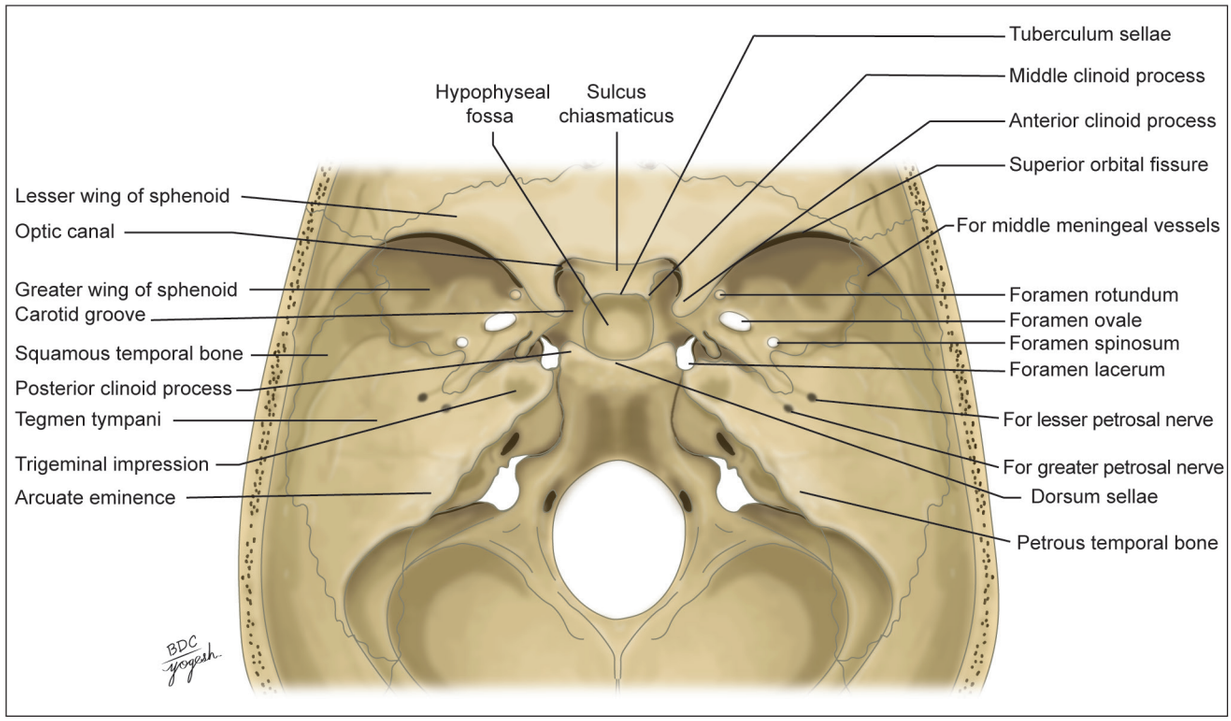
Median area: The body of the sphenoid presents the following features:

1. ***Sulcus chiasmaticus*** or *optic groove* leads, on each side, to the optic canal. The optic chiasma does not occupy the sulcus, it lies at a higher level well behind the sulcus.
2. ***Optic canal*** leads to the orbit. It is bounded laterally by the lesser wing of the sphenoid, in front and behind by the two roots of the lesser wing, and medially by the body of sphenoid.
3. ***Sella turcica*** (pituitary fossa or hypophyseal fossa): The upper surface of the body of the sphenoid is hollowed out in the form of a Turkish saddle, and is known as the *sella turcica*. It consists of the *tuberculum sellae* in front, the *hypophyseal fossa* in the middle and the *dorsum sellae* behind.
4. ***Tuberculum sellae*** separates the optic groove from the *hypophyseal fossa*. Its lateral ends form the *middle clinoid process*, which may join the anterior clinoid process.
5. ***Hypophyseal fossa*** lodges the hypophysis cerebri. Beneath the floor of fossa lie the sphenoidal air sinuses.
6. ***Dorsum sellae*** is a transverse plate of bone projecting upwards; it forms the back of the saddle. The superolateral angles of the dorsum sellae are expanded to form the *posterior clinoid processes*.

Lateral area

1. The lateral area is deep and lodges the temporal lobe of the brain.
2. ***Superior orbital fissure*** opens anteriorly into the orbit. It is *bounded* above by the lesser wing, below by the greater wing, and medially by the body of the sphenoid. Its medial end is wider than the lateral. The long axis of the fissure is directed laterally, upwards and forwards. The lower border is marked by a small projection, which provides attachment to the *common tendinous ring of Zinn*. The ring divides the fissure into three parts.
3. ***Greater wing of the sphenoid*** presents the following features:
   a. ***Foramen rotundum*** leads anteriorly to the pterygopalatine fossa containing pterygopalatine ganglia.
   b. ***Foramen ovale*** lies posterolateral to the foramen rotundum and lateral to the lingula. It leads inferiorly to the infratemporal fossa.
   c. ***Foramen spinosum*** lies posterolateral to the foramen ovale. It also leads, inferiorly, to the infratemporal fossa.
   d. ***Emissary sphenoidal foramen*** or foramen of Vesalius carries an emissary vein.
4. ***Foramen lacerum*** lies at the posterior end of the carotid groove, posteromedial to the foramen ovale.
5. ***Anterior surface of the petrous temporal bone*** presents the following features:
   a. *Trigeminal impression* lies near the apex, behind the foramen lacerum. It lodges the trigeminal ganglion within its dural cave.
   b. *Hiatus and groove for the greater petrosal nerve* are present lateral to the trigeminal impression. They lead to the foramen lacerum.
   c. *Hiatus* and *groove for the lesser petrosal nerve* lie lateral to the hiatus for the greater petrosal nerve. They lead to the foramen ovale or to canaliculus innominatus to relay in otic ganglion.

Plate 1.12: Features of middle cranial fossa



d. Still more laterally there is the *arcuate eminence* produced by the superior semicircular canal.
e. ***Tegmen tympani*** is a thin plate of bone anterolateral to the arcuate eminence. It forms a continuous sloping roof for the tympanic antrum, for the tympanic cavity and for the canal for the tensor tympani. The lateral margin of the tegmen tympani is turned downwards; it forms the lateral wall of the bony auditory tube. Its lower edge is seen in the squamotympanic fissure and divides it into the petrosquamous and petrotympanic fissures.

6. ***Cerebral surface of the squamous temporal bone*** is concave. It shows impressions for the temporal lobe and grooves for branches of the middle meningeal vessels.

CLINICAL ANATOMY

Fracture of the middle cranial fossa produces:

a. Bleeding and discharge of CSF through the ear.
b. Bleeding through the nose or mouth may occur due to involvement of the sphenoid bone.
c. The seventh and eighth cranial nerves may be damaged, if the fracture also passes through the internal acoustic meatus. If a semicircular canal is damaged, vertigo may occur.

Posterior Cranial Fossa

This is the largest and deepest of the three cranial fossae. The posterior cranial fossa contains the *hindbrain*, which consists of the *cerebellum behind and the pons and medulla in front* (Plate 1.13).

Floor

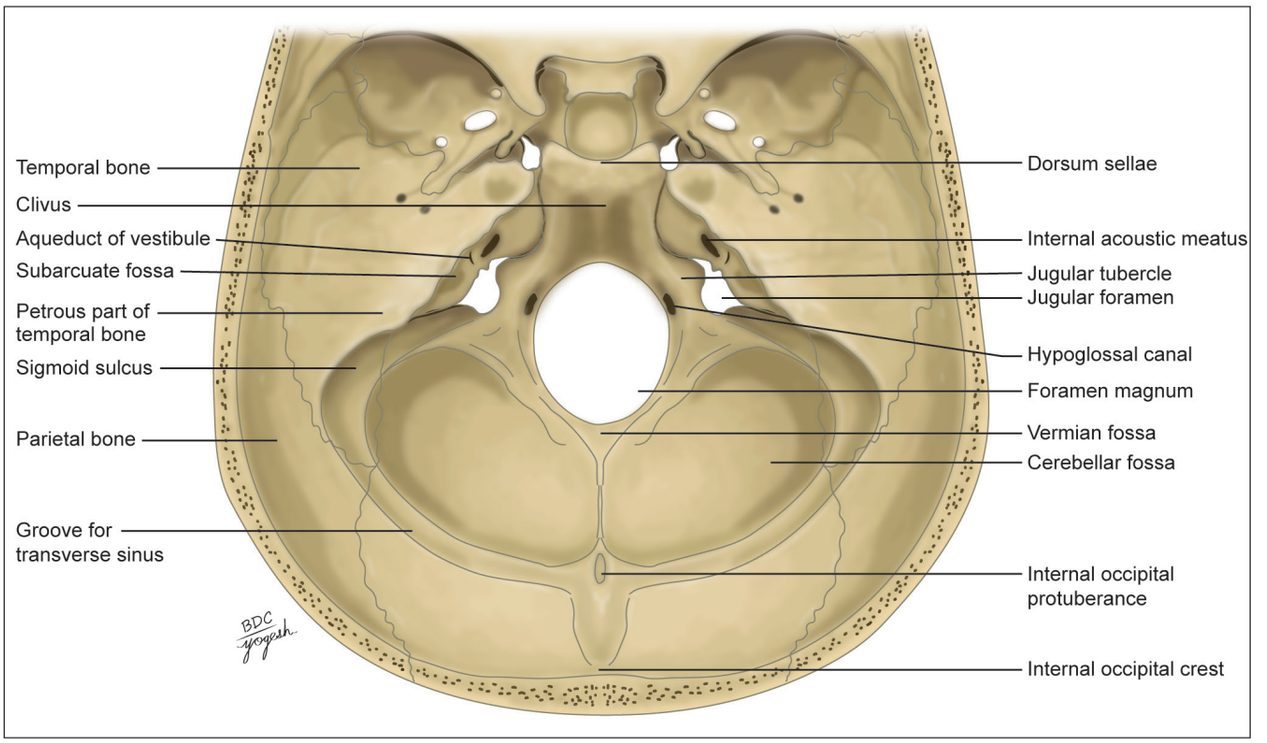
It is formed by clivus, foramen magnum and part of temporal and occipital bones.

Features

Median area

1. ***Clivus*** is the sloping surface in front of the foramen magnum. It is formed by fusion of the posterior part of the body of the sphenoid, including the dorsum sellae with the basilar part of the occipital bone or basiocciput. It is related to the *basilar plexus of veins*, and supports the pons and medulla.
2. On each side, the clivus is separated from the petrous temporal bone by the *petro-occipital fissure*, which is grooved by the inferior petrosal sinus, and is continuous behind with the jugular foramen.
3. ***Foramen magnum*** lies in the floor of the fossa. The anterior part of the foramen is narrow because it is *overlapped* by the medial surfaces of the occipital condyles.
4. ***Squamous part of the occipital bone*** shows the following features:
   a. ***Internal occipital protuberance*** lies opposite the external occipital protuberance. It is related to the confluence of sinuses, and is grooved on each side by the beginning of transverse sinuses.
   b. ***Internal occipital crest*** runs in the median plane from the internal occipital protuberance to the

Plate 1.13: Features of the posterior cranial fossa



foramen magnum where it forms a shallow depression, the *vermian fossa.*

c. ***Transverse sulcus*** is quite wide and runs laterally from the internal occipital protuberance to the mastoid angle of the parietal bone where it becomes continuous with the sigmoid sulcus. The transverse sulcus lodges the *transverse sinus.* The right transverse sulcus is usually wider than the left and is continuous medially with the superior sagittal sulcus.

d. On each side of the internal occipital crest, there are *deep fossae*, which lodge the cerebellar hemispheres.

Lateral area

1. ***Condylar part of the occipital bone*** is marked by the following features:
   a. ***Jugular tubercle*** lies over the occipital condyle.
   b. ***Hypoglossal canal*** (anterior condylar canal) pierces the bone posteroanterior to the jugular tubercle and runs obliquely forwards and laterally along the line of fusion between the basilar and the condylar parts of the occipital bone.
   c. *Condylar canal* (posterior condylar canal) opens in the lower part of the sigmoid sulcus, which indents the jugular process of occipital bone.
2. ***Posterior surface of the petrous part of the temporal bone*** forms the anterolateral wall of the posterior cranial fossa. The following features may be noted:
   a. ***Internal acoustic meatus*** opens above the anterior part of the jugular foramen. It is about 1 cm long and runs transversely in a lateral direction. It is closed laterally by a perforated plate of bone known as *lamina cribrosa*, which separates it from the internal ear.
   b. The orifice of the *aqueduct of the vestibule* is a narrow slit lying behind the internal acoustic meatus.
   c. The *subarcuate fossa* lies below the arcuate eminence, lateral to the internal acoustic meatus. It lodges the flocculus of the cerebellum.
3. ***Jugular foramen*** lies at the posterior end of the petro-occipital fissure. The upper margin is sharp and irregular, and presents the *glossopharyngeal notch*. The lower margin is smooth and regular.
4. *Mastoid part of the temporal bone* forms the lateral wall of the posterior cranial fossa just behind the petrous part of the bone. Anteriorly, it is marked by the *sigmoid sulcus*, which begins as a downward continuation of the transverse sulcus at the mastoid angle of the parietal bone, and ends at the jugular foramen. The sigmoid sulcus lodges the *sigmoid sinus*, which become the internal jugular vein at the jugular foramen. The sulcus is related anteriorly to the *tympanic antrum.* The *mastoid foramen* opens into the upper part of the sulcus.

CLINICAL ANATOMY

Fracture of the posterior cranial fossa causes bruising over the mastoid region extending down over the sternocleidomastoid muscle.

ATTACHMENTS AND RELATIONS: INTERIOR OF THE SKULL

Attachment on Vault

1. The frontal crest gives attachment to the falx cerebri.
2. The lips of the sagittal sulcus give attachment to the falx cerebri.

Anterior Cranial Fossa

1. The crista galli gives attachment to the falx cerebri.
2. The orbital surface of the frontal bone supports the frontal lobe of the brain.
3. The anterior clinoid processes give attachment to the free margin of the tentorium cerebelli.

Middle Cranial Fossa

1. The middle cranial fossa lodges the *temporal lobe of the cerebral hemisphere.*
2. The tuberculum sellae provides attachment to the *diaphragma sellae*
3. The hypophyseal fossa lodges the *hypophysis cerebri.*
4. Upper margin of the dorsum sellae provides attachment to the diaphragma sellae, and the posterior clinoid process to anterior end of the attached margin of tentorium cerebelli
5. One *cavernous sinus* lies on each side of the body of the sphenoid. The internal carotid artery passes through the cavernous sinus.
6. The superior border of the petrous temporal bone is grooved by the *superior petrosal sinus* and provides attachment to the *attached margin of the tentorium cerebelli*. It is grooved in its medial part by the *trigeminal nerve* (trigeminal impression).

Posterior Cranial Fossa

1. The posterior cranial fossa contains the hindbrain, which consists of the cerebellum behind, and the pons and medulla in front (Plate 1.13).
2. The lower part of the clivus provides attachment from above downwards to: Membrana tectoria, upper vertical band of cruciate ligament and apical ligament (MCA).
3. The internal occipital crest gives attachment to the falx cerebelli.
4. The jugular tubercle is grooved by the *ninth, tenth and eleventh cranial nerves* as they pass to the jugular foramen.
5. The subarcuate fossa on the posterior surface of petrous temporal bone lodges the *flocculus of the cerebellum*.

Competency:
AN30.2 Describe and identify major foramina with structures passing through them.

Structures Passing Through Foramina

The following foramina seen in the cranial fossae have been dealt with under the norma basalis: Foramen ovale, foramen spinosum, emissary sphenoidal foramen, foramen lacerum, foramen magnum, jugular foramen, hypoglossal canal and posterior condylar canal. Additional foramina seen in the cranial fossae are listed in Table 1.4.

TABLE 1.4: Additional foramina seen in the cranial fossae and structures passing through them

Foramen	*Structures*
Foramen caecum	Usually blind, but occasionally it transmits emissary vein to superior sagittal sinus from upper part of nose
Posterior ethmoidal canal	Vessels of the same name. Note that the posterior ethmoidal nerve does not pass through the canal
Anterior ethmoidal canal	Corresponding nerve and vessels
Foramina of cribriform plate	Olfactory nerve rootlets
Optic canal (Fig. 1.19)	Optic nerve Ophthalmic artery
Superior orbital fissure (Fig. 1.19)	Lateral part 1. Lacrimal nerve 2. Frontal nerve 3. Trochlear nerve 4. Superior ophthalmic vein Middle part 1. Upper and lower divisions of the oculomotor nerve 2. Nasociliary nerve in between the two divisions of the oculomotor 3. The abducent nerve, inferolateral to the foregoing nerves Medial part 1. Inferior ophthalmic vein 2. Sympathetic nerves from the plexus around the internal carotid artery
Foramen rotundum	Maxillary nerve
Internal acoustic meatus	Seventh and eighth cranial nerves Labyrinthine vessels
External opening of vestibular aqueduct	Endolymphatic duct

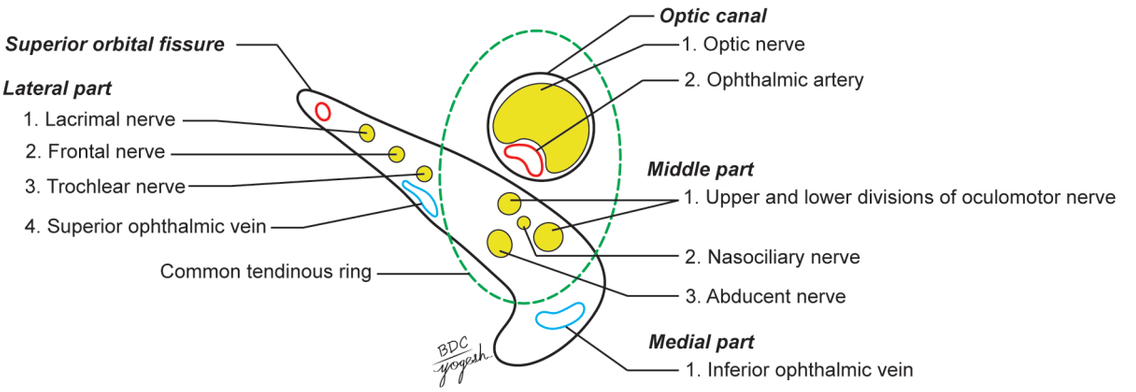


Fig. 1.19: Superior orbital fissure and optic canal

FOETAL SKULL/NEONATAL SKULL

Features of Foetal of Newborn Skull (Fig. 1.20)

1. The foetal or newborn skull is large in proportion to the other parts of skeleton.
2. *Facial skeleton* is small as compared to calvaria. In foetal skull, the facial skeleton is 1/7th of calvaria; in adults, it is half of calvaria.
   Anatomical justification: The facial skeleton is small due to rudimentary mandible and maxillae, non-eruption of teeth and small size of maxillary sinus and nasal cavity. The large size of calvaria is due to precocious growth of brain.
3. *Base of the skull* is short and narrow, though internal ear is almost of adult size, the petrous temporal has not reached the adult length.
4. *Structure of bones*: The bones of cranial vault are smooth and unilamellar; there is no diploe. The tables and diploes appear by 4th year of age.
5. *Bony prominences*
   - Frontal and parietal tubera are prominent.
   - Glabella, superciliary arches and mastoid processes are not developed.
6. *Paranasal air sinuses:* These are rudimentary or absent.
7. *Temporal bone*
   - The internal ear, tympanic cavity, tympanic antrum and ear ossicles are of adult size.
   - The tympanic part is represented by an incomplete tympanic ring.
   - Mastoid process is absent, it appears during the later part of second year.
   - External acoustic meatus is short and straight. Its bony part is unossified and represented by a fibrocartilaginous plate.
   - Tympanic membrane faces more downwards than laterally due to the absence of mastoid process.
   - Stylomastoid foramen is exposed on the lateral surface of the skull because mastoid portion is flat.
   - Styloid process lies immediately behind the tympanic ring and has not fused with the remainder of the temporal bone.
   - Mandibular fossa is flat and placed more laterally, and the anterior root/articular tubercle has not developed.
   - The subarcuate fossa is very deep and prominent.
   - Facial canal is short.
8. *Orbits:* These are large. The germs of developing teeth lies close to the orbital floor. Orbit comprises base or an outer opening with upper, lower, medial and lateral walls. Its apex lies at the optic foramen/canal. It also has superior and inferior orbital fissures.

OSSIFICATION

- Two halves of frontal bone are separated by metopic suture.
- The mandible is also present in two halves. It is a derivative of 1st branchial arch.
- Occipital bone is in four parts (squamous one, condylar two and basilar one).
- The four bony elements of temporal bone are separate, except for the commencing union of the tympanic part with the squamous and petrous parts. The second centre for styloid process has not appeared.
- Unossified membranous gaps, a total of 6 fontanelles at the angles of the parietal bones are present.
- Squamous suture between parietal and squamous temporal bones is present.

POSTNATAL GROWTH OF SKULL

The growth of calvaria and facial skeleton proceeds at different rates and over different periods. Growth of calvaria is related to growth of brain, whereas that of the facial skeleton is related to the development of dentition, muscles of mastication and of the tongue. The rates of growth of the base and vault are also different.

Growth of the Vault

1. *Rate:* Rapid during 1st year, and then it slows up to the 7th year when it is almost of adult size.
2. *Growth in breadth:* This growth occurs at the sagittal suture, sutures bordering greater wings, occipitomastoid suture, and the petro-occipital suture at the base.

3. *Growth in height*: This growth occurs at the fronto-zygomatic suture, pterion, squamosal suture and asterion.
4. *Growth in anteroposterior diameter:* This growth occurs at the coronal and lambdoid sutures.

Growth of the Base

The base grows in anteroposterior diameter at three cartilaginous plates situated between the occipital and sphenoid bones, between the pre- and post-sphenoids, and between the sphenoid and ethmoid.

Growth of the Face

1. Growth of orbits and ethmoid is completed by 7th year.
2. In the face, the growth occurs mostly during first year, although it continues till puberty and even later.

Thickening of Bones

1. Two tables and diploe appear by 4th year. Differentiation reaches maximum by about 35 years, when the diploic veins produce characteristic marking in the radiographs.
2. Mastoid process appears during 2nd year, and the mastoid air cells during 6th year.

Obliteration of Sutures of the Vault

1. Obliteration begins on the inner surface between 30 and 40 years, and on the outer surface between 40 and 50 years.
2. The timings are variable, but it usually takes place first in the lower part of the coronal suture, next in the posterior part of the sagittal suture and then in the lambdoid suture.
3. Obliteration of suture and age
   - Sagittal suture: 35 years
   - Coronal suture: 38–41 years
   - Vomero-ethmoid suture: 45 years
   - Lambdoid suture: Before 50 years
   - Sphenoparietal and sphenofrontal suture: 65 years
   - Temporosphenoid suture: 70 years

In Old Age

The skull generally becomes thinner and lighter but in small proportion of cases, it increases in thickness and weight. The most striking feature is reduction in the size of mandible and maxillae due to loss of teeth and absorption of alveolar processes. This causes decrease in the vertical height of the face and a change in the angles of the mandible, which become more obtuse.

Closure of Fontanelles

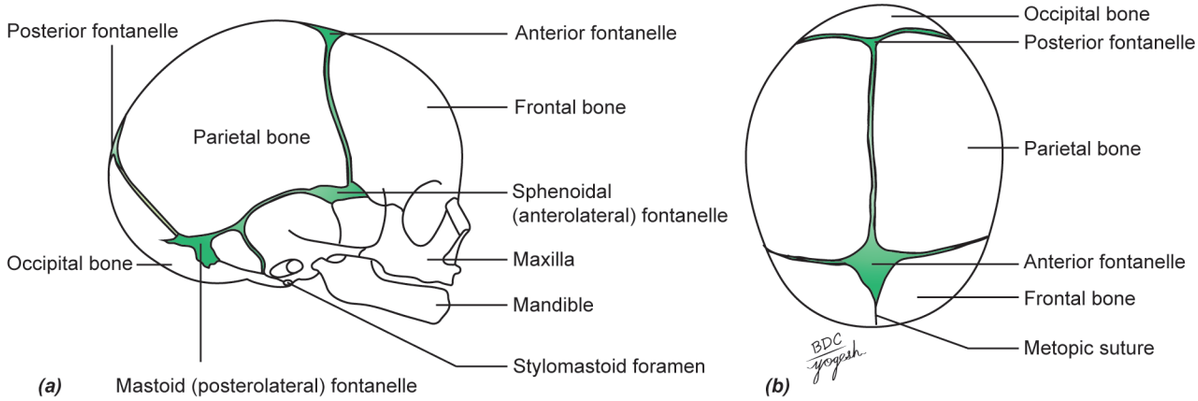
Anterior fontanelle (bregma) closes by 18 months, mastoid fontanelle by 12 months, posterior fontanelle (lambda) by 2–3 months and sphenoidal fontanelle also by 2–3 months.

Note: ***Wormian or sutural bones:*** These are small irregular bones found in the region of the fontanelles, and are formed by additional ossification centres. They are most common at the lambda and at the asterion; common at the pterion (epipteric bone); and rare at the bregma (Os Kerckring). Wormian bones are common in hydrocephalic skulls.

CLINICAL ANATOMY

Fontanelles

- Fontanelles are soft membranous gaps present in the skull vault of newborn.
- There are 6 fontanelles at birth as follows (Figs 1.20a and b):
- *Anterior fontanelle* between frontal and parietal bones. Anterior fontanelle is the largest fontanelle. It lies at the bregma.
- *Posterior fontanelle* between occipital and parietal bones. It lies at the lambda.
- *Anterolateral (sphenoid) fontanelle* between greater wing of sphenoid, squamous temporal, frontal and parietal bones. It lies at the pterion.
- *Posterolateral (mastoid) fontanelle* between parietal, occipital, squamous temporal and occipital bones. It lies at the asterion.
- *Closure of fontanelle*
  - Anterolateral, posterolateral and posterior fontanelles close within 3–4 months after birth.
  - Anterior fontanelle closes by 2–3 years of age.



Figs 1.20a and b: Fontanelles of skull: (a) Lateral aspect and (b) superior aspect

- *Function of fontanelles*
  - Allow moulding of skull during the birth passage of body.
  - Permit growth of skull bones to increase the cranial capacity.
  - Accommodate developing brain.
- *Clinical aspects*
  1. Closure of fontanelles gives an idea about the age of the newborn.
  2. The anterior fontanelle is largest and of great clinical significance. Appearance of anterior fontanelle gives an idea of intracranial pressure.
     - Bulging fontanelles indicate increased intracranial pressure.
     - Depressed fontanelles indicate dehydration cases.
  3. If fontanelles fuse early, brain growth is stunted; such children are less intelligent.
  4. Bones override at the fontanelle helping to decrease size of head during vaginal delivery.
  5. ***Caput succedaneum*** is soft tissue swelling on any part of skull due to rupture of capillaries during delivery. Skull becomes normal within a few days in postnatal life (Fig. 1.21).

Fig. 1.21: Caput succedaneum

SEX DIFFERENCES IN THE SKULL

There are no sex differences until puberty. The postpubertal differences are listed in Table 1.5.

TABLE 1.5: Sex differences in the skull

Features	*Males*	*Females*
1. Weight	Heavier	Lighter
2. Size	Larger	Smaller
3. Capacity	Greater in males	10% less than males
4. Walls	Thicker	Thinner
5. Muscular ridges, glabella, superciliary arches, temporal lines, mastoid processes, superior nuchal lines and external occipital protuberance	More marked	Less marked
6. Tympanic plate	Larger and margins are more roughened	Smaller and margins are less roughened
7. Supraorbital margin	More rounded	Sharp
8. Forehead	Sloping (receding)	Vertical
9. Frontal and parietal tubera	Less prominent	More prominent
10. Vault	Rounded	Somewhat flattened

CRANIOMETRY

Craniometry is the process of recording various measurements of the skull.

Cephalic Index

It expresses the shape of the head, and is the proportion of breadth to length of the skull. Thus:

$$\text{Cephalic index} = \frac{\text{Maximum cranial breath}}{\text{Maximum cranial length}} \times 100$$

The length or the longest diameter is measured from the glabella to the occipital point, the breadth or the widest diameter is measured usually a little below the parietal tubera.

Note: Human races may be:

1. *Dolichocephalic* or long-headed when the index is 75 or less.
2. *Mesaticephalic* when the index is between 76 and 80.
3. *Brachycephalic* or short-headed or round-headed when the index is above 80.
4. Dolichocephaly is a feature of primitive races, like Eskimos, Negroes, etc.
5. Brachycephaly through mesaticephaly has been a continuous change in the advanced races, like the Europeans.

Facial Angle

This is the angle between two lines drawn from the nasion to the basion or anterior margin of foramen magnum and a line drawn from basion to the prosthion or central point on upper incisor alveolus (Fig. 1.9).

Facial angle is a rough index of the degree of development of the brain because it is the angle between facial skeleton, i.e. viscerocranium, and the calvaria, i.e. neurocranium, which are inversely proportional to each other. The angle is the smallest in the most evolved races of man, it is larger in lower races, and still larger in anthropoids.

Note:

Abnormal crania

1. ***Oxycephaly or acrocephaly, tower-skull, or steeple skull*** is an abnormally tall skull. It is due to premature closure of the suture between presphenoid and postsphenoid in the base, and the coronal suture in skull cap, so that the skull is very short anteroposteriorly. Compensation is done by the upward growth of skull for the enlarging brain.

2. ***Scaphocephaly or boat-shaped skull*** is due to premature synostosis in the sagittal suture; as a result, the skull is very narrow from side-to-side but greatly elongated.

Competency:
AN26.4 Describe morphological features of mandible.

MANDIBLE

The *mandible*, or the lower jaw, is the largest and the strongest bone of the face. It develops from the *1st pharyngeal arch*.

It is a horseshoe-shaped bone. It consists of three parts (Plate 1.14, Figs 1.22 and 1.23, Flowchart 1.14):

- *Body* – horizontally placed
- *Two rami* – vertically placed.

BODY OF MANDIBLE

Each half of the body has:
Two surfaces: External and internal
Two borders: Superior border or alveolar process and inferior border or base of the mandible.

Outer surface presents the following features:

1. ***Symphysis menti*** is the line at which the right and left halves of the bone meet each other. It is marked by a faint ridge.
2. ***Mental protuberance*** (*mentum* = chin) is a median triangular projecting area in the lower part of the midline. The inferolateral angles of the protuberance form the *mental tubercles*.
3. ***Mental foramen*** lies below the interval between the premolar teeth.
4. The *oblique line* is the continuation of the sharp anterior border of the ramus of the mandible. It runs downwards and forwards towards the mental tubercle.
5. The *incisive fossa* is a depression that lies just below the incisor teeth.

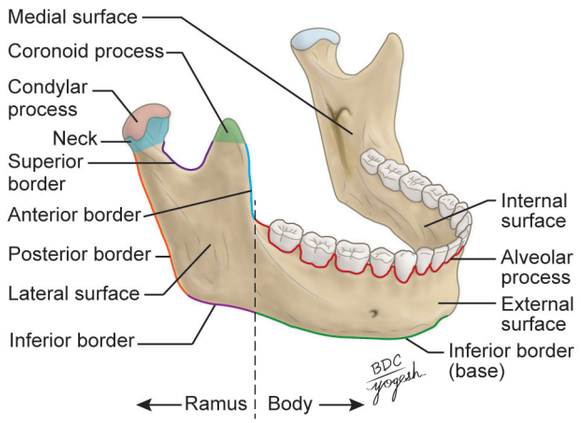


Fig. 1.22: Parts of mandible

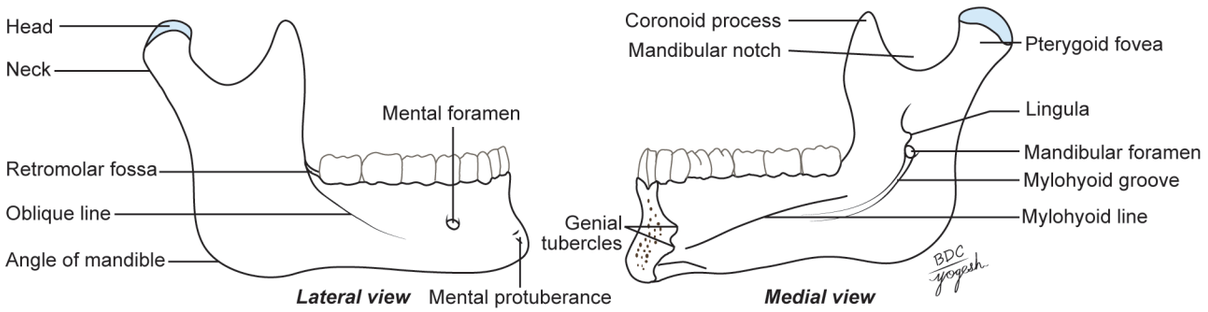


Fig. 1.23: Mandible (lateral and medial views)

Flowchart 1.14: Mandible

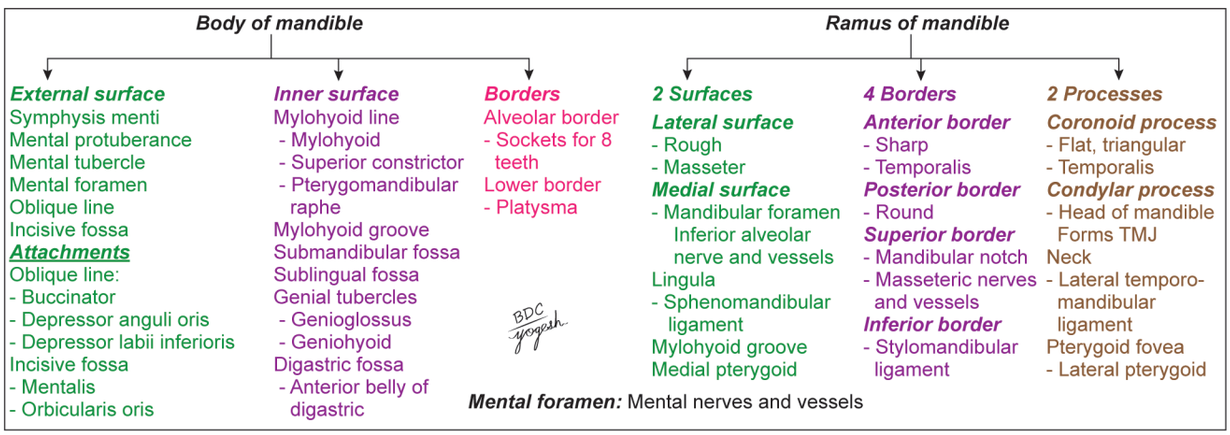
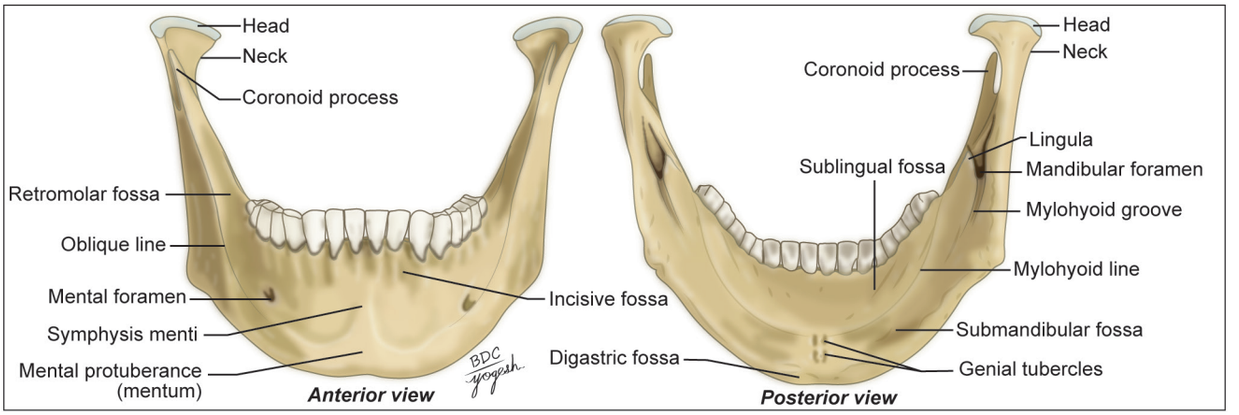


Plate 1.14: Mandible



Inner surface presents the following features:

1. ***Mylohyoid line*** is a prominent ridge that runs obliquely downwards and forwards from below the third molar tooth to the median area below the genial tubercles (*see* below). The mylohyoid groove (present on the ramus) extends onto the body below the posterior end of the mylohyoid line.
2. Below the mylohyoid line, the surface is slightly hollowed out to form the ***submandibular fossa***, which lodges the submandibular gland.
3. Above the mylohyoid line, there is the *sublingual fossa* in which the sublingual gland lies.
4. The posterior surface of the symphysis menti is marked by four small elevations called the *superior and inferior* ***genial tubercles***.

Upper or alveolar border bears sockets for the teeth.

Lower border of the mandible is also called the *base*. Near the midline, the base shows an oval depression called the *digastric fossa*.

RAMUS

The ramus is quadrilateral in shape and has:

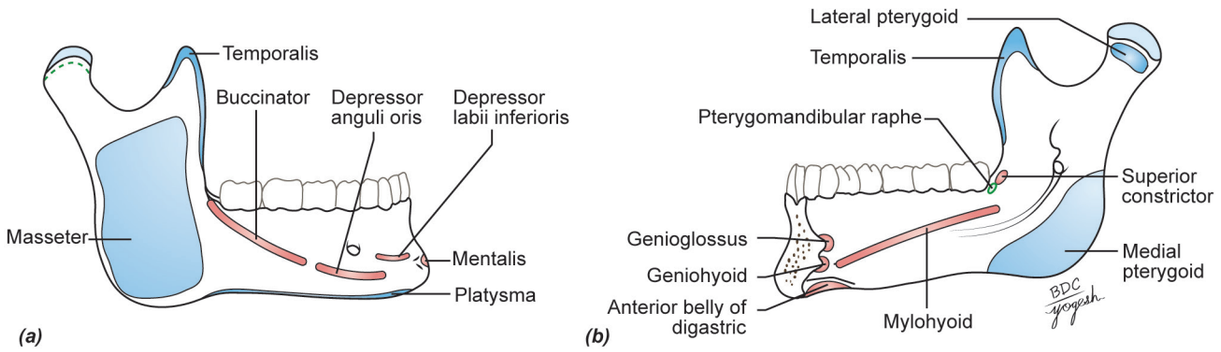
- *Two surfaces* — lateral and medial
- *Four borders* — upper, lower, anterior and posterior
- *Two processes* — coronoid and condyloid.

- ***Lateral surface*** is flat and bears a number of oblique ridges.
- ***Medial surface*** presents the following features:
  1. ***Mandibular foramen*** lies a little above the centre of ramus at the level of occlusal surfaces of the teeth. It leads into the *mandibular canal*, which descends into the body of the mandible and opens at the *mental foramen* (Fig. 1.23).
  2. The anterior margin of the mandibular foramen is marked by a sharp tongue-shaped projection called the ***lingula***. The lingula is directed towards the head or condyloid process of the mandible.
  3. The *mylohyoid groove* begins just below the mandibular foramen, and runs downwards and forwards to be gradually lost over the submandibular fossa.
- ***Upper border*** of the ramus is thin and is curved downwards forming the *mandibular notch.*
- ***Lower border*** is the backward continuation of the base of the mandible. Posteriorly, it ends by becoming continuous with the posterior border at the *angle* of the mandible (Fig. 1.23).
- ***Anterior border*** is thin, while the *posterior border* is thick.
- ***Coronoid process*** (Greek *crow's beak*) is a flattened triangular upward projection from the anterosuperior part of the ramus. Its anterior border is continuous with the anterior border of the ramus. The posterior border bounds the mandibular notch.
- ***Condyloid process*** (Latin *knuckle-like*) is a strong upward projection from the posterosuperior part of the ramus. Its upper end is expanded from side-to-side to form the ***head***. The head is covered with fibrocartilage and articulates with the temporal bone to form the temporomandibular joint. The constriction below the head is the ***neck***. Its anterior surface presents a depression called the ***pterygoid fovea***.

ATTACHMENTS AND RELATIONS OF THE MANDIBLE

Muscles

1. The oblique line on the lateral side of the body gives origin to the buccinator as far forwards as the anterior border of the first molar tooth. In front of this origin, the depressor labii inferioris and the depressor anguli oris arise from the oblique line below the mental foramen (Figs 1.24a and b).
2. The incisive fossa gives origin to the mentalis and mental slips of the orbicularis oris.
3. The parts of both the inner and outer surfaces just below the alveolar margin are covered by the mucous membrane of the mouth.
4. Mylohyoid line gives origin to the mylohyoid muscle.
5. Superior constrictor muscle of the pharynx arises from an area above the posterior end of the mylohyoid line.
6. *Upper genial tubercle* gives origin to the genioglossus, and the *lower tubercle* to geniohyoid.



Figs 1.24a and b: Attachments of the mandible: (a) Lateral surface of the right half of the mandible and (b) inner surface of right half of the mandible

7. Anterior belly of the digastric muscle arises from the digastric fossa.
8. Platysma is inserted into the lower border.
9. Whole of the lateral surface of ramus except the posterosuperior part provides insertion to the masseter muscle.
10. Medial pterygoid muscle is inserted on the medial surface of the ramus, on the roughened area below and behind the mylohyoid groove.
11. Temporalis is inserted into the apex and medial surface of the coronoid process. The insertion extends downwards on the anterior border of the ramus.
12. Lateral pterygoid muscle is inserted into the pterygoid fovea on the anterior aspect of the neck.

Ligaments

1. Pterygomandibular raphe is attached immediately behind the third molar tooth in continuation with the origin of superior constrictor.
2. Deep cervical fascia (investing layer) is attached to the whole length of lower border.
3. Sphenomandibular ligament is attached to the lingula.
4. The lateral surface of neck provides attachment to the lateral ligament of the temporomandibular joint.
5. Stylomandibular ligament is attached to the angle of the mandible.

NERVES AND VESSELS RELATED TO THE MANDIBLE (Figs 1.25a and b)

1. The mental foramen transmits the *mental nerve and vessels*.
2. The *inferior alveolar nerve and vessels* enter the *mandibular canal through the mandibular foramen*, and run forwards within the canal.
3. The *mylohyoid nerve and vessels* lie in the *mylohyoid groove*.
4. The *lingual nerve* is related to the medial surface of the ramus in front of the mylohyoid groove.
5. The area above and behind the mandibular foramen is related to the *inferior alveolar nerve and vessels* and to the *maxillary artery*.
6. The *masseteric nerve and vessels* pass through the mandibular notch.
7. The *auriculotemporal nerve* and *superficial temporal artery* are related to the medial side of the neck of mandible.
8. Facial artery is palpable on the lower border of mandible at anteroinferior angle of masseter.

Note: Facial and maxillary arteries are not accompanied by respective nerves. The lingual nerve does not get company of its artery.

Structures related to mandible

1. Salivary glands: Parotid, submandibular and sublingual.
2. Lymph nodes: Parotid, submandibular and submental.
3. Arteries (7): Maxillary, superficial temporal, masseteric, inferior alveolar, mylohyoid, mental and facial.
4. Nerves (6): Lingual, auriculotemporal, masseteric, inferior alveolar, mylohyoid and mental.
5. Muscles of mastication: Insertions of temporalis, masseter, medial pterygoid and lateral pterygoid.
6. Ligaments: Lateral ligament of temporomandibular joint, stylomandibular ligament, sphenomandibular and pterygomandibular raphe.

[*Mnemonics*

Nerves related to mandible M³LIA: **M³–** masseteric nerve, mental nerve and nerve to mylohyoid; **L–** lingual nerve; **I**– inferior alveolar nerve, **A**– auriculotemporal nerve.

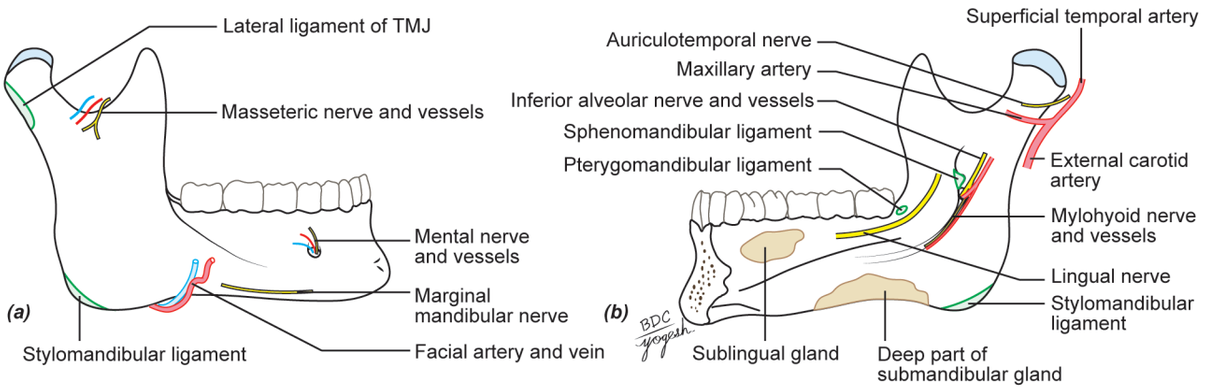
Arteries related to mandible: M⁴IFS: **M⁴**– masseteric, maxillary, mental arteries and artery to mylohyoid; **I**– inferior alveolar artery, **F**– facial artery, **S**– superficial temporal artery; forearm and hand].

OSSIFICATION

The mandible is the *second bone, next to the clavicle, to ossify* in the body. Its greater part ossifies *in membrane*. The parts ossifying in *cartilage* include the *incisive part* below the incisor teeth, the *coronoid and condyloid processes* and the *upper half of the ramus* above the level of the mandibular foramen.

Each half of the mandible ossifies from only one *centre*, which appears at about the 6*th week* of intrauterine life in the mesenchymal *sheath of Meckel's cartilage* near the future mental foramen. Meckel's cartilage is the skeletal element of 1*st pharyngeal arch*.

At birth, the mandible consists of two halves connected at the *symphysis menti* by fibrous tissue. Bony union takes place during the first year of life.



Figs 1.25a and b: Relations of the mandible: (a) Lateral surface of the right half of the mandible and (b) inner surface of right half of the mandible

AGE CHANGES IN THE MANDIBLE

The mandible shows considerable changes with age. The changes are observed in the following points (Fig. 1.26, Table 1.6):

1. Position of mental foramen
2. Angle of mandible
3. Relationship between condylar and coronoid processes
4. Location of mandibular canal
5. Alveolar process and teeth.

CLINICAL ANATOMY

- The mandible is commonly fractured at the canine socket where it is weak.
- Involvement of the inferior alveolar nerve in the callus may cause neuralgic pain, which may be referred to the areas of distribution of the buccal and auriculotemporal nerves. If the nerve is damaged, the areas supplied by these nerves become insensitive.
- The next common fracture of the mandible occurs at the angle and neck of mandible. Toothache of lower jaw referred to external auditory meatus, as both are supplied by branches of mandibular division of trigeminal nerve.

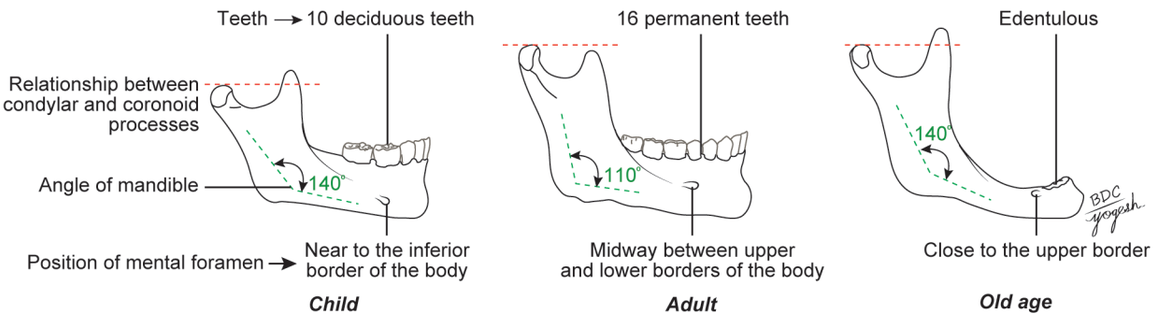


Fig 1.26: Age changes in the mandible

TABLE 1.6: Age changes in mandible

Feature	*In children*	*In adult*	*In old age*
Angle of mandible	140°	110°	140°
Direction of mental foramen	Upward and backward	Horizontally backward	Forward
Position of mental foramen	Near the inferior border of the body	Midway between upper and lower borders of the body	Close to the upper border
Alveolar process	Rudimentary	Well-developed	Absorbed to form alveolar ridge, edentulous
Teeth	Ten deciduous teeth	16 permanent teeth	Edentulous
Relationship between condylar and coronoid processes	Coronoid process lies at a higher level than condylar process	Condylar process lies at a higher level than the coronoid process	Coronoid process lies at higher level than the condylar process
Height of body	Gradually increases	Maximum	Gradually decreases
Position of mandibular body	Runs near the lower border	Runs parallel to the mylohyoid line	Runs close to the upper border

MAXILLA

Maxilla (cheek) is the second largest bone of the face, the first being the mandible. The two maxillae form the whole of the upper jaw (Plate 1.15).

SIDE DETERMINATION

1. Anterior surface ends medially into a deeply concave border, called the *nasal notch*. Posterior surface is convex.
2. Alveolar border with sockets for upper teeth faces downwards with its convexity directed outwards. Frontal process is the longest process, which is directed upwards.
3. Medial surface is marked by a large irregular penning, the *maxillary hiatus* / antrum of Highmore for maxillary air sinus.

FEATURES

Each maxilla consists of (Plate 1.15):

1. Body
2. Four processes: Frontal, zygomatic, palatine and alveolar.

Body of Maxilla

It is pyramidal in shape, with its base directed medially at the nasal surface, and the apex directed laterally at the zygomatic process. It has four surfaces and encloses a large cavity, the *maxillary sinus* described in Chapter 15, page 252.

It has four surfaces:

1. Anterior or facial,
2. Posterior or infratemporal,
3. Superior or orbital and
4. Medial or nasal.

Anterior or Facial Surface

1. Anterior surface forms a part of norma frontalis.
2. Above the incisor teeth, there is a slight depression, the *incisive fossa*, which gives origin to depressor septi. Incisivus labii superioris (part of orbicularis oris) arises from the alveolar margin below the fossa, and the *nasalis* superolateral to the fossa along the nasal notch.
3. Lateral to canine eminence, there is a larger and deeper depression, the *canine fossa*, which gives origin to levator anguli oris.
4. Above the canine fossa, there is *infraorbital foramen*, which transmits *infraorbital nerve and vessels*.
5. Levator labii superioris arises between the infraorbital margin and infraorbital foramen.
6. Medially, the anterior surface ends in a deeply concave border, the nasal notch, which terminates below into a process that, along with the corresponding process of the opposite maxilla, forms the anterior nasal spine. Anterior surface bordering the nasal notch gives origin to nasalis and depressor septi.

Posterior or Infratemporal Surface

1. It forms the anterior wall of *infratemporal fossa*, and is separated from anterior surface by the zygomatic process and a rounded ridge, which descends from the process of the first molar tooth.
2. Near the centre of the surface open two or three *alveolar canals* for *posterior superior alveolar nerve and vessels.*
3. Posteroinferiorly, there is a rounded eminence, the ***maxillary tuberosity***, which articulates superomedially with pyramidal process of palatine bone, and gives origin laterally to the superficial head of medial pterygoid muscle.
4. Above the maxillary tuberosity, the smooth surface forms anterior wall of *pterygopalatine fossa*, and is grooved by *maxillary nerve.*

Superior or Orbital Surface

1. Superior surface is smooth, triangular and slightly concave, and forms the greater part of the *floor of orbit*.
2. The surface presents *infraorbital groove* leading forwards to *infraorbital canal*, which opens on the anterior surface as *infraorbital foramen*. The groove, canal and foramen transmit the *infraorbital nerve and vessels*. Near the midpoint, the canal gives off laterally a branch, the *canalis sinuous*, for the passage of *anterior superior alveolar nerve and vessels*.
3. Inferior oblique muscle of eyeball arises from a depression just lateral to lacrimal notch at the anteromedial angle of the surface.

Medial or Nasal Surface

1. Medial surface forms a part of the *lateral wall of nose*.
2. *Posterosuperiorly*, it displays a large irregular opening of the maxillary sinus, the *maxillary hiatus*.
3. Below the hiatus, the smooth concave surface forms a part of *inferior meatus of nose*.
4. Behind the hiatus, the surface articulates with perpendicular plate of palatine bone, enclosing the *greater palatine canal*, which runs downwards and forwards, and transmits *greater palatine vessels and the anterior, middle and posterior palatine nerves*.
5. In front of the hiatus, there is *nasolacrimal groove*, which is converted into the nasolacrimal canal by articulation with the *descending process of lacrimal bone* and the *lacrimal process of inferior nasal concha*. The canal transmits *nasolacrimal duct to the inferior meatus of nose*.
6. More anteriorly, an oblique ridge forms the *conchal crest* for articulation with the inferior nasal concha.
7. Above the conchal crest, the shallow depression forms a part of the *atrium of middle meatus* of nose.

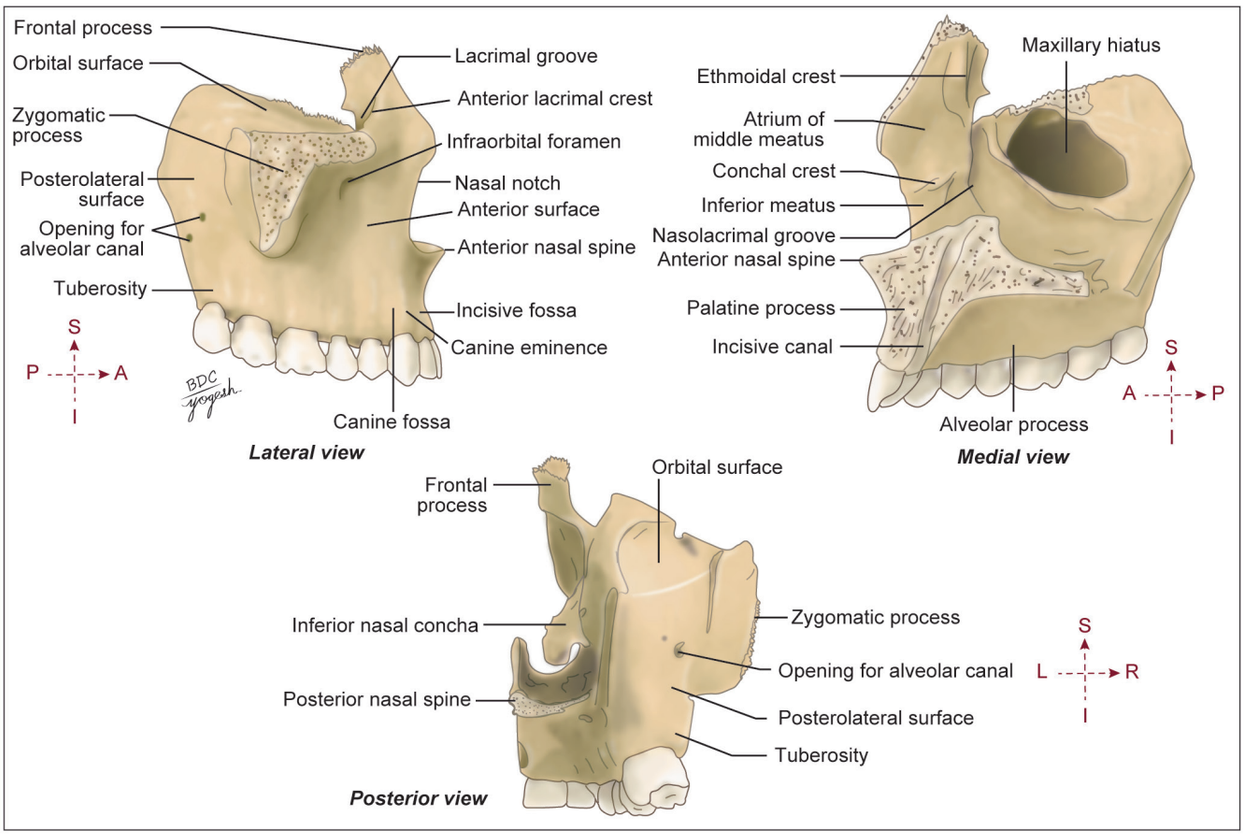
Processes of Maxilla

It has four processes: Frontal, zygomatic, palatine and alveolar (Plate 1.15).

Zygomatic Process

The zygomatic process is a pyramidal lateral projection that articulates with the zygomatic bone.

Plate 1.15: Right maxilla



Frontal Process

1. The frontal process projects upwards to *articulate* above with the frontal bone, in front with nasal bone and behind with lacrimal bone.
2. *Lateral surface* is divided by a vertical ridge, the ***anterior lacrimal crest***, into a smooth anterior part and a grooved posterior part.
3. The anterior lacrimal crest gives attachment to lacrimal fascia and the medial palpebral ligament. The anterior smooth area gives origin to the orbital part of orbicularis oculi and levator labii superioris alaeque nasi. The posterior grooved area forms the anterior half of the floor of *lacrimal groove*.
4. *Medial surface* of the frontal process has horizontal *ethmoidal crest* that articulates with middle nasal concha. The area below the ethmoidal crest is hollowed out to form the atrium of the middle meatus of nose.

Alveolar Process

1. The alveolar process forms half of the alveolar arch, and bears sockets for the roots of upper 8 teeth.
2. Buccinator arises from the posterior part of its outer surface up to the 1st molar tooth.

Palatine Process

1. Palatine process is a thick horizontal plate projecting medially to form a part of the hard.
2. Its medial border is raised superiorly to form the *nasal crest*. The groove between the nasal crests of two maxillae receives lower border of vomer; anterior part of the ridge is high and is known as *incisor crest*, which terminates anteriorly into the anterior nasal spine.
3. Incisive canal traverses near the anterior part of the medial border.

Note: The maxilla and premaxilla ossify from primary ossification centres that appear in 7th week of intrauterine life and three secondary ossification centres that appear in 8th week after birth. The premaxilla fuse with alveolar process almost immediately after the ossification. There is no evidence of a separate centre of ossification for the incisor-bearing portion of the maxilla (premaxilla). A small maxillary sinus is present at birth which enlarges until the eruption of permanent dentition.

PARIETAL BONE

Two parietal bones form a large part of the roof and sides of vault of skull. Each bone is roughly quadrilateral in shape with its convexity directed outwards (Plate 1.16).

SIDE DETERMINATION

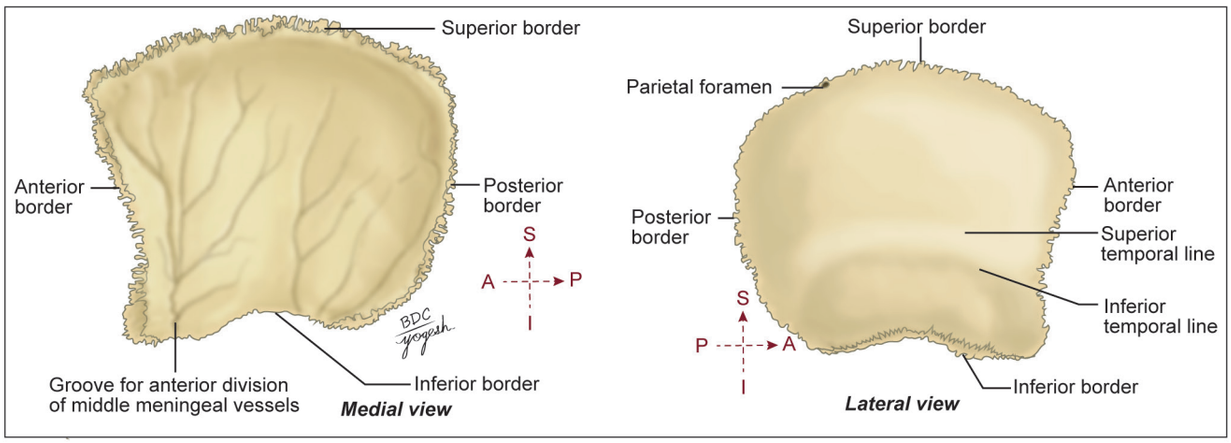
Outer surface is convex and smooth, inner surface is concave and depicts vascular markings.

Anteroinferior angle is pointed and shows a groove for anterior division of middle meningeal artery.

FEATURES

Parietal bone has two surfaces, four borders and four angles (Plate 1.16).

Plate 1.16: Parietal bone (medial and lateral views)



Surfaces

1. Outer convex
2. Inner concave

Borders

1. Superior or sagittal
2. Inferior or squamosal
3. Anterior or frontal
4. Posterior or occipital

Angles

1. Anterosuperior or frontal
2. Anteroinferior or sphenoidal
3. Posterosuperior or occipital
4. Posteroinferior or mastoid

At each of the four angles, are four fontanelles. These are:

a. One anterior fontanelle
b. One posterior fontanelle
c. Two anterolateral or sphenoidal fontanelles
d. Two posterolateral or mastoid fontanelles.

Details can be studied from *norma verticalis* and *norma lateralis* and *inner aspect of skull cap*.

OCCIPITAL BONE

Single occipital bone occupies posterior and inferior parts of the skull (Plate 1.17).

ANATOMICAL POSITION

It is concave forwards and encloses the largest foramen of skull, foramen magnum, through which cranial cavity communicates with the vertebral canal. On each side of foramen magnum is the occipital condyle, which articulates with atlas vertebra.

FEATURES

Occipital bone is divided into three parts (Plate 1.17):

1. Squamous part – expanded plate of the bone that lies behind the foramen magnum.
2. Basilar part – lies in front of foramen magnum.
3. Condylar or lateral part – on each side of foramen magnum.

Squamous Part

Comprises two surfaces, three angles and four borders.

Surfaces: External convex surface and internal concave surface.

Angles: One superior angle and two lateral angles.

Borders: Two lambdoid borders in upper part and two mastoid borders in lower part.

Basilar Part

The basilar part of occipital bone is called basiocciput. It articulates with basisphenoid to form the base of skull. It is quadrilateral in shape and comprises two surfaces and four borders.

Surfaces are superior and inferior.

Borders are anterior, posterior and two lateral, on each side.

Condylar Part

It comprises:

- Superior surface
- Inferior surface which shows occipital condyles and hypoglossal canal.

The details can be read from descriptions of *norma occipitalis* and *posterior cranial fossa*.

FRONTAL BONE

Frontal bone forms the forehead, most of the roof of orbit, and most of the floor of anterior cranial fossa. Its parts are squamous, orbital and nasal parts (Plate 1.18).

ANATOMICAL POSITION

Squamous part is vertical and is convex forwards. Two orbital plates are horizontal thin plates projecting backwards. Nasal part is directed forwards and downwards.

Plate 1.17: Occipital bone (#: posterior condylar canal)

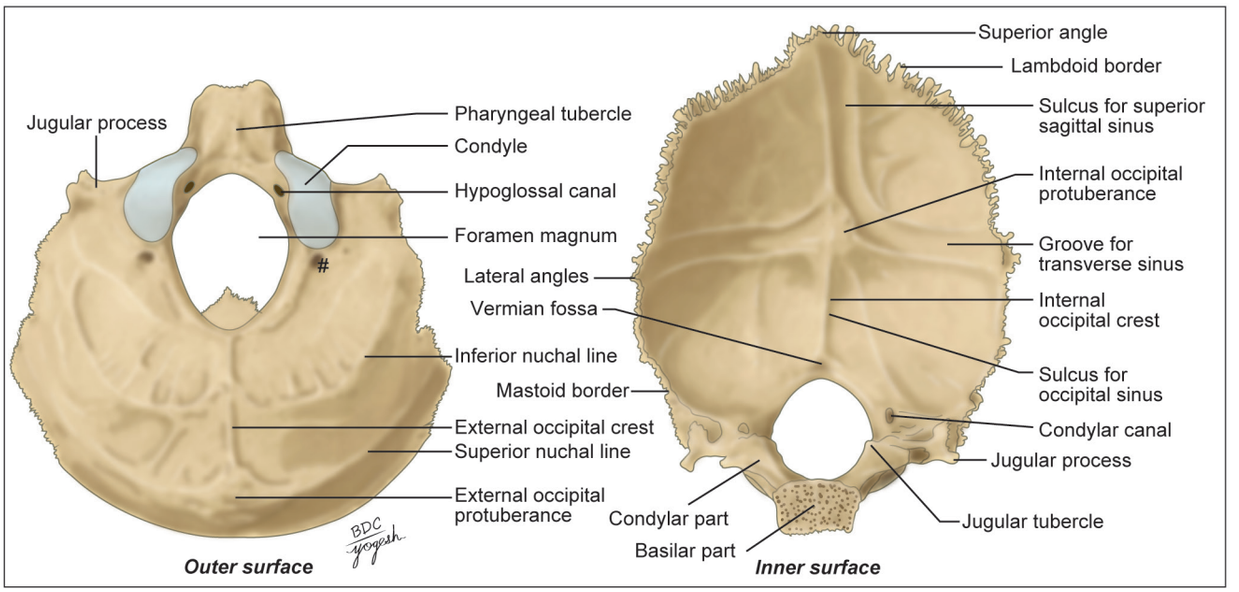
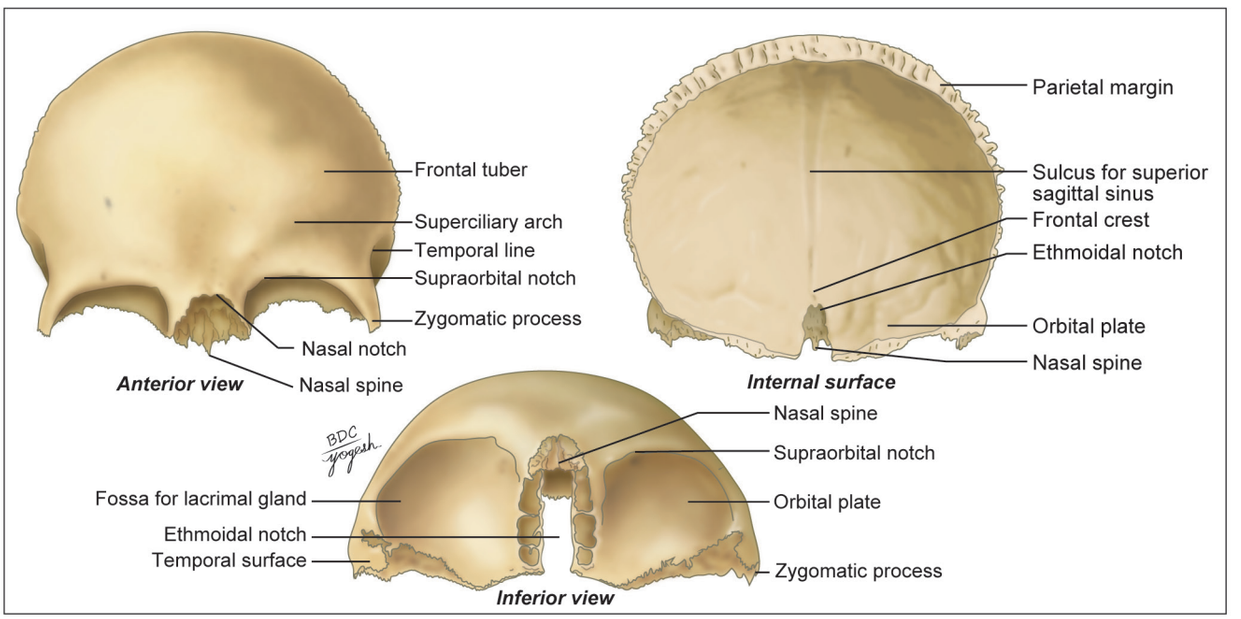


Plate 1.18: Frontal bone



Squamous Part

The squamous part presents two surfaces, two borders and encloses a pair of frontal air sinuses.

Outer Surface

It is smooth and shows:

1. Frontal tuberosity
2. Superciliary arches
3. Glabella
4. Frontal air sinus is a cavity within outer and inner tables of frontal bone, divided by a bony septum into two parts
5. Metopic suture
6. Upper or parietal border: Articulates with parietal bone
7. Lower or orbital border: Free, presents supra-orbital notch foramen
8. Zygomatic process
9. Temporal line and temporal surfaces.

Inner Surface

It is concave and presents:

1. Sagittal sulcus
2. Frontal crest

Orbital Parts (Plates)

Orbital plates are separated from each other by a wide gap – the ethmoidal notch.

Orbital or inferior surface of the plate is smooth and presents lacrimal fossa anterolaterally and trochlear spine anteromedially.

Ethmoidal notch is occupied by cribriform plate of ethmoid bone. On each side of notch are small air spaces, which articulate with the labyrinth of ethmoid to complete ethmoidal air sinuses. At the margins are anterior and posterior ethmoidal canals.

Nasal Part

Lies between two supraorbital margins. The margins of the nasal notch on each side articulate with nasal, frontal process of maxilla and lacrimal bones.

Details can be studied from descriptions of *norma frontalis, norma lateralis, inner aspect of skull cap and anterior cranial fossa*.

TEMPORAL BONE

Temporal bones are situated at the sides and base of skull (Plate 1.19).

SIDE DETERMINATION

- Plate-like squamous part is directed upwards and laterally.
- Strong zygomatic process is directed forwards.
- Petromastoid part, triangular in shape, is directed medially.
- External acoustic meatus, enclosed between squamous and tympanic parts, is directed laterally.

FEATURES

The temporal bone consists of the following parts (Plate 1.19):

1. Squamous
2. Mastoid
3. Petrous
4. Tympanic
5. Styloid process.

Squamous Part

It is expanded, thin, translucent portion of the bone. It shows the following features:

1. *Temporal or external surface:* It forms the greater part of the temporal fossa. It gives origin to the temporalis muscle.
2. *Groove for middle temporal vessels* is a vertical groove that ascends upward from the external acoustic meatus.
3. *Supramastoid crest* is a curved ridge that ascends upward and backward from the anterior part of the external acoustic meatus. It gives attachment to the *temporal fascia* and marks the posterior boundary of the temporal fossa.
4. *Auricularis posterior* muscle arises from the space between the supramastoid crest and the line of the squamomastoid suture.
5. *Suprameatal spine* is a bony projection on the medial side of the suprameatal triangle.
6. *Internal surface* is concave. It is marked by irregular impressions for the temporal gyri and presents grooves for the middle meningeal vessels.

Zygomatic Process of the Temporal Bone

It forms an elongated bony process. It articulates with the temporal process of the zygomatic bone to form the *zygomatic arch*. It consists of

Two roots: *anterior and posterior*

Elongated thin anterior part.

1. *Roots of the zygomatic process* are anterior and posterior, and they converge to meet at a point to form a tubercle known as the *tubercle of the root of the zygoma*. It gives attachment to the *lateral temporomandibular ligament*.
2. At the tubercle, the process is twisted and the thin anterior part projects forward from it.
3. The *anterior root of the zygoma* projects horizontally lateralward and its inferior surface is convex and smooth. It forms a thickened bar of the bone in front of the articular fossa and is known as the *articular tubercle* (*eminence*).
4. The *posterior root* is directed downward and forward. It is continuous behind with the supramastoid crest and in front with the superior border of the thin anterior part of the zygoma.
5. The thin anterior part of the zygomatic process is subcutaneous.
6. The medial surface and inferior border of zygomatic process give origin to *masseter* muscle. Its superior border gives attachment to the *temporal fascia*.

Mandibular Fossa

It is formed partly by the squamous part and partly by the tympanic part. It consists of:

a. an *articular part* formed by the squamous part of the temporal bone, and
b. a *nonarticular part* formed by the tympanic part of the bone.

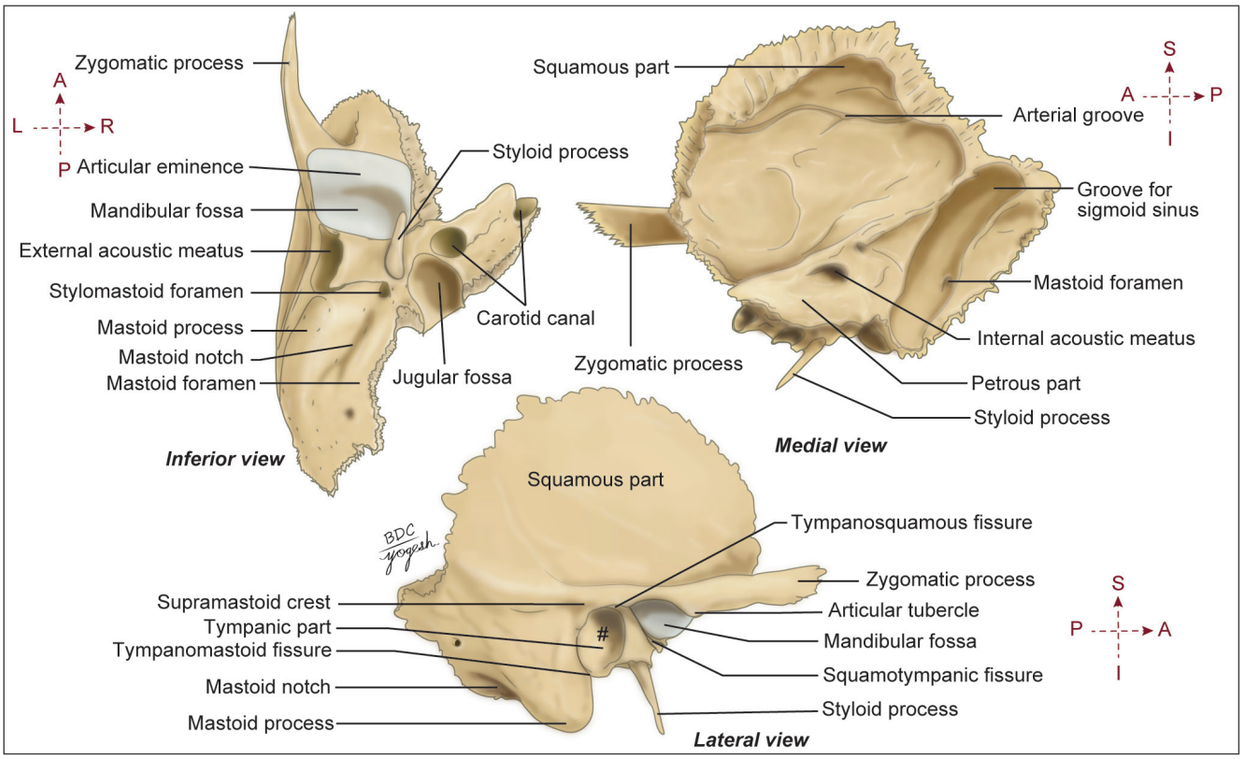
1. *Squamotympanic fissure* separates the articular part from the tympanic part medially.
2. The downturned anterolateral portion of the *tegmen tympani* projects into this fissure and subdivides it into *petrotympanic and petrosquamosal fissures*.
3. *Petrotympanic fissure* communicates with the tympanic cavity. It transmits *anterior ligament of the malleus* and *anterior tympanic branch* of the maxillary artery. It has *anterior canaliculus* for the chorda tympani nerve at its medial end. This canal transmits the *chorda tympani nerve*.

Mastoid Part

It is thick. It presents the following features:

1. *External surface* is convex.

Plate 1.19: Right temporal bone



2. It forms a conical projection known as the ***mastoid process***. It gives
   i. Origin to *occipital belly of the occipitofrontalis*
   ii. Insertion to the sternocleidomastoid, splenius capitis and longissimus capitis (from above downward).
3. ***Mastoid notch*** on the medial aspect of the mastoid process gives origin to the *posterior belly of the digastric* muscle.
4. *Groove* located below the digastric lodges the *occipital artery*.
5. *Mastoid foramen* lies below the groove for the occipital artery and close to the posterior border of the mastoid process.
6. The internal surface of the mastoid part is marked by a deep curved groove for sigmoid sinus. The mastoid foramen opens into its floor.
7. **Section of the mastoid part**
   1. It contains a number of irregular *mastoid air cells*.
   2. *Mastoid or tympanic antrum*: It is a large irregular space situated at the upper and anterior portions of the mastoid part.

Petrous Part

It forms a cylindrical process of bone. It lies between the greater wing of the sphenoid and the occipital bone at the base of the skull.

1. *Base* of the petrous part is fused with the squamous and the mastoid parts, and the apex articulates with the petrosal process of the sphenoid. It is directed upward, forward and medially.
2. *Anterior surface* of the petrous part lies in the middle cranial fossa and is marked by impressions for the temporal lobe of the brain. Immediately behind the apex, this surface presents a depression known as the *trigeminal impression*. It lodges the *trigeminal ganglion*. Behind the trigeminal impression, there is an eminence known as the *arcuate eminence*. It is formed by the *superior semicircular canal* of the internal ear.
3. *Tegmen tympani*
   - On the lateral side of the anterior surface, there is a thin plate of bone called the *tegmen tympani*. It forms the roof of the tympanic antrum, tympanic cavity and the canals for the tensor tympani and the auditory tube.
   - Laterally, the tegmen tympani is bend itself and descends downward on the medial side of the squamous part and forms the lateral wall of the auditory tube.
   - Its anterolateral portion projects into the squamotympanic fissure.
   - On the anterior part of the tegmen tympani, there is a faint groove that leads posteriorly into an *opening for the greater superficial petrosal nerve*.
   - Lateral to this opening, there is another *opening for the lesser petrosal nerve*.
   - *Posterior surface* forms the anterior part of the posterior cranial fossa.
4. *Internal acoustic meatus* is a circular aperture. It extends laterally for about 1 cm.

5. Bottom of the internal auditory meatus is closed by *perforated plate* of bone for the transmission of nerve rootlets of vestibulocochlear nerve.
6. *Inferior surface* of the petrous part is faced downward. Close to the apex, it gives origin to the levator veli palatini muscle.
   - It shows a circular opening of the *carotid canal*, which transmits the *internal carotid artery* with its plexus of sympathetic nerves.
   - Behind the carotid opening there is *jugular fossa*, which lodges the *superior bulb of the internal jugular vein*.
   - At the jugular fossa, there is *tympanic canaliculus* that transmits the *tympanic branch of the glossopharyngeal nerve*.
   - *Jugular surface*: It is a small quadrilateral articular area behind the jugular fossa. It articulates with the jugular process of the occipital bone.
   - *Mastoid canaliculus*: It a small foramen on the lateral wall of the jugular fossa. It transmits the *auricular branch of the vagus nerve*.
   - *Styloid process*: It is a slender process that projects downward.
   - *Stylomastoid foramen*: It lies behind the styloid process. It gives passage to the *facial nerve* and *stylomastoid branch of the posterior auricular artery*.
7. *Superior border* of the petrous part presents a narrow *groove for the superior petrosal sinus* and the margins of the groove give attachment to the *tentorium cerebelli*.
8. *Posterior border* and basilar part of the occipital bone forms a *groove for the inferior petrosal sinus*.
9. *Anterior border* is divided into two parts, a lateral and a medial part; the lateral part joins with the squamous part at the petrosquamosal suture and its medial part articulates with the greater wing of the sphenoid.

Tympanic Part

It is a plate of bone that lies between the squamous and the mastoid parts. In front, it articulates with the squamous part at the *squamotympanic fissure*, and behind, with the mastoid process at the *tympanomastoid fissure*. The tympanomastoid fissure transmits the *auricular branch of the vagus nerve*. Internally, it is fused with the petrous part of the temporal bone.

It presents the following features:

1. *Anterior surface* forms the posterior nonarticular part of the mandibular fossa and lodges a portion of the parotid gland.
2. *Posterior surface* is concave. It forms the anterior and part of the posterior wall and the floor of the external acoustic meatus. The medial part of this surface has a circular *tympanic sulcus*, which gives attachment to the *tympanic membrane*.
3. *Lateral margin* forms the margin of the bony external ear. It gives attachment to the cartilaginous part of the external ear.
4. *Superior border* articulates with the squamous part medially at the *squamotympanic fissure*.
5. *Lower border* extends from the carotid canal to the styloid process. It forms a *sheath of styloid process*.

Styloid Process

Styloid (Greek *pillar form*) process is long pointed process directed downwards, forwards and medially between parotid gland and internal jugular vein (Plate 1.19).

- Its base is related to facial nerve
- Its apex is crossed by external carotid artery
- It gives attachment to three muscles and two ligaments.

SPHENOID BONE

Sphenoid (Greek *wedge*) bone resembles a bat with outstretched wings. It comprises (Plate 1.20):

- A body in the centre.
- Two lesser wings from the anterior part of body.
- Two greater wings from the lateral part of body.
- Two pterygoid (wing-like) processes, directed downwards from the junction of body and greater wings.

BODY OF SPHENOID

It comprises six surfaces and encloses a pair of sphenoidal air sinuses.

Superior or Cerebral Surface

It articulates with ethmoid bone anteriorly and basilar part of occipital bone posteriorly. It shows:

1. Jugum sphenoidale
2. Sulcus chiasmaticus
3. Tuberculum sellae
4. Sella turcica
5. Dorsum sellae
6. Clivus

Inferior Surface

1. Rostrum of sphenoid
2. Sphenoid conchae
3. Vaginal processes of medial pterygoid plate.

Anterior Surface

Sphenoidal crest articulates with perpendicular plate of ethmoid to form a small part of septum of nose.

Opening of sphenoidal air sinus is seen. Sphenoidal conchae close the sphenoid air sinuses leaving the openings. Each half of anterior surface has two parts—superolateral and inferomedial.

The superolateral depression articulates with labyrinth of ethmoid to complete the posterior ethmoidal air sinuses. The inferomedial smooth triangular area forms the posterior part of the root of the nose.

Posterior Surface

It articulates with basilar part of occipital bone.

Lateral Surfaces

Carotid sulcus, a broad groove curved like letter 'f' for lodging cavernous sinus and internal carotid artery. Below the sulcus, it articulates with greater wing of sphenoid laterally and with pterygoid process, which is directed downwards.

Sphenoidal Air Sinuses

These are asymmetrical air sinuses in the body of sphenoid, and are closed by sphenoidal conchae. The sinus opens into the lateral wall of nose in the sphenoethmoidal recess above the superior concha.

GREATER WINGS

These are two strong processes that curve laterally and upwards from the sides of the body. It has three surfaces.

Superior or Cerebral Surface

It forms the floor of middle cranial fossa and presents from before backwards:

1. Foramen rotundum
2. Foramen ovale
3. Emissary sphenoidale foramen
4. Foramen spinosum.

Lateral Surface

A horizontal ridge, the infratemporal crest divides this surface into upper or temporal surface and a lower or infratemporal surface. It is pierced by foramen ovale and foramen spinosum. Its posterior part presents spine of sphenoid.

Orbital Surface

Forms the posterior wall of the lateral wall of orbit. Its medial border bears a small tubercle for attachment of a common tendinous ring for the origin of recti muscles of the eyeball. Below the medial end of superior orbital fissure, the grooved area forms the posterior wall of the pterygopalatine fossa and is pierced by foramen rotundum. Borders are surrounding the greater wing of sphenoid.

LESSER WINGS

Lesser wings are two triangular plates projecting laterally from the anterosuperior part of the body. It comprises:

- A base forming medial end of the wing. It is connected to the body by two roots which enclose the optic canal.
- Tip forms the lateral end of the wing.
- Superior surface forming floor of anterior cranial fossa.
- Inferior surface forming upper boundary of superior orbital fissure.
- Anterior border articulates with the posterior border of orbital plate of frontal bone.
- Posterior border is free and projects into the stem of lateral sulcus of brain. Medially, it terminates into the anterior clinoid process.

Superior Orbital Fissure

It is a triangular gap through which middle cranial fossa communicates with the orbit. The structures passing through it are put in list of foramina and structures passing through them.

PTERYGOID PROCESSES

One pterygoid (Greek *wing*) process on each side projects downwards from the junction of the body with the greater wing of sphenoid (Plate 1.20).

Each pterygoid process divides inferiorly into the medial and lateral pterygoid plates. The plates are fused together in their upper parts, but are separated in their lower parts by the pterygoid fissure. Posteriorly, the pterygoid plates enclose a 'V-shaped interval', the pterygoid fossa. The medial pterygoid plate in its upper part presents a scaphoid fossa. *Refer* to *norma basalis* for medial and lateral pterygoid plates

ETHMOID BONE

Ethmoid (Greek *sieve*) is a very light cuboidal bone situated in the anterior base of cranial cavity between the two orbits (Plate 1.21).

It forms:

1. Part of nasal septum
2. Part of medial wall of orbit
3. Lateral walls of the nasal cavity

Ethmoid bone comprises:

1. Cribriform plate
2. Perpendicular plate
3. A pair of labyrinth

CRIBRIFORM PLATE

It is a horizontal perforated bony lamina, occupying ethmoidal notch of frontal bone. It contains foramina for olfactory nerve rootlets.

Crista Galli

Crista galli is a median, tooth-like upward projection in the floor of anterior cranial fossa. Foramen transmitting anterior ethmoidal nerve to nasal cavity is situated by the side of crista galli.

PERPENDICULAR PLATE

It is a thin lamina projecting downwards from the undersurface of the cribriform plate, forming upper part of nasal septum.

Plate 1.20: Sphenoid bone

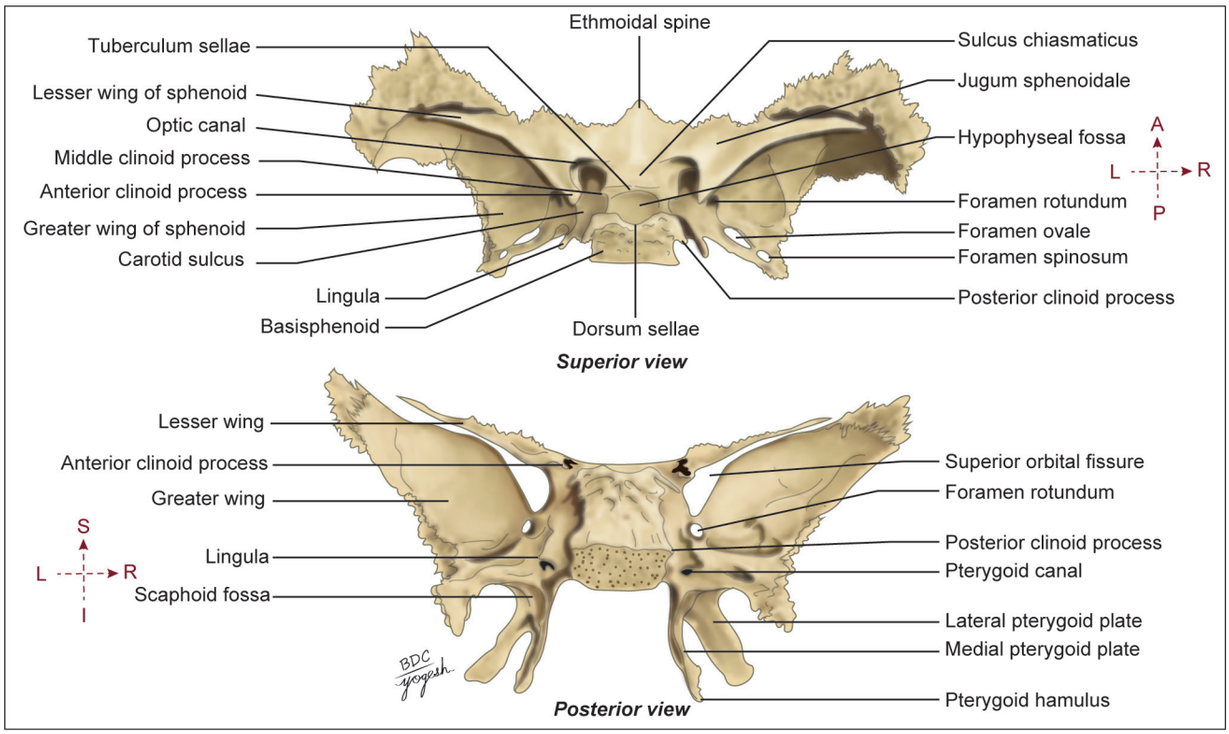
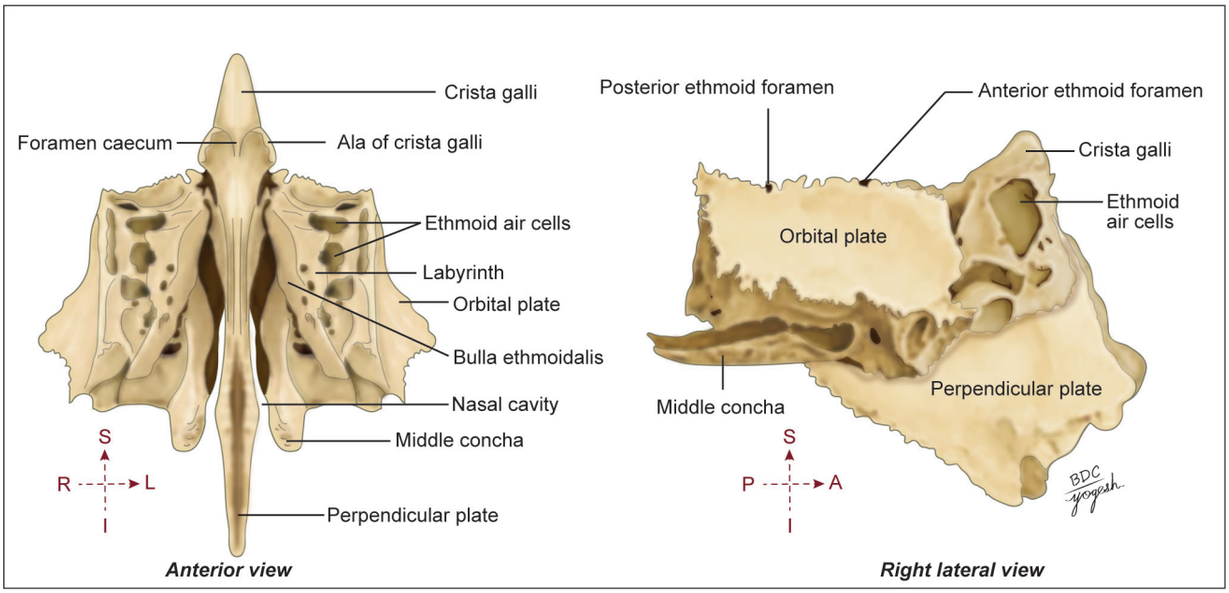


Plate 1.21: Right ethmoid bone



LABYRINTHS

These are two light cubical masses situated on each side of the perpendicular plate, suspended from the undersurface of the cribriform plate (Plate 1.21). Each labyrinth also encloses large number of 'air cells' arranged in three groups—the anterior, middle and posterior ethmoidal air sinuses. Its surfaces are:

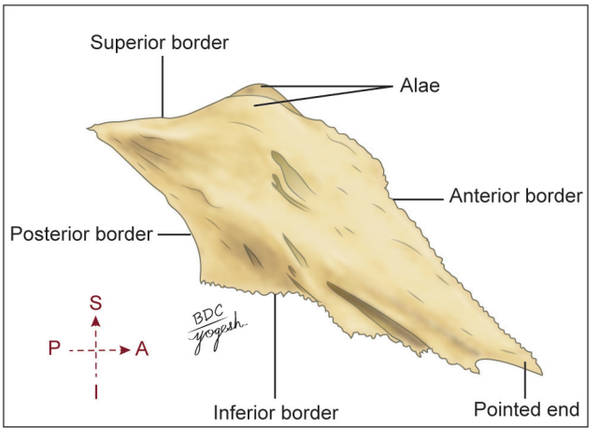
- Anterior surface articulates with frontal process of maxilla to complete anterior ethmoidal air cells.
- Posterior surface articulates with sphenoidal concha to complete posterior ethmoidal air cells.
- Superior surface articulates with orbital plate of frontal bone.
- Inferior surface articulates with nasal surface of maxilla.
- Lateral surface forms medial wall of orbit.
- Medial surface presents small superior nasal concha, middle nasal concha, superior meatus below superior concha and middle meatus below middle concha.

VOMER

Vomer (Latin *plough share*) is a single thin, flat bone forming posteroinferior part of the nasal septum. It comprises:

- Right and left surfaces marked by nasopalatine nerves which course downwards and forwards (Plate 1.22).
- Superior border splits into two alae with a groove occupied by rostrum of sphenoid.
- Inferior border articulates with nasal crests of maxillae and palatine bones.
- Anterior, longest border, articulates with perpendicular plate of ethmoid above and with septal cartilage below.
- Posterior border is free and separates the two posterior nasal openings.

Plate 1.22: Right vomer

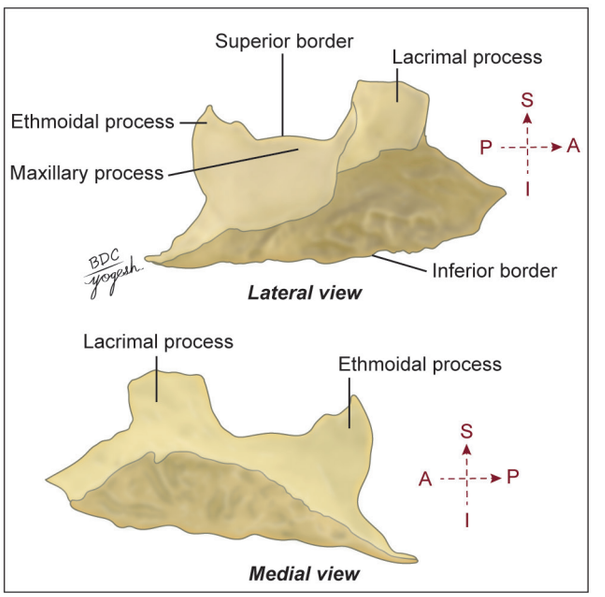


INFERIOR NASAL CONCHAE

The inferior nasal conchae are two curved bony laminae, these are horizontally placed in the lower part of lateral walls of the nose. Between this concha and floor of the nose lies the inferior meatus of the nose. It comprises two surfaces, two borders and two ends.

- Medial convex surface is marked by vascular grooves.
- Lateral concave surface forms the medial wall of inferior meatus of the nose.
- Superior border is irregular and articulates with lacrimal, maxilla, ethmoid and palatine bones (Plate 1.23).
- Inferior border is free, thick and spongy.
- Posterior end is more pointed than the anterior end.

Plate 1.23: Right inferior nasal concha



ZYGOMATIC BONES

These are two small quadrilateral bones present in the upper and lateral part of face. The bone forms prominence of the cheeks. Each bone takes part in the formation of (Plate 1.24):

- Floor and lateral wall of the orbit
- Walls of temporal and infraorbital fossae.

Zygomatic bone comprises three surfaces, four borders and two processes.

Surfaces

1. Lateral surface presenting zygomaticofacial foramen.
2. Temporal surface is smooth and concave and presents zygomaticotemporal foramen.
3. Orbital surface is also smooth and concave with one or two zygomatico-orbital foramen on this surface and this leads to zygomaticofacial and zygomaticotemporal foramina.

Borders

1. Anterosuperior or orbital
2. Anteroinferior or maxillary
3. Posterosuperior or temporal border
4. Posteroinferior border

Processes

1. Frontal process, which is directed upwards.
2. Temporal process, which is directed backwards.

NASAL BONES

Nasal bones are two small oblong bones, which form the bridge of the nerve.

Each nasal bone has two surfaces and four borders (Plate 1.25).

Surfaces

1. The outer surface is convex from side-to-side.
2. The inner surface is concave from side-to-side and is traversed by a vertical groove for anterior ethmoidal nerve.

Borders

1. Superior border is thick and serrated and articulates with nasal part of frontal bone.

Plate 1.24: Right zygomatic bone

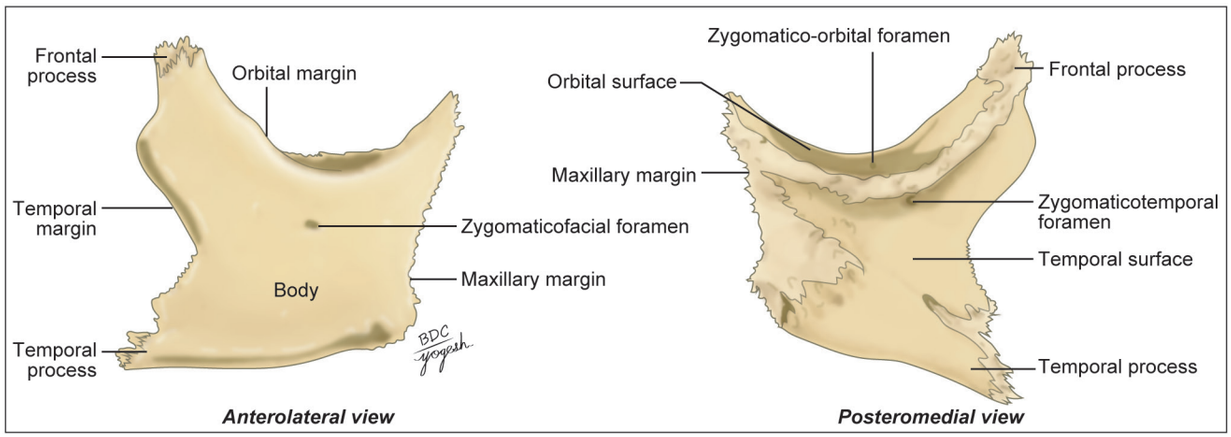


Plate 1.25: Nasal bones

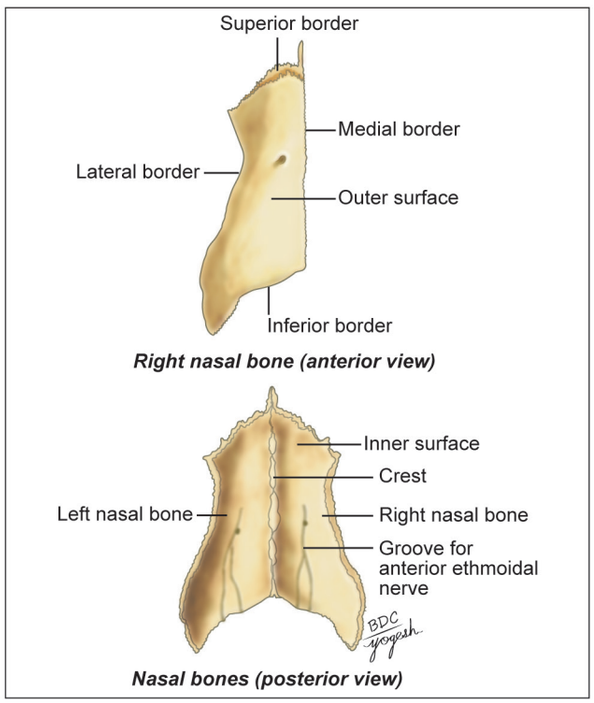
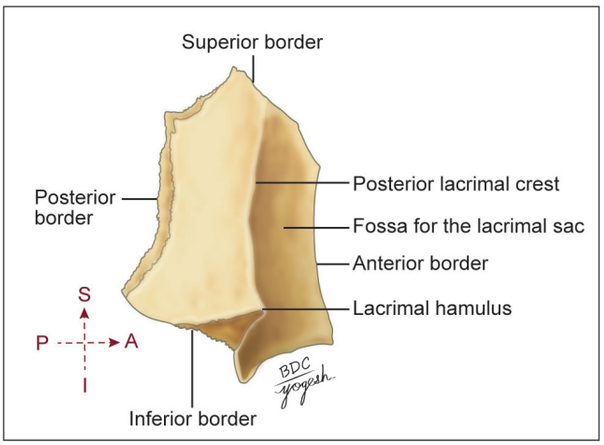


Plate 1.26: Right lacrimal bone (lateral view)



2. Inferior border is thin and notched and articulates with superior nasal cartilage.
3. Medial border articulates with opposite nasal bone.
4. Lateral border articulates with frontal process of maxilla.

LACRIMAL BONES

Lacrimal bones are extremely delicate and smallest of the skull bones. These form the anterior part of the medial part of the orbit. Each lacrimal bone comprises two surfaces and four borders (Plate 1.26)

Surfaces

1. Lateral or orbital surface is divided by posterior lacrimal crest into anterior and posterior parts. The anterior grooved part forms posterior half of the floor of lacrimal groove for lacrimal sac. The posterior smooth part forms part of medial wall of orbit.
2. Medial or nasal surface forms a part of middle meatus of the nose.

Borders

1. Anterior border articulates with frontal process of maxilla.
2. Posterior border with orbital plate of ethmoid.
3. Superior border with frontal bone.
4. Inferior border with orbital surface of maxilla.

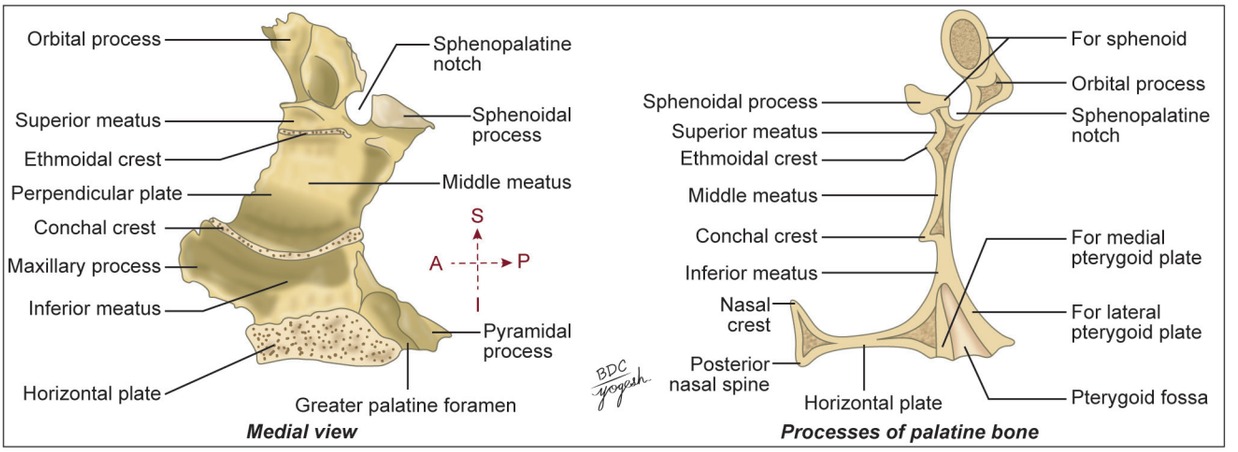
PALATINE BONES

Palatine bones are two L-shaped bones present in the posterior part of nasal cavity. Each bone forms:

- Lateral wall and floor of nasal cavity (Plate 1.27).
- Roof of mouth cavity
- Floor of the orbit
- Parts of pterygopalatine fossa.

Each palatine bone has two plates and three processes.

Plate 1.27: Right palatine bone



Plates

1. Horizontal plate forms posterior one-fourth part of bony palate. It has two surfaces and four borders.
2. Perpendicular plate of palatine bone is oblong in shape and comprises two surfaces and four borders *(refer to norma basalis)*.

Processes

Pyramidal

Pyramidal process projects downwards from the junction of two plates. Its inferior surface is pierced by lesser palatine foramina.

Orbital

Orbital process projects upwards and laterally from the perpendicular plate. Its orbital surface is triangular and forms the posterior part of the floor of the orbit.

Sphenoidal

Sphenoidal process projects upwards and medially from the perpendicular plate. Its lateral surface articulates with medial pterygoid plate.

HYOID BONE

The hyoid (Greek *U-shaped*) bone is U-shaped. It is situated in the anterior midline of the neck between the chin and the thyroid cartilage (Plate 1.28, Flowchart 1.15).

At rest, it lies at the level of the 3rd cervical vertebra behind and the base of the mandible in front.

It is kept suspended in position by muscles and ligaments.

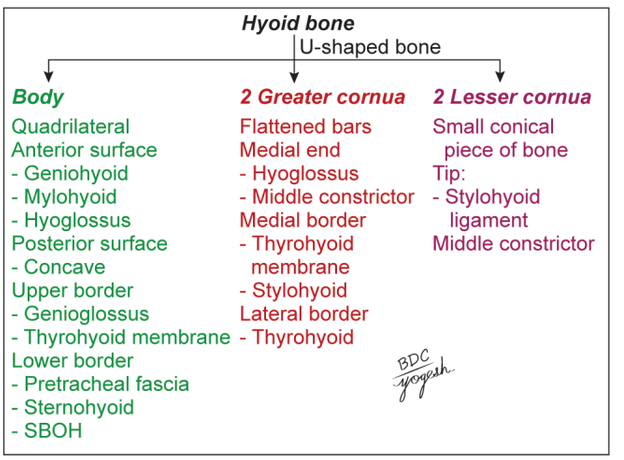
The hyoid bone provides attachment to the muscles of the floor of the mouth and to the tongue above, to the larynx below and to the epiglottis and pharynx behind (Fig. 1.27).

Parts of Hyoid Bone

The hyoid bone consists of the following parts (Plate 1.28, Fig. 1.27):

1. Body

Flowchart 1.15: Hyoid bone



(SBOH: Superior belly of omohyoid)

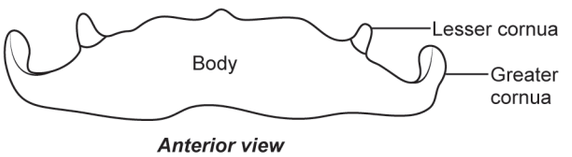


Fig. 1.27: Features of hyoid bone

2. Pair of greater cornua
3. Pair of lesser cornua

Body

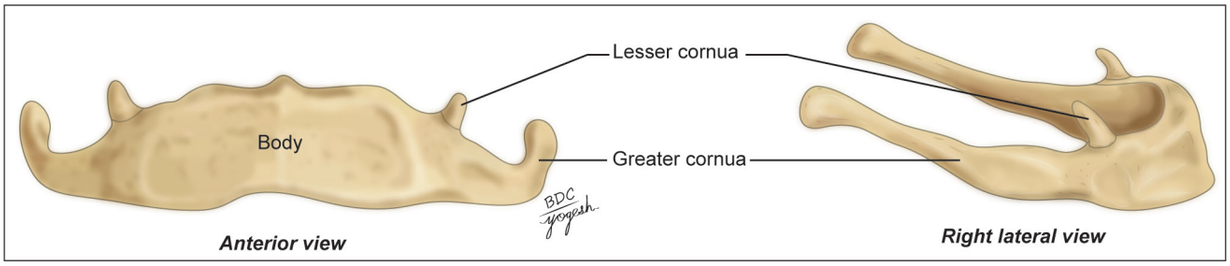
It has two surfaces—anterior and posterior, and two borders—upper and lower.

The *anterior surface* is convex and is directed forwards and upwards. It is often divided by a median ridge into two lateral halves.

The *posterior surface* is concave and is directed backwards and downwards.

Each lateral end of the body is continuous posteriorly with the greater horn or cornua. However, till middle life, the connection between the body and greater cornua is fibrous.

Plate 1.28: Hyoid bone



Greater Cornua

These are flattened from above downwards. Each cornua tapers posteriorly but ends in a tubercle. It has two surfaces—upper and lower, two borders—medial and lateral and a tubercle.

Lesser Cornua

These are small conical pieces of bone that project upwards from the junction of the body and greater cornua. The lesser cornua are connected to the body by fibrous tissue. Occasionally, they are connected to the greater cornua by synovial joints, which usually persist throughout life but may get ankylosed.

ATTACHMENTS ON THE HYOID BONE

1. Anterior surface of the body provides insertion to the geniohyoid and mylohyoid muscles and gives origin to a part of the hyoglossus, which extends to the greater cornua (Fig. 1.28).
2. *Upper border* of the body provides insertion to the lower fibres of the genioglossi and attachment to the thyrohyoid membrane.
3. *Lower border* of the body provides attachment to the pretracheal fascia. In front of the fascia, the *sternohyoid* is inserted medially and the superior belly of omohyoid laterally.
4. Below the omohyoid, there is the linear attachment of the thyrohyoid, extending back to the lower border of the greater cornua.

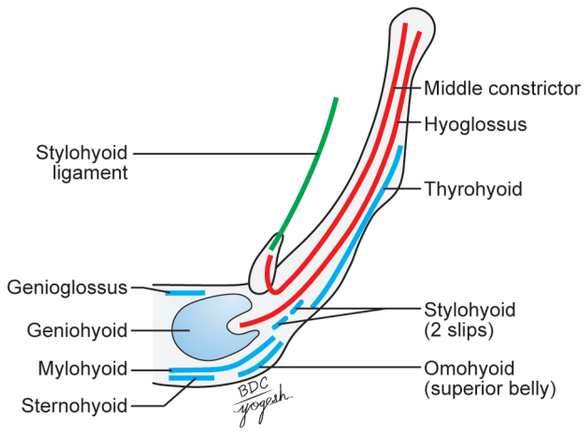


Fig. 1.28: Attachments of the hyoid bone

5. *Medial border* of the greater cornua provides attachment to the thyrohyoid membrane, two slips each of stylohyoid muscle and digastric pulley.
6. *Lateral border* of the greater cornua provides insertion to the thyrohyoid muscle anteriorly. The investing fascia is attached throughout its length.
7. The lesser cornua provides attachment to the stylohyoid ligament at its tip. The middle constrictor muscle arises from its posterolateral aspect extending onto the greater cornua.

DEVELOPMENT

Upper part of body and lesser cornua develop from 2nd branchial arch, while lower part of body and greater cornua develop from the 3rd arch.

CLINICAL ANATOMY

- Hyoid fractures are common in throttling and strangulation.
- Palpation of greater cornua of hyoid bone: It can be palpated in the relaxed neck, at the anterior border of sternocleidomastoid muscle, midway between the mastoid process and the laryngeal prominence.

Competency:
AN26.5 Describe features of typical and atypical cervical vertebrae (atlas and axis).

CERVICAL VERTEBRAE

IDENTIFICATION

The cervical vertebrae are identified by the presence of foramina transversaria.

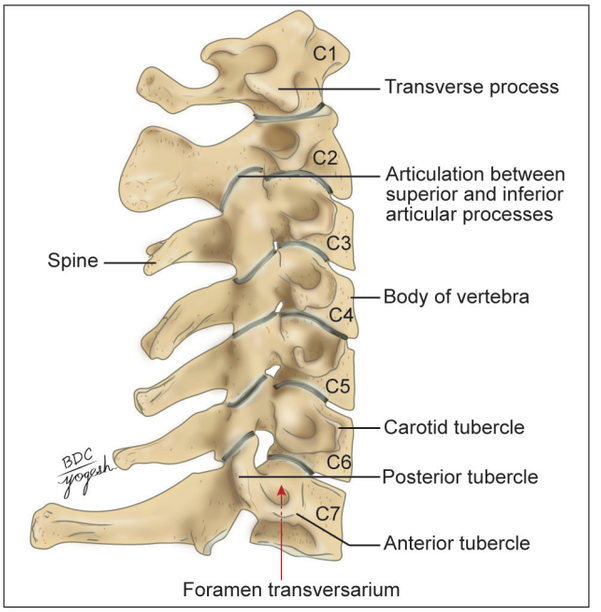
There are seven cervical vertebrae, out of which the 3rd to 6th are ***typical***, while the 1st, 2nd and 7th are ***atypical*** (Plate 1.29).

TYPICAL CERVICAL VERTEBRAE

Body

1. The body is *small* and *broader* from side-to-side than from before backwards.

Plate 1.29: Articulated cervical vertebrae (right lateral view)



2. Its *superior surface* is concave transversely with upward projecting lips on each side. The anterior border of this surface may be bevelled.
3. The *inferior surface* is saddle-shaped, being convex from side-to-side and concave from before backwards. The lateral borders are bevelled and form synovial joints with the projecting lips of the next lower vertebra. The anterior border projects downwards and may hide the intervertebral disc.
4. The *anterior and posterior surfaces* resemble those of other vertebrae (Plate 1.30, Fig. 1.29, Flowchart 1.16).

Vertebral Foramen

Vertebral foramen is larger than the body. It is triangular in shape because the pedicles are directed backwards and laterally.

Vertebral Arch

1. ***Pedicles*** are directed backwards and laterally. The superior and inferior vertebral notches are of equal size.
2. ***Laminae*** are relatively long and narrow, being thinner above than below.
3. The *superior and inferior articular processes* form articular pillars, which project laterally at the junction of pedicle and the lamina. The superior articular facets are flat. They are directed backwards and upwards. The inferior articular facets are also flat but are directed forwards and downwards.
4. The ***transverse processes*** are pierced by foramina transversaria. Each process has *anterior* and *posterior roots*, which end in tubercles joined by the *costotransverse bar*.

   Note: The ***costal element*** is represented by the *anterior root, anterior tubercle, the costotransverse bar and the posterior tubercle*. Posterior root represents the transverse process.

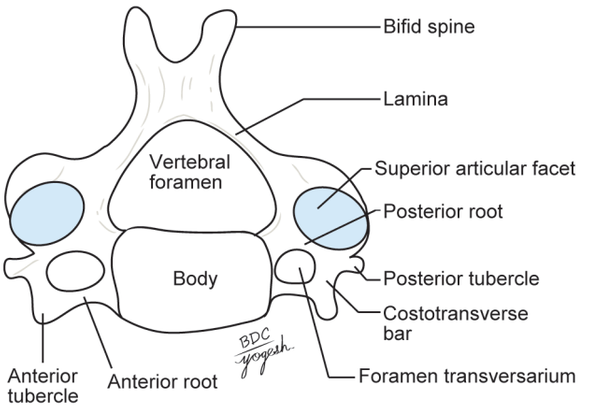


Fig. 1.29: Typical cervical vertebra seen from above

Flowchart 1.16: Typical cervical vertebra

Typical cervical vertebra — 3rd to 6th vertebre

Body	***Vertebral foramen***	***Articular facets***
Broader from side-to-side	- Large, triangular	Superior: Directed upward and backward
Superior surface	***Pedicles***	Inferior: Directed downward and forward
- Concave with upward projecting lateral lips	- Superior and inferior vertebral notches	***Transverse process***
Inferior surface	***Laminae***	- Anterior and posterior tubercles
- Beveled lateral margins	- Longer, thinner	- Costotransverse bar
Anterior and posterior surfaces	***Spinous process***	
- Flat	- Bifid	

Foramen transversarium: Vertebral artery and vein, branches of inferior cervical sympathetic ganglion

BDC yogesh

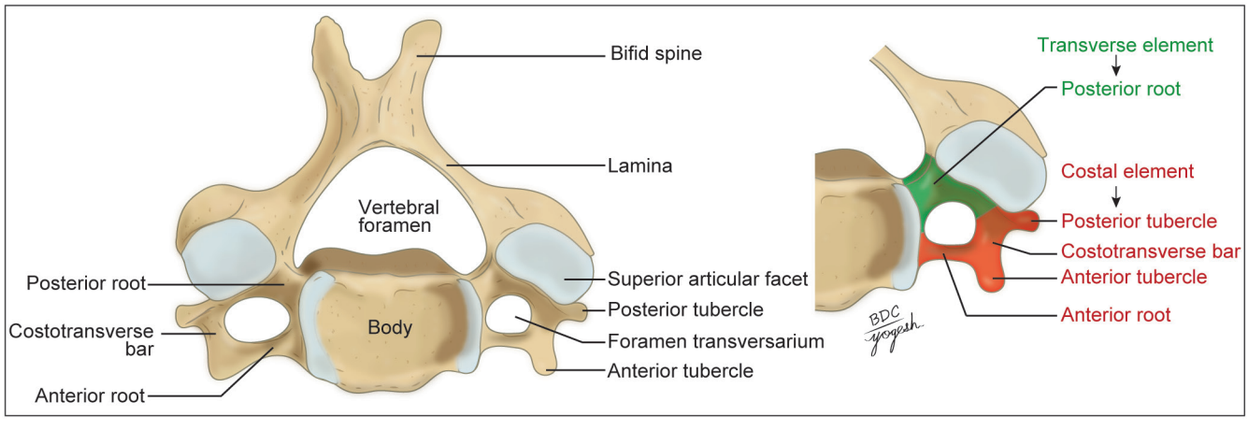
The anterior tubercle of the 6th cervical vertebra is large and is called the ***carotid tubercle*** because the common carotid artery can be compressed against it.

5. ***Spine*** is short and bifid. The notch is filled up by the ligamentum nuchae.

Attachments and Relations

1. The anterior and posterior longitudinal ligaments are attached to the upper and lower borders of the body in front and behind, respectively. On each side of the anterior longitudinal ligament, the vertical part of the longus colli is attached to the anterior surface. The posterior surface has two or more foramina for passage of *basivertebral veins*.
2. The upper borders and lower parts of the anterior surfaces of the laminae provide attachment to the ligamenta flava.
3. The *foramen transversarium* transmits the *vertebral artery*, the *vertebral veins* and a *branch from the inferior cervical ganglion*. The *anterior tubercles* give origin to the scalenus anterior, the longus capitis and the oblique part of the longus colli.
4. The *costotransverse bars* are grooved by the *anterior primary rami* of the corresponding cervical nerves.
5. The *posterior tubercles* give origin to the scalenus medius, scalenus posterior, levator scapulae. The

Plate 1.30: Typical cervical vertebra (4th cervical vertebra)



splenius cervicis, the longissimus cervicis and the iliocostalis cervicis are inserted into posterior tubercles.

6. The spine gives origin to the deep muscles of the back of the neck—spinalis cervicis, semispinalis cervicis and thoracis and multifidus.

OSSIFICATION

A typical cervical vertebra ossifies from three primary and six secondary centres.

There is one *primary centre* for each half of the neural arch during 9 to 10 weeks of foetal life and one for the *centrum* in 3 to 4 months of foetal life. The two halves of the neural arch fuse posteriorly with each other during the 1st year. Synostosis at the neurocentral synchondrosis occurs during the 3rd year.

The *secondary centres, two* for the annular epiphyseal discs for the peripheral parts of the upper and lower surfaces of the body, *two* for the tips of the transverse processes and *two* for the bifid spine, appear during puberty and fuse with the rest of the vertebrae by 25 years.

FIRST CERVICAL VERTEBRA

It is called the ***atlas*** (Tiltan, who supported the heaven).

It can be identified by the following features:

1. It is ring-shaped. It has neither a body nor a spine (Plate 1.31, Figs 1.30 and 1.31, Flowchart 1.17).
2. The atlas has a short anterior arch, a long posterior arch, right and left lateral masses and transverse processes.
3. ***Anterior arch*** is marked by a median *anterior tubercle* on its anterior aspect. Its posterior surface bears an *oval facet* that articulates with the *dens.*
4. ***Posterior arch*** forms about 2/5th of the ring and is much longer than the anterior arch. Its posterior surface is marked by a median posterior tubercle. The upper surface of the arch is marked behind the lateral mass by a *groove*. Each *lateral mass* shows the following important features.

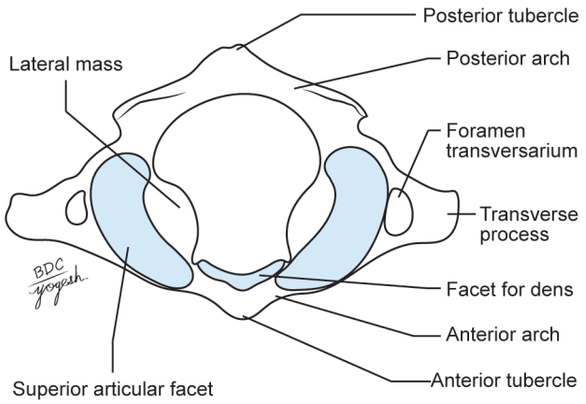


Fig. 1.30: Atlas vertebra

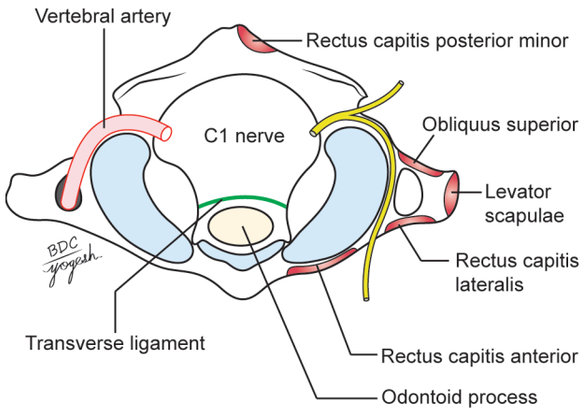
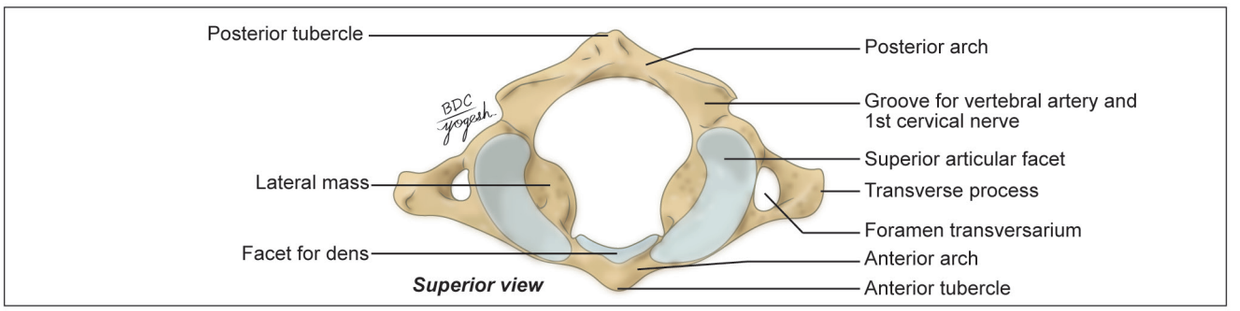


Fig. 1.31: Relations of atlas vertebra

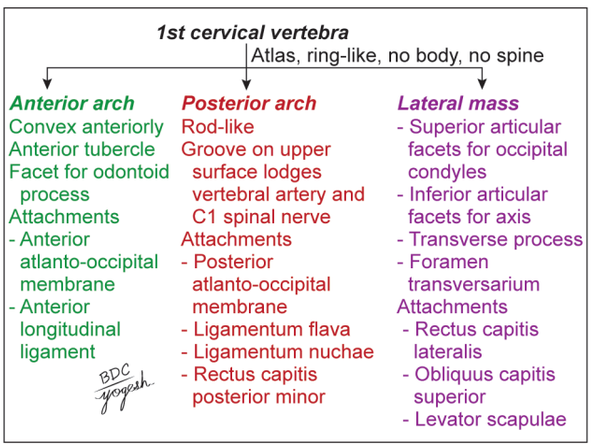
a. Its upper surface bears the *superior articular facet.* This facet is elongated (forwards and medially), concave and is directed upwards and medially. It articulates with the corresponding condyle of the occipital bone to form an atlanto-occipital joint.

b. The lower surface is marked by the *inferior articular facet*. This facet is nearly circular, more or less flat and is directed downwards, medially and backwards. It articulates with

Plate 1.31: Atlas vertebra



Flowchart 1.17: 1st cervical vertebra



the corresponding facet on the axis vertebra to form an atlantoaxial joint.

c. The medial surface of the lateral mass is marked by a small roughened tubercle.

d. The *transverse process* projects laterally from the lateral mass. The transverse process is pierced by the foramen transversarium.

Attachments and Relations (Fig. 1.31)

1. The anterior tubercle provides attachment (in the median plane) to the anterior longitudinal ligament, and provides insertion on each side to the upper oblique part of longus colli.
2. The upper border of the anterior arch gives attachment to the anterior atlanto-occipital membrane.
3. The lower border of the anterior arch gives attachment to the lateral fibres of the anterior longitudinal ligament.
4. The posterior tubercle provides attachment to the ligamentum nuchae in the median plane and gives origin to the rectus capitis posterior minor on each side.
5. The groove on the upper surface of the posterior arch is occupied by the *vertebral artery* and by the *first cervical nerve*. Behind the groove, the upper border of the posterior arch gives attachment to the posterior atlanto-occipital membrane.
6. The lower border of the posterior arch gives attachment to the highest pair of ligamenta flava.
7. The tubercle on the medial side of the lateral mass gives attachment to the transverse ligament of the atlas.
8. The anterior surface of the lateral mass gives origin to the rectus capitis anterior.
9. The transverse process gives origin to the rectus capitis lateralis from its upper surface anteriorly, obliquus capitis superior from its upper surface posteriorly, levator scapulae from its lateral margin and lower border and insertion to obliquus capitis inferior from its lower surface of the tip. Its posterior tubercle gives insertion to splenius cervicis.

OSSIFICATION

Atlas ossifies from three centres, one for each lateral mass with half of the posterior arch, one for the anterior arch. The centres for the lateral masses appear during 7th week of intrauterine life and unite posteriorly at about 3 years. The centre for anterior arch appears at about 1st year and unites with the lateral mass at about 7 years.

SECOND CERVICAL VERTEBRA

This is called the *axis* (Latin *axile*). It is identified by the presence of the dens or *odontoid* (Greek *tooth*) process, which is a strong, tooth-like process projecting upwards from the body. The dens is usually believed to represent the centrum or body of the atlas, which has fused with the centrum of the axis (Plate 1.32, Fig. 1.32).

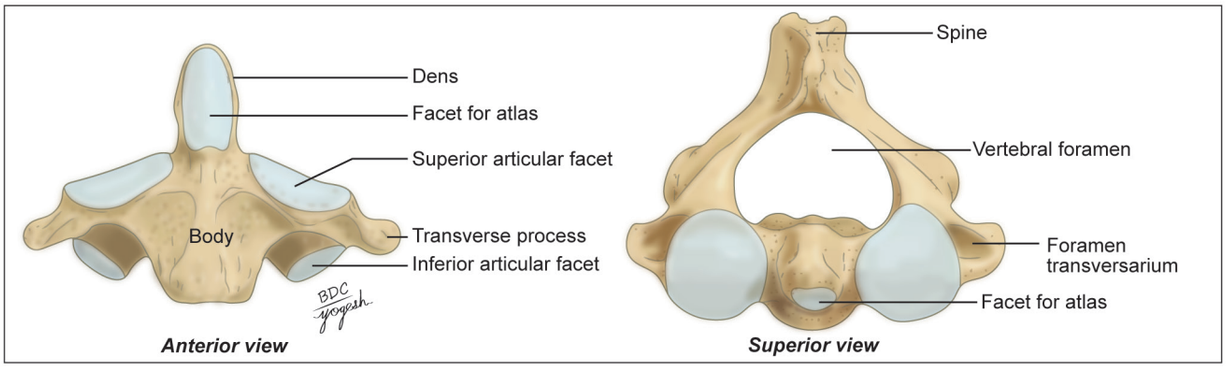
Body and Dens

1. The *superior surface* of the body is fused with the ***dens*** and is encroached upon on each side by the superior articular facets. The dens articulates anteriorly with oval fact on posterior surface of the anterior arch of the atlas, and posteriorly with the transverse ligament of the atlas.
2. The *inferior surface* has a prominent anterior margin, which projects downwards.
3. The *anterior surface* presents a median ridge on each side of which there are hollowed-out impressions.

Vertebral Arch

1. The ***pedicles*** are concealed superiorly by the superior articular processes. The inferior surface presents a deep

Plate 1.32: Axis vertebra



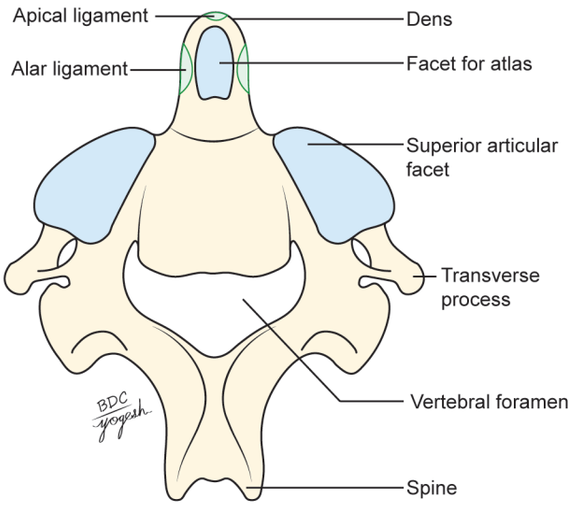


Fig. 1.32: Axis vertebra

and wide *inferior vertebral notch*, placed in front of the inferior articular process. The superior vertebral notch is very shallow and is placed on the upper border of the lamina, behind the superior articular process.

2. The ***laminae*** are thick and strong.
3. ***Articular facets***: Each *superior articular facet* occupies the upper surfaces of the body and of the massive pedicle. Laterally, it overhangs the foramen transversarium. It is a large, flat, circular facet that is directed upwards and laterally. It articulates with the inferior facet of the atlas vertebra to form the atlantoaxial joint. Each *inferior articular facet* lies posterior to the transverse process and is directed downwards and forwards to articulate with the third cervical vertebra.
4. The ***transverse processes*** are very small and represent the true posterior tubercles only. The foramen transversarium is directed upwards and laterally.
5. The ***spine*** is large, thick and very strong. It is deeply grooved inferiorly. Its tip is bifid, terminating in two rough tubercles.

Attachments

1. The dens provides attachment at its apex to the apical ligament, and on each side, below the apex to the alar ligaments.
2. The anterior surface of the body receives the insertion of the longus colli. The anterior longitudinal ligament is also attached to the anterior surface.
3. The posterior surface of the body provides attachment, from below upwards, to the (A) posterior longitudinal ligament, (B) the membrana tectoria and (C) the vertical limb of the cruciate ligament.
4. The laminae provide attachment to the ligamenta flava.
5. The transverse process gives origin by its tip to the levator scapulae, the scalenus medius anteriorly and the splenius cervicis posteriorly. The *intertransverse muscles* are attached to the upper and lower surfaces of the process.
6. The spine gives attachment to the ligamentum nuchae, the semispinalis cervicis, the spinalis cervicis, the interspinalis and the multifidus and origin to rectus capitis posterior major and the obliquus capitis inferior.

Competency:
AN26.7 Describe the features of the 7th cervical vertebra.

SEVENTH CERVICAL VERTEBRA

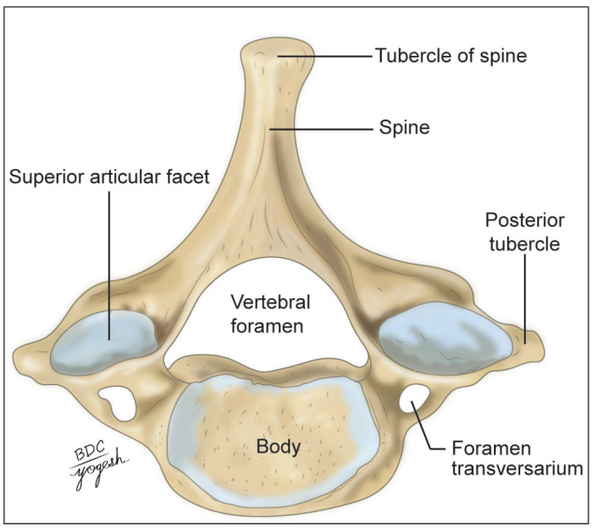
It is also known as the ***vertebra prominens*** because of its long spinous process, the tip of which can be felt through the skin at the lower end of the nuchal furrow. Its spine is thick, long and nearly horizontal. It is not bifid but ends in a tubercle (Plate 1.33).

The transverse processes are comparatively large in size, the posterior root is larger than the anterior. The anterior tubercle is absent. The foramen transversarium is relatively small, sometimes double, or may be entirely absent. It does not transmit the vertebral artery.

Attachments

1. The tip of the *spine* provides attachment to the ligamentum nuchae, trapezius, rhomboid minor, serratus posterior superior, splenius capitis, spinalis cervicis, semispinalis thoracis, interspinales and the multifidus.
2. *Transverse process:* The *foramen transversarium* usually transmits only an accessory vertebral vein. The *posterior tubercle* provides attachment to the

Plate 1.33: C7 vertebra



suprapleural membrane. The lower *border* provides attachment to the first pair of levatores costarum.

3. The anterior root of the transverse process may sometimes be separate. It then forms a *cervical rib* of variable size.

OSSIFICATION

Its ossification is similar to that of a typical cervical vertebra. In addition, separate centre for each costal process appears during 6th month of intrauterine life and fuses with the body and transverse process during 5th to 6th years of life.

CLINICAL ANATOMY

- The costal element of 7th cervical vertebra may get enlarged to form a ***cervical rib*** (Fig. 1.33). A cervical rib is an additional rib arising from the C7 vertebra and usually gets attached to the 1st rib near the insertion of scalenus anterior. If the rib is more than 5 cm long, it usually displaces the brachial plexus and the subclavian artery upwards. The symptoms are tingling pain along the inner border of the forearm and hand including weakness and even paralysis of the muscles of the palm.
- The intervertebral foramina of the cervical vertebrae lie anterior to the joints between the articular processes. Arthritic changes in these joints, if occur, cause tiny projections or osteophytes. These osteophytes may press on the anteriorly placed cervical spinal nerves in the foramina causing pain along the course and distribution of these nerves.
- The joints in the lateral parts of adjacent bodies of cervical vertebrae are called Luschka's joints. The intervertebral foramen lies between Luschka's joints and facet joints. The cervical nerve roots may get pressed by osteophytes in these joints causing pain (Fig. 1.34).
- The vertebral artery coursing through the foramen transversarium lies lateral to Luschka's joints. The osteophytes of Luschka's joints may cause distortion of the vertebral artery leading to vertebrobasilar insufficiency. This may cause vertigo, dizziness, etc.
- Prolapse of the intervertebral disc occurs at the junction of different curvatures. So, the common site is lower cervical and upper lumbar vertebral regions. In the cervical region, the disc involved is above or below 6th cervical vertebra. The nerve roots affected are C6 and C7. There is pain and numbness along the lateral side of forearm and hand. There may be wasting of muscles of thenar eminence.
- During judicial hanging, the odontoid process usually breaks to hit upon the vital centres in the medulla oblongata (Fig. 1.35).
- Atlas may fuse with the occipital bone. This is called *occipitalisation of atlas* and this may at times compress the spinal cord, which requires surgical decompression.
- The pharyngeal and retropharyngeal inflammations may cause decalcification of atlas vertebra. This may lead to loosening of the attachments of transverse ligament, which may eventually yield, causing *sudden death* from *dislocation of dens*.

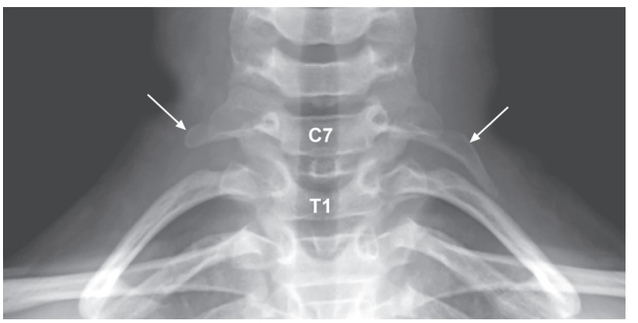


Fig. 1.33: Bilateral cervical ribs

Fig. 1.34: Pressure on the cervical nerve due to bony changes

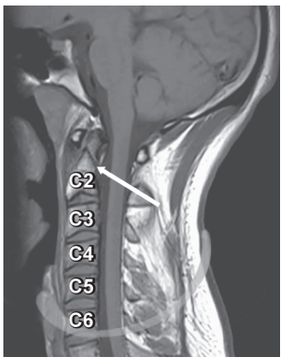


Fig. 1.35: Fracture of the odontoid process during hanging (fracture marked by arrow)

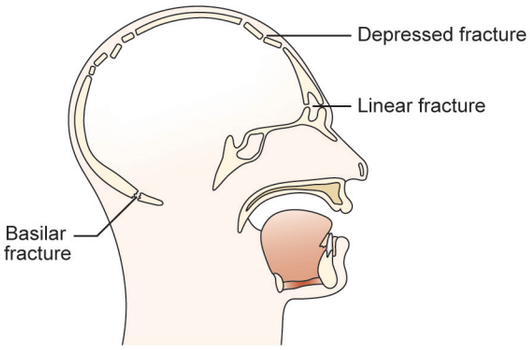


Fig. 1.36: Types of fracture of the skull

- Fractures of skull may be depressed, linear and basilar (Fig. 1.36).
- Hangman's fracture occurs due to fracture of the pedicles of axis vertebra. As the vertebral canal gets enlarged, the spinal cord does not get pressed.

VIDEO

Video 3.1 Bones of Skull: Introduction, Bones of skull, Anterior cranial fossa, Middle cranial fossa, Posterior cranial fossa, Orbit, Mandible, Foramina, Norma frontalis, Hyoid bone, Cervical vertebrae.

Facts to Remember

- Eight bones in the calvaria and 14 facial bones make up the skull.
- Most of the joints are 'suture' type of joints. The joint between teeth and gums is gomphosis. There is a pair of temporomandibular joints, which is of synovial variety.
- The bony ossicles are malleus, incus and stapes and are 'bone within bone', as these are present in the petrous temporal bone. Between these three ossicles are two synovial joints.
- Diploe veins contain manufactured RBCs, granulocytes and platelets. These drain into the neighbouring veins.
- Paranasal sinuses give resonance to the voice, besides humidifying and warming up the inspired air.

BDC's Anatomy *e*-book

1. Principles governing fractures of the skull
2. Age changes in maxilla
3. Ossification of cranial bones
4. Development of neurocranium
5. Further reading
6. Viva voce